Week 4

The psychology of the user interface
Why UIs are like they are?

Are there any laws or theory that tell us how to design a user interface?
Human processor

Modeling humans as an information processing system

(Card, Moran & Newell 1983)
Human processor

- Sensory organs
- Sensory storage
- Perceptual processor
- Cognitive processor
- Long term memory
- Working memory
- Feedback
- Muscles
- Motor processor
**Human processor**

- Sensory organs
- Sensory storage
- Perceptual processor
- Long term memory
- Working memory
- Cognitive processor
- Motor processor
- Attention

Feedforward and feedback connections

(Wickens, 1984)
Processors

Each processor has a processing cycle
   Necessary duration to treat an input and produce an output

Speed of processing depends on individual humans and external conditions
   (e.g., intensity of the stimulus, noise, alcohol,...)
   The fastest speed can be 10 times faster than the slowest

\[
T_p \approx 100\,\text{ms} \ (50-200\,\text{ms})
\]

\[
T_c \approx 70\,\text{ms} \ (30-100\,\text{ms})
\]

\[
T_m \approx 70\,\text{ms} \ (25-170\,\text{ms})
\]
Visual perception
Visual perception

red–green color blindness (daltonism) is very common (8% of adult males)

Don’t use only color to highlight differences, or use choose colors that are difficult to confuse

Ishihara Test for Colour Blindness
Visual perception

Colors of different wavelengths are hard to tell apart
  Don’t use red text on blue background

With age, blue becomes harder to read

Change Blindness (Cécité au changement)
  Difficult to see visual changes when our vision is interrupted
  Avoid abrupt changes in the interface (show animations, highlight changes)
Visual perception
Visual perception
Gestaltism (psych. of the form)

A theory claiming that the perception processing and the mental/cognitive representation of information, process spontaneously (« pre-attentively ») the surrounding phenomena as groups of structures (forms), and not as several discrete elements

Theory that has a psychological, philosophical and biological influences and implications, and is relevant to perception and cognition
Gestalt laws of perception

Continuity  
Proximity  
Similarity  
Symmetry  
Closure  
Common fate  
Past experience  
Figure-ground

These laws act at the same time and can be occasionally contradictory
Continuity

Elements arranged on a line or curve are perceived as more related than elements not on the line or curve

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Continuity

We tend to perceive elements grouped together, and integrated into perceptual « wholes » if they are aligned

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We tend to perceive elements grouped together, and integrated into perceptual « wholes » if they are aligned.

E.g., different style options in a UI presented one after the other.
Proximity

We group objects first by their proximity between them e.g., functions in a dialogue box
If distance (proximity) does not allow grouping, we tend to group objects based on their perceived similarity in form e.g., similar file icons to visually organize and remember their applications (shape, size, color)
Symmetry

Symmetries are aesthetically pleasing, and we tend to group symmetrical objects as one group with a central point.

\{ \} [ ] ( )

e.g., symmetrical actions in the UI have symmetrical icons and are seen as a group.
Closure

We perceive objects such as shapes, letters, pictures, etc., as being whole even when they are not complete (we complete the missing parts)

e.g., we can group items in a UI by explicit or implicit borders
Common fate

Elements moving in the same trajectory with the same speed are seen as a group

e.g., if you select and drag some icons, shadows of these items all move at the same direction and speed
Past experience

Past experience and context affect the interpretation of elements in a group
Figure - Ground

Perception consists of a distinction between the graphical figure (target) and ground (context). It should always be clear in the UI.
Cognition
Cognitive processes

Responsible for decisions
- Comparison and process of stimuli and selection of a response

Types
- Mechanical, based on habits and repetition (e.g. walk, point, speak)
- Bases on rules (e.g. if there is an obstacle walk around it)
- Based on knowledge and experience (problem solving)
Reaction time

A lamp will be lit. Press on the associated button (in your head) as fast as possible
Reaction time
Reaction time
Reaction time
Hick-Hyman law

Describes the time it takes to make a simple decision given a number of choices

\[ T = a + b \cdot \log_2(n+1) \]

- \( n \): number of choices
- \( a, b \): constants

Humans divide the number of choices in categories: binary search
Attention

Capacity to focus on important things/objects
  linked to visual and auditory perception

but ....
  humans have limited cognitive resources
Attention resources

divided attention: many stimuli, shallow level
focused attention: few stimuli, deep level

practice reduces required attention
Attention

It is easier to pay attention to well-structured information.

Pennsylvania
Bedford Motel/Hotel: Crinaline Courts
(814) 623-9511 S: $18 D: $20
Bedford Motel/Hotel: Holiday Inn
(814) 623-9006 S: $29 D: $36
Bedford Motel/Hotel: Midway
(814) 623-8107 S: $21 D: $26
Bedford Motel/Hotel: Penn Manor
(814) 623-8177 S: $19 D: $25
Bedford Motel/Hotel: Quality Inn
(814) 623-5189 S: $23 D: $28
Bedford Motel/Hotel: Terrace
(814) 623-5111 S: $22 D: $24
Bradley Motel/Hotel: De Soto
(814) 362-3567 S: $20 D: $24
Bradley Motel/Hotel: Holiday House
(814) 362-4511 S: $22 D: $25
Bradley Motel/Hotel: Holiday Inn
(814) 362-4501 S: $32 D: $40
Breezewood Motel/Hotel: Best Western Plaza
(814) 735-4350 S: $20 D: $27
Breezewood Motel/Hotel: Motel 70
(814) 735-4385 S: $16 D: $18

South Carolina

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Attention

Make important information that needs attending salient (noticeable)
  colour, animation, underline, etc.
  but do not unnecessarily distract users

Structure information (ordering, spacing)
Avoid non-functional clutter
Memory and learning

Responsible for encoding, maintaining & retrieving information:

- filtering (what)
- context (when, where)
Memory and learning

To be shown for a few seconds. Try to memorize them.

http://faculty.washington.edu/chudler/puzmatch.html
Memory and learning

Write down as many as you can.

http://faculty.washington.edu/chudler/puzmatch.html
Memory and learning

Short term memory

Working memory
Small storage duration (10 – 30s)
Small capacity: 7 ± 2 items (Miller, 56)
Later studies have shown that this range can be lower and depends on several factors, e.g., type & complexity of the item

Long term memory

Infinite capacity
Unlimited storage duration
Associative access
Memory and learning

Learning and memorization by repetition
(short term ➔ long term)

Interferences degrade short term memory faster
Chunking (grouping)

Perception and memory elements are grouped in « chunks »

Try to memorize this number:

456789067
Chunking (grouping)

Perception and memory elements are grouped in « chunks »

Try to memorize this number:

456789067

... and then this one:

456-789-067
Chunking (grouping)

Perception and memory elements are grouped in « chunks »

Try to memorize this number:

456789067

... and then this one:

456-789-067

The 7± 2 rule for short term memory is applicable on the number of « chunks » rather than number of unique elements.
The rule of 7 plus/minus 2

Some UI design guidelines suggest the application of the rule to menus, toolbars, slides, etc.

Do you think that this is appropriate?
The rule of 7 plus/minus 2

Some UI design guidelines suggest the application of the rule to menus, toolbars, slides, etc.

Do you think that this is appropriate?

Consider that such elements require us to recognize, not to recall! They have nothing to do with working memory.
Recall vs. Recognition

We are better at recognizing then remembering
command line vs. GUI
search box vs. list of options
keyboard shortcut vs. actions in the menu

We are better at remembering images than words
icons vs. items of a menu
Interferences: Stroop effect

Test 1

Identify the color of the following words in order, as fast as possible
Stroop effect

Book
Crayon
Car
Time
Mouse
Stroop effect

Test 2

Identify the color of the following words in order, as fast as possible
Stroop effect

Black
Blue
Red
Green
Orange
Stroop effect

Interference between the main task (identify the color) and a cognitive process (read a word)

Affects reaction time and error rate
Some general guides

Avoid complex mappings (risk of interferences)
Support both recall and recognition
    but recognition is easier (e.g., menus, icons, lists)

Group/chunk related information
    e.g., tabs, sub-menus

Aid associative learning
    e.g., help, hints

Aid association by providing context
    e.g., colors, labeling, temporal metadata
Externalization of cognition

External representations and tools to support cognition

Externalizing to reduce cognitive load
  computational offloading
  annotating and cognitive tracing
Externalization of cognition

Externalization to reduce cognitive load (memory)
   agendas, calendars, notes, lists, ...

External representations to remind us:
   that we need to do something (e.g., alarm)
   what to do (e.g., pay taxes)
   when to do them (e.g., the 15 of April)
Externalization of cognition

Computational offloading
  e.g., paper and pen, calculator, spreadsheet

Try to calculate $234 \times 456 = ?$
(a) in your mind
(b) on paper
(c) with a calculator
Externalization of cognition

Annotation involves modifying existing representations through making marks to mark progression in tasks
  e.g., crossing off, ticking, underlining

Cognitive tracing involves externally manipulating items into different orders or structures that are easier to remember
  e.g., playing scrabble, playing cards, history
Motor system
Motor system

A movement is a series of micro-movements

Open-loop
The motor does an autonomous action without feedback
Cycle duration: $T_m \approx 70\text{ms}$

Closed-loop
Muscle movement is perceived and compared to desired result
$T_{\text{total}} = T_p + T_c + T_m \approx 240\text{ms}$

$T_p \approx 100\text{ms} (50-200 \text{ ms})$  $T_c \approx 70\text{ms} (30-100 \text{ ms})$  $T_m \approx 70\text{ms} (25-170 \text{ ms})$
Task: Put your cursor on the origin and then point at the target as fast as possible. Try to avoid errors.
**Fitts’ law (1954)**

Describes the duration of movement as a function of the distance $D$ and the target size $W$

$$T = a + b \cdot \log_2 \left( \frac{D}{W} + 1 \right)$$

$a, b$ : constants, device-dependent
Fitts’ law (1954)

\[ T = a + b \cdot \log_2 \left( \frac{D}{W} + 1 \right) \]

Distance \( D \)

Size \( W \)

Movement origin

Movement target
Fitts’ law (1954)

\[ T = a + b \cdot \log_2 \left( \frac{D}{W} + 1 \right) \]
Fitts’ law (1954)

Example of real data for two different input devices. The equation is a product of a linear regression on the means of user performance for a combination of D, W.
Mac OS vs Window Menu bars

Is the predicted time slower or faster to select a menu on Mac OS X?
Crossing rather than pointing?

Again, Fitts’ law equation is still valid (Accot & Zhai, 2002)

\[ T = a + b \cdot \log_2 \left( \frac{D}{W} + 1 \right) \]
Crossing rather than pointing?

In certain situations, performance with crossing is superior (Accot & Zhai, 2002)

(a) To trigger an action: on the left we push the button; on the right we cross the goal.

(b) Unlike a traditional check box, a goal can “store” two visual states depending on the crossing direction.

(a) Pointing at targets  (b) Crossing the arcs
Steering movements (Accot & Zhai, 97)

Task: Steer through the path with the cursor without exiting the path. Complete the task as fast as possible. Try to avoid errors.
Steering movements (Accot & Zhai, 97)

Steering law

\[ T = a + b \frac{D}{W} \]

\( a, b : \text{constants} \)
Movement and menus
Movement and menus
Movement and menus

A → B: pointing
Movement and menus

A → B: pointing

B → C: steering movement
Movement and menus

A → B: pointing

B → C: steering movement

C → D: pointing
Movement and menus

A → B: pointing

B → C: steering movement

C → D: pointing

\[ T \approx a + b_1 \cdot \log_2 (1 + \frac{|AB|}{W}) + b_2 \cdot \frac{|BC|}{W} + b_1 \cdot \log_2 (1 + \frac{|CD|}{W}) \]
Menus in Mac OS X

The user can move the cursor towards the submenu, staying within a triangle and without exceeding a time threshold (~ 400 ms)

size of path >> w
Choice and visual search

and how long does it take to find the item in a menu?

Find Item 7!
Choice and visual search

and how long does it take to find the item in a menu?

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<th>Item 1</th>
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</table>

Find Item 7!
Choice and visual search

and how long does it take to find the item in a menu?

Find Item 7!
Choice and visual search

and how long does it take to find the item in a menu?

A. If the items are ordered (e.g., alphabetically), the choice time is approximated by Hick’s law (logarithmic)
   → **expert use**

B. If the items are randomly ordered and the user does not know their position, they need to search for the target in a linear way (rather than logarithmic)
   → **novice use**
Frequency-based menus

(Sears & Shneiderman, 1994)

Most frequent items. Sears & Shneiderman recommend up to four items in this area.

They showed that split menus can improve user performance when some items are more frequent than others.
Adaptive pull-down menus in MS Office 2000. They were abandoned in more recent versions. What do you think went wrong?

**Frequency-based menus**

Short version

Expanded version
**Semantic grouping**

Menus are usually organized into groups of semantically related items.
Broader, shallower menu trees yield faster search than narrower, deeper ones (Landauer & Nachbar, 1985). In practice, more than two levels are rarely used.
Designing menus

Optimize for what?

Visual search? (e.g., mostly novice use)
Motor performance? (e.g., mostly expert use)
Spatial stability?
Consistency among applications?

MenuOptimizer (Bailly et al., 2013)