Lecture 13

Ergonomics and Human Factors for Interaction Techniques

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05-899A/05-499A

Spring, 2014

Source: Maltron
User Modeling

Source: CMU
User Modeling

Even if we can’t perfectly simulate the human brain, we can approximate it with theories that match what we observe, and model how it behaves. If we do it well, then the models will match experiments.
Keystroke Level Models

- Very, very low level
- Task-centered
- Provides timing data
- Find places to optimize
- Potential error cases

Source: nap.edu
Keystroke Level Models

• Make an ordered list of actions
  – Keys you press
  – Clicking the mouse
  – Scrolling, moving the mouse
  – User physical movements
  – User consideration, judgment, or thinking
  – System responses (does the user have to wait?)

• Assign and add up execution times for all the items in the list
## Keystroke Level Models

<table>
<thead>
<tr>
<th>Description</th>
<th>Operation</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach for mouse</td>
<td>H[mouse]</td>
<td>0.40</td>
</tr>
<tr>
<td>Move pointer to &quot;Replace&quot; button</td>
<td>P[menu item]</td>
<td>1.10</td>
</tr>
<tr>
<td>Click on &quot;Replace&quot; command</td>
<td>K[mouse]</td>
<td>0.20</td>
</tr>
<tr>
<td>Home on keyboard</td>
<td>H[keyboard]</td>
<td>0.40</td>
</tr>
<tr>
<td>Specify word to be replaced</td>
<td>M4K[word]</td>
<td>2.15</td>
</tr>
<tr>
<td>Reach for mouse</td>
<td>H[mouse]</td>
<td>0.40</td>
</tr>
<tr>
<td>Point to correct field</td>
<td>P[field]</td>
<td>1.10</td>
</tr>
<tr>
<td>Click on field</td>
<td>K[mouse]</td>
<td>0.20</td>
</tr>
<tr>
<td>Home on keyboard</td>
<td>H[keyboard]</td>
<td>0.40</td>
</tr>
<tr>
<td>Type new word</td>
<td>M4K[word]</td>
<td>2.15</td>
</tr>
<tr>
<td>Reach for mouse</td>
<td>H[mouse]</td>
<td>0.40</td>
</tr>
<tr>
<td>Move pointer on Replace-all</td>
<td>P[replace-all]</td>
<td>1.10</td>
</tr>
<tr>
<td>Click on field</td>
<td>K[mouse]</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>10.2</strong></td>
</tr>
</tbody>
</table>

Source: [Hochstein](https://example.com/hochstein)
Keystroke Level Models

• Different kinds of users?
• More than timing data?
• Complex tasks?
• Incorporating subtasks?
Check it out: Rzeszotarski & Kittur, 2012
GOMS

- High level
- More detailed than KLM
- Describe your tasks, (users), and interface elements
- Generate measurements
GOMS

• Judge interface performance without user testing or experiments
• Compare designs / prototypes
• Study different user profiles
• Generate tutorials or resources
• (Evaluate learning and cognition)
GOMS...

GOALS

something the user tries to do
verb/noun e.g. delete word.

METHODS

accomplished by...

SELECTED RULES

if... then use...

* Basic actions
move hand to mouse

OPERATORS

actions the user executes
eg. move left cursor (goal)
presseye (operator)

Source: beheconomics.blogspot
GOAL: MOVE-TEXT
.  GOAL: CUT-TEXT
   .  GOAL: HIGHLIGHT-TEXT
      .  [select**]: GOAL: HIGHLIGHT-WORD
      .  MOVE-CURSOR-TO-WORD
      .  DOUBLE-CLICK-MOUSE-BUTTON
      .  VERIFY-HIGHLIGHT
      .  GOAL: HIGHLIGHT-ARBITRARY-TEXT
      .  MOVE-CURSOR-TO-BEGINNING  1.10
      .  CLICK-MOUSE-BUTTON  0.20
      .  MOVE-CURSOR-TO-END  1.10
      .  SHIFT-CLICK-MOUSE-BUTTON  0.48
      .  VERIFY-HIGHLIGHT]  1.35
     GOAL: ISSUE-CUT-COMMAND
     .  MOVE-CURSOR-TO-EDIT-MENU  1.10
     .  PRESS-MOUSE-BUTTON  0.10
     .  MOVE-CURSOR-TO-CUT-ITEM  1.10
     .  VERIFY-HIGHLIGHT  1.35
     .  RELEASE-MOUSE-BUTTON  0.10
   GOAL: PASTE-TEXT
   .  GOAL: POSITION-CURSOR-AT-INSERTION-POINT
      .  MOVE-CURSOR-TO-INSERTION-POINT  1.10
      .  CLICK-MOUSE-BUTTON  0.20
      .  VERIFY-POSITION  1.35
     GOAL: ISSUE-PASTE-COMMAND
     .  MOVE-CURSOR-TO-EDIT-MENU  1.10
     .  PRESS-MOUSE-BUTTON  0.10
     .  MOVE-MOUSE-TO-PASTE-ITEM  1.10
     .  VERIFY-HIGHLIGHT  1.35
     .  RELEASE-MOUSE-BUTTON  0.10

TOTAL TIME PREDICTED (SEC)  14.38

Source: Hochstein
GOMS

• vs User Studies
  – Sometimes faster, sometimes slower
  – More detailed feedback

• Requires a goal
  – What about browsing?

• Doesn’t evaluate design, human factors, social, or organizational impact
Other Task Analyses

plan 0
1 make tea
   do 1
   at the same time, if pot is full, do 2
   3–4–5
   after four or five minutes do 6

1. boil water
2. empty pot
3. put tea in pot
4. pour water
5. wait
6. pour tea

plan 1
1.1–1.2–1.3–1.4
   when kettle boils 1.5

1.1. fill kettle
1.2. light stove
1.3. put kettle on stove
1.4. wait
1.5. turn off gas

Source: Blustein
Human Factors & Ergonomics

Human factors is concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.
Human Factors

• Investigations of disasters / accidents
  – see Air Crash Investigation series for a demo of this process, or this Therac 25 report

• Understanding where errors may happen

• Designing new products or systems

• Physiological, cognitive, behavioral, social, organizational, cultural, etc.
Human Factors

An Introduction to Human Factors Engineering

The Design of Everyday Things

Don Norman
Time and Motion Studies
Time and Motion Studies

• Taylor, Gilbreth, Ford
• Improve worker performance through scientific practice – Scientific Management
• Observe experts, figure out why they perform well, make others like them

• Worker rights
• Injury and other human factors
Time and Motion Studies

Check out this instructional General Motors video from 1946 here

(pardon the dated, 40s depictions of gender, home, and society)
Anthropometry

45 Hand breadth. The breadth of the hand, measured across the ends of the metacarpal bones (metacarpal-phalangeal joints).

<table>
<thead>
<tr>
<th>Sample</th>
<th>1st</th>
<th>5th</th>
<th>Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm</td>
<td>(in)</td>
<td>1st</td>
</tr>
<tr>
<td>A Men</td>
<td>8.1</td>
<td>(3.2)</td>
<td>8.4</td>
</tr>
<tr>
<td>B Women</td>
<td>7.1</td>
<td>(2.8)</td>
<td>7.3</td>
</tr>
</tbody>
</table>

46 Hand length. The distance from the base of the hand at the wrist crease to the tip of the middle finger.

<table>
<thead>
<tr>
<th>Sample</th>
<th>1st</th>
<th>5th</th>
<th>Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm</td>
<td>(in)</td>
<td>1st</td>
</tr>
<tr>
<td>A Men</td>
<td>17.3</td>
<td>(6.8)</td>
<td>17.9</td>
</tr>
<tr>
<td>B Women</td>
<td>15.9</td>
<td>(6.3)</td>
<td>16.5</td>
</tr>
</tbody>
</table>

47 Hand circumference. The circumference of the hand, measured around the knuckles (metacarpal-phalangeal joints).

<table>
<thead>
<tr>
<th>Sample</th>
<th>1st</th>
<th>5th</th>
<th>Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cm</td>
<td>(in)</td>
<td>1st</td>
</tr>
<tr>
<td>A Men</td>
<td>19.2</td>
<td>(7.6)</td>
<td>19.9</td>
</tr>
<tr>
<td>B Women</td>
<td>16.7</td>
<td>(6.6)</td>
<td>17.3</td>
</tr>
</tbody>
</table>
Anthropometry

• Measure populations to understand human body’s structure
• Drive design to incorporate measurement and compatibility with variety of bodies

• Is there such a thing as an ‘average’ person in a population?
• Airplane seats vs. changing populations
Anthropometry

Dimensions:
- 2.72" / 69.1mm
- 5.20" / 132.1mm
Physical Factors

INCORRECT

CORRECT
“Ergonomics”

• Work-related injuries
  – OSHA

• Musculoskeletal injuries
  – Repetitive strain injuries
  – Vibration injuries
  – Fractures, sprains, and breaks

• Vision, hearing, or cognitive impairment

• Accidents
Human Decision Making

• Delayed gratification
  – Bias towards immediate gains

• Framing - cost vs. gain
  – Losses ‘worse’ than equal gains
Computer Posture

• Seating position
  – Erect posture
  – Back supported
  – Feet flat on ground
  – Eyes forward
  – 90 degree elbow
  – Wrist straightened
  – Adjustable chair
  – ’60 on, 15 off’
As physical or virtual interface designers, we must be proactive in preventing injuries.
RSI

• Repetitive strain injuries

• Repetition of many physical actions over time, performed in an unsafe manner
  – Muscles in tension or nerves compressed

• No sudden onset – may take 5 years
• Permanent, irreversible damage
RSI
Pointing Device Injuries
Pointing Device Injuries
Pointing Device Injuries
Pointing Device Injuries

VS
“Gorilla arm” Syndrome
Text Entry Injuries
Text Entry Injuries
“Blackberry thumb” RSI
Strain from Interactions
Strain from Interactions
Strain from Interactions

Figure 1: The word “finished” written on a circular, word-level soft keyboard.
Other Physical Issues

• Displays
  – Eye focus problems
  – Lighting vs. environment – flashing vision
    • “Watch in a well-lit room” warnings

• Noise – can’t close your ears
  – Deafness in Inuit hunters
Cognitive / Behavioral Factors
Top-down vs. Bottom-up Processing

THE CAT
Expectation Matching
DANS, KÖN OCH JAGPROJEKT

På jakt efter ungdomars kroppsspråk och den "synkretiska dansen", en sammanvävning av olika kulturers dans, har jag i mitt fältarbete under hösten rört mig på olika arenor inom skolans värld. Nordiska, afrikanska, syd- och östeuropeiska ungdomar gör sina röster hörda genom sång, musik, skrik, skratt och gestalter känslor och uttryck med hjälp av kroppsspråk och dans.

Den individuella estetiken framträdde i kläder, frisyrer och symboliska tecken som förstärker ungdomarnas "jagprojekt" där också den egna stilen i kroppsrörelserna spelar en betydande roll i identitetsprövningen. Upphållsrummet fungerar som offentlig arena där ungdomarna spelar upp sina performanceliknande kroppsspråk...
Eye Movements

• Eye does not make smooth movements
  – *Saccades* – jumps from region to region

• Area of attention is not necessarily the precise center of eye focus

• Often a top-down process
Eye Tracking

1. Free examination.
2. Estimate material circumstances of the family.
3. Give the ages of the people.
4. Surmise what the family had been doing before the arrival of the unexpected visitor.
5. Remember the clothes worn by the people.
6. Remember positions of people and objects in the room.
7. Estimate how long the visitor had been away from the family.

3 min. recordings of the same subject.
Eye Tracking

• Why might eye tracking be hard to use as a pointing device?

• What about scrolling using eye tracking?
  – “Midas problem”
Visual Noise

- Visual system breaks down when there is too much clutter
Visual Noise

• Visual system breaks down when there is too much clutter

• But it is very good at finding patterns
  – Contrast differences
  – Shape boundaries
Visual Noise

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Visual Noise

• Visual system breaks down when there is too much clutter

• But it is very good at finding patterns
  – Contrast differences
  – Shape boundaries
Searching vs. Browsing

• Visual search much, much faster

Find “Paste”

vs.

Is there a way to delete all selected text?
Gestalt Theory

- Stimuli are encoded in their simplest form
Icons

• We can process images as/more rapidly than text
• Have to know what icon means
• Browsing goes faster if icons well designed
Window Overlap

Gestalt Processing

- Stimuli are encoded
Mobile Parallax

• See video here
Fisheye Menus

• We perceive larger things as more salient
Feedback

• Actions in the physical world have immediate feedback
• What about digital actions?
  • Airplane throttle lag – accidents!
  • Vibration on tap on smartphones
  • Flashes in Windows and OSX
Feedback – Interface Latency

• Time delay in response or feedback for interface action
• Users may not realize that latency is the problem
Memory

Working Memory

Procedural Memory

Declarative Memory
Working Memory

- **4-7** units of information

- **Chunking** – we ‘package’ information rather than store as-is
Working Memory

NCIFBSRSIASIAIAIAIAIAIAIAIAIAIAIAI
Working Memory
Working Memory

C I A  N S A  I R S  F B I  U S A
Working Memory
Working Memory

Did you store those differently?
Working Memory

• Experts chunk information differently
  – Chess masters can look more moves ahead because they store more efficiently
  – Memory experts use advanced chunking techniques to memorize hundreds of digits

• Check out these articles
Working Memory

• You can help users chunk information in interfaces

• (412) 286-2000
• Menu hierarchies
• Other examples?
Working Memory - Menus

• Norton suggests we use ‘broad’ menus rather than ‘deep’ ones. Why?

• How do you think we store what we’ve put into a clipboard?
Procedural Memory

• How to accomplish a task
• Subconscious

• Experienced driving, touch-typing, using keyboard accelerators
Procedural Memory

• Acquired during expertise development
• Process called “automatization”
• Automatized tasks don’t require much attention to perform

• Can *interfere* if tasks are similar
  – Switching from QWERTY to Dvorak
Interference

Scroll direction: natural
Content tracks finger movement

Zoom in or out
Pinch with two fingers

Smart zoom
Double-tap with two fingers

Rotate
Rotate with two fingers

Set Up Bluetooth Trackpad...
Attention

• Finite pool of *attention resources*
• Multitasking divides the pool

• *Overload* - Insufficient resources cause mistakes or poor performance
Attention

• Finite pool of attention resources
• Multitasking divides the pool

• Overload - Insufficient resources cause mistakes or poor performance
Attention

• What tasks do you have to balance here, assuming you aren’t an expert?
Attention

- Design to help both novice and ‘automatized’ users at once
- **Discoverability**
Case Study – Modal Interfaces

- Are there human factors reasons for why modal interfaces aren’t as common now?
ACBGEN. Application control block generation.

ACB name. (1) The name of an ACB macroinstruction. (2) A name specified e
Contrast with network name.

ACC. (1) Accumulate. (2) Accumulator. (3) Application control code.

acceleration time. That part of access time required to bring an auxiliary storage
accelerator. (1) In the AIXwindows program, a keyboard alternative to a mouse
the same way that a mouse button action does. Accelerators typically provide in
combination of keys that invokes an application-defined function.

********** Next

accept. (1) In a VTAM application program, to establish a session with a logica
request may begin when a terminal user logs on, a VTAM application program
moves distributed code and MVS-type programs to the distribution libraries.

• **What human factors principles do the two scrolling tasks use?**

• **What guidelines/principles does the testing software violation?**
Case Study – Laptops

• Does anyone have a laptop that has egregious human factors problems?
Case Study: Therac 25
# Case Study: Therac 25

<table>
<thead>
<tr>
<th>Field</th>
<th>Actual</th>
<th>Prescribed</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Name</td>
<td>TEST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment Mode</td>
<td>FIX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam Type</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy (MeV)</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit Rate/Minute</td>
<td>0</td>
<td>200</td>
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<tr>
<td>Monitor Units</td>
<td>50</td>
<td>200</td>
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</tr>
<tr>
<td>Time (Min)</td>
<td>0.27</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Gantry Rotation (Deg)</td>
<td>0.0</td>
<td>0</td>
<td>VERIFIED</td>
</tr>
<tr>
<td>Collimator Rotation (Deg)</td>
<td>359.2</td>
<td>359</td>
<td>VERIFIED</td>
</tr>
<tr>
<td>Collimator X (CM)</td>
<td>14.2</td>
<td>14.3</td>
<td>VERIFIED</td>
</tr>
<tr>
<td>Collimator Y (CM)</td>
<td>27.2</td>
<td>27.3</td>
<td>VERIFIED</td>
</tr>
<tr>
<td>Wedge Number</td>
<td>1</td>
<td>1</td>
<td>VERIFIED</td>
</tr>
<tr>
<td>Accessory Number</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Date</td>
<td>84-OCT-26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>12:55:8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Oper. Mode</td>
<td>TREAT</td>
<td>TREAT PAUSE</td>
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<tr>
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<tr>
<td>Reason</td>
<td>OPERATOR</td>
<td></td>
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<tr>
<td>Command</td>
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