Cognitive Science Approach to Understanding Human-Computer Interaction in Medicine

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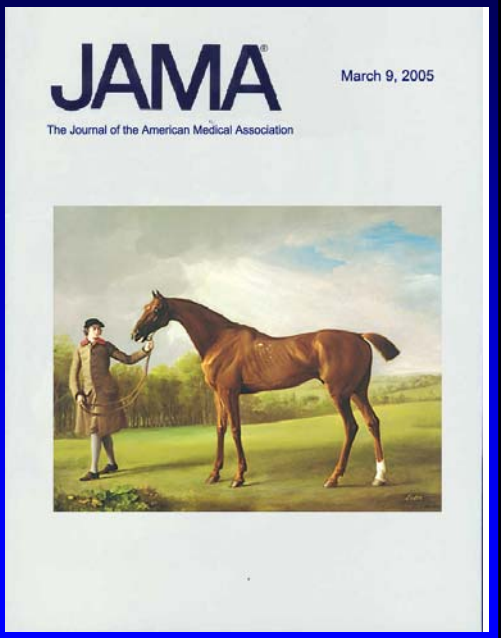
Koppel R, Metlay JP, Cohen A, Abaluck B, Localio AR, Kimmel SE, et al.

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

JAMA 2005;293:1197-203.



Another Case

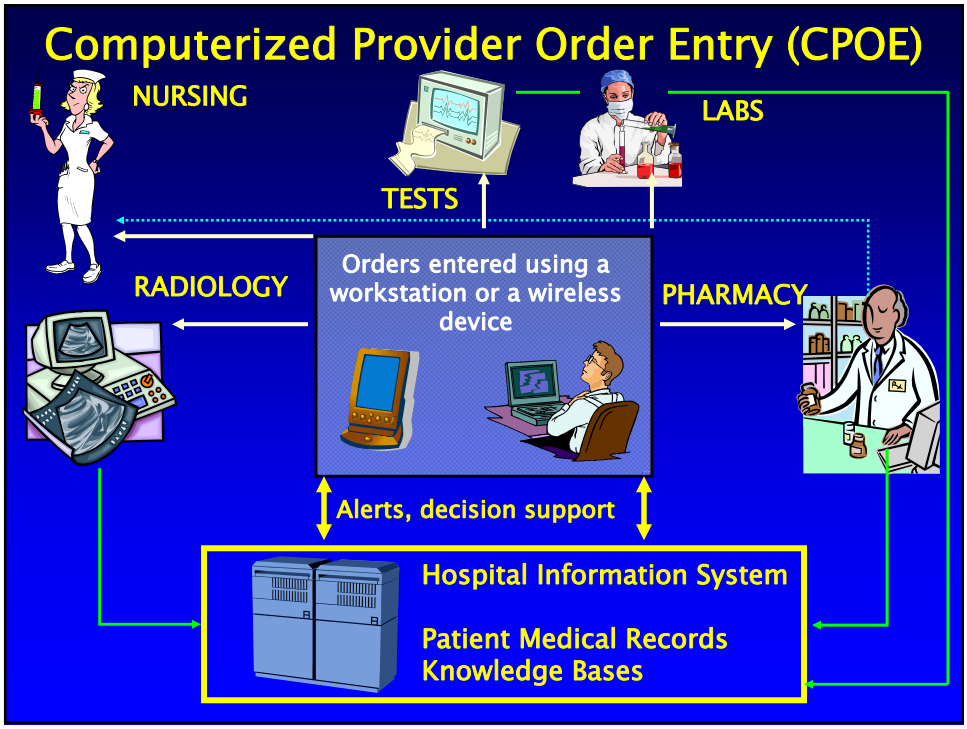
Potassium chloride (KCl) ordered as IV injection and as IV fluid additive using vendor's CPOE system:

- 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

Horsky J, Kuperman GJ, Patel VL. Comprehensive analysis of a medication dosing error related to CPOE: A case report. J Am Med Inform Assoc 2005;12:377-382

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



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

Horsky J, Zhang J, Patel VL. To err is not entirely human: Complex systems and user cognition. Journal of Biomedical Informatics 2005;38 264-266.

Dimensions of Human Computer Interaction (HCI)

- Technological
  - Hardware and Software Advances
- Cognitive
  - Representation
  - Knowledge Organization
  - Reasoning and Strategies

What is Cognitive Science?

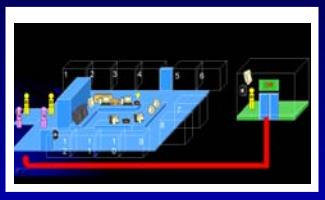
Multidisciplinary field incorporating theories and methods from psychology, linguistics, philosophy, anthropology, and computer science in the investigation of cognitive processes in humans and machines

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

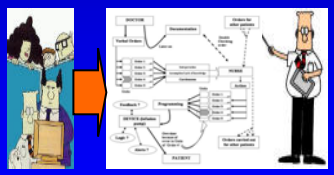
Specific Methods

Shadowing of medical team personnel during 'Crucial Periods' pertinent to the individual



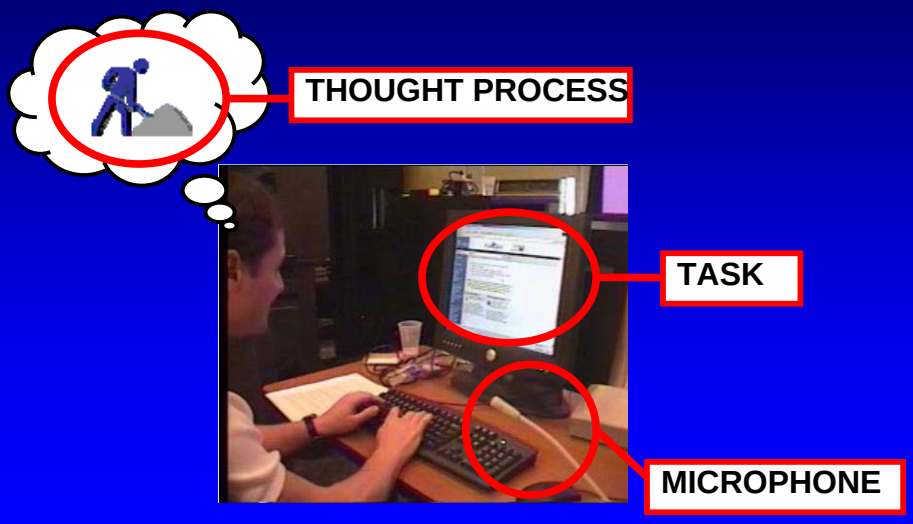
Mapping the activities to the ICU/ER layout and time-stamping each interaction or event

Conducting brief interviews to gain insight on infrastructure, roles, shifts, timings



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

Patel V, Kushniruk A,Yang S,Yale J-F, Impact of a computer-based patient record system on data collection,knowledge organization and reasoning. *JAMIA*,7(6)569-85,2001

Information in EMR and Hand-Written Records

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

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

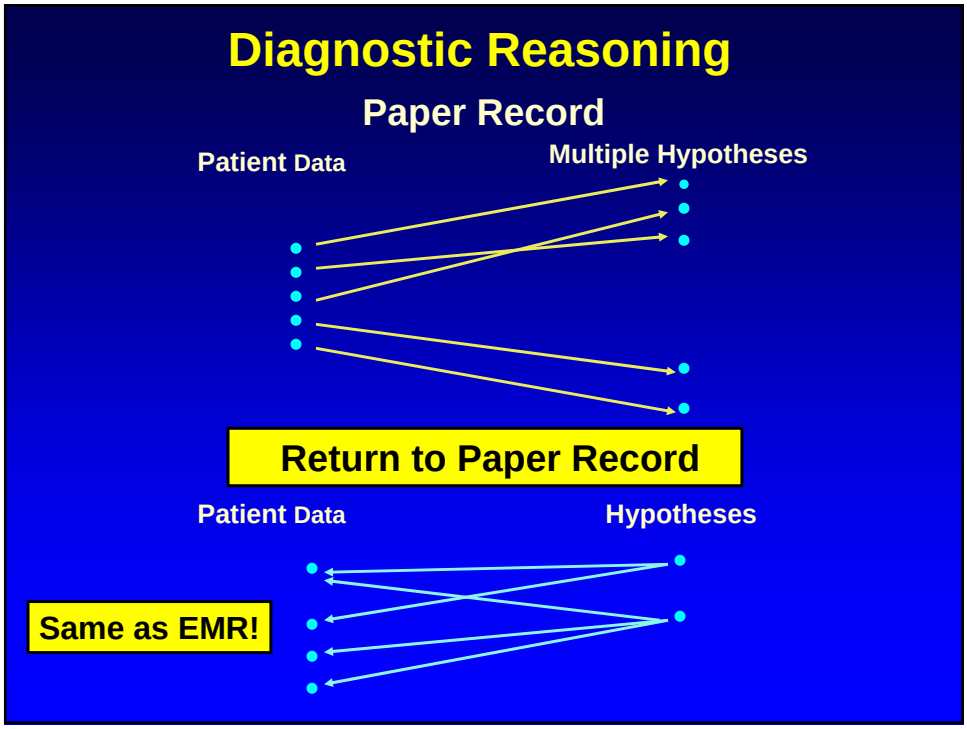
Currently on N54 - N28

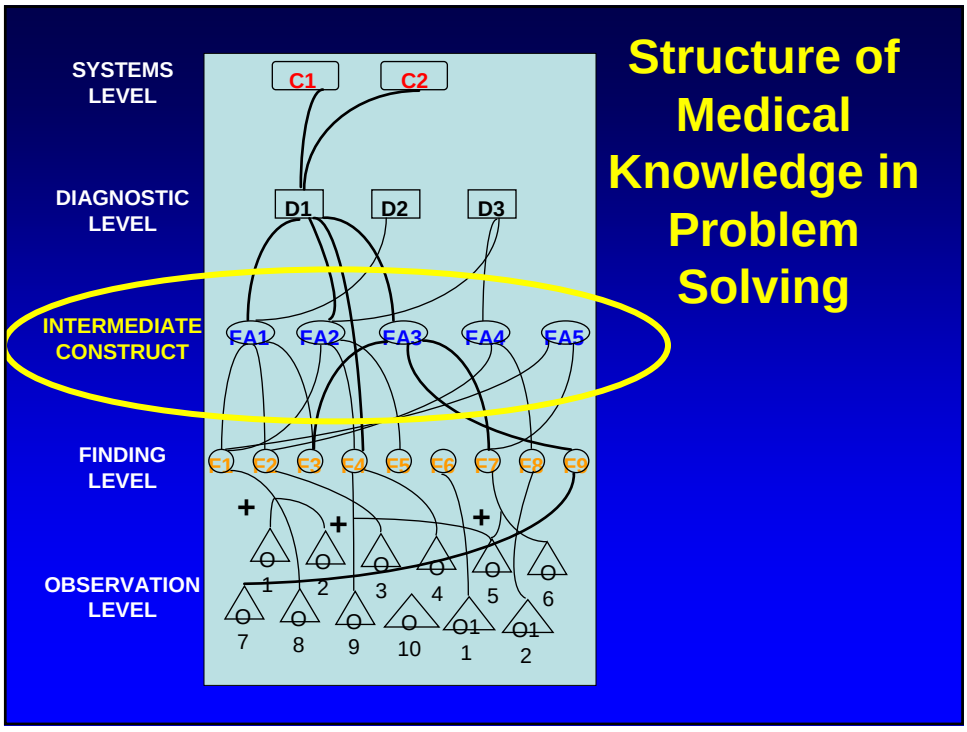
	R6 - R2	Measure with OT II	
Glucose levels:	<130	130-180	>180
AM	IIIIIII	IIIIIIIIIIIIII	
Lunch			
Supper	IIIIIIIII		
Bedtime	IIIIIIII	IIIIIIIIII	

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





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

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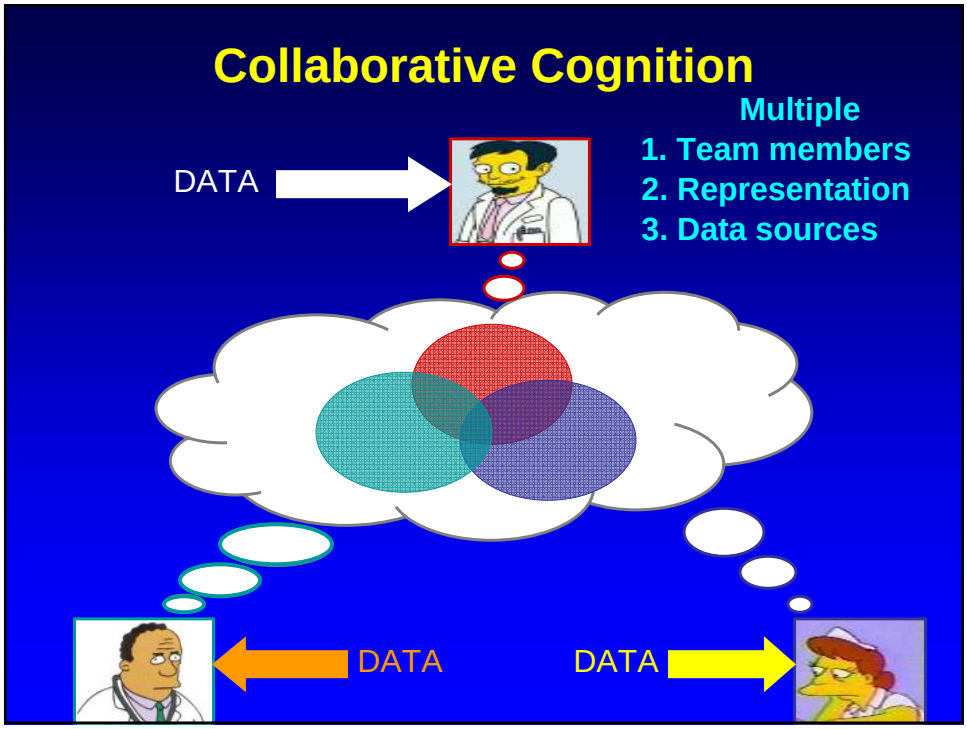
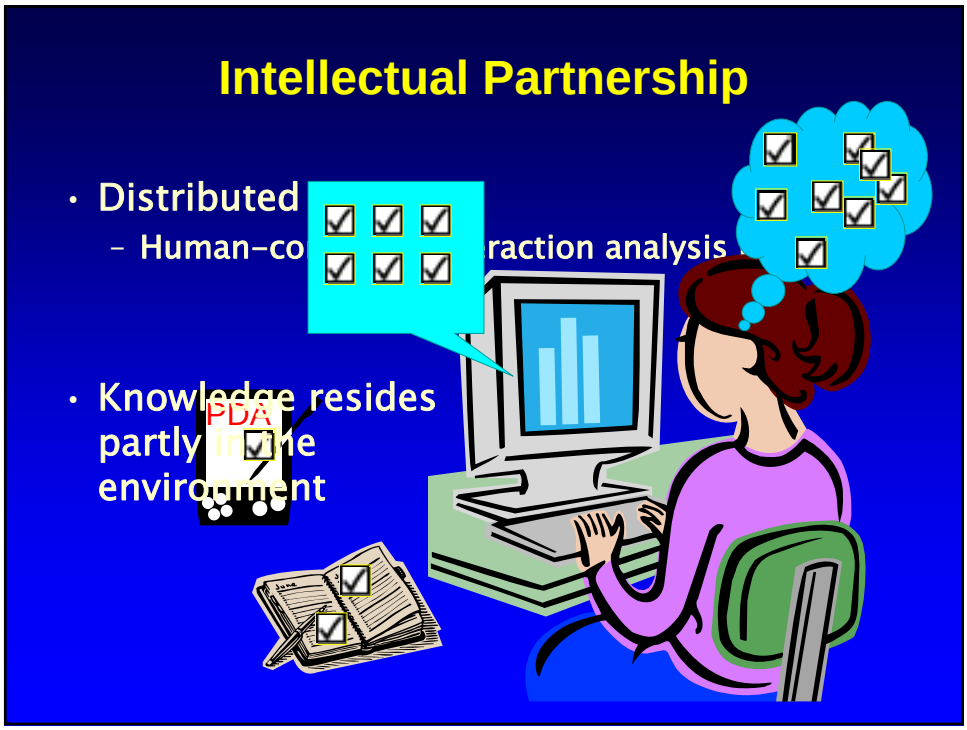




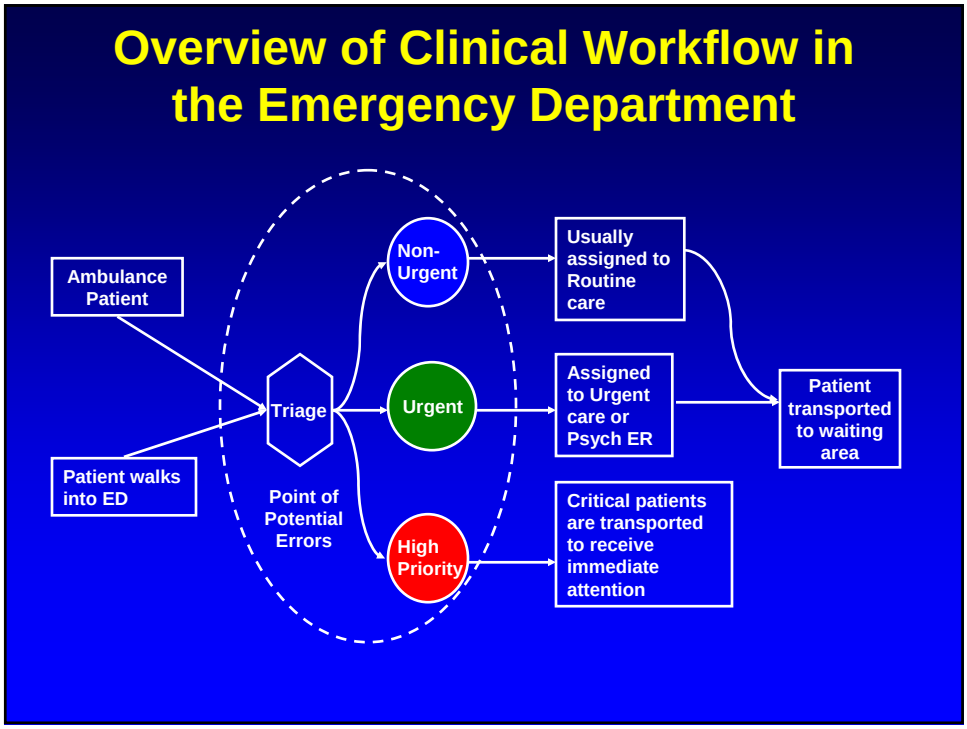
Intellectual Partnership

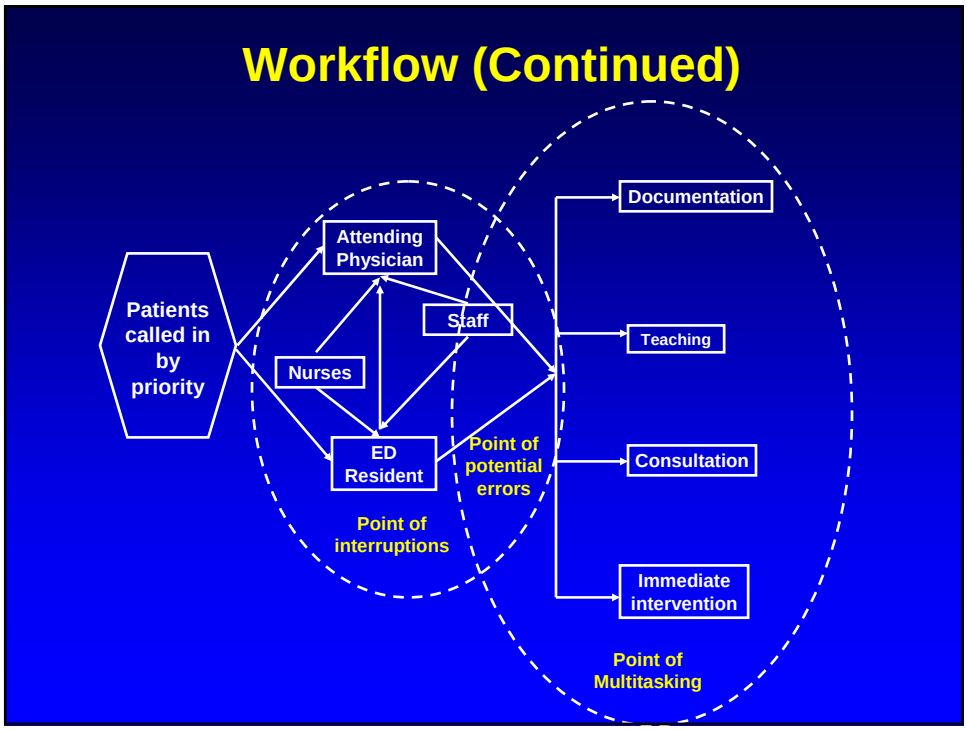
- Coordinating internal (user's mind) and external (interface, environment) resources

References

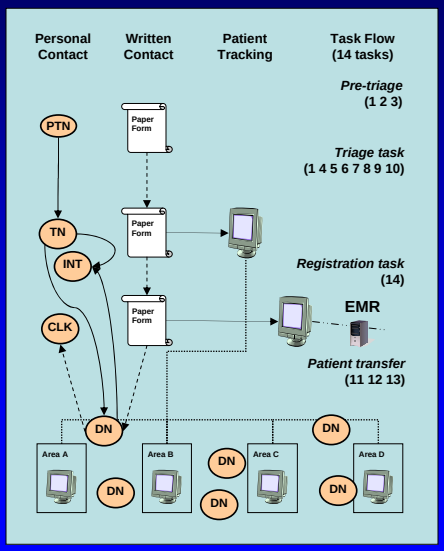
Maholtra, S., Jordan, D., Shortliffe, E.H., & Patel, V.L. (2006). Workflow in critical care: Piecing together your own puzzle. *Journal of Biomedical Informatics* 40(2);81-92

Cohen, T., Blatter, B., Almeida, C., Shortliffe, E., & Patel, V. (2006). Distributed cognition in the Psychiatric Emergency Department: A cognitive blueprint of a collaboration in context. *Artificial Intelligence in Medicine*, *37*, 73-83

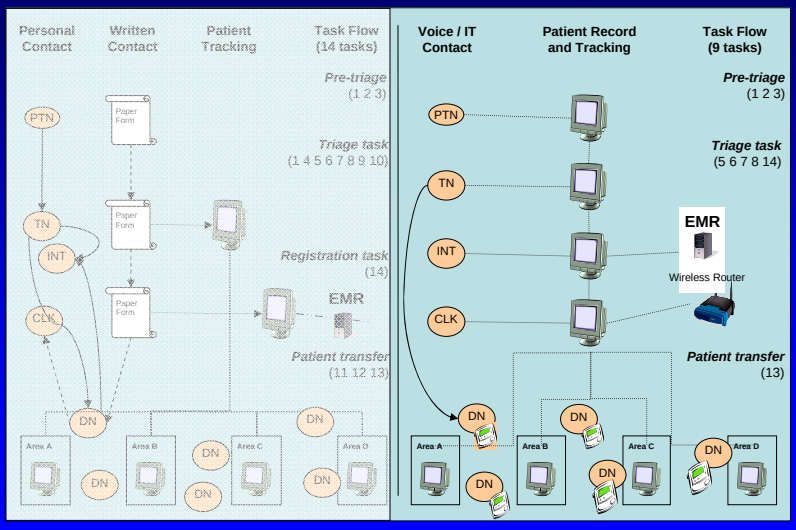




Clinical Workflow in Emergency Room Triage



Proposed Clinical Workflow in Emergency Room Triage



Clinical Applications and Cognition

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  - Infusion pump

Example of Product Evaluation

Heuristic Evaluation of Infusion Pump

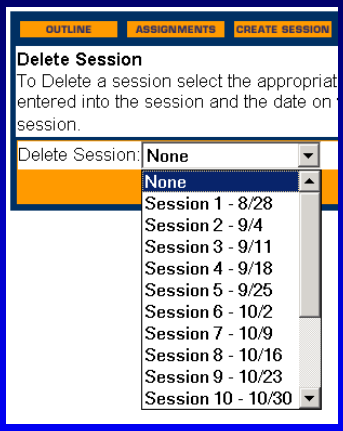
Graham MJ, Kubose TK Jordan D, Zhang J, Johnson TR, & Patel VL. Heuristic Evaluation of Infusion Pumps: Implications for Patient Safety in Intensive Care Units. *Journal of Biomedical Informatics*. 2004;73(11-12):771-9.

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