Human Capabilities

Understanding Users

Instructor: Michael McGuffin

Acknowledgements: Some of the material in these lectures are based on material prepared by Ravin Balakrishnan, Saul Greenberg, James Landay, Ron Baecker, monica schraefel, and Colin Ware.

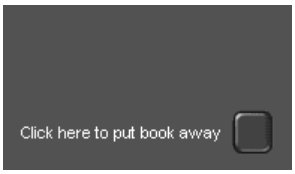
What are humans good at ?

- Allows for informed design
  - Extend human capabilities
  - Compensate for weaknesses
- 3 components
  - Perception
  - Cognition
  - Motor Skills

Perception

Vision

UI hall of shame

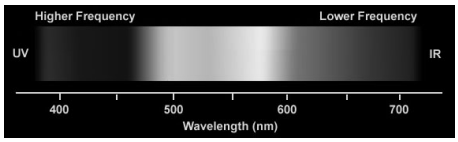


- From IBM's RealCD
  - Prompt
  - Button
- Black on Black?
  - Cool!
  - But you can't see it!
  - "click here …" prompt should not be needed.

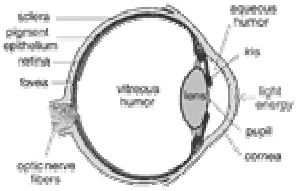
Why study colour?

Colour can be a powerful tool to improve user interfaces, but its inappropriate use can severely reduce the performance of the systems we build

Visible Spectrum



Human Visual System



- Light passes through lens
- Focused on retina

Retina

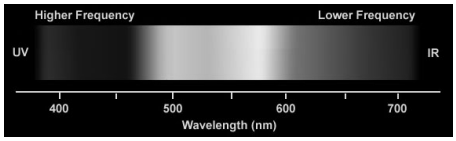
- covered with light-sensitive receptors
  - rods
    - sensitive to broad spectrum of light
    - primarily for night vision & perceiving movement
    - can't discriminate between colours
    - sense intensity or shades of gray
  - cones
    - used to sense colour

Retina

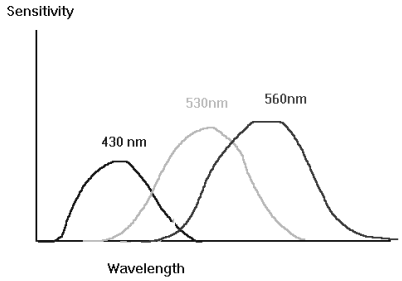
- Center of retina has most of the cones
  - allows for high acuity of objects focused at center
- Edge of retina is dominated by rods
  - allows detecting motion of threats in periphery

Trichromacy theory

- Cone receptors used to sense colour
- 3 types: blue, green, red
  - each sensitive to different band of spectrum
  - ratio of neural activity of the 3 → colour
    - other colours are perceived by combining stimulation



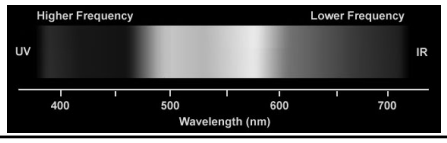
Colour Sensitivity



from: http://www.cs.gsu.edu/classes/hypgraph/colour/coloureff.htm

Distribution of cones

- Not distributed evenly
  - mainly reds (64%) & very few blues (4%)
    - insensitivity to short wavelengths
      - cyan to deep-blue
- Center of retina (high acuity) has no blue cones
  - small blue objects you fixate on disappear



Colour Sensitivity (cont.)

- As we age
  - lens yellows & absorbs shorter wavelengths
    - sensitivity to blue is even more reduced
  - fluid between lens and retina absorbs more light
    - perceive a lower level of brightness
- Implications

Blue text on a dark background to be avoided. We have few short-wavelength sensitive cones in the retina and they are not very sensitive.
Older users need brighter colours

Focus

- Different wavelengths of light focused at different distances behind eye's lens
  - need for constant refocusing
    - causes fatigue
  - careful about colour combinations
- Pure (saturated) colours require more focusing then less pure (desaturated)
  - don't use saturated colours in UIs unless you really need something to stand out (stop sign)

Peripheral acuity

With strict fixation of the center spot, each letter is equally legible because it is about ten times its threshold size. This is true at any viewing distance. Chart shows the increasingly coarse grain of the retinal periphery. Each letter is viewed by an equal area of visual cortex ("cortical magnification factor") (Anstis, S.M., Vision Research 1974) http://www-psy.ucsd.edu/~sanstis/SABlur.html

Colour blindness

- Trouble discriminating colours
  - besets about 9% of population
- Different photopigment response
  - reduces capability to discern small colour diffs
    - particularly those of low brightness
- Red green deficiency is best known
  - lack of either green or red photopigment
    - can't discriminate colours dependent on R & G
- Colour blind acceptable palette?
  - Yellow-blue, and grey variation ok

Luminance contrast

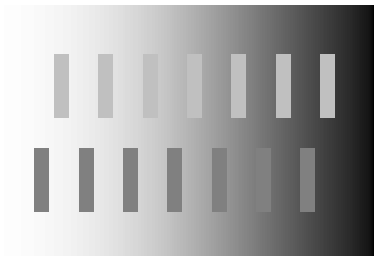
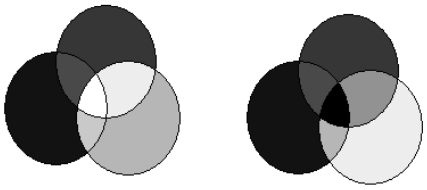


Illustration of simultaneous luminance contrast. The upper row of rectangles are an identical gray. The lower rectangles are a lighter gray but also identical

A note on "Primary Colours"



•Light mixes additively

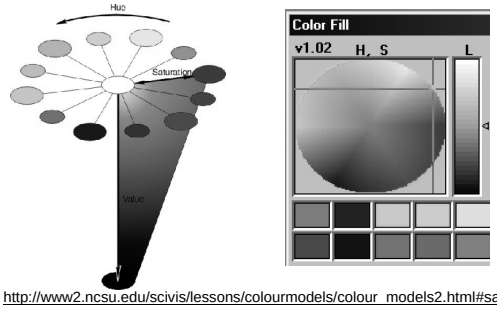
•Pigments mix subtractively

Colour spaces

- Because cones are only tuned to three different frequencies, the space of all visible colours has 3 dimensions
  - E.g., RGB, HSV, etc.
- Alien beings, with more types of cones, would perceive more “shades” of colours

Colour Spaces

- Hue, Saturation, Value (HSV) model



from http://www2.ncsu.edu/scivis/lessons/colourmodels/colour_models2.html#saturation.

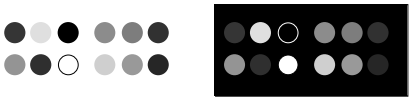
HSV colour components

- Hue
  - property of the wavelengths of light (i.e., “colour”)
- Lightness (or value)
  - how much light appears to be reflected from a surface
  - some hues are inherently lighter or darker
- Saturation
  - purity of the hue
    - e.g., red is more saturated than pink
  - colour is mixture of pure hue & achromatic colour
    - portion of pure hue is the degree of saturation

Colour coding/labeling

- Large areas: low saturation
- Small areas: high saturation

- Recommended colours for coding:



- Widely agreed upon names
- First 4 + black & white are unique and mark ends of opponent colour axes
- Entire set correspond to most common colour names found across cultures
- Choose from set of first six, then from second set of six

Colour coding/labeling (cont.)

The same rules apply to colour coding text and other similar information. Small areas should have high saturation colours

Large areas should be coded with low saturation colours

Avoid high saturation colours for large areas

Colour guidelines

- Size of detectable changes in colour varies
  - hard to detect changes in reds, purples, & greens
  - easier to detect changes in yellows & blue greens
- Older users need higher brightness levels to distinguish colours

Colour guidelines (cont.)

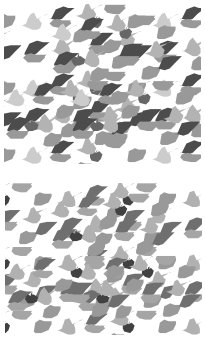
- Avoid red & green in the periphery- why?
  - lack of RG cones there -- yellows & blues work in periphery
- Avoid pure blue for text, lines, & small shapes
  - blue makes a fine background colour
  - avoid adjacent colours that differ only in blue
- Avoid single colour distinctions
  - mixtures of colours should differ in 2 or 3 colours
    - e.g., 2 colours shouldn't differ only by amount of red
  - helps colour-deficient observers

Perception primitives

- Whole visual field processed in parallel
- Can tell us what kinds of information is easily distinguished
- Popout effects (attention)
- Segmentation effects (division of the visual field)

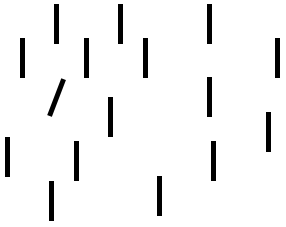
Colour great for classification

- Rapid visual segmentation
- Helps determine type

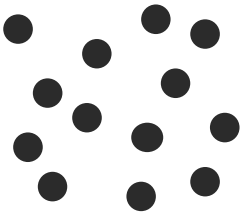


Colour

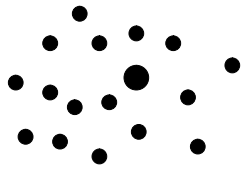
Orientation



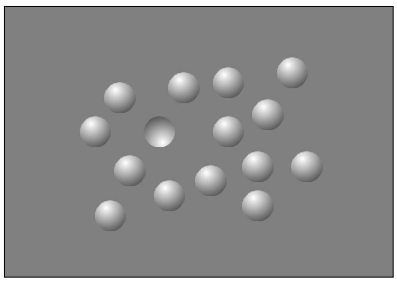
Motion



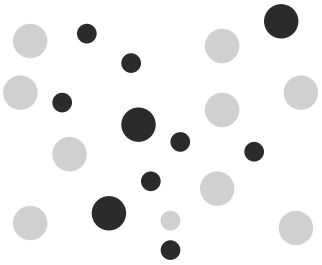
Size



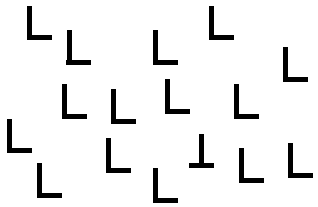
Simple shading



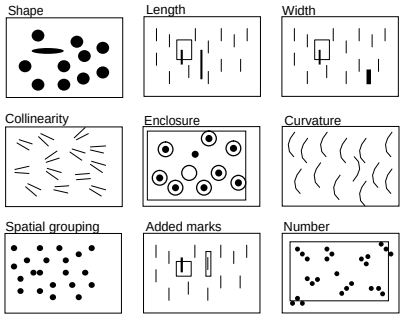
Conjunction (does not pop out)



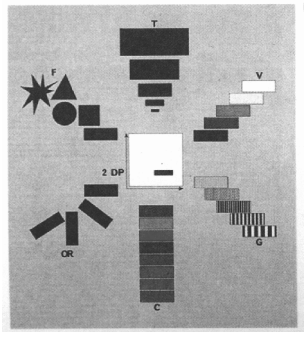
Compound features (do not pop out)



More Preattentive channels



Jacque Bertin's graphical variables



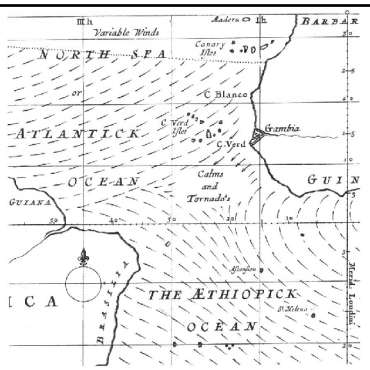
- Position
- Direction (orientation)
- Size
- Colour (hue)
- Contrast (greyness)
- 'grain' (texture)
- shape

Mijksenaar, Visual Function, p. 38

Jacque Bertin's graphical variables

3 Three examples from Bertin. Left the original sociographical data; right, two different ways of rendering the same quantitative data graphically.

Mijksenaar, Visual Function, p. 39



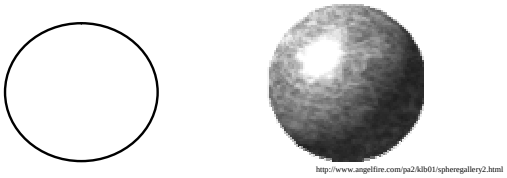
Edmond Halley, "An Historical Account of the Trade Winds, and Monsoons, Observable in the Seas Between and Near the Tropicks; With an Attempt to Assign the Phisical Cause of Said Winds," *Philosophical Transactions*, 183 (1686), 153–168.

Reproduced in Tufte, "The Visual Display of Quantitative Information"

Example:

The cow jumped over the moon.

The moon is the largest natural satellite of the earth, and is composed of 30 % cheddar, 40 % mozzarella, 25 % star dust, and 5 % Elmer's glue. Yesterday, at 12:15 pm, the cow owned by Mrs. Farmwell jumped over the moon.



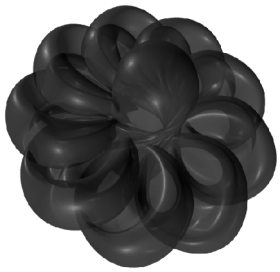
http://www.angelfire.com/pa2/klb01/spheregallery2.html

•To *not* use visual cues seems like a waste of bandwidth

Depth Cues

- Occlusion, transparency
- Motion parallax
- Shadows, shading, specular highlights, reflections
- Relative size
- Converging lines
- Foreshortening

Sphere Eversion



http://www.geom.umn.edu/graphics/pix/Video_Productions/Outside_In/blue-red-alpha.html

Perception

The senses in general,
and forms of feedback

Taxonomy of feedback

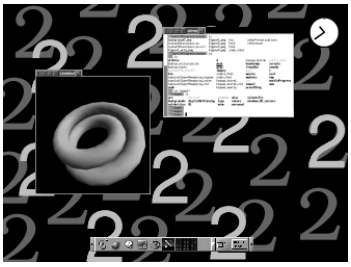
- Modality (visual, auditory, kinesthetic, …)
- Reactive vs Proactive
- Transient vs Sustained
- Demanding vs Avoidable
- User-maintained vs System-maintained

Reference: Sellen, Kurtenbach, Buxton (1992)

Examples

- Visual feedback
  - Usually avoidable (even when it's at the cursor!) and system-maintained
  - Not the best for indicating mode switch
  - Often leads to mode errors
- Kinesthetically held feedback
  - E.g. holding the shift key or a mouse button
  - demanding and user-maintained
  - Good for indicating mode switch
  - "Quasimodes"

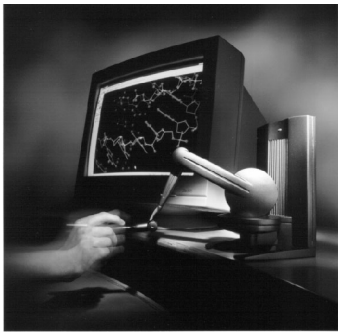
Background/ambient information



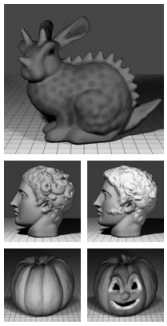
•Harder to avoid, but not obtrusive

•Easily noticed whenever user looks for it; no active searching required

Haptic feedback: The Phantom



http://www.sensable.com



R. Jagnow and J. Dorsey.
Virtual sculpting with haptic displacement maps.
Proceedings of Graphics Interface, 2002.

Cognition

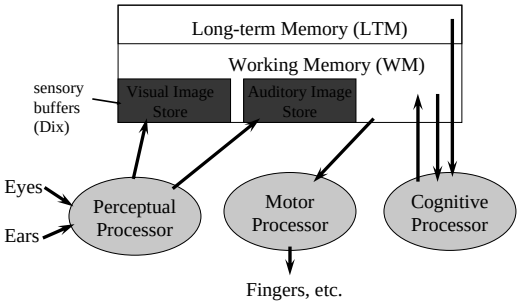
memory

What is cognition ?

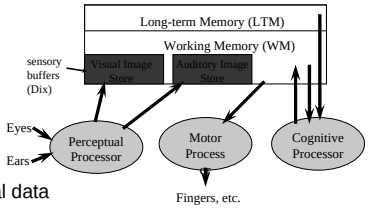
- Thinking, learning, remembering, understanding, planning, deciding, problem solving, …
- Most relevant (and most studied) aspect: **memory**

Model Human Processor (MHP)

- Developed by Card, Moran, & Newell ('83)



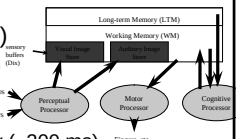
MHP Basics



- Based on empirical data
- Three interacting subsystems
  - perceptual, motor, cognitive
- Sometimes serial, sometimes parallel
  - serial in action & parallel in recognition
    - pressing key in response to light
    - driving, reading signs, & hearing at once
- Parameters
  - processors have cycle time (T) ~ 100-200 ms
  - memories have capacity, decay time, & type

Memory

- Working memory (short term)
  - small capacity (7 ± 2 "chunks")
    - 6174591765 vs. (617) 459-1765
    - DECIBMGMC vs. DEC IBM GMC
  - rapid access (~ 70ms) & decay (~200 ms)
    - pass to LTM after a few seconds



- Long term memory
  - huge (if not "unlimited")
  - slower access time (~100 ms) w/ little decay

Simple experiment

- Volunteer
- Start saying **colours** you see in list of words
  - when slide comes up
  - as fast as you can
- Say "done" when finished
- Everyone else time it…

Green
White
Yellow
Red
Black
Blue

Simple Experiment …

- Do it again…

Paper
Back
Home
Schedule
Change
Page

Simple Experiment …

- Do it again…

Blue
Red
Black
White
Green
Yellow

Memory

- Interference
  - two strong cues in working memory
  - link to different chunks in long term memory
- Why learn about memory?
  - know what's behind many HCI techniques
  - helps you understand what users will "get"
  - aging population of users

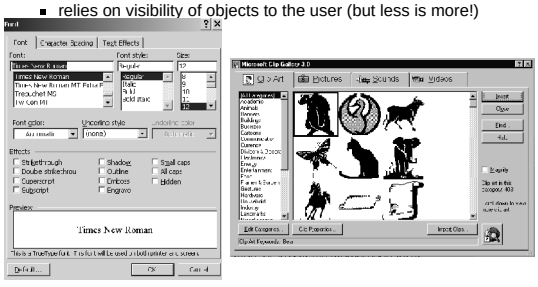
Recognition over Recall

- Recall
  - info reproduced from memory
- Recognition
  - presentation of info provides knowledge that info has been seen before
  - easier because of cues to retrieval
- E.g.
  - Command line (recall)

  vs. GUI (recognition) interfaces
- (remember Nielson's Heuristic #6)

H2-6: Recognition rather than recall

- Computers good at remembering things, people aren't!
- Promote recognition over recall
  - menus, icons, choice dialog boxes vs command lines, field formats
  - relies on visibility of objects to the user (but less is more!)

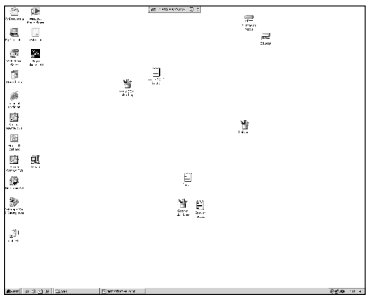


Facilitating Retrieval: Cues

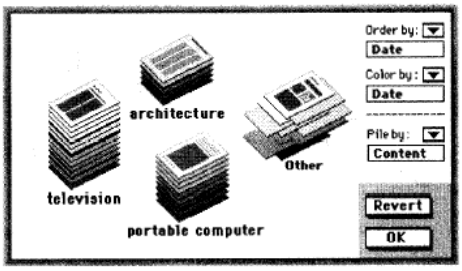
- Any stimulus that improves retrieval
  - example: giving hints
  - other examples in software?
    - icons, labels, menu names, etc.
- Anything related to
  - item or situation where it was learned
- Can facilitate memory in any system
- What are we taking advantage of?
  - recognition over recall!

Spatial Memory

Status quo: virtual desktop



Piles (Mandler et al., Xerox PARC)



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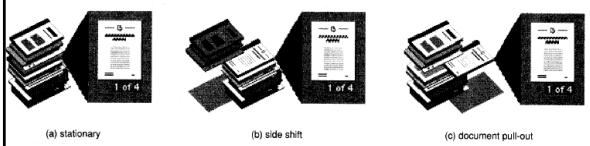


(a) stationary (b) side shift (c) document pull-out

Data Mountain (G. Robertson et al.)

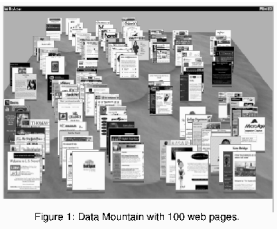
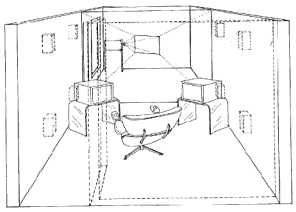


Figure 1: Data Mountain with 100 web pages.

"Our pre-attentive ability to recognize spatial relationships [...] makes it possible to place pages at a distance (thereby using less screen space) and understand their spatial relationships without thinking about it."

G. Robertson et al.
Data Mountain: Using spatial memory for document management. UIST '98.

MIT's Media Room (1980)



Reference: Bolt, "put that there", SIGGRAPH 1980

Task Gallery (G. Robertson et al.)

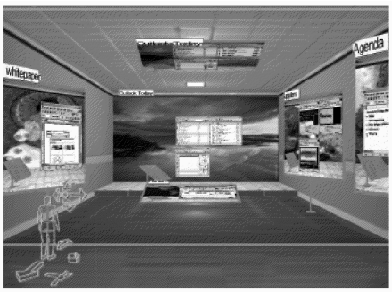


Figure 1. The Task Gallery.

G. Robertson et al.
The Task Gallery: A 3D Window Manager. CHI 2000.

Virtual Reality (VR)

Head-mounted display

High DOF input device

Proprioception and VR

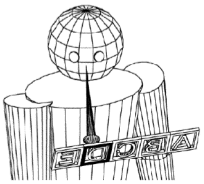


Figure 4: Look-at menu.

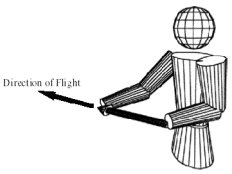


Figure 5: Two-handed flying.

Reference for above pictures: SIGGRAPH 97. For related work, see also Pierce, Conway, van Dantzich, Robertson (1999), Toolspaces and Glances, I3D'99

Motor Skills

How can humans input information ?

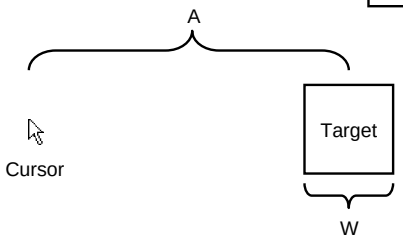
- Voice
- Hand gestures
- Facial expressions
- Typing
- Pointing (e.g. with a mouse)

Why study pointing tasks ?

- Mice are in widespread use
- On many systems, mice are used for everything other than typing
- Can leverage knowledge of motor control theory
  - Models of performance

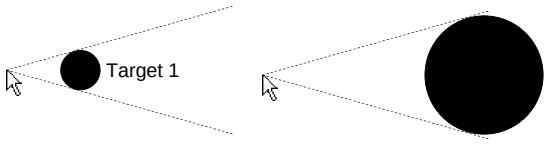
Fitts' Law (rapid, aimed motion)

$$MT = a + b \cdot ID, \quad ID = \log_2(\frac{A}{W} + 1)$$



Fitts' Law

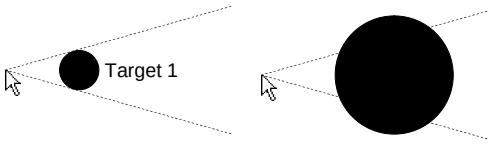
$$MT = a + b \cdot ID, \quad ID = \log_2(\frac{A}{W} + 1)$$



Same ID ? Same Difficulty

Fitts' Law

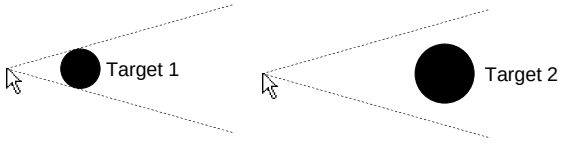
$$MT = a + b \cdot ID, \quad ID = \log_2(\frac{A}{W} + 1)$$



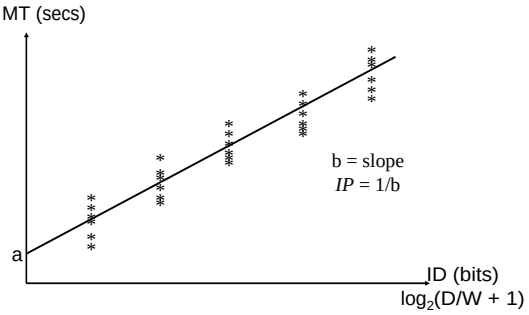
Smaller ID ? Easier

Fitts' Law

$$MT = a + b \cdot ID, \quad ID = \log_2(\frac{A}{W} + 1)$$



Larger ID ? Harder



$$MT = a + b \log_2(\frac{D}{W} + 1)$$

50 years of data

Device	Study	IP (bits/s)
Hand	Fitts (1954)	10.6
Mouse	Card, English, & Burr (1978)	10.4
Joystick	Card, English, & Burr (1978)	5.0
Trackball	Epps (1986)	2.9
Touchpad	Epps (1986)	1.6
Eyetracker	Ware & Mikaelian (1987)	13.7

Reference:
MacKenzie, I. Fitts' Law as a research and design tool in human computer interaction. Human Computer Interaction, 1992, Vol. 7, pp. 91-139

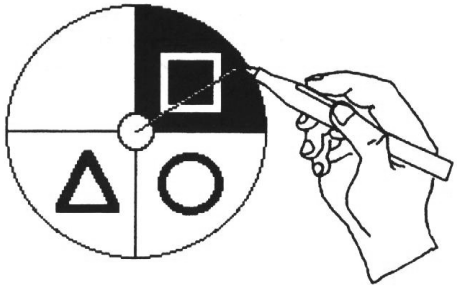
Lessons from Fitts' law

- Speed/accuracy tradeoff
  - Targets that are big or closer can be selected faster
- Scale invariance
- Can use Fitts' law as
  - A predictive tool
  - A comparitive metric
  - A guide for better design

Split Menus (Sears & Shneiderman, 1992)

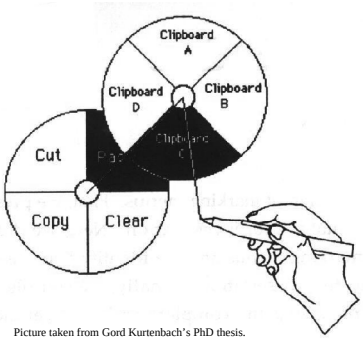
http://psychology.wichita.edu/surl/usabilitynews/41/adapt_menus.htm

Radial Menus



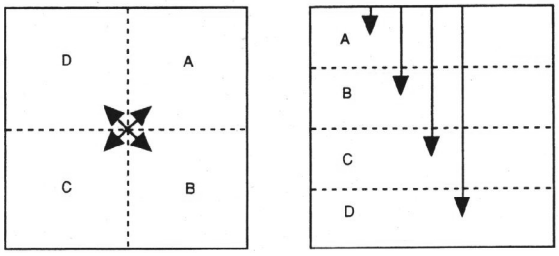
Picture taken from Gord Kurtenbach's PhD thesis.

Hierarchical Radial Menus



Picture taken from Gord Kurtenbach's PhD thesis.

Radial vs Linear



Picture taken from Gord Kurtenbach's PhD thesis.

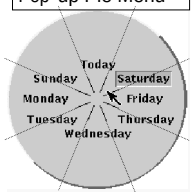
Hick's law

- Reaction time = a + $b\log_2(C)$
  - Where C is the number of choices
  - a, b empirically determined constants
  - $\log_2(C)$ represents amount of information processed by human operator (in Bits)

Using these law's to predict performance

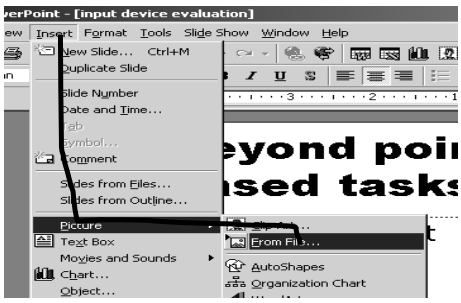
Pop-up Linear Menu

Pop-up Pie Menu



- Which will be faster on average?
  - pie menu (bigger targets & less distance)?

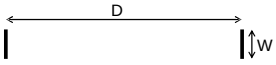
Beyond pointing: Trajectory based tasks



From targets to tunnels…

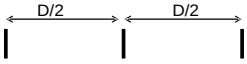
- 2 goals passing

$$ID = \log_2(\frac{D}{W} + 1)$$



- 3 goals passing

$$ID = 2\log_2(\frac{D}{2W} + 1)$$

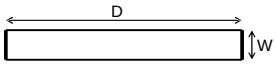


- N+1 goals passing

$$ID = N\log_2(\frac{D}{NW} + 1)$$

- ∞ goals passing

$$ID_\infty = \frac{D}{W}?$$

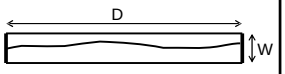


Steering Law (Accot, 1997)

"Beyond Fitts' Law: Models for trajectory based HCI tasks."
Proceedings of ACM CHI 1997 Conference

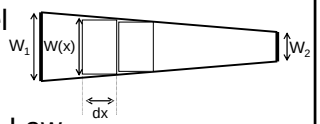
- Fixed width tunnel

$$ID = \frac{D}{W},\quad MT = a + b\frac{D}{W}$$



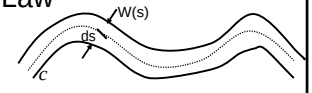
- Narrowing tunnel

$$ID = \int_0^D \frac{dx}{W(x)}$$



- General Steering Law

$$ID = \int_C \frac{ds}{W(s)}$$



Some results (from Accot, 1997)