Human Abilities

Understanding Users

Lecturer: Michael McGuffin

Acknowledgements: Some of the material in this lecture is based on material prepared by Colin Ware, Ravin Balakrishnan, and possibly also Ron Baecker, Saul Greenberg, and James Landay. Used with permission.

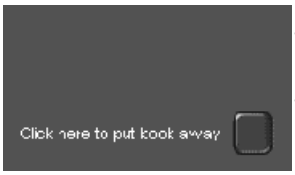
What are humans good at ?

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

Perception

Vision

UI hall of shame

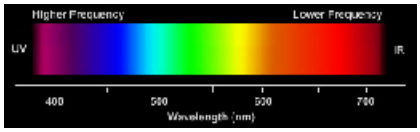


- From IBM's RealCD
  - Prompt
  - Button
- Black on Black?
  - Cool!
  - But you can't see it!
  - "click here …" prompt should not be needed.

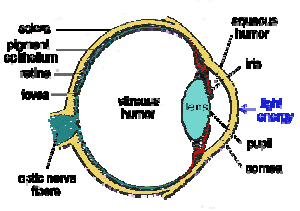
Why study colour?

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
- 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

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

Luminance contrast

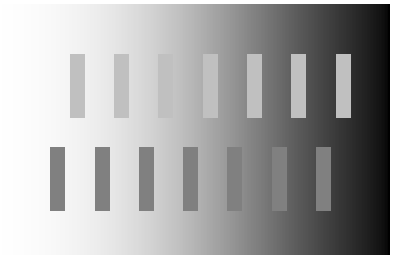
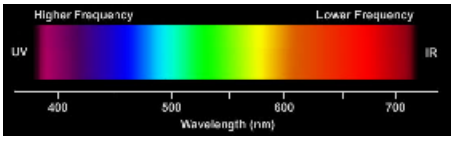


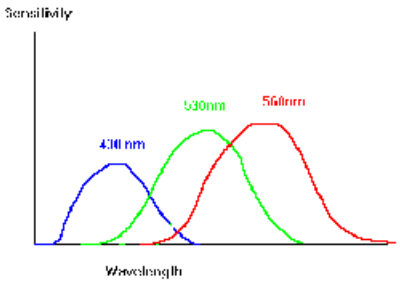
Illustration of simultaneous luminance contrast. The upper row of rectangles are an identical gray. The lower rectangles are a darker gray but also identical.

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



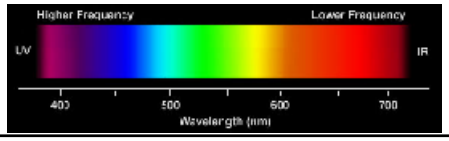
Colour Sensitivity



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

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 (e.g. stop sign, cursor, warning, attention-grabber, etc.)

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

A note on "Primary Colours"

•Light mixes additively

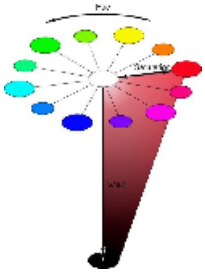
•Pigments mix subtractively

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

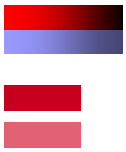
- Hue, Saturation, Value (HSV) model



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

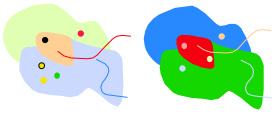
HSV colour components

- 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 (or chroma)
  - 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, even across cultures
- Choose from set of first six, then from second set of six

Colour guidelines

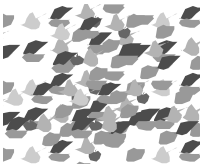
- Avoid red & green in the periphery - why?
  - lack of RG cones there -- yellows & blues work in periphery
- Avoid pure blue for text, lines, & small shapes
  - blue makes a fine background colour
  - avoid adjacent colours that differ only in blue
- Avoid single-component distinctions
  - sets of colours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

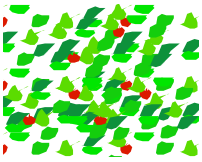
Perception primitives

- 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)

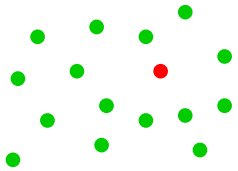
Colour great for classification

- Rapid visual segmentation
- Helps determine type

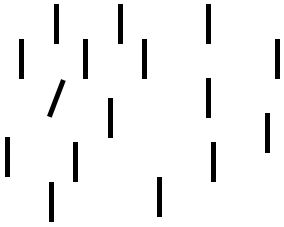




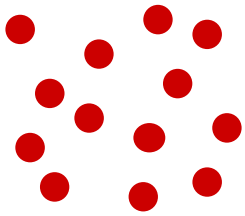
Colour



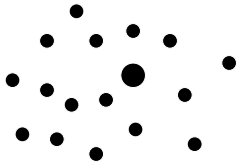
Orientation



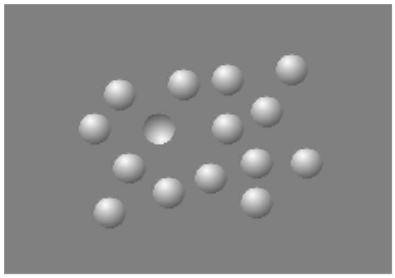
Motion



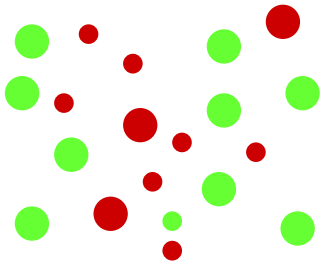
Size



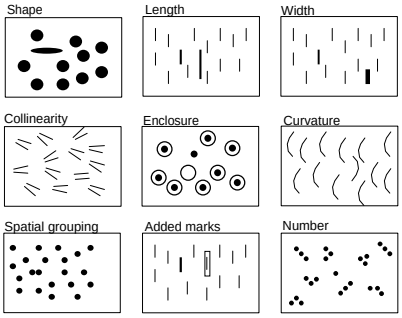
Simple shading



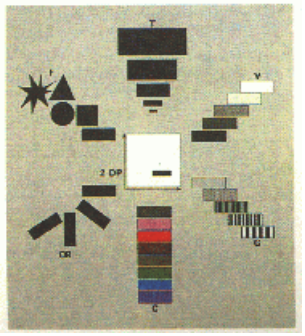
Conjunction (does not pop out)



More Preattentive channels



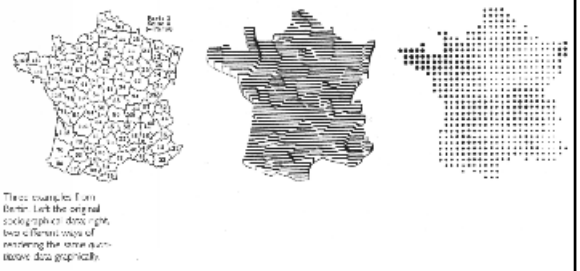
Jacque Bertin's graphical variables



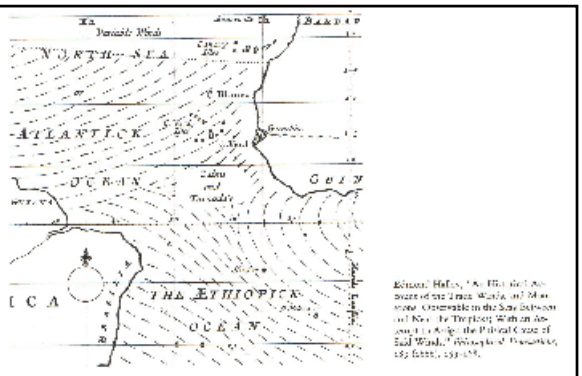
- Position
- Direction (orientation)
- Size
- Colour (hue)
- Contrast (greyness)
- 'grain' (texture)
- shape

Mijksenaar, Visual Function, p. 38

Jacque Bertin's graphical variables



Mijksenaar, Visual Function, p. 39



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

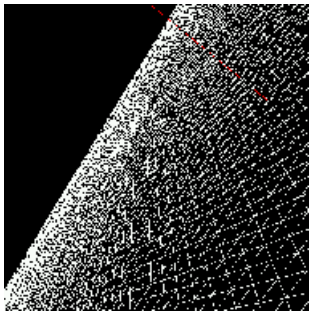
3D visual cues

Visual Depth Cues

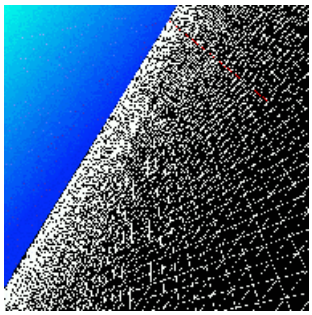
- Occlusion, transparency
- Motion parallax
- Shadows, shading, specular highlights, reflections
- Relative size, foreshortening
- Converging lines
- Ground plane grid, coloured sky
- Landmarks, compass arrows

Where am I ?

Where am I ?

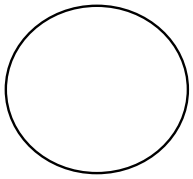


Where am I ?



Visual cues increases the amount of information that can be processed quickly.

The cow jumped over the moon.

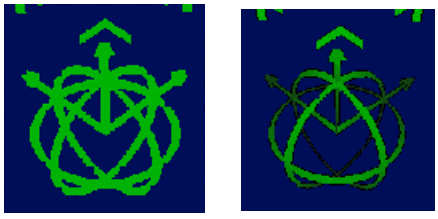


The moon is the largest natural satellite of the earth, and is composed of 30 % cheddar, 40 % mozzarella, 25 % star dust, and 5 % Elmer's glue. Yesterday, at 12:15 pm, the cow owned by Mrs. Farmwell jumped over the moon.

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

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

Example: Foreshortening and Shading used to enhance sense of depth



Example: transparency and shading use to show Sphere Eversion

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

Example: Depth cues used to enhance visual metaphors

Perception

The senses in general,
and forms of feedback

Taxonomy of feedback

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

Reference: Sellen, Kurtenbach, Buxton (1992)

Examples

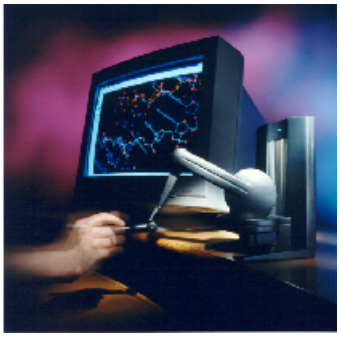
- Visual feedback
  - Usually avoidable (even when it's at the cursor!) and system-maintained
  - Not the best for indicating mode switch
  - Often leads to mode errors
- Kinesthetically held feedback
  - E.g. holding the shift key or a mouse button
  - demanding and user-maintained
  - Good for indicating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

Background/ambient information

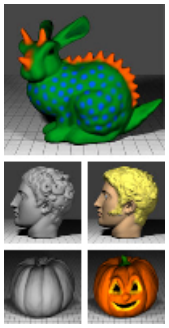
•Harder to avoid, but not obtrusive

•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

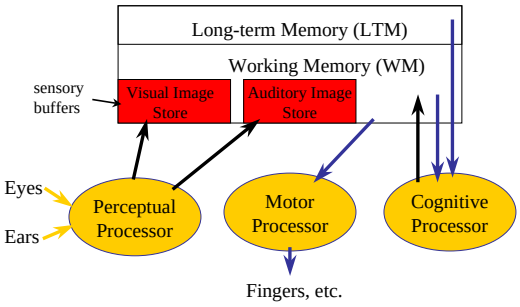
memory

What is cognition ?

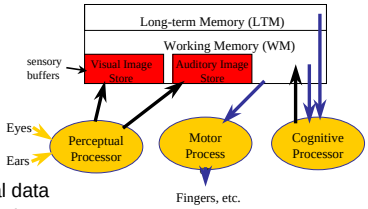
- Thinking, learning, remembering, understanding, planning, deciding, problem solving, …
- Most relevant (and most studied) aspect: **memory**

Model Human Processor (MHP)

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



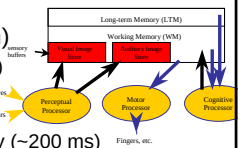
MHP Basics



- 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

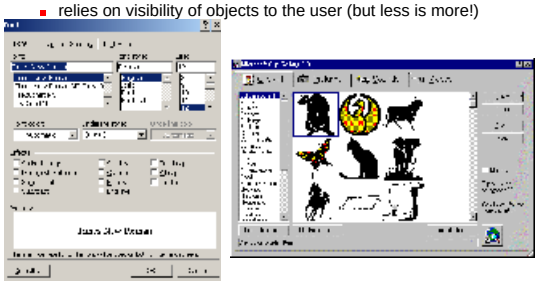
Recognition over Recall

- 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!)



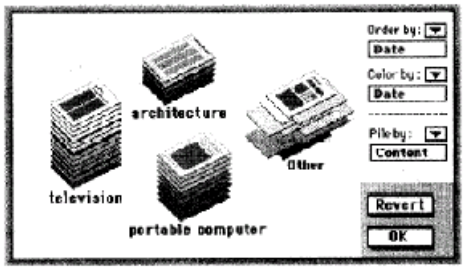
Facilitating Retrieval: Cues

- 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!

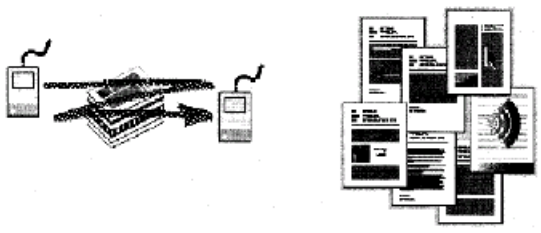
Spatial Memory

Status quo: virtual desktop

Piles (Mandler et al., Xerox PARC)



Piles (Mandler et al., Xerox PARC)



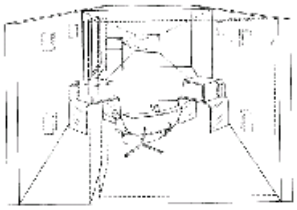
Piles (Mandler et al., Xerox PARC)

Data Mountain (G. Robertson et al.)

"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.)

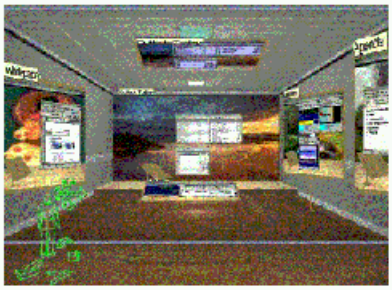


Figure 1. The Task Gallery.

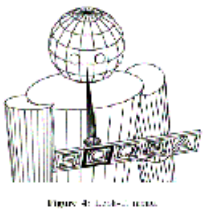
G. Robertson et al.
The Task Gallery: A 3D Window Manager. CHI 2000.

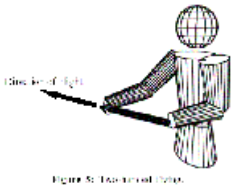
Virtual Reality (VR)

Head-mounted display

High DOF input device

Proprioception and VR





Reference for above pictures: Mine et al., "Moving objects in space: exploiting proprioception in virtual-environment interaction", SIGGRAPH '97. For related work, see also Pierce, Conway, van Dantzich, Robertson (1999), Toolspaces and Glances, I3D'99

Motor Skills

Motor : something that imparts motion

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

Pointing Task Exercise

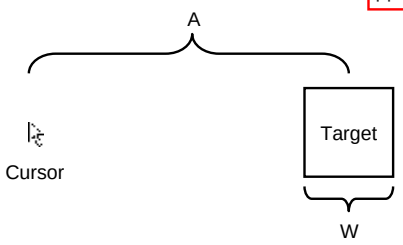
- Try reciprocal tapping exercise on blackboard (volunteer please …)
- Blackboard "derivation" of Fitts' Law

Fitts' Law

- Originally used to model reciprocal tapping task in 1D (1954)
- Was subsequently also shown to model discrete ("one shot") pointing in 1D (1964)
- Hundreds (thousands?) of subsequent studies have confirmed Fitts' Law in various different situations
- Remains one of the only robust mathematical models available to UI designers and HCI researchers

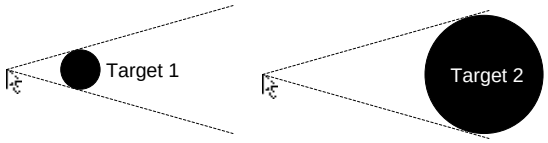
Fitts' Law (for rapid, aimed motion)

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



Fitts' Law

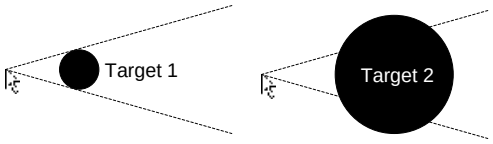
$$MT = a + b \cdot ID, \quad ID = \log_2\left(\frac{A}{W} + 1\right)$$



Same ID ? Same Difficulty

Fitts' Law

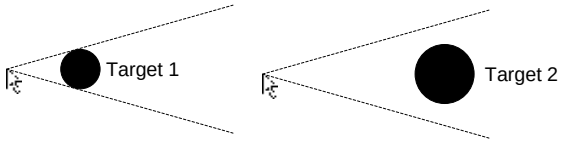
$$MT = a + b \cdot ID, \quad ID = \log_2\left(\frac{A}{W} + 1\right)$$



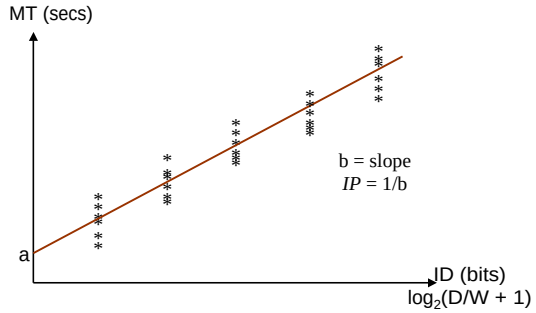
Smaller ID ? Easier

Fitts' Law

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



Larger ID ? Harder



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

ID = index of difficulty

IP = 1/b = index of performance

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

Fitts' Law models

- Reciprocal "back and forth" movements in 1D, and discrete "one shot" uni-directional movements in 1D

And applies to

- Hand and foot movements
- Movements in air, underwater, and under a microscope
- Grasping, pointing, dart throwing
- Mice, trackballs, joysticks, touchpads, helmet-mounted sights, eye trackers
- Position and velocity control input devices
- Linear and rotary movements
- Mentally retarded individuals and pre-school children

Note: in each case, the constants a and b may change !

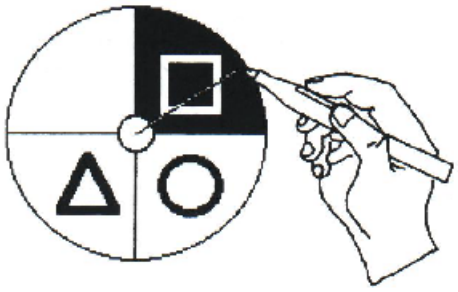
Lessons from Fitts' law

- 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)

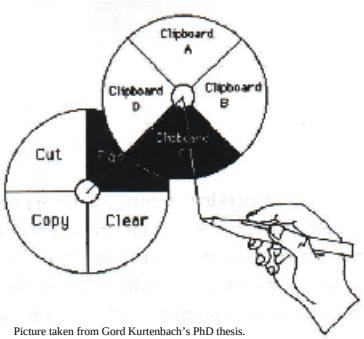
http://psychology.wichita.edu/surl/usabilitynews/41/adapt_menus.htm

Radial Menus



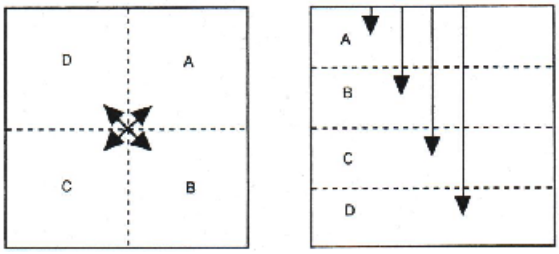
Picture taken from Gord Kurtenbach's PhD thesis.

Hierarchical Radial Menus



Picture taken from Gord Kurtenbach's PhD thesis.

Radial vs Linear



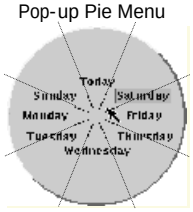
Picture taken from Gord Kurtenbach's PhD thesis.

Using these law's to predict performance

Pop-up Linear Menu

Today
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday

Pop-up Pie Menu



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

Miniature keyboards for 2-thumb typing: Where's the best place for the spacebar ?

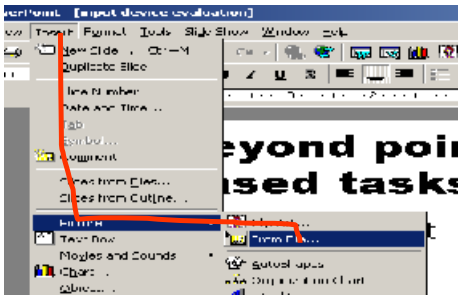
http://www.yorku.ca/mack/gi2002.html

Using Fitts' Law to model 2-thumb typing

- Take into account size and spacing between buttons
- Assume thumbs alternate in typing whenever possible (maximizes speed)
- Given a corpus of text, compute frequencies of sequences of letters
- Weigh the time to type in each sequence by its frequency
- Arrive at (upper bound for) average typing speed
- MacKenzie and Soukoreff's (2002) estimate:

  60.7 wpm !
- Assumes spacebar in centre. If spacebar is on left or right, estimate drops to 49.9, 56.5 wpm respectively.

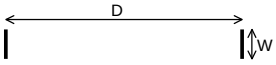
Beyond pointing: Trajectory based tasks



From targets to tunnels…

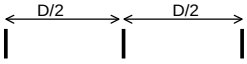
- 2 goals passing

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



- 3 goals passing

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

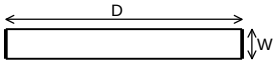


- N+1 goals passing

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

- ∞ goals passing

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

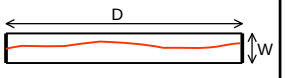


Steering Law (Accot, 1997)

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

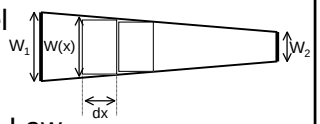
- Fixed width tunnel

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



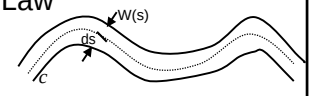
- Narrowing tunnel

  $ID = \int_D \frac{dx}{W(x)}$

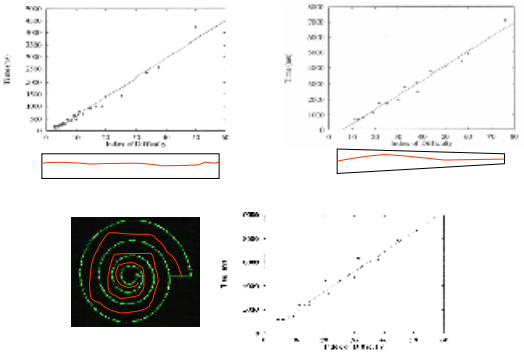


- General Steering Law

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



Some results (from Accot, 1997)



- Questions ?
- Video / Demo of Marking Menus ?
  - volunteer please …