CSE 440: Introduction to HCI
User Interface Design, Prototyping, and Evaluation

Lecture 08:
Human Performance

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David Wang
Elisabeth Chin
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Tuesday / Thursday
10:30 to 11:50
Some Reminders

Task Analysis Critique Tomorrow
  Do tasks reveal insight into underlying problem
  Do tasks expose an interesting design space

Keep your design options open

Our critique is not “the answer”
  We cannot pave a path to insight

Reading 2 Due Tomorrow Night
These are Examples of What?

Popsicle-stick bridge

\[ x = x_0 + v_0 t + \frac{1}{2} a t^2 \]

ACT-R

Goffman’s Negotiated Approach

Norman’s Execution-Evaluation Cycle
Models

We have said models describe phenomena, isolating components and allowing a closer look.

Today is a closer look at modeling humans.

- **Capture essential pieces**
  - Model should have what it needs but no more
  - Thus avoid underfitting or overfitting model

- **Allow us to measure**
  - Collect data, put in model, compare model terms

- **Allow us to predict**
  - The better the model, the better the predictions
Definition of Interaction?

Two-Way

  one-way is a reaction

Communicative

  information is sent

Receptive

  information is received

Effective

  the parties are changed as a result
Definition of Interaction?

Knocking over a chair
Clicking a Submit button on a web page
Two televisions, turned on, facing each other
A computer sending data to another via a network
Typing on a computer that is turned off
Picking up a telephone and putting it to your ear
Typing ESC on a screen that does not allow it
Models of Interaction

Models of interaction allow a closer look

- Define and describe an interaction
- Isolate areas where problems occur
- Design new interaction

Two examples at different scales

- Norman’s Execution-Evaluation Cycle
- Buxton’s 3-State Model
Models of Interaction

Models of interaction allow a closer look

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- Isolate areas where problems occur
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Two examples at different scales

- Norman’s Execution-Evaluation Cycle
- Buxton’s 3-State Model

“All models are wrong, but some are useful”

George Box
Norman’s Execution-Evaluation Cycle

Gulf of Execution
- Goals
  - Evaluate Goals
  - Form Intention
    - Develop Action Plan
      - Execute Actions

Gulf of Evaluation
- Observe State
  - Interpret State
- System Change
Buxton’s 3-State Model

Mouse

- State 1
  - Button up
  - Tracking
  - Out of Range

- State 2
  - Button Down
  - Dragging

Touchpad

- State 0
  - Release
  - Touch
  - Out of Range

- State 1
  - Tracking

Stylus

- State 0
  - Stylus Lift
  - Stylus On
  - Out of Range

- State 1
  - Tip Switch Open

- State 2
  - Tip Switch Close
  - Tracking
  - Dragging

Touch Screen

- State 0
  - Release Contact

- State 1
  - Contact

- State 2
  - Selection
  - Passive Tracking
Buxton’s 3-State Model

Mouse

Touchpad

Stylus

Touch Screen

Which can support tooltip previews?
Creating a Model

How would you go about creating a model?
Creating a Model

How would you go about creating a model?

One approach:

Observe, Collect Data, Find Patterns, Draw Analogies, Devise Model, Test Fit to Data, Test Predictions, Revise

Fundamentally an inductive process

From specific observations to broader generalization
Today

Some example models of human performance

Visual System

Model Human Processor

Fitts’s Law

Gestalt Principles

Biological Model

Higher-Level Model

Model by Analogy

Predict Interpretation
Human Visual System

Light passes through lens, focused on retina

Blind Spot?
Blind Spot

Use right eye, look at letters
Blind Spot

Use left eye, look at cross
Visible Spectrum
Retina

Covered with light-sensitive receptors

Rods (120 million)
- Sensitive to broad spectrum of light
- Sensitive to small amounts of light
- Cannot discriminate between colors
- Sense intensity or shades of gray
- Primarily for night vision & perceiving movement

Cones (6 million)
- Used to sense color
Retina

Center of retina has most of the …
Retina

Center of retina has most of the cones

Allows for high acuity of objects focused at center
Retina

Center of retina has most of the cones

  Allows for high acuity of objects focused at center

Edge of retina is dominated by …
Retina

Center of retina has most of the cones
  Allows for high acuity of objects focused at center

Edge of retina is dominated by rods
  Allows detecting motion of threats in periphery
Retina

Center of retina has most of the cones
  Allows for high acuity of objects focused at center

Edge of retina is dominated by rods
  Allows detecting motion of threats in periphery

What does that mean for you?
Retina

Center of retina has most of the cones
  Allows for high acuity of objects focused at center

Edge of retina is dominated by rods
  Allows detecting motion of threats in periphery

What does that mean for you?
  Peripheral movement is easily distracting
Retina

Center of retina has most of the cones
  Allows for high acuity of objects focused at center

Edge of retina is dominated by rods
  Allows detecting motion of threats in periphery

What does that mean for you?
  Peripheral movement is easily distracting
Color Perception via Cones

Photopigments used to sense color

3 types: blue, green, “red” (actually yellow)

Each sensitive to different band of spectrum

Ratio of neural activity stimulation for the three types of gives us a continuous perception of color
Color Sensitivity

[Graph showing the absorption spectra of different types of cones and rods in the eye, with peak sensitivities at different wavelengths: blue cone at 437 nm, rod at 498 nm, green cone at 533 nm, and red cone at 564 nm. The graph includes a range of wavelengths from 400 nm to 700 nm on the x-axis and relative absorbance on the y-axis. The source is Dowling, 1987.]
Distribution of Photopigments

Not distributed evenly

Mainly reds (64%), Very few blues (4%)
Insensitivity to short wavelengths (i.e., blue)

No blue cones in retina center

Fixation on small blue object yields “disappearance”

Lens yellows with age, absorbs short wavelengths
Sensitivity to blue is reduced even further
Color Sensitivity & Image Detection

Most sensitive to center of spectrum

To be perceived as the same, blues and reds must be brighter than greens and yellows

Brightness determined mainly by red and green

\[ Y = 0.3 \text{ Red} + 0.59 \text{ Green} + 0.11 \text{ Blue} \]

Shapes detected by finding edges

We use brightness and color difference

Implication

Blue edges and shapes are hard
Color Sensitivity & Image Detection

Most sensitive to center of spectrum

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Shapes detected by finding edges

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Implication

Blue edges and shapes are hard
Focus

Different wavelengths of light focused at different distances behind eye’s lens

Constant refocusing causes fatigue

Saturated colors (i.e., pure colors) require more focusing than desaturated (i.e., pastels)
Focus

Different wavelengths of light focused at different distances behind eye’s lens

Constant refocusing causes fatigue

Saturated colors (i.e., pure colors) require more focusing than desaturated (i.e., pastels)

This hurts, why?
Color Deficiency

Trouble discriminating colors
  Affects about 9% of population

Two main types
  Different photopigment response most common
    Reduces capability to discern small color differences
  Red-Green deficiency is best known
    Lack of either green or red photopigment, cannot discriminate colors dependent on red and green

Also known as color blindness
Red-Green Deficiency Test
Dual / Redundant Encoding

http://danielsolisblog.blogspot.com/2011_03_01_archive.html
Add/Update Shipping Information

We found an error while verifying your shipping address.
We've marked the problem in red for you.

Update the address book.

Required information is marked in GREEN CAPS.
HELP for questions about shipping.

NICKNAME: MYSELF

firstname: DOUGLAS

last name:

address: 245 SAN JOSE RD

city: LOS GATOS

city: California

state: (International use only)

zip/postal code: 95333

country: Select a country

shipping method: In the U.S.: Standard UPS (2 business days plus)

International: Canada Post (4-10 business days)
Today

Some example models of human performance

Visual System
Model Human Processor
Fitts’s Law
Gestalt Principles

Biological Model
Higher-Level Model
Model by Analogy
Predict Interpretation
The Model Human Processor

Developed by Card, Moran, & Newell (1983)

Based on empirical data
Summarizing human behavior in a manner easy to consume and act upon

Same book that named human computer interaction
The Model Human Processor

Long-term Memory

Working Memory

Visual Image Store

Auditory Image Store

Sensory Buffers

Eyes

Ears

Perceptual Processor

Motor Processor

Cognitive Processor

Fingers, etc.
Basics of Model Human Processor

Sometimes serial, sometimes parallel

  Serial in action and parallel in recognition
  Pressing key in response to light
  Driving, reading signs, hearing all simultaneously

Parameters

  Processors have cycle time, about 100-200ms
  Memories have capacity, decay time, and type
A Working Memory Experiment
BM  CIA  CSE I
Memory

Working memory (also known as short-term)

Small capacity ($7 \pm 2$ “chunks”)
- $6174591765$ vs. $(617) 459-1765$
- IBMCIACSE vs. IBM CIA CSE

Rapid access (~70ms) and decay (~200 ms)
- Pass to LTM after a few seconds of continued storage

Long-term memory

Huge (if not “unlimited”)
- Slower access time (~100 ms) with little decay
Activation Experiment

Volunteer
Activation Experiment

Volunteer

Start saying colors you see in list of words
  When slide comes up, as fast as you can
  There will be three columns of words

Say “done” when finished
  Everyone else time how long it takes
## Activation Experiment

<table>
<thead>
<tr>
<th>word</th>
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<tbody>
<tr>
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</table>
Activation Experiment

Volunteer
<table>
<thead>
<tr>
<th>red</th>
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<th>blue</th>
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<tbody>
<tr>
<td>yellow</td>
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<tr>
<td>red</td>
<td>green</td>
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</tbody>
</table>
Activation Experiment

Do it again

Say “done” when finished
Activation Experiment

Do it again

Say “done” when finished
<table>
<thead>
<tr>
<th>red</th>
<th>red</th>
<th>green</th>
</tr>
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<tbody>
<tr>
<td>blue</td>
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</table>
Model Human Processor Operation

Recognize-Act Cycle of the Cognitive Processor
On each cycle, contents in working memory initiate actions associatively linked in long-term memory
Actions modify the contents of working memory

Discrimination Principle
Retrieval is determined by candidates that exist in memory relative to retrieval cues
Interference created by strongly activated chunks

See also Freudian slips
Perceptual Causality

How soon must the red ball move after cue ball collides with it?
Perceptual Causality

Stimuli that occur within one cycle of the perceptual processor fuse into a single concept

Requirement

If you want to create the perception of causality, then you need to be sufficiently responsive

Caution

Two stimuli intended to be distinct can fuse if the first event appears to cause the other
Today

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</table>
Fitts’s Law (1954)

Models time to acquire targets in aimed movement

- Reaching for a control in a cockpit
- Moving across a dashboard
- Pulling defective items from a conveyor belt
- Clicking on icons using a mouse

Very powerful, widely used

- Holds for many circumstances (e.g., under water)
- Allows for comparison among different experiments
- Used both to measure and to predict
Fitts’s Law (1954)

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James’s use of ’s is correct, but most people say Fitts’ Law
Fitts’s Law (1954)

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https://en.wikipedia.org/wiki/Fitts%27s_law
Reciprocal Point-Select Task

Width

Amplitude
Closed Loop versus Open Loop

What is closed loop motion?

What is open loop motion?
Closed Loop versus Open Loop

What is closed loop motion?
- Rapid aimed movements with feedback correction
- Fitts’s law models this

What is open loop motion?
- Ballistic movements without feedback correction
- Example: Throwing a dart
- See Schmidt’s Law (1979)
Model by Analogy

Analogy to Information Transmission
Shannon and Weaver, 1959
Model by Analogy

Analogy to Information Transmission
Shannon and Weaver, 1959

Your Knowledge
Fitts’s Law

MT = a + b log2(A / W + 1)

What kind of equation does this remind you of?
Fitts’s Law

MT = a + b \log_2(A / W + 1)

What kind of equation does this remind you of?

\[ y = mx + b \]

MT = a + bx, where \( x = \log_2(A / W + 1) \)

\( x \) is called the Index of Difficulty (ID)

As “A” goes up, ID goes up

As “W” goes up, ID goes down
Index of Difficulty (ID)

log2(A / W + 1)

Fitts's Law claims that the time to acquire a target increases linearly with the log of the ratio of the movement distance (A) to target width (W)

Why is it significant that it is a ratio?
Index of Difficulty (ID)

\[ \log_2 \left( \frac{A}{W} + 1 \right) \]

Fitts's Law claims that the time to acquire a target increases linearly with the log of the ratio of the movement distance (A) to target width (W).

Why is it significant that it is a ratio?

Units of A and W don’t matter
Allows comparison across experiments
Index of Difficulty (ID)

\[ \log_2 \left( \frac{A}{W} + 1 \right) \]

Fitts’s Law claims that the time to acquire a target increases linearly with the log of the ratio of the movement distance (A) to target width (W).

ID units typically in “bits”

Because of association with information capacity and somewhat arbitrary use of base-2 logarithm.
Index of Performance (IP)

MT = a + b \log_2(A / W + 1)

b is slope

1/b is called Index of Performance (IP)

If MT is in seconds, IP is in bits/second

Also called “throughput” or “bandwidth”

Consistent with analogy of the interaction as an information channel from human to target
A Fitts’s Law Experiment
Experimental Design and Analysis

Factorial Design
  Experiment with more than one manipulation
Within vs. Between Participant Design
  Statistical power versus potential confounds
Carryover Effects and Counterbalanced Designs

Latin Square Design

https://depts.washington.edu/aimgroup/proj/ps4hci/
“Beating” Fitts’s law

It is the law, right?

\[ MT = a + b \log_2(A / W + 1) \]

So how can we reduce movement time?

Reduce A
Increase W
Fitts’s Law Related Techniques

Put targets closer together

Make targets bigger

Make cursor bigger
   - Area cursors
   - Bubble cursor

Use impenetrable edges
Fitts’s Law Examples

Which will be faster on average?

Pop-up Linear Menu

<table>
<thead>
<tr>
<th>Today</th>
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<tbody>
<tr>
<td>Sunday</td>
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<td>Friday</td>
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<td>Saturday</td>
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Pop-up Pie Menu
Pie Menus in Use

The Sims

Rainbow 6

Maya
Fitts’s Law Examples

Which will be faster on average?

Pop-up Linear Menu

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</table>

Pop-up Pie Menu

What about adaptive menus?
Fitts’s Law in Windowing

Windows 95: Missed by a pixel
Windows XP: Good to the last drop

Macintosh Menu
Fitts’s Law in MS Office 2007

Larger, labeled controls can be clicked more quickly.

Mini toolbar is close to the cursor.

Magic Corner:
Office Button in the upper-left corner.
Bubble Cursor

Grossman and Balakrishnan, 2005
Bubble Cursor with Prefab

Dixon et al, 2012
Zhai et al. (2002) pose stylus keyboard layout as an optimization of all key pairs, weighted by language frequency.

\[ MT = a + b \log_2 \left( \frac{D_{ij}}{W_j} + 1 \right), \]

\[ t = \sum_{i=1}^{27} \sum_{j=1}^{27} \frac{P_{ij}}{IP} \log_2 \left( \frac{D_{ij}}{W_j} + 1 \right), \]
Hooke’s Keyboard

Optimizes a system of springs
Metropolis Keyboard

Random walk minimizing scoring function
Considering Multiple Space Keys

FITALY Keyboard

Textware Solutions

<table>
<thead>
<tr>
<th>Z</th>
<th>V</th>
<th>C</th>
<th>H</th>
<th>W</th>
<th>K</th>
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<td>Q</td>
<td>J</td>
<td>U</td>
<td>M</td>
<td>P</td>
<td>X</td>
</tr>
</tbody>
</table>

OPTI Keyboard

MacKenzie and Zhang 1999

Space 1

Space 2

Space 3

Space 4
Considering Multiple Space Keys

FITALLY Keyboard
Textware Solutions

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<tr>
<th>Z</th>
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</table>

OPTI Keyboard
MacKenzie and Zhang 1999

Correct choice of space key becomes important
Requires planning head to be optimal
ATOMIK Keyboard

Optimized keyboard, adjusted for early letters in upper left and later letters in lower right
Using Motor Ability in Design

- Pointing
- Dragging
- List Selection

Gajos et al. 2007
Interface Generation As Optimization

\[ $(\text{Interface}) = \text{Estimated task completion time} \]
# Manufacturer Interface

## Font Formatting

### Type, Style and Size

<table>
<thead>
<tr>
<th>Font</th>
<th>Style</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arial</td>
<td>Regular</td>
<td>8</td>
</tr>
<tr>
<td>Arial Black</td>
<td>Italic</td>
<td>9</td>
</tr>
<tr>
<td>Comic Sans MS</td>
<td>Bold</td>
<td>10</td>
</tr>
<tr>
<td>Courier New</td>
<td>Bold Italic</td>
<td>11</td>
</tr>
<tr>
<td>Franklin Gothic Medium</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

- **Underline style**: (none)

### Effects

- **Strikethrough**: [ ]
- **Double Strikethrough**: [ ]
- **Superscript**: [ ]
- **Subscript**: [ ]
- **Shadow**: [ ]
- **Outline**: [ ]
- **Small Caps**: [ ]
- **Emboss**: [ ]
- **Engrave**: [ ]
- **All Caps**: [ ]
- **Hidden**: [ ]

## Preview

```
Times New Roman
```

[Ok][Cancel]
Person with Cerebral Palsy
Person with Muscular Dystrophy
Interface Generation As Optimization

In a study with 11 participants with diverse motor impairments:

Consistently faster with generated interfaces (26%)

Fewer errors with generated interfaces (73% fewer)

Strongly preferred generated interfaces
Fitts’s Law Related Techniques

Gravity Fields
  Pointer gets close, gets “sucked in” to target

Sticky Icons
  When within target, pointer “sticks”

Constrained Motion
  Snapping, holding Shift to limit degrees of movement

Target Prediction
  Determine likely target, move it nearer or expand it
Fitts’s Law, Edge Targets, and Touch
Fitts’s Law, Edge Targets, and Touch

Avrahami finds edge targets are actually slower with touch devices, at same physical location.

Are people border cautious?
Today

Some example models of human performance

Visual System
Model Human Processor
Fitts’s Law
Gestalt Principles

Biological Model
Higher-Level Model
Model by Analogy
Predict Interpretation
Gestalt Psychology

Described loosely in the context of this lecture and associated work, not a real definition

Perception is neither bottom-up nor top-down, rather both inform the other as a whole
Gestalt Psychology

You can still see the dog...
Gestalt Psychology

You can still see the dog…
Spinning Wheel

Follow the red dots vs follow the yellow dots
Blind Spot Interpolation

Use right eye, look at letters
Difficult to Reconcile
Proximity

Objects close to each other form a group
Proximity

Using Lies in Research
By Nate Bolt  •  March 8, 2011
While it might be an uncomfortable topic, uncovering the lies behind a product or interface can be one of the most effective ways to turn ailing projects around.
Read More

Considerations for Mobile Design (Part 2): Dimensions
By David Leggett  •  March 1, 2011
In part two of this series, David helps readers adapt their design regimes to the (typically) small screens of mobile devices. Using responsive design, our experiences adapt to a variety of conditions.
Read More

A Simple, Usable Review
By Paul Seys  •  February 24, 2011
In this detailed review, Paul Seys describes an up-and-coming UX title that's jam-packed with lessons for designers both new and established. Follow along to learn how author Giles Colborne's teaches his readers the essence of great design.
Read More
Proximity

1. Tell us about yourself...
   - My Name: First Name
   - Gender: - Select One -
   - Birthday: - Select Month - Day Year
   - I live in: United States
   - Postal Code:

2. Select an ID and password
   - Yahoo! ID and Email: @ yahoo.com
   - Password:
   - Re-type Password:

3. In case you forget your ID or password...
   - Alternate Email:
   - 1.Security Question: - Select One -
     - Your Answer:
   - 2.Security Question: - Select One -
     - Your Answer:
Similarity

Objects that are similar form a group
Similarity
Proximity and Similarity
Proximity and Similarity

After discovering that one of these accesses a menu, people will expect they all access a menu. They are the same.
Closure

Even incomplete objects are perceived as whole

Increases regularity of stimuli
Closure

The Sims

Rainbow 6
Symmetry

Objects are perceived as symmetrical and forming around a center point.

If you fight symmetry, be sure you have a reason.
Continuity

Objects perceived as grouped when they align
Remain distinct even with overlap
Preferred over abrupt directional changes

what most people see

not this
Continuity
Models from Different Perspectives

Some example models of human performance

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<tr>
<td>Visual System</td>
<td>Biological Model</td>
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<tr>
<td>Model Human Processor</td>
<td>Higher-Level Model</td>
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<td>Fitts’s Law</td>
<td>Model by Analogy</td>
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<tr>
<td>Gestalt Principles</td>
<td>Predict Interpretation</td>
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</tbody>
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CSE 440: Introduction to HCI
User Interface Design, Prototyping, and Evaluation

Lecture 08:
Human Performance

James Fogarty
Eunice Jun
David Wang
Elisabeth Chin
Ravi Karkar

Tuesday / Thursday
10:30 to 11:50