A Human Factors Perspective on Systems, Patient Safety, and Simulation

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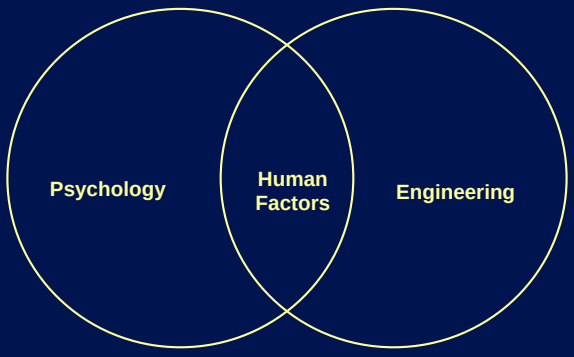
Human Factors Engineering

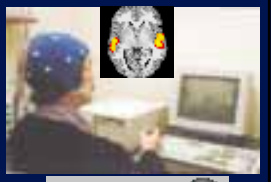
- *a discipline concerned with specifying the capacities and limitations of the human and designing machines and systems that accommodate the limits of the human user.*

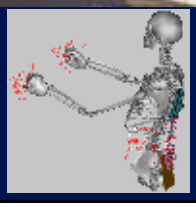
Human Factors



Human Factors
Knowledge of Mind, Brain, & Body…

- Sensation & Perception
- Cognition
- Physiological
- Social
- Personality
- Industrial/Organizational
- Anthropometrics
- Biomechanics
- Experimental Design



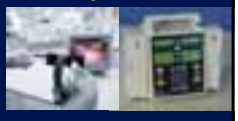


Human Factors
Applied to:

Computers

Consumer Products

Medical Systems/Devices



Aerospace Systems

Transportation

Military Systems

Goals of Human Factors

- **reduce errors**
- **increase safety**
- **increase reliability of systems**
- **reduce training requirements**
- **improve maintainability**
- **increase efficiency**
- **increase productivity**
- **improve the working environment**
- **reduce fatigue and stress**
- **increase human comfort**
- **reduce monotony**
- **increase convenience of use**
- **increase user acceptance**
- **increase job satisfaction**
- **improve the quality of life**

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The Problem

CNN.com

Study: Hospital errors cause 195,000 deaths

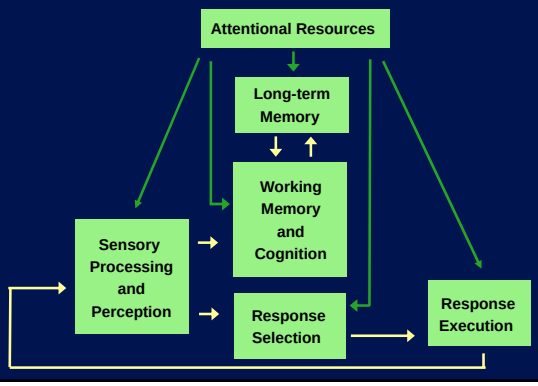
Report doubles earlier Institute of Medicine estimate

CNN.com

Hospital halts stomach-staple operations after death

Where do the errors originate?

Human Information Processing

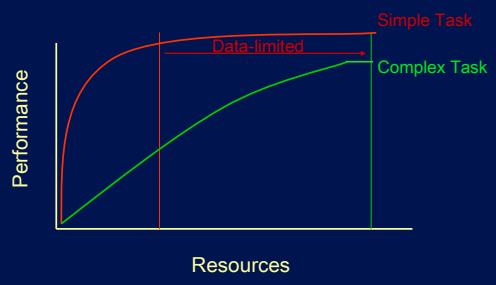


Origins of Error

- Attentional resources and workload

Performance Resource Function

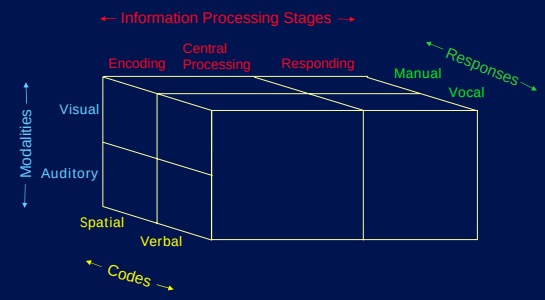
(Norman & Bobrow, 1975)



Origins of Error

- Attentional resources and workload
- Competing demands for the same pools of resources

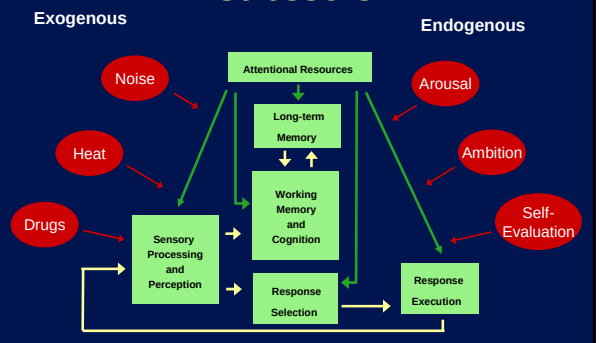
Multiple-Resource Theory
(Wickens, 1984)



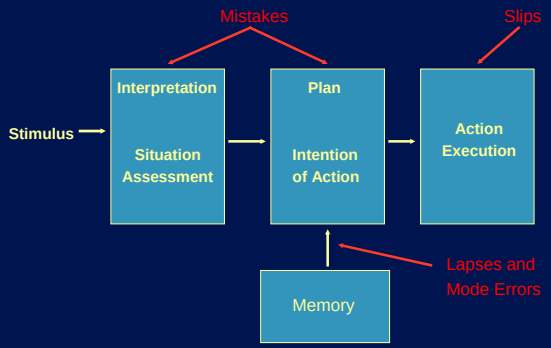
Origins of Error

- Attentional resources and workload
- Competing demands for the same pools of resources
- Stressors

Stressors



Model of Human Error
Wickens (1992)



Mistakes

- Failures to formulate the right intentions or execute the right plan
  - *Knowledge-based*
    - incorrect plans are executed based on faulty/incomplete information and/or cognitive biases (low confidence regarding execution).
    - low familiarity with the situation and high attentional demands.
  - *Rule-based*
    - plan is implemented in an inappropriate situation often when initial conditions differ in subtle and novel ways (high confidence regarding execution).
    - associated with high levels of skill.

Slips

- Failures to properly execute the correct intentions
  - e.g., typing “yjr” instead of “the” – the finger movements are correct, but all shifted one key to the right.
  - The action sequence is usually fairly automatic (requires few attentional resources).
  - Often, the tactile feedback does not distinguish between the correct and incorrect action.
  - more common when attention is diverted away from the action.
  - more readily detectable because feedback indicating a mismatch between outcome and intentions occurs quickly.

Lapses

- Failures to execute the plan
  - e.g., forgetting to remove your keys from the ignition when locking and shutting the car door.
  - They represent a failure of memory.
  - Often, they are omissions of steps in a sequence caused by an interruption.
  - feedback regarding intentions and outcomes may be delayed or not detectable by the individual.

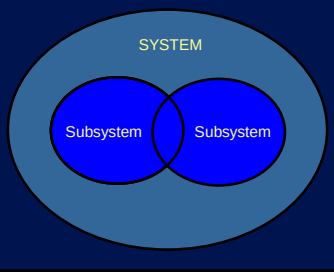
Mode Errors

- Similar to slips but also have a failure of memory component
  - e.g., forgetting to step on the accelerator to maintain speed after cruise control has been disengaged.
  - They represent a failure of memory tied to modes of operation.

Systems Perspective

(Ackoff, 1994)

- A system is a whole that contains two or more parts that satisfy the following conditions:

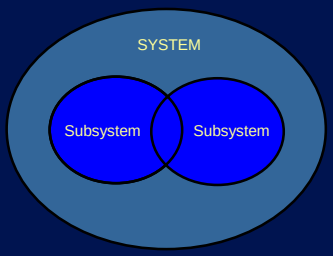


Systems Perspective

(Ackoff, 1994)

- A system is a whole that contains two or more parts that satisfy the following conditions:

  The whole SYSTEM has one or more defining functions.

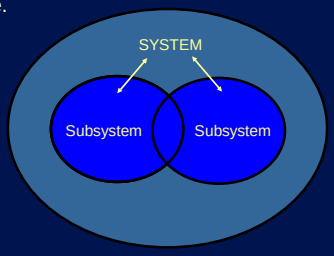


Systems Perspective

(Ackoff, 1994)

- A system is a whole that contains two or more parts that satisfy the following conditions:

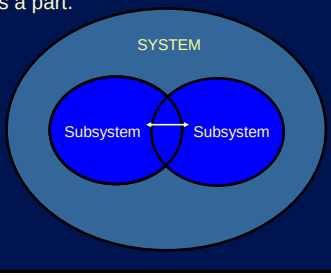
  Each subsystem can affect the behavior or properties of the whole.



Systems Perspective

(Ackoff, 1994)

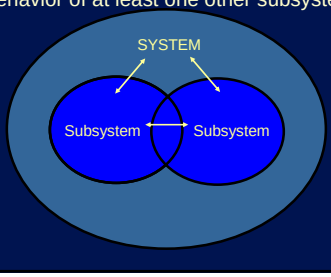
- A system is a whole that contains two or more parts that satisfy the following conditions:
  No subsystem has an independent effect on the system of which it is a part.



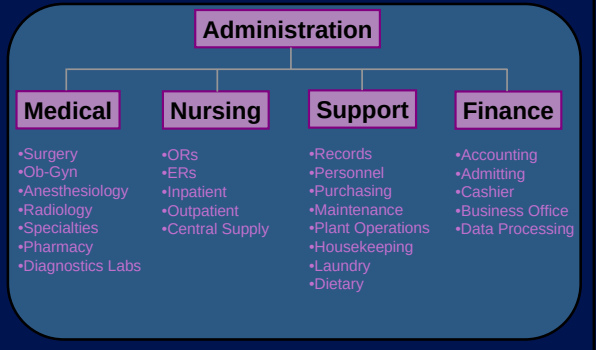
Systems Perspective

(Ackoff, 1994)

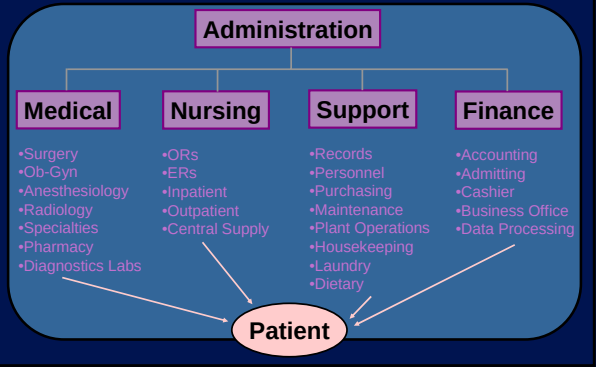
- A system is a whole that contains two or more parts that satisfy the following conditions:
  The effect of any subsystem on the whole system depends on the behavior of at least one other subsystem.



Hospital System



Hospital System



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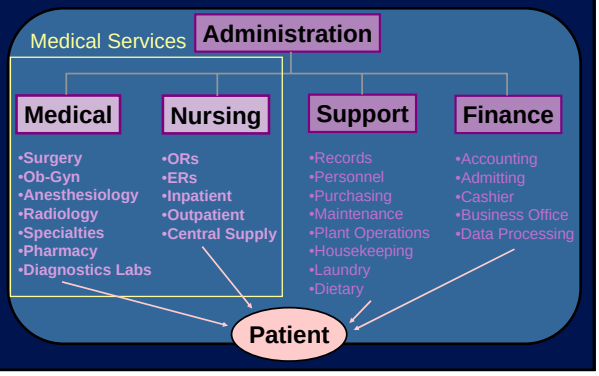
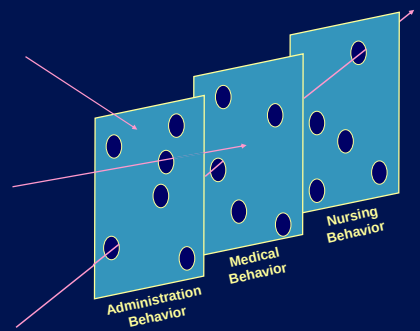


James Reason's (1990) Model



Planes of Unsafe Acts

Medical Services System
(based on Moray, 1994)

PHYSICAL DEVICES

Devices
Casey (1993)

- A patient received a lethal overdose of radiation exposure during treatment for a shoulder tumor.
- The technician entered the wrong exposure level on the radiation therapy device.
- Realizing her error, she attempted to correct her mistake by quickly entering the proper keystroke sequence to cancel the setting. However,…

Devices
Casey (1993)

- The keystrokes were entered faster than the device could accept new information.
- The device displayed a malfunction mode error message but remained at the initial setting level.
- The device delivered a dose 125 times higher than intended, but provided no indication that any radiation had been delivered.

US FDA Manufacturer and User Facility Device Experience Database (1997-2002)
(Al-Tarawneh, Stevens, Arndt, 2004)

- Manufacturer Reported Device-Related Hospital Incidents
  - 2,046 fatalities
  - 40,573 serious injuries

Unsafe Acts - Devices

- Devices can and do fail.
- ALL users rarely receive full training on new devices.
- Devices are rarely evaluated under the conditions in which will be used.

Medical Services System
(based on Moray, 1994)

ERGONOMICS: displays, controls, workplace layout

PHYSICAL DEVICES

Ergonomics
Casey (1993)

- A 4-yr old girl was electrocuted while being monitored with an EKG device.
- The EKG device was well-designed and working properly. However,…

Ergonomics
Casey (1993)

- The 6-pin connector from the EKG leads was compatible with sockets in other nearby devices.
- A nurse mistakenly plugged the connector into an infusion pump causing a lethal shock.

ICU Environment

ICU Environment

ICU Environment

Unsafe Acts - Ergonomics in the ICU
(Donchin, 2004)

- Up to 12 different devices from different vendors for each patient in a unit
- Each device may have both auditory and visual alarms making critical information noisy and difficult to detect and identify
- ICU staff monitors patients more from device output and lab tests than physical inspection – access to the patient is constrained by equipment
- Working conditions are both physically and mentally challenging

Unsafe Acts - Ergonomics in the OR

- Multiple devices from different vendors
- Each device may have both auditory and visual alarms that are difficult to distinguish from one another
- Location of displays are rarely co-located with task activities
- Working conditions can be both physically and mentally challenging

Unsafe Acts - Ergonomics of Laparoscopy

- Factors that force surgeon to adopt suboptimal body postures (Matern, 2004)
  - Monitor locations – force head and neck into uncomfortable positions

Open Procedures

Laparoscopic Procedures

Unsafe Acts - Ergonomics of Laparoscopy

- Factors that force surgeon to adopt suboptimal body postures (Matern, 2004)
  - Monitor locations
  - Instrument design/patient positioning – creates awkward arm positioning for the surgeon leading to increased fatigue, cramping, and pain

Ergonomics of Laparoscopy

Unsafe Acts - Ergonomics of Laparoscopy

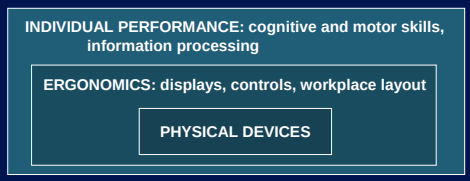
- Factors that force surgeon to adopt suboptimal body postures (Matern, 2004)
  - Monitor locations
  - Instrument design/patient positioning
  - Foot controls – limit space under the table and are a potential hazard if placed on foot stools for short surgeons

Unsafe Acts - Ergonomics of Laparoscopy

- Factors that force surgeon to adopt suboptimal body postures (Matern, 2004)
  - Monitor locations
  - Instrument design/patient positioning
  - Foot controls
  - Height of operating table – almost all OR tables are designed for open procedures and are typically too high for laparoscopic procedures

Medical Services System

(based on Moray, 1994)



Individual Performance

Merry & Smith (2001)

- A patient emerging from general anesthesia bit down on her endotracheal tube and cutting off her air supply and developed cyanosis.
- The anesthesiologist decided to administer the analeptic drug dopram, However,…

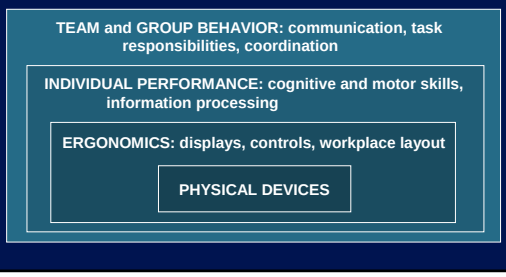
Individual Performance

Merry & Smith (2001)

- He reached into a drawer labeled Dopram, but took out an ampoule of dopamine that had been placed there.
- He injected the full, undiluted contents of the ampoule into the patient.
- The patient went into cardiac arrest. Although she was resuscitated, she suffered irreversible brain damage and died shortly thereafter.

Medical Services System

(based on Moray, 1994)



Team Behavior

Chassin & Becher (2002)

- An elderly woman was being treated for two large cerebral aneurysms.
- She had surgery for one aneurysm and was to be discharged and return later to treat the other aneurysm. However,…

Team Behavior

Chassin & Becher (2002)

- After surgery, she was moved to the hospital's oncology unit.
- The next morning she was taken to a lab for a heart procedure despite her protests and without written orders on her chart.
- The physician in the lab did not confirm the patient's identity or orders.
- A nurse in the lab indicated that no patient by that name was scheduled, but the lab physician insisted he had the right patient and began prepping her for the procedure before the mistaken identity error was caught.

Unsafe Acts – Team Behavior

- Health care providers who work together on patients do not train together. They are educated independently and they function independently.
- Team membership changes monthly, weekly, daily, and even within a procedure.
- There are little or no formal methods of communication among team members.

Medical Services System

(based on Moray, 1994)

Organizational Practices

Wachter & Sojania (2004)

- A 17-yr old woman born with restrictive cardiomyopathy needed a heart-lung transplant.
- After a 10-month wait, donor organs became available. The organs were designated for the 17-yr old patient even though she had not been entered into the UNOS system. The surgeon who harvested the organs was told the donor had blood type A and it was clearly marked on the cooler used for transport. However,…

Organizational Practices

Wachter & Sojania (2004)

- The transplant surgeon placed the donor organs in the patients chest cavity soon after they arrived.
- Five hours later, the immunological lab discovered that the donor organs did not match the patient's blood type O and notified the surgeon.
- Large doses of anti-rejection drugs were administered, but the rejection process began about an hour after surgery.

Medical Services System

(based on Moray, 1994)

Societal Pressures

Wachter & Sojania (2004)

- Two weeks after the surgeon placed the heart and lungs in the recipient without checking the blood type, a second set of donor organs became available. By now, the patient was in a severely weakened state. However,…

Societal Pressures

Wachter & Sojania (2004)

- A second transplant surgery was performed.
- The patient died shortly thereafter.

Cultural Differences

Wachter & Sojania (2004)

- An elderly African-American woman came into the ER with chest pain and was given an EKG.
- The EKG showed an atypical tracing, but not grossly abnormal. Her blood troponin levels were also elevated, but not specific for MI. She had an elevated HR, but other vital signs were normal. Pressure applied to the chest exacerbated her pain, However,…

Cultural Differences

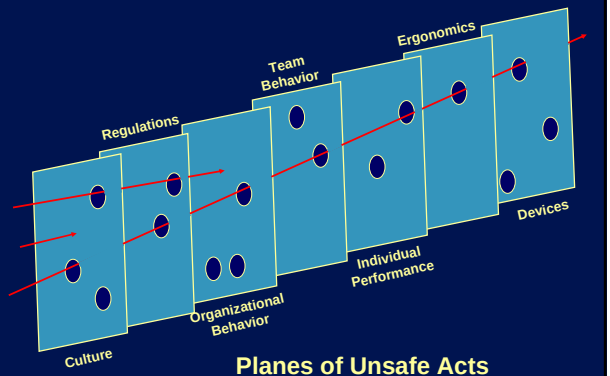
Wachter & Sojania (2004)

- The ER physician concluded that she had costochondritis, prescribed Advil, sent her home, and told her to rest.
- The patient died the next day.

Unsafe Acts – Legal, Societal Pressures, and Cultural Differences

- Adverse events that bring on media scrutiny change policies. Adverse events that go unreported may be considered in M&M settings, but rarely change policy.
- Misunderstandings of cultural differences among patients can lead to inappropriate problem-solving heuristics.
- Liability and reimbursement considerations affect decision-making and actions taken.

James Reason's Model (1990)



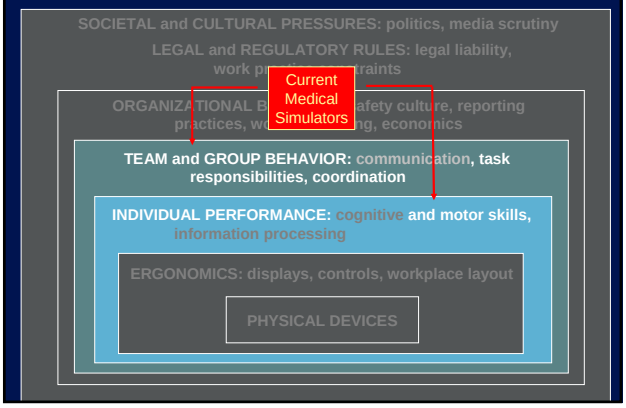
Planes of Unsafe Acts

How do we address all of the sources of errors in the health care system?

Major Types of Medical Simulators

- Mannequins
- Virtual Reality Systems
- Hybrid Systems
- Standardized Patients

Sources of Error in Medical Services System

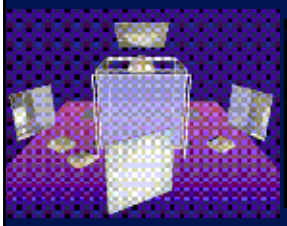


The Virtual Operating Room

The Virtual Operating Room

- allows us *to train the way we operate.*
- allows medical personnel (surgeons, anesthesiologists, nurses, residents, students) to train individually or in teams.
- can integrate all current forms of medical simulators into one coherent educational experience.
- provides a test bed for new medical devices to be evaluated within the appropriate context.
- provides a laboratory to study changes in organizational policies, regulations, and individual/cultural differences in the OR.
- *All without putting a single patient at risk!*

CAVE Immersive Virtual Environment

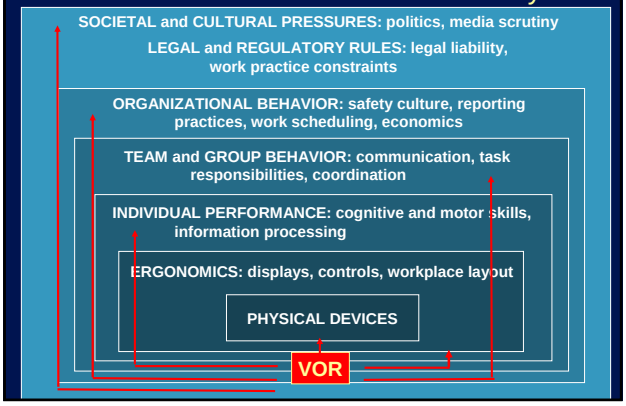


An Examination of Surgical Procedures under Simulated Combat Conditions

(Scerbo, Weireter, Bliss, Schmidt, & Hanner-Bailey, 2005)

The Virtual Operating Room (VOR)

The VOR Provides a Platform to Address all Sources of Error in the Medical Services System



Error Remediation

- Selection
- Training and education
- Assists, job aids, checklists
- Design
  - Eliminate the possibility for error
  - Error tolerant systems
  - Fail-safe systems
  - Minimize consequences of error

The VOR Provides a Platform to Address Each Category of Error Remediation

- *Selection* – identifying those who meet performance criteria
- *Training and education* – providing a holistic approach to training for both individuals and teams
- *Assists, job aids, checklists* – all memory aids can be pilot-tested within the appropriate environment
- *Design* – all approaches to design can be pilot-tested within the appropriate context

The VOR can Support Safety and Human Factors Design Processes

- *Validity Engineering* – a structured, systematic approach to risk reduction
- *Failure Mode and Effects Analysis* – a human factors method for identifying and eliminating known and potential errors/failures in the design process.
- *Reach Envelopes and Workspace Layouts* – measures for optimizing user workspace

Contributing Factors to Errors in the Heath Care System

(Leape & Berwick, 2005)

- Modern health care is more complex than other industries
- Commitment to individual autonomy
- Change avoidance among professionals
- Lack of leadership at hospital or health plan level
- Paucity of robust measures
- Current reimbursement structure pays for services that address injuries from adverse events, but not for new practices that may reduce errors.

Near-term Solutions for Improving Patient Safety

(Leape & Berwick,2005)

- Electronic heath records
- Wide diffusion of safe practices
- Increased team training
- Full disclosure to patients following injury

Near-term Solutions for Improving Patient Safety

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Computerized Physician Order Entry Systems

- Promise to
  - reduce prescription handwriting errors
  - provide quick links to drug interaction warnings
  - be more readily integrated with medical records and decision-support systems
  - save billions in annual costs
- Are supported by preliminary research showing positive benefits
- However,…

An Analysis of Computerized Physician Order Entry Systems

(Koppel, et al. 2005, Nemeth & Cook, 2005)

- A widely used CPOE system was studied within a 750 bed tertiary-care teaching hospital with 39,000 annual discharges
- Results showed that the system actually *facilitated* 22 types of medication error risks including:
  - Using the system to determine low dose, dose ranges, and infrequently used medications
  - Increased uncertainty of patient meds due to multiple-screen displays
  - Increased difficulty specifying meds due to limited flexibility inherent in the system

An Analysis of Computerized Physician Order Entry Systems

(Koppel, et al. 2005, Nemeth & Cook, 2005)

- Some error risks were observed by 50%-90% of house staff and occurred weekly
- House staff often developed work-arounds to avoid problems
- The problem is not human error. Error is a consequence of interaction with technology rather than a cause of adverse outcomes.

New Technology

Be careful what you wish for!

Complex Technological Systems

- Often include far more features than most workers use.
- Rarely conform to each organization's unique methods of operation.
- Can induce complacency.
- Often result in "automation surprises".
- Fail in a less predictable manner.
- Can create problems that propagate more quickly through highly coupled subsystems.

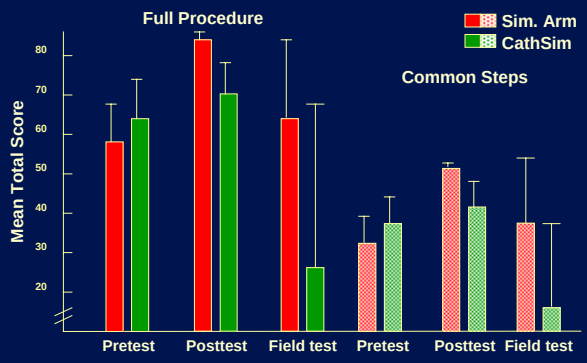
Problems that Lie Ahead

- Medical systems, equipment, and services are becoming more complex.
- Synthesis of health record information-based systems and control devices.
- Procedure-based medical simulators that do not faithfully reproduce critical information.

A Comparison of CathSim™ and Simulated Limbs for Training Phlebotomy

(Scerbo, Bliss, Schmidt, & Thompson, in press)

Phlebotomy Results



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- Procedure-based medical simulators that do not faithfully reproduce critical information.
- Procedure-based medical simulators that do not faithfully reproduce critical information and patient-specific data.

Five System Barriers to Achieving Ultrasafe Health Care

(Amalberti, Auray, Berwick, & Barach, 2005)

- Acceptance of limitations on maximum performance
- Abandonment of professional autonomy in favor of team performance
- Transition from craftsman to equivalent actor
- Need for system-level arbitration to optimize safety strategies
- Need to simplify professional rules and regulations

Thank You!

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