Patient Safety Analysis & Human Factors Engineering: Essential Skills for Residents & Faculty

At Michigan Summit on Quality Improvement & Patient Safety

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Objectives

- Gain an understanding of human factors engineering (HFE) as applied to patient safety
  - Using human factors methods to identify safety hazards
  - Using HFE to design and test patient safety actions (interventions)
  - Emphasis on resident learning and projects
Overview-Agenda

- Basics of Human Factors Engineering
  - Interactive demos
- Usability testing exercises
- Example frontline HFE projects
- Residents and BME students
- HFE and homecare (as example)
Human Factors Model
(covered in detail by Dr Wears)

**Psychomotor**
- Hands
- Feet

**Senses**
- Vision
- Hearing
- Touch
- etc

**Input Devices**
- Buttons
- Foot pedal

**Output**
- Visual display
- Sound
- Vibratory alarm
- etc
Our performance is influenced by:

1) Inherent human traits
2) Design

- Devices, tools, software
- Labels & instructions
- Training & education
- Policy & procedures
- Order forms
- Layout of rooms, floors, entire facilities
- Work environment: lighting, temp, humidity, noise
Performance

1) The influence of human traits…

2) The influence of design …
## Demonstration #2: Stroop Effect

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<th>Row 1</th>
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<td>Green</td>
<td>Yellow</td>
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<tbody>
<tr>
<td>Blue</td>
<td>Yellow</td>
<td>Red</td>
<td>Green</td>
</tr>
</tbody>
</table>
Learned Intuition

- Secretaries learning to use mice (in olden days – 1990s)
- Where did they “naturally” place them?
  - Hint: not on the mouse pad

- Your examples…
Learned Intuition

- Difficult to be a naïve user

- You can’t remember not knowing...
Experiment

- 24 radiologists
  - Examine five CT scans of lungs
  - Task: look for nodules
Results

- Dancing gorilla → 48 times larger than the average nodule

- 83% missed the gorilla!
Inattentional Blindness

- Another human trait affecting design

- “Attention searchlight” is more approachable concept (term)

- What is impact on RCAs, adverse events?
Performance

1) The influence of human traits...

2) The influence of design ...
Design of everyday things...

Which way do you rotate the knob?

- Expectations
- Prior Training
- Conventions & norms
- Implied relationships
- Design of knob
Radar Scope to Detect “Enemy” Ships
Performance Graph (curve)

Performance (accuracy) vs Time (hours)

- 100%
- 90%
- 80%
- 70%

- Data points and error bars indicating performance accuracy over time.
- The graph shows a downward trend, indicating decreasing performance with time.
Good Design / Bad Design?

- Set time & date?
- Set reminder alarms?
- Run a blood test?
- Assemble?
- Check stored results?
- Initiate?
- Change?
- Save?
- Exit?
Like a spoon (on top)?

Like a paint brush (at the end)?
Human Factors Engineering

- Root Cause Analysis (RCA)
- Failure Mode & Effects Analysis (FMEA)

Find root causes
Identify Failure Modes
Usability Testing – Key HFE Method

- Gold standard method for finding design hazards (see details in your packet)
- During development of device or software itself
- Aids purchase decisions
- Developing Training Focusing on Error Prone tasks
- Developing Quick Reference Guides
- Since 2011, required by FDA for all devices
Usability Testing

- Participants who use the device or software
- Realistic setting (simulator or real)
- Realistic tasks and scenario
- Measurements
  - Error rate and type
  - Confusions and close calls
  - Time on task

- PREFERENCE ≠ PERFORMANCE
Usability Testing in the Hospital

Judith Anderson,¹ Julia Wagner,² Mary Bessesen,² and Linda C. Williams³

¹ VA National Center for Patient Safety, Denver, CO
² Denver VAMC
³ VA National Center for Patient Safety, Ann Arbor, MI

Abstract

It is not unusual for hospitals to purchase equipment, devices, and materials based on preferences expressed by staff, based on economics and the best offer, or based on the promise of improvement by a new version. However, routinely subjecting potential purchases to basic usability testing provides valuable information upon which to base the decisions. Responsible manufacturers are interested in knowing of needed improvements to their products. Usability testing will also guide training and implementation. Usability testing is included in an introductory human factors engineering...
Food Anaphylaxis

- Now up to 2-4% all children ("Epidemic")
- Only 20% “outgrow” it
- No cure

**Chronic Illness Plan:**
- Avoidance
- Rescue with epinephrine auto-injector (sometimes twice - biphasic)
Group Exercise

- 6 Volunteers
- I will describe scenario
Fleshing out the Test Plan

- **Discovery steps**
  - interview others familiar with food or bee sting allergy

- **End users**
  - Primary users; their training
  - Secondary users; their training

- **Environment / Context of use**
  - Time pressure

- **Scenario / Task**
  - Time between training and actual use? (days – decades)

- **Performance Measures**

- **Data Capturing**

- 100 doctors at a tertiary pediatric hospital
- **Only 2%** demonstrated all 6 correct steps
- Errors
  - Failure to hold pen in place for > 5 sec (57%)
  - Failure to activate by applying pressure (21%)
  - Self–injection into thumb (16%)
What we did not simulate…Where does the Epipen come from?
HFE Redesign = Key

- An Emergency Action Plan form
- Defibrillator
- Pediatric patient room
“Emergency Action Plan”
Read this in an emergency!

- Flushing, swelling
- Wheezing, SOB, cough
- Headache
- Nausea, vomiting
- Sense of doom

**WHAT TO DO**
1. Inject EpiPen
   Time Given __________
2. CALL 9-1-1
   Report anaphylactic reaction to______

**ANAPHYLAXIS**
**SYMPTOMS: WHAT TO LOOK FOR**
An anaphylactic reaction can occur at any time from a few seconds to a few hours after exposure to the allergen. Raised rashes—often the first to occur—may be accompanied by swelling of the eyes, nose, or throat. Benadryl may be of use and is not harmful. Symptoms that signal the onset of an extreme allergic reaction include:
- Flushing, swelling of the tissues of lips, throat, tongue, and hard palate
- Wheezing, shortness of breath, hoarseness
- Headache
- Nausea, vomiting, and feeling of impending doom

**WHAT TO DO**
1. Inject EpiPen
   Time Given __________
2. CALL 9-1-1
   Report anaphylactic reaction to______

**Design of this form influences performance, too!**
Use “First Aid” for Signs & Forms

- See handout
- One page
- Organized to mirror real live work practice
- Look like what it’s supposed to look like
- White Space, color highlight, bolding
First Aid for Forms

**Length and Format**

1. One page!
2. Make it look like a form or checklist (NOT like legalese, “nice to know”, or background)
3. Logical **grouping** of ideas or actions
4. Flow of document **matches work flow**

**Warnings**

- White space is the “supreme ruler” of visual attention
- Also use graphics, highlighting, and borders

**Warning**: Follow this Warning Guidance!

**Key Information**

- White space is the “supreme ruler” of visual attention
- Overview and major steps should be most conspicuous
  - Use of Border
  - Add Highlighting
  - Understandable and simple graphics

**Graphics**

- Sketches are generally better than photos
- Test them early and often – they are easily misunderstood
- Cartoon balloons are suggestive of completion of action
Redesign with the following functions:
- On/Off
- Set Energy (Joules)
- Charge
- Shock
- Choose between Defib and Pacing
Nurse with medications. Finds counter and sink area full. Places on tray table

Parents change diapers (x3) and place on floor next to tray table. Must keep track of urine output – later, diapers placed in bathroom

Nurse assistant with hands full of towels and new diapers, goes to wash hands but nowhere to set down stuff. Sets them down on tray table. Goes to bathroom to remove dirty diapers. Finds none, returns to table to unpack and stow diapers

Physician brings in chart, sets on tray table while talking to parents, sets it on crib sheets while examining child, sits down on bed to chat further
HFE

- HFE examples – beyond devices
  - Staplers

- Practical application of usability testing
  - Order Set
  - Code Cart Drawer
HFE and Internal Surgical Staplers

Design could be improved

1) Inadvertently closed upon a metal clip
   - These clips can be everywhere, and are hard to see

2) “Did I only Clamp it?” or “Clamp and staple it?”
   - Because I’m Cutting next!
Surgical Stapler “Primer”

1) Open up “jaws”

2) Compress Handle
   (now it’s clamped)

3) RE-Open

4) RE-compress Handle (now it’s stapled)
Re-design CHF order set

- Emergency Medicine Department
  - Advocate Christ Center, Oak Lawn, IL
  - Previous attempts with “standard” change management had failed…

- Applied human factors engineering principles

- Before and after study
  - 87 CHF patients before new order sets, 84 patients after
  - 60 emergency medicine attendings and residents
New HFE Design Features (in comparison)

- One page
- Separate medications into groupings
- Highlighted headings
- Check boxes (not parentheses)
- Vertically aligned boxes
Impact of HFE-Designed Order Set

<table>
<thead>
<tr>
<th>Timing</th>
<th>% Physicians Using CHF order set</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-15 months PRIOR</td>
<td>9%</td>
</tr>
<tr>
<td>7 Months AFTER</td>
<td>60%</td>
</tr>
<tr>
<td>13 Months AFTER</td>
<td>72%</td>
</tr>
</tbody>
</table>

Baseline Drawer for Code Cart
Nurses’ task: remove 10 items
Range = 2:43-3:58 min, Avg=3:07 min
Code Cart Drawer Fifth Version
Range = :55-1:25 min, Avg=1:08
Example In-Hospital HFE Projects

- Personal protective equipment (PPE)
- Exam Table
Personal protective equipment (PPE)

- Family vs infrequent clinicians vs frequent
- Work station layout and labeling
- Signage
- Discard
Exam Table Cause & Effect Diagram

Patient falls off table, sustains injury

- It is hard to stay on the table
- No hand rails
- Design, doctors need access to patient for exam
- Gown promotes ease of exam
- Patient cannot step backwards to sit on table in one motion
- Patient has a medical condition or balance trouble
- Table is at fixed height
- Doctors need appropriate height for exam
- Design to house stirrups, drawers

- It is difficult to get on the table
  - Pt must wear gown, limits ROM uncomfortable
  - Patient must use small step as pivot point
  - Table is too high to ascend without a step
  - Table is at fixed height
  - Compact storage, ease of walking around table

- Patient is unsteady or weak
  - Patient has med condition (joint, neuro, vision)
  - Paper surface is slippery
  - Step is small so it can slide into table for storage
  - Paper easy to remove, clean table
  - Staff unaware of patient's needs
  - Did not ask
  - New diagnosis

- There was no assistance
  - Patient told to get on table without help
  - Nurse or doctor busy or not in room
  - Washing hands, at computer, otherwise occupied
  - Forgot, not in habit of asking
(Int Med Resident): “This patient is not breathing and heart has stopped. Push the button for help”

(Non-clinician BME Student): “Okay, I will push this button...”
HFE Projects by Chief Residents in Quality and Safety in VA System (~60 each year)

- Minneapolis VA Medical CR
  - Design flaws in CVC and paracentesis kits
  - Redesign and usability testing
  - Impacted new design and procurement

- Pittsburgh VA
  - Usability testing of select devices to guide procurement
  - Lead by former VA Safety Fellow
Medical Device Sandbox Project

- Identify use errors and design flaws of medical devices
- Gain ability to re-design devices to address design flaws
- Stimulate creative, collaborative design skills
- Enhance understanding of clinical perspective of device use
- Participate in interprofessional learning
- Understand use of medical devices by various clinicians and patients
Desired Outcomes

- BME Student Design Projects: incorporate usability testing and clinical context
- Resident Patient Safety Projects: include simulation and redesign
- Medical Students: As above; and pursue safety as “minor”
Team and Support

- John Gosbee (Internal Medicine Dept)
- Jan Stegemann, Rachael Schmedlen (BME Dept)
- Jennifer Lee (BME student – 2017; MHEAL)
- Stephanie Kusano (UM CRLT)

- Letters of Support – Raj Mangrulkar (UMMS), John Del Valle (IM)

- UM 3rd Century Initiative (Quick Wins Grant, 2015-6)

- NIH – NIBIB Grant
Overview

- 28 Sessions (Sept 2015 – March 2017)
- 60 medical students
- 16 nursing and MPH students
- 45 internal medicine residents (some twice)
- 120 BME students
MDS Exercises

- AED
- Exam Table
- Epinephrine autoinjector
- Paramedic Bag
- Medication organizer
- Guides for resuscitation (Broselow, AHA)
- Pulse oximeter
- Medical Suction
- IV, feeding, and other catheters
Project Specific Exercises

- Resident safety projects
  - EKG machine prototypes
  - Paracentesis kit
  - Code button on headwall of hospital room
  - Tele-ophthalmoscope

- BME design projects
  - Liver Biopsy prototype (BME 451)
  - Catheter removal strain gauge (BME 450)
  - Bladder catheter with electrodes (BME 451)
Settings

- Clinical Experiential Learning and Assessment Center (Taubman Library)
  - Large Exam room & Classroom
- Clinical Simulation Center (Towsley)
- Lurie Biomedical Engineering Bldg Project Room
- Nursing Simulation Center (UM Nursing School)
AED Usability Test
AED Redesign
Procedure Tray – Simulation with physician doing procedures infrequently
Home Care Challenges

- Readmission of patients with chronic dz
- Hospital-centered or Clinician-centered
- “We” rarely go into the home
Chronic Disease Management:
Improving Continuity of Care with Human Factors Engineering

Laura Lin Gosbee
Red Forest Consulting, LLC

The management of chronic disease by patients in the home care setting can involve a varied and complex set of tasks. Food allergy, a chronic and potentially life-threatening condition, is used as a case study to explore the role that human factors engineering can play to improve the continuity of care of patients. In order to gain insight into the cognitive demands involved in the management of this chronic disease, cognitive task analysis was conducted to identify and characterize the critical decision making tasks confronting food allergy patients. This can provide valuable input to the design and development of tools and resources for use by the clinical practitioner and patient alike. Such tools can assist the clinical
Wake up

Weigh self
Check for swelling
Other vitals
Write down

Extra diuretic

Take meds

Drink coffee
Prepare meal

Go out for day

Take meds
Go to sleep
Bathroom
Sleep
Wake

Caregiver

Univ Wisconsin Homecare of CHF and HFE
Diabetes Home Care Struggles

One more day...

You thought iPod headphones were a nightmare to untangle?

Type 1 Diabetes Memes

Photo submitted by Angelica Jacobs
Today I'll explain the biggest current pain in my neck...the JP drains. These drains are a necessary evil, because they carry the post-op fluids out of my body. If the drain is pulled too early, it could cause a seroma...I now feel that I've typed enough that the squeamish folks could have clicked away without accidentally seeing anything...

This last step is to make sure there are no clogs. It's difficult to strip it without pulling, and pulling HURTS. I'm learning to pinch with one hand and use the other hand to strip the hose. Whatever.

[Life and Stuff Blog – accessed Sept 2014]
<table>
<thead>
<tr>
<th><strong>Neurontin</strong></th>
<th>2 Pills</th>
<th><strong>7-8AM</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advil</strong></td>
<td>1-2 Pills</td>
<td><strong>7-8AM</strong></td>
</tr>
<tr>
<td><strong>Eat Breakfast</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Decadron</strong></td>
<td>2mg pill</td>
<td><strong>With food</strong></td>
</tr>
<tr>
<td><strong>Capecitabine</strong></td>
<td>3 pills</td>
<td><strong>With food</strong></td>
</tr>
<tr>
<td><strong>Set Timer for 1 hour</strong></td>
<td></td>
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<tr>
<td><strong>Lapatnib</strong></td>
<td>2 pills</td>
<td></td>
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<tr>
<td><strong>Set Timer for 1 hour</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Eat Lunch</strong></td>
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<tr>
<td><strong>Eat Dinner</strong></td>
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<tr>
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<tr>
<td><strong>Neurontin</strong></td>
<td>2 pills</td>
<td><strong>Midnight</strong></td>
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Discharge Instructions
(illegible or phone books)
Parent of Colleague had Lots of Admits

- Recently hemi-paretic from stroke
- CHF and hypertension
- Lived alone and wanted to be left alone
Why the all the ED and hospital admits?

- They went to his home and WATCHED
- Filling and dispensing from his pill organizer
- Ooops…
  - One-handed filling and refilling tough to do
  - Dispensing one-handed caused spill over into next day
Academia

- University of Wisconsin
  - Series of courses for masters in HFE and patient safety
  - One Week HFE and Patient Safety workshop every August
    - [http://www.engr.wisc.edu/ie/](http://www.engr.wisc.edu/ie/)

- Georgetown University
  - New, large center devoted to human factors engineering
  - Terry Fairbanks, MD = Center Director
    - [http://medicalhumanfactors.net/](http://medicalhumanfactors.net/)
HFE Books and Articles


HFE Web Resources

- FDA Web Site and Publications (free and good!)
  - http://www.fda.gov/cdrh/humanfactors/
  - Human Factors Engineering and Medical Devices ("Do It By Design" & "Device Use Safety")

- Red Forest Consulting

HFE and Home Care Publications


Rogers, WA, Mykityshyn AL, Campbell RH. Analysis of a “simple” medical device. *Ergonomics in Design*. Winter 2001; 6-14
Thank you!

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www.RedForestConsulting.com