Human Information Processing

CS160: User Interfaces
John Canny
Human Info. Processor
- Perceptual
- Cognitive
- Motor (will discuss later)
- Working memory
- Long-term memory

Unified model
- Probably inaccurate
- Predicts perf. well
- Very influential

Key
- $\delta$ = half-life
- $\mu$ = capacity
- $\kappa$ = memory type
Perceptual Processor

Physical store from our senses: sight, sound, touch, …
  – Code directly based on sense used
    • Visual, audio, haptic, … features

Selective
  • Spatial
  • Pre-attentive: color, direction…

Capacity
  – Example: 17 letters for visual image store

Decay 200ms

Recoded for transfer to working memory
  – Progressive: 10ms/letter
How many 3’s

1281768756138976546984506985604982826762980985845822450985645894509845098094358590910302099059595957725646750506789045678845789809821677654876364908560912949686

[based on slide from Stasko]
How many 3’s

[based on slide from Stasko]
Visual Pop-Out: Color

http://www.csc.ncsu.edu/faculty/healey/PP/index.html
Visual Pop-Out: Shape

http://www.csc.ncsu.edu/faculty/healey/PP/index.html
Feature Conjunctions

http://www.csc.ncsu.edu/faculty/healey/PP/index.html
Attention

I’m going to display an image briefly, and then hide it.

I’m going to ask you about a particular shape.

Please raise hand if you saw the requested shape.
Attention

Orange circle?

Purple square?
Attention

Orange circle? Yes

Purple square? No
Attention
Attention

Next slide:

Raise hand if you see an orange triangle
Attention
Attention

Was there a red square?

Was there a purple circle?
Selective Attention

Was there a red square? No

Was there a purple circle? Yes
Selective Attention
Perceptual Processor

Cycle time

- Quantum experience: 100ms
  - Percept fusion
Perceptual Processor

Cycle time
- Quantum experience: 100ms
  - Percept fusion
- Frame rate necessary for movies to look continuous?
  - time for 1 frame < $T_p$ (100 msec) -> 10 frame/sec.
  - Note: flicker sensitivity much faster (60-70 f/s)
- Max. morse code rate can be similarly calculated

Perceptual causality
- Two distinct stimuli can fuse if the first event appears to cause the other
- Events must occur in the same cycle
Perception of Causality

Michotte demonstration 1. What do you see? Most observers report that the red ball hit the blue ball. The blue ball moved “because the red ball hit it.” Thus, the red ball is perceived to “cause” the red ball to move, even though the balls are nothing more than color disks on your screen that move according to a program.

http://cogweb.ucla.edu/Discourse/Narrative/Heider_45.html
Perception of Causality

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Perceptual Processor

Cycle time

- Quantum experience: 100ms
  - Causality
Working Memory

Access in chunks
- Task dependent construct
- 7 +/- 2 (Miller)

Decay
- Content dependent
  - 1 chunk 73 sec
  - 3 chunks 7 sec
- Attention span
  - Interruptions > decay time
Long Term Memory

Very large capacity
  – Semantic encoding

Associative access
  – Fast read: 70ms
  – Expensive write: 10s
    • Can also move from WM to LTM via rehearsal

Context at the time of acquisition key for retrieval
Memory Experiment
Simple Experiment

Volunteer

Start saying **colors** you see in list of words
  – When slide comes up
  – As fast as you can

Say “done” when finished

Everyone else time it…
Simple Experiment

Do it again

Say “done” when finished
Blue
Red
Black
White
Green
Yellow
Stage Theory

Sensory Image Store → Working Memory → Long Term Memory

- Sensory Image Store: decay
- Working Memory: decay, displacement
- Long Term Memory: decay? interference?

Maintenance rehearsal

Chunking/elaboration
LTM and Elaboration

Recodes information

Organize (chunking)

Relate new material to already learned material

Link to existing knowledge, categories

Attach meaning
  – Make a story
  – Make it nonsense and funny
  – Make it visual
Streets of San Francisco

Ellis
O’Farrell
Geary
Post
Sutter
Bush
Pine
California
Sacramento
Clay
...

An immigrant on Ellis Island saw a barrel floating in the water and said "O Barrel, where are you going?" The barrel was Geary and heading for the Post Office. At the post office was a Sitter who was trying to post a
Streets of San Francisco

Bush to his friend who lived in a Pine Tree. Pine trees are BIG in California, but there are few in Sacramento, also known as the “Capitol of Clay”...
Many students study by “cramming” or studying from a “fact sheet”. The best known example is flash cards.

Good aspects:
- Self-testing, review, graduated recall

Bad aspects:
- Much better for short-term learning than long-term
- Not building understanding (or efficient coding)
- Empirical results poor to mixed
Recognition over Recall

Recall
- Info reproduced from memory

Recognition
- Presentation of info helps retrieve info (helps remember it was seen before)
- Easier because of cues to retrieval

We want to design UIs that rely on recognition!
Facilitating Retrieval: Cues

Any stimulus that improves retrieval
  – Example: giving hints
  – Other examples in software?
    • icons, labels, menu names, etc.

Anything related to
  – Item or situation where it was learned
Facilitating Retrieval: Cues

US Presidents with first name “William”?
Facilitating Retrieval: Cues

US Presidents with first name “William”?
Facilitating Retrieval: Cues

US Presidents with first name “William”?

Clinton

Harrison

McKinley

Taft
Decision Making and Learning
Power Law of Practice

- Task time on the nth trial follows a power law
  \[ T_n = T_1 n^{-a} + c \]
  where a = .4, c = limiting constant
  – You get faster the more times you do it!

Applies to skilled behavior (sensory & motor)

Does not apply to
  – Knowledge acquisition
  – Improving quality
Problem solving
Manual skills

Writing books
Fitts’ Law
Motor Processor

Receive input from the cognitive processor
Execute motor programs
  – Pianist: up to 16 finger movements per second
  – Point of no-return for muscle action
Hand movement based on series of microcorrections

\[ X_i = \text{remaining distance after } \text{ith move} \]

Relative movement accuracy remains constant \( \Rightarrow \frac{X_i}{X_{i-1}} = \varepsilon \)
Hand movement based on series of microcorrections

\[ X_i = \text{remaining distance after } i\text{th move} \]

relative movement accuracy remains constant \( \Rightarrow \)

\[ \frac{X_i}{X_{i-1}} = \varepsilon \]

Each microstep reduces the log of the error by \( \log \varepsilon \)

The number of steps grows with \( \log \frac{D}{S} \)
Fitts’ Law

\[ T = a + b \log_2 (D/S + 1) \]

a, b = constants (empirically derived)
D = distance
S = size

ID is Index of Difficulty = \( \log_2 (D/S + 1) \)

• Models well-rehearsed selection task
• T increases as the distance to the target increases
• T decreases as the size of the target increases
Experimental Data

TARGET WIDTHS

- 2 in.
- 1 in.
- 1/2 in.
- 1/4 in.

Time Per Movement (sec)

$\log_2 (D/S + .5)$ Corrected for Errors
Microsoft Toolbars offer the user the option of displaying a label below each tool. Name at least one reason why labeled tools can be accessed faster. (Assume, for this, that the user knows the tool.)
1. The label becomes part of the target. The target is therefore bigger. Bigger targets, all else being equal, can always be accessed faster, by Fitt's Law

2. When labels are not used, the tool icons crowd together
Tool Matrix Example

You have a palette of 16 tools in a graphics application that consists of a matrix of fixed-size icons.

which array design would be faster, an 8x2 array or a 16x1 array?
Which Pointer is faster?

Engelbart

Experiment: Mice are fastest!

Fitts’ Law

• Time $T_{\text{pos}}$ to move the hand to target size $S$ which is distance $D$ away is given by:

$$T_{\text{pos}} = a + b \log_2 (D/S + 1)$$

*Index of Difficulty (ID)*

Only *relative precision* matters

Fitts’ Law

• Time $T_{pos}$ to move the hand to target size $S$ which is distance $D$ away is given by:

$$T_{pos} = a + b \log_2 (D/S + 1)$$

Device Characteristics
(bandwidth of human muscle group & of device)

$a$: start/stop time

$b$: speed

Bandwidth of Human Muscle Groups

Why is the mouse fastest?

Why these results?

Time to position mouse proportional to Fitts’ Index of Difficulty $I_D$.

[i.e. how well can the muscles direct the input device]

Therefore speed limit is in the eye-hand system, not the mouse.

Therefore, mouse is a near optimal device.

Fitts’ Law in Microsoft Office 2007

Larger, labeled controls can be clicked more quickly

Magic Corner: Office Button in the upper-left corner

Mini Toolbar: Close to the cursor

Review

MHP consists of multiple, dedicated processors running asynchronously.

Visual systems are mostly bottom-up but attention can shape recognition top-down.

Memory principles: multi-level, rehearsal, linking
Fitt’s Law
Power Law of Practice
UI optimization