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

Lecture 07:
Human Performance

James Fogarty
Alex Fiannaca
Lauren Milne
Saba Kawas
Kelsey Munsell

Tuesday/Thursday
12:00 to 1:20
Some Reminders

Task Analysis Critique Tomorrow
- do tasks reveal insight into the underlying problem
- do tasks expose an interesting design space

Keep your design options open

Our critique is not your answer
- we cannot pave a path to insight
- we will not always be consistent in our response
Today

Human Performance

- Visual System
- Model Human Processor
- Fitts’s Law
- Gestalt Principles
These are Examples of What?

- Popsicle-stick bridge

\[ x = x_0 + v_0t + \frac{1}{2} at^2 \]

- 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
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

Model by Analogy
- Biological Model
- Higher-Level Model
- 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

![Diagram showing the relative absorbance of different wavelengths for blue cones, rods, green cones, and red cones.](image)

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

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

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Shapes detected by finding edges

We use brightness and color difference

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)
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
Dual / Redundant Encoding

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 of

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

NICKNAME: MYSELF
Have signup a nickname for the person, you're shipping to. You may change or delete this information at any time.

FIRST NAME: DOUGLAS

LAST NAME:

ADDRESS: 245 SAN JOSE RD

CITY: LOS GATOS

STATE/PROVINCE: California

ZIP/POSTAL CODE: 95333

COUNTRY: Select a country

SHIPPING METHOD: In the U.S.: Standard UPS (2 business days plus); International: Standard UPS (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
- 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, approximately 100-200ms
- Memories have capacity, decay time, and type
A Working Memory Experiment
BMCIACSEI
Memory

Working memory (also known as short-term)

- Small capacity (7 ± 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
<table>
<thead>
<tr>
<th>red</th>
<th>green</th>
<th>blue</th>
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<tbody>
<tr>
<td>yellow</td>
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<td>red</td>
<td>green</td>
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</table>
Activation Experiment

Do it again

Say “done” when finished
<table>
<thead>
<tr>
<th>ivd</th>
<th>olftcs</th>
<th>fwax</th>
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</thead>
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<tr>
<td>ncudgt</td>
<td>zjdcv</td>
<td>lxngyt</td>
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<td>mkbh</td>
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<td>bhfe</td>
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<td>dalcrd</td>
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Activation Experiment

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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

Some example models of human performance

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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)

Models time to acquire targets in aimed movement

- Reaching for a control in a cockpit
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- 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
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
Fitts’s Law

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

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)

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

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?
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)

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)

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

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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?

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<tr>
<th>Pop-up Linear Menu</th>
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Pie Menus in Use

The Sims

Rainbow 6

Maya
Fitts’s Law Examples

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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

Magic Corner: Office Button in the upper-left corner

Mini toolbar is close to the cursor
Bubble Cursor

Grossman and Balakrishnan, 2005
Bubble Cursor with Prefab

Dixon et al, 2012
Bubble Cursor with Prefab

Dixon et al, 2012
Fitts’s Law and Keyboard Layout

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

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

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

Optimizes a system of springs
Metropolis Keyboard

Random walk minimizing scoring function
Considering Multiple Space Keys

FITALY Keyboard

Textware Solutions

OPTI Keyboard

MacKenzie and Zhang 1999
Considering Multiple Space Keys

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

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

Font Formatting

<table>
<thead>
<tr>
<th>Type, Style and Size</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: [ ]
- All Caps: [ ]
- Engrave: [ ]
- 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 using generated interfaces (26%)

Fewer errors using 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

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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
Painful Image Warning
Difficult to Reconcile
Proximity

Objects close to each other form a group
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 Owoh
   - 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
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 are 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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