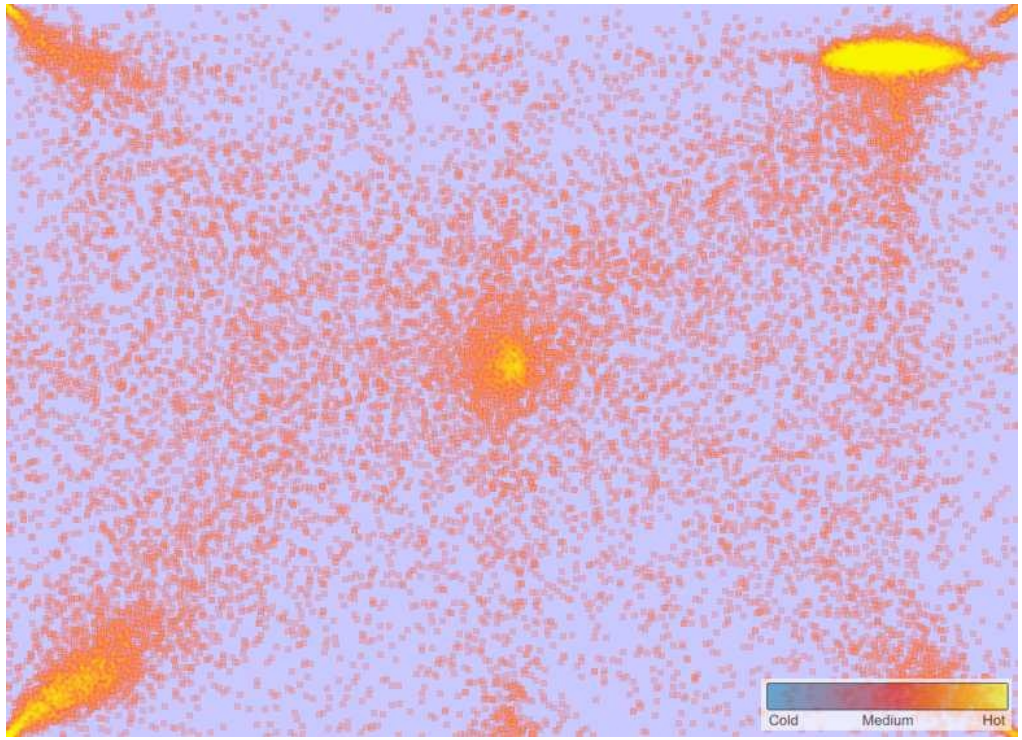
# The Human

Finished files are the result of years of scientific study, combined with the experience of many years.

# blogoscoped.com/click2



# Human Factors

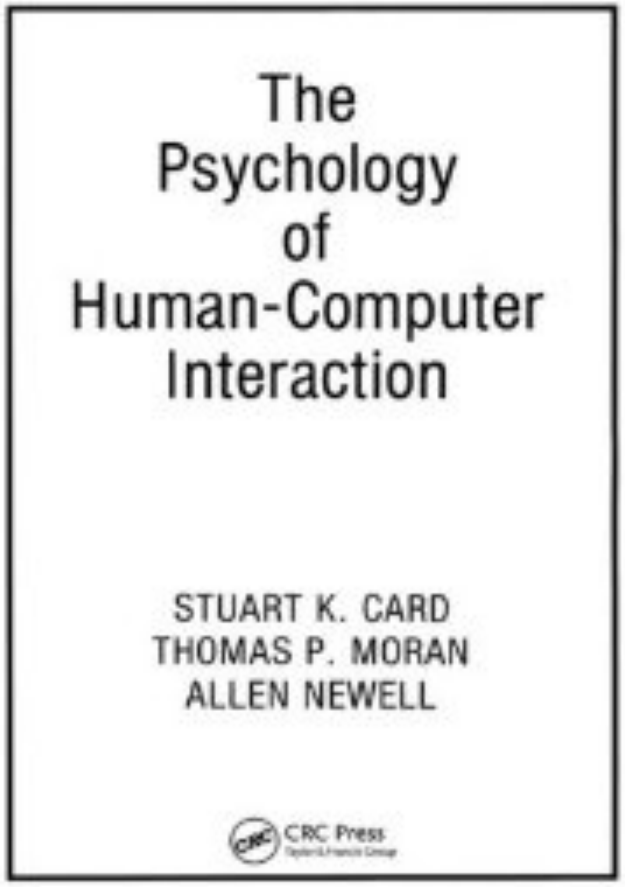
- Psychological and physiological abilities (users and designers) have implications for design
  - Perceptual: how we perceive things (input)
  - Cognitive: how we processes information
  - Motor: how we perform actions (output)
  - Social: how we interact with others
- Understand efficiencies, problems, causes, etc.
- Predict interaction

Also: NASA Man-Systems Integration Standards: https://msis.jsc.nasa.gov/Volume1.htm

# The Human Information Processor

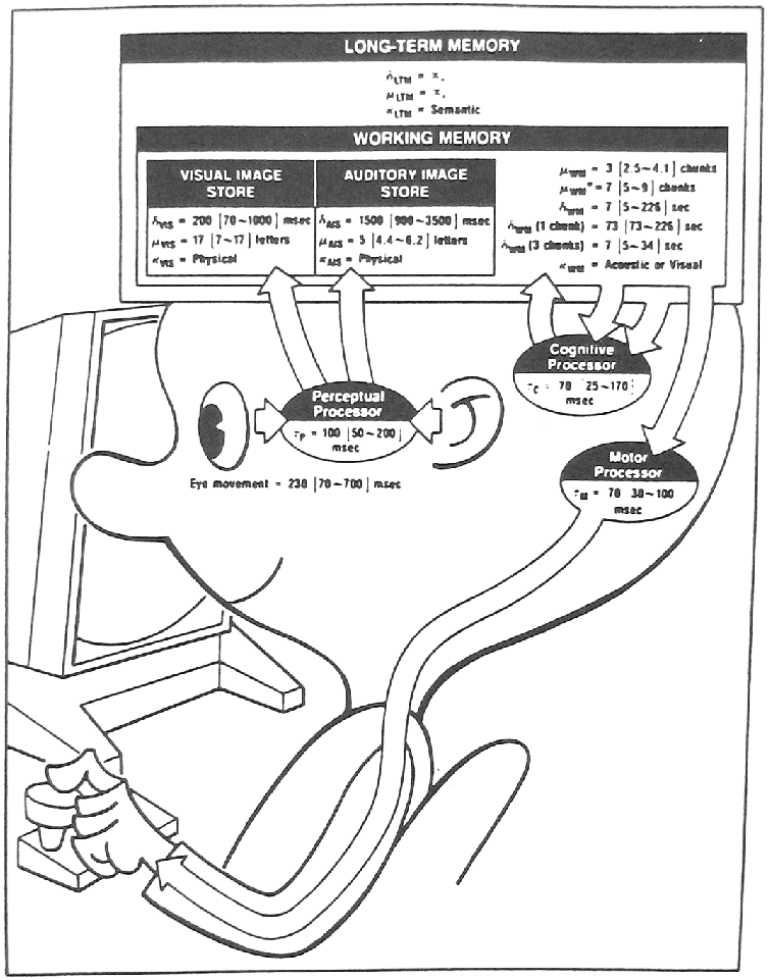
Card, Moran, Newell 1983

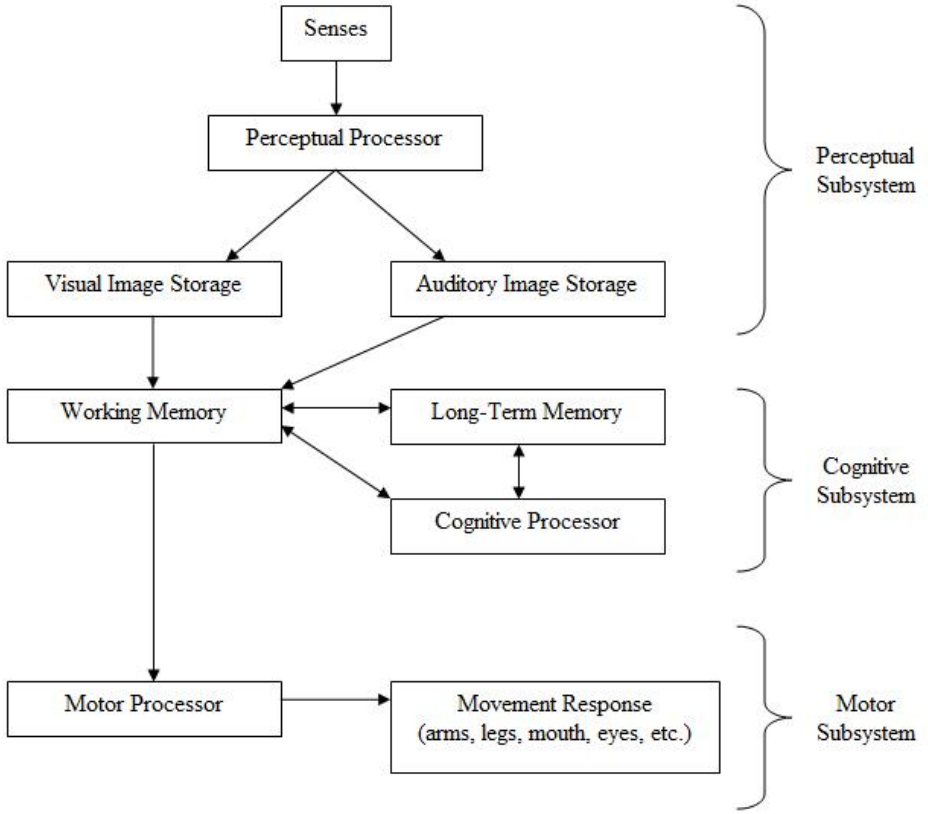
- Underlying psychology of interaction
- Predictive engineering models (GOMS/KLM)
- Extensive empirical validation
- Core computer science!



# The Human Information Processor

Card, Moran, Newell 1983

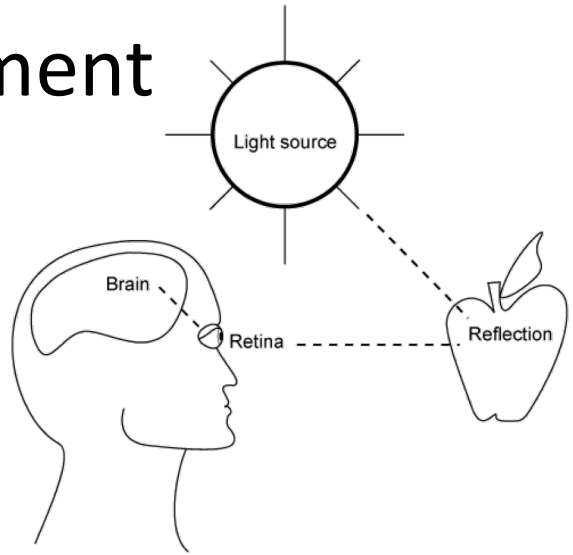


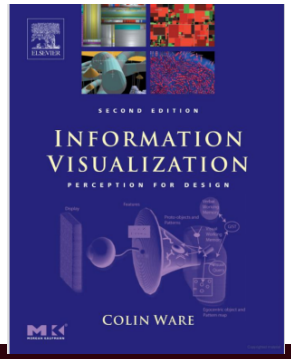

Also: NASA Man-Systems Integration Standards: https://msis.jsc.nasa.gov/Volume1.htm

# Human Input: Vision

- Mechanics, acuity & movement
- Size and depth
- Colour
- Reading

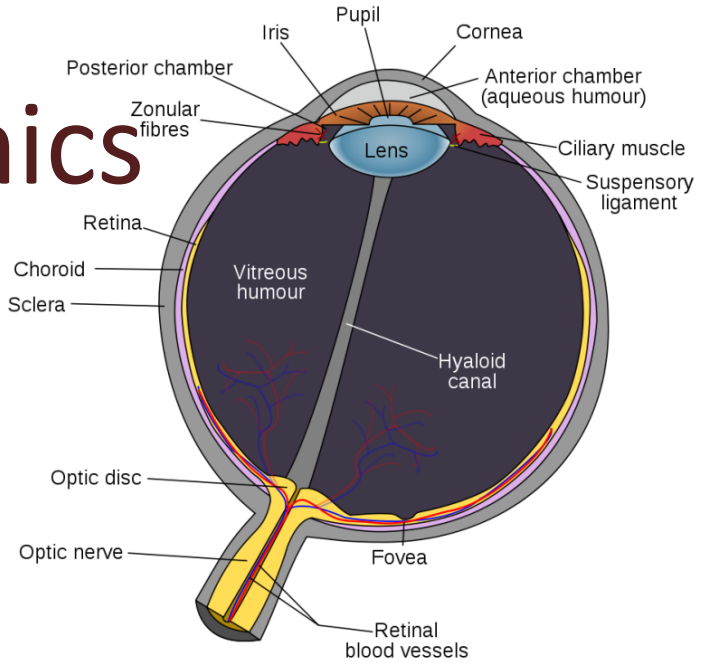


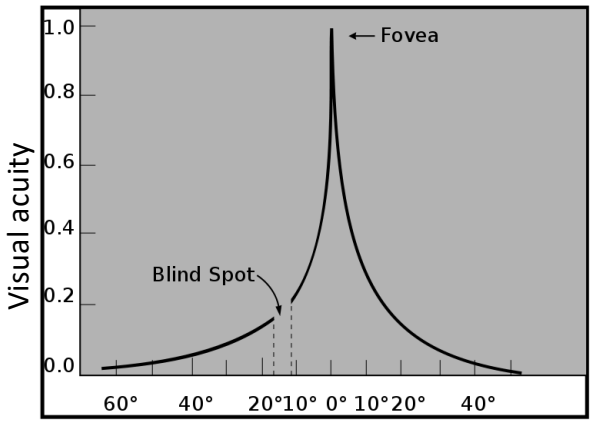

- Colin Ware. Information Visualization: Perception by Design



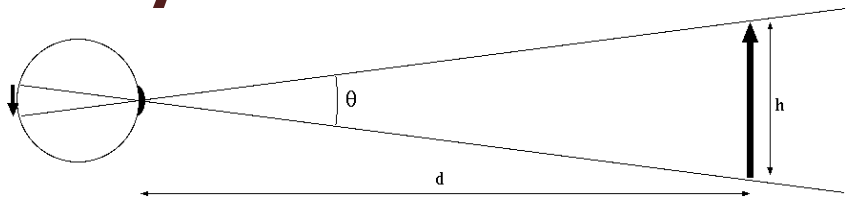
# Vision Mechanics

- Photoreceptors cells
  - Rods: low light, monochrome, 100M across retina (not fovea)
  - Cones: normal light, colour, 6M, in fovea
- Fovea: detailed vision of ≈2°
- Retina: non-detailed vision of ≈140°; sensitive to movement



# Visual Acuity




- Point acuity: ••
  1 minute of arc
- Grating acuity: IIIII
  1-2 minutes of arc
- Letter acuity: E
  5 minutes of arc
- Vernier acuity: ——— ———
  10 seconds of arc

# Popout Across Visual Field

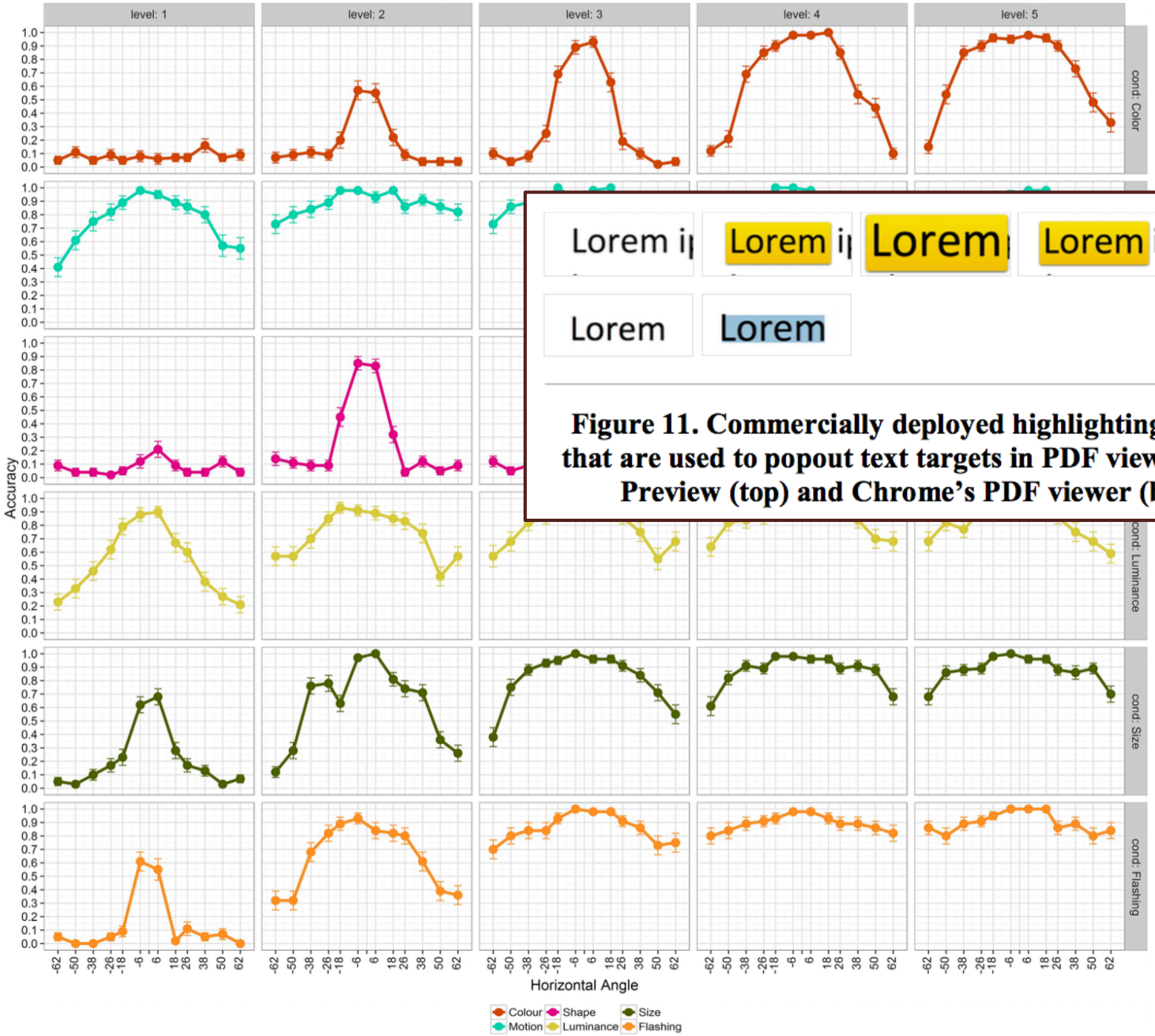



Figure 6. Accuracy ±s.e. by Variable (rows), Intensity Level (columns), and Angle (x-axis). Target-present trials only.




**Figure 11. Commercially deployed highlighting techniques that are used to popout text targets in PDF viewers: Apple's Preview (top) and Chrome's PDF viewer (bottom).**

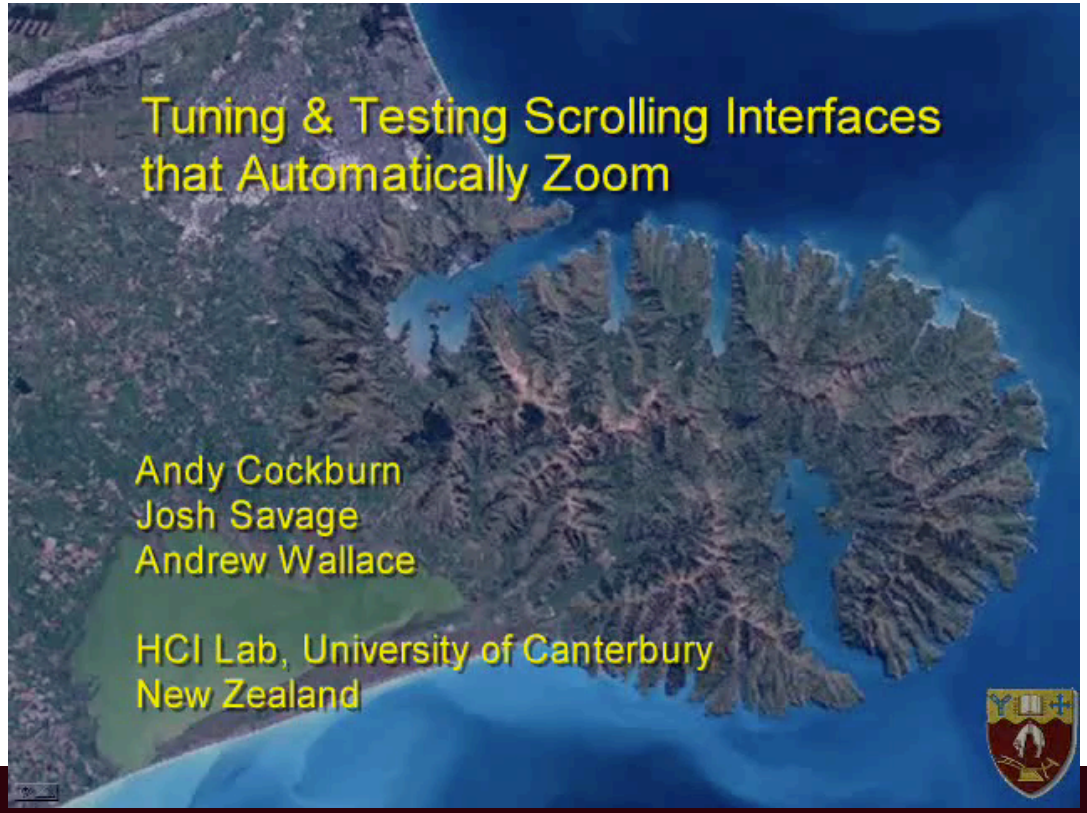
Gutwin, Cockburn, Coveney, 2017

# Eye movement

- Fixations: visual processing occurs when the eye is stationary (nearly)
- Saccades: rapid eye movements (900° sec), blind
- Smooth-pursuit: for tracking moving objects; up to 100° sec; cannot be induced voluntarily
  - relevant in scrolling, e.g. SDAZ

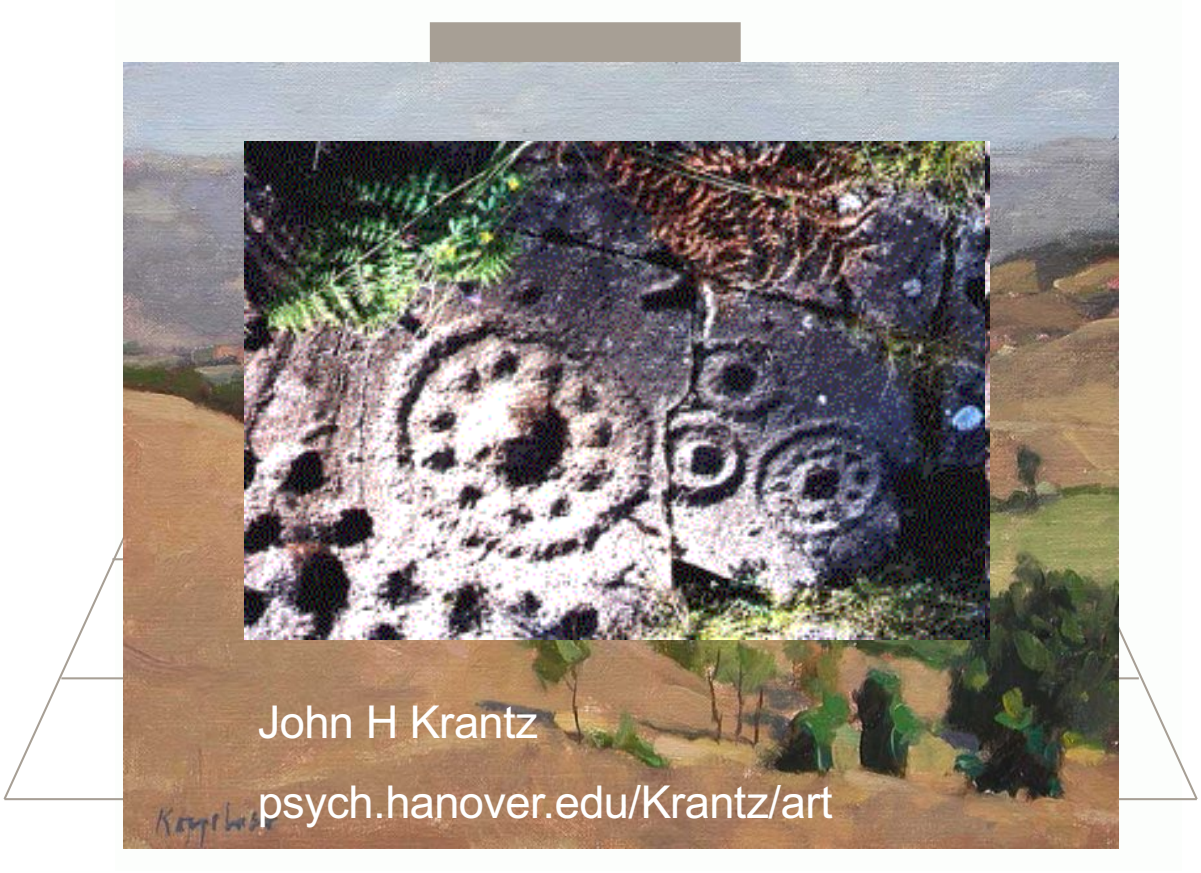
# Demo: SDAZ

- Speed-dependent automatic zooming: overcome motion blur…

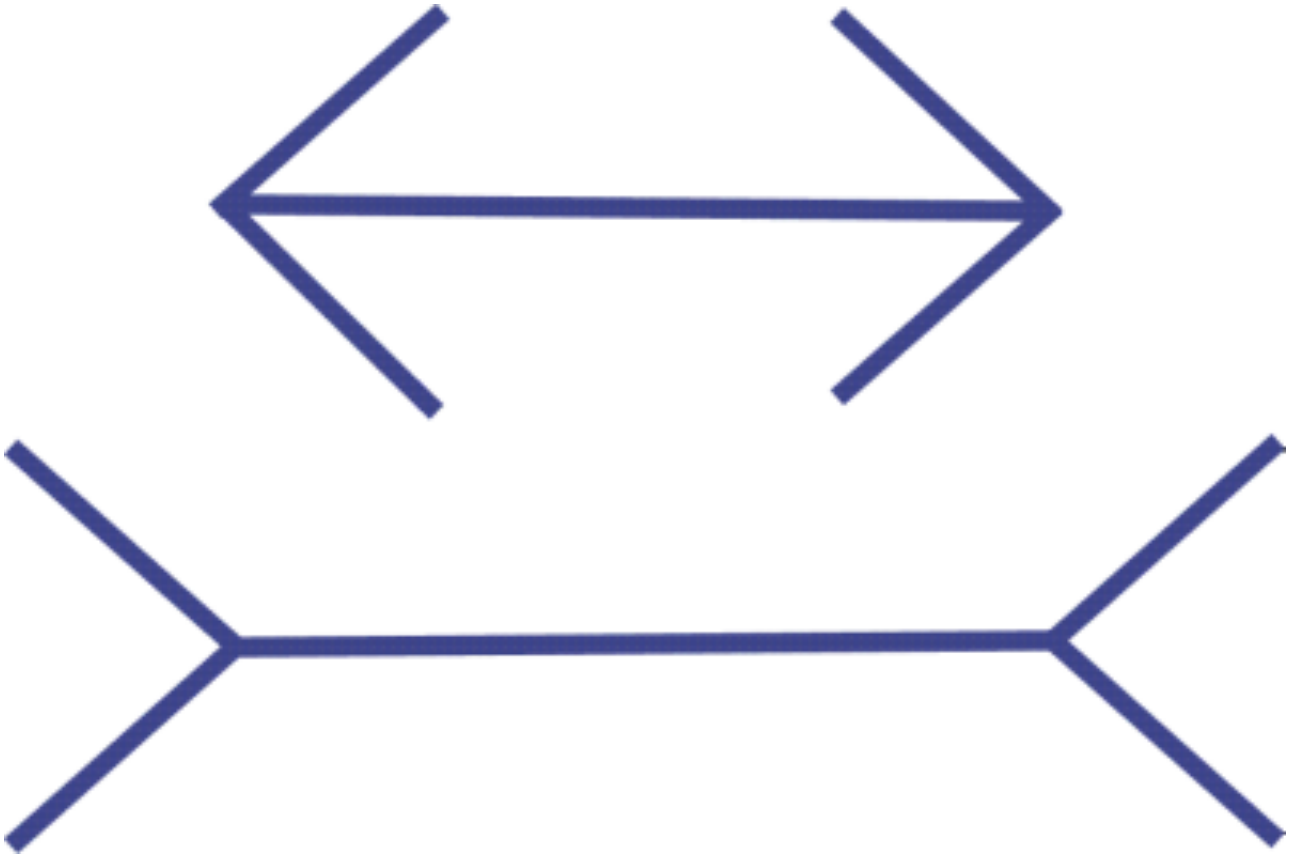


# Size/Depth Cues

- Familiarity
- Linear perspective
- Horizon distance
- Size constancy
- Texture gradient
- Occlusion
- Depth of focus
- Aerial perspective
- Shadows/Shading
- Stereoscopy
  (ineffective beyond 10m; best within 1m)



# Muller-Lyer Illusion



# Size/Distance Ambiguity

Father Ted. Cows

# Colour

- Colour can clarify information and enhance subjective experience
- 8% males, 0.4% females have some form of colour deficiency
  - Protanomaly : red; 1% M, 0.01% F
  - Deuteranomaly: green;  6% M, 0.4% F
  - Tritanomaly: blue, 0.01% M, F
- Sensitivity to blue is lowest (2% cones)

# Colour


Protanopic color vision.


Normal trichromatic color vision.


Deuteranopic color vision.

Image checker…

http://www.vischeck.com/vischeck/vischeckImage.php


Chesham
Chalfont & Latimer
Amersham
Chorleywood
Watford
Croxley
Rickmansworth
Moor Park
Northwood
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Cutty Sark for Maritime Greenwich
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Upminster
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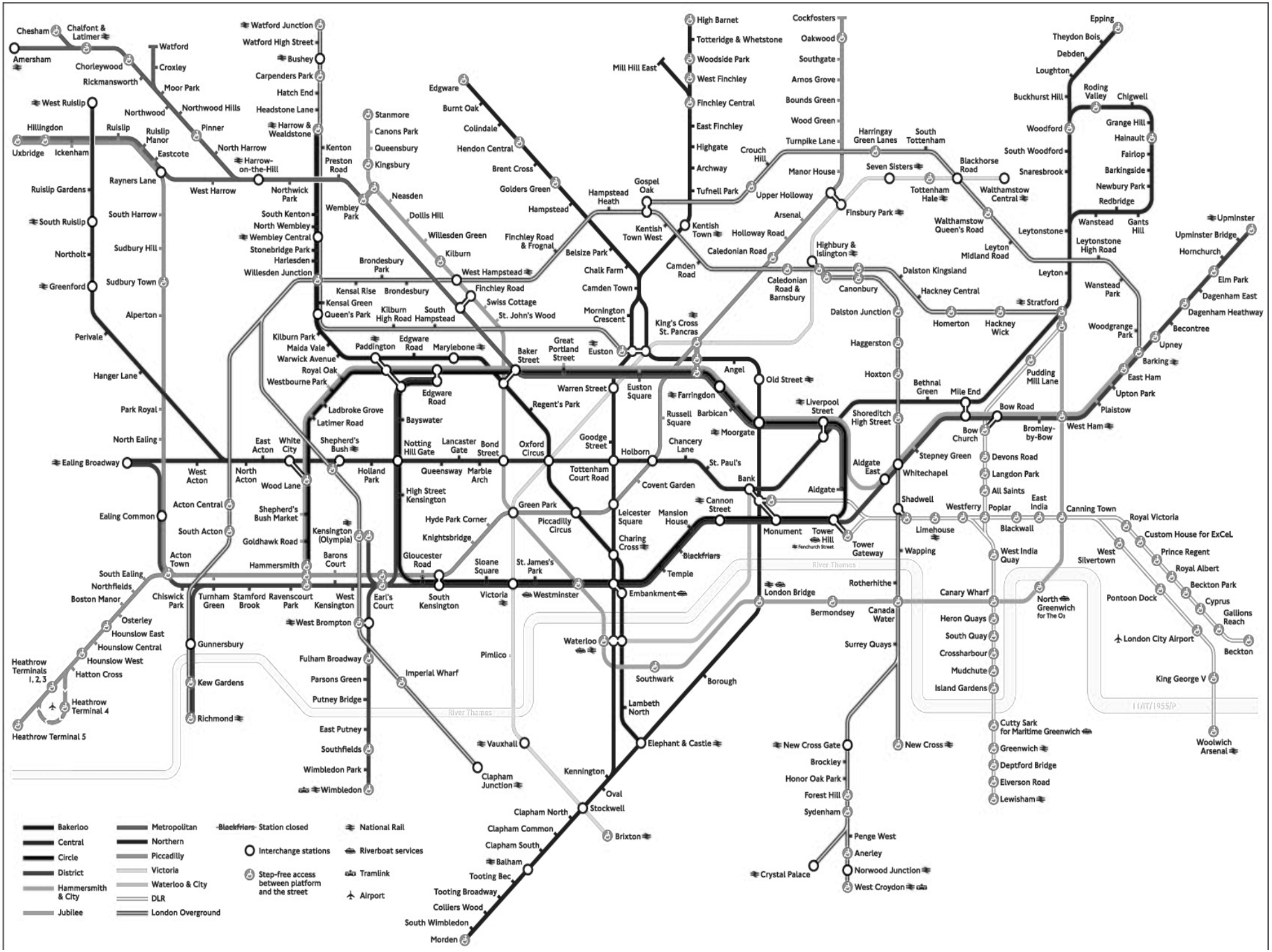
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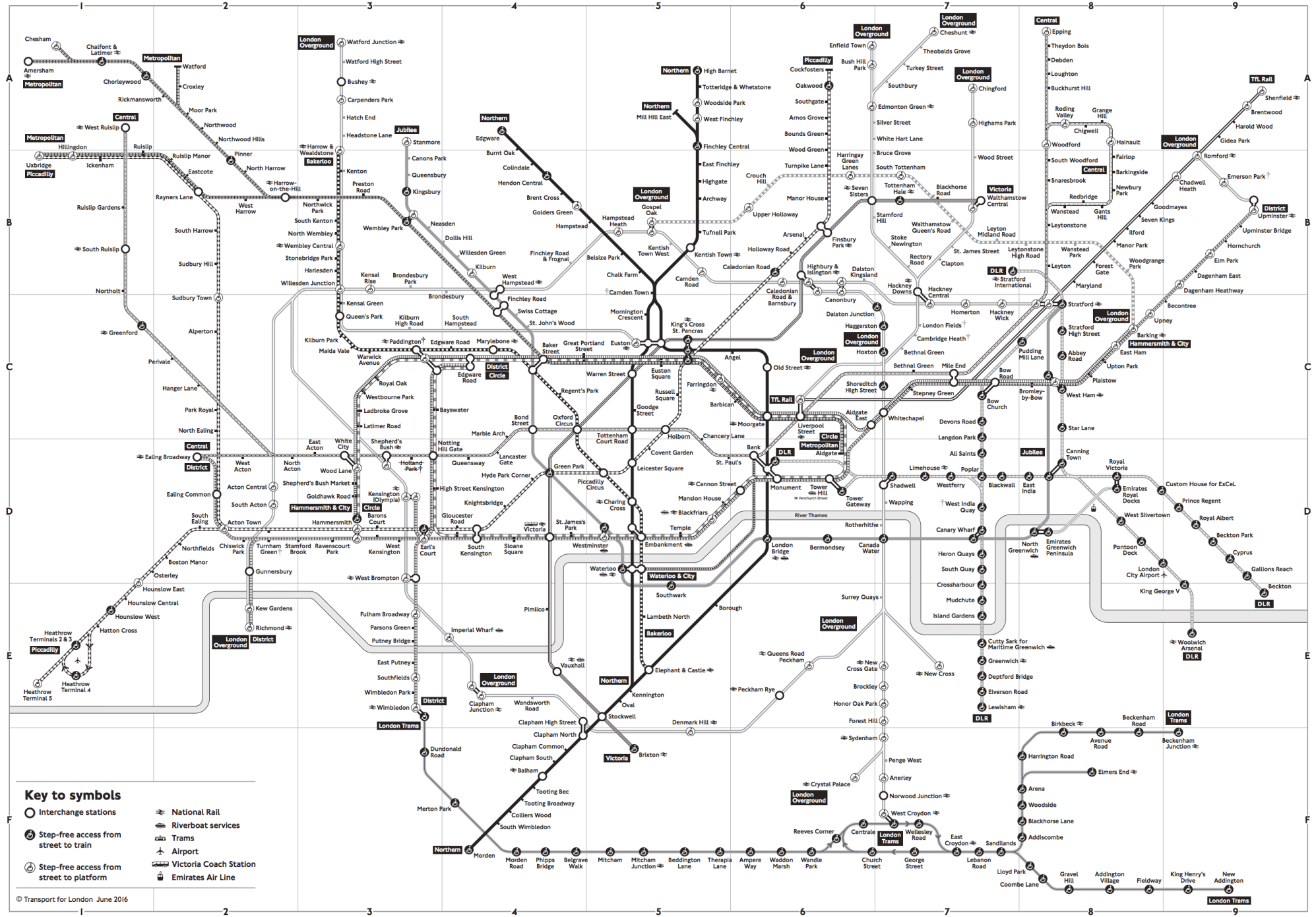
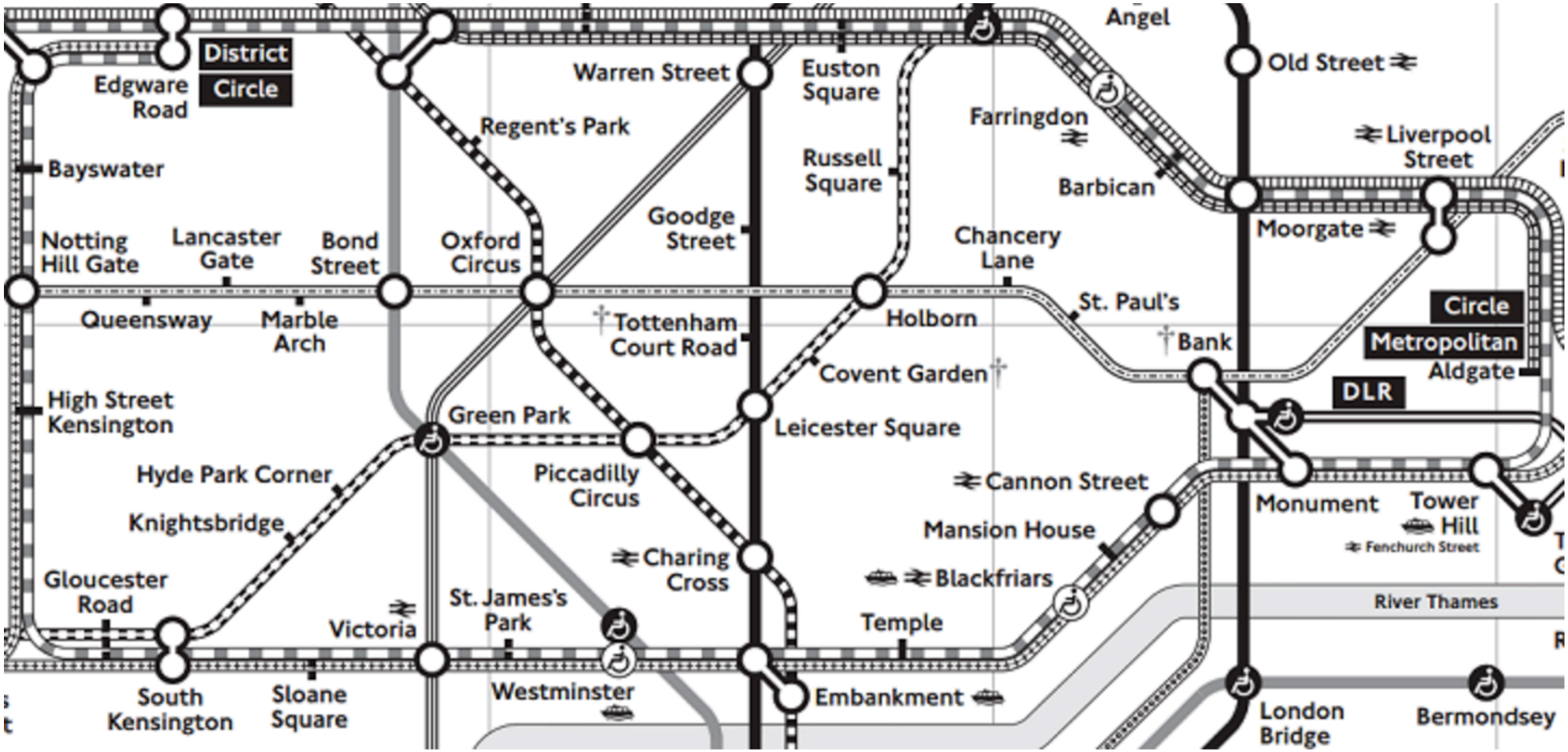

Key to symbols
Interchange stations
Step-free access from street to train
Step-free access from street to platform
National Rail
Riverboat services
Trams
Airport
Victoria Coach Station
Emirates Air Line
© Transport for London June 2016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London Bridge
Bermondsey

# Reading

- Saccades, fixations (94% time), regressions
- ≈ 250 words/min (first time)
- Reading speed impaired by ALL CAPS, probably due to reduced character legibility

# Human Input: Auditory

- Part of eyes-free interaction
- Pitch: ≈ 20Hz to 15 KHz; good to poor distinction
- Many parameters: amplitude, timbre, direction
- Filtering capabilities (e.g., cocktail party effect)
- Problems with signal interference and noise!

# Human Input: Haptic

- Haptics =
  - Proprioception: sense of limb location +
  - Kinaesthesia: particularly limb movement +
  - Tactition: skin sensations
- Potentially powerful: eg Braille

- H
  -
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- P

# Human Input: Olfactory!

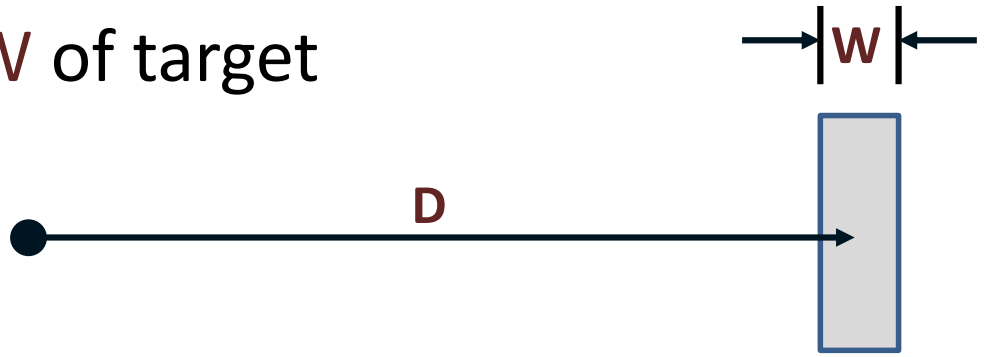
# Human Output

- Motor response times depend on stimuli:
  - Visual ≈ 200 ms, audio ≈ 150 ms, haptics ≈ 700 ms
  - Faster for combined signals

- Muscle actions:
  - Isotonic: contraction yields movement (e.g., mouse)
  - Isometric: contraction with no movement

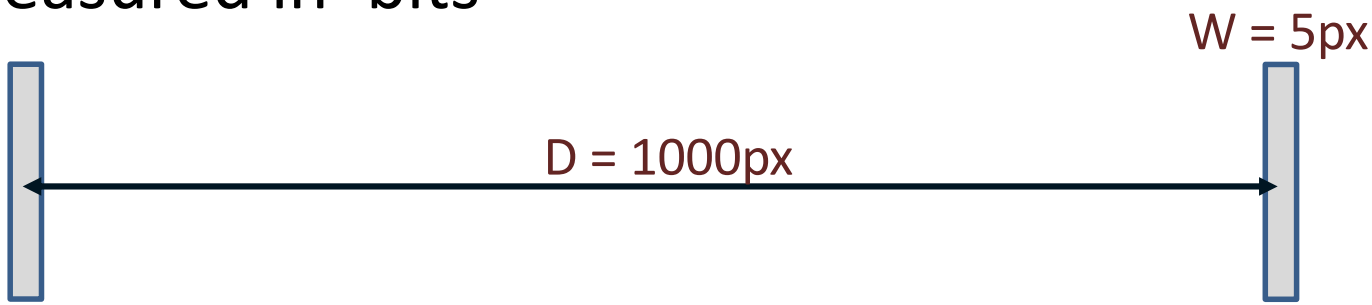
# Human Output: Fitts' Law

- A model of rapid, aimed human movement:
- Predictive of tasks; descriptive of devices
- Derived from Shannon's theory of capacity of information channels:
  - 'Signal': distance D of movement (or A for amplitude)
  - 'Noise': width W of target



# Human Output: Fitts' Law

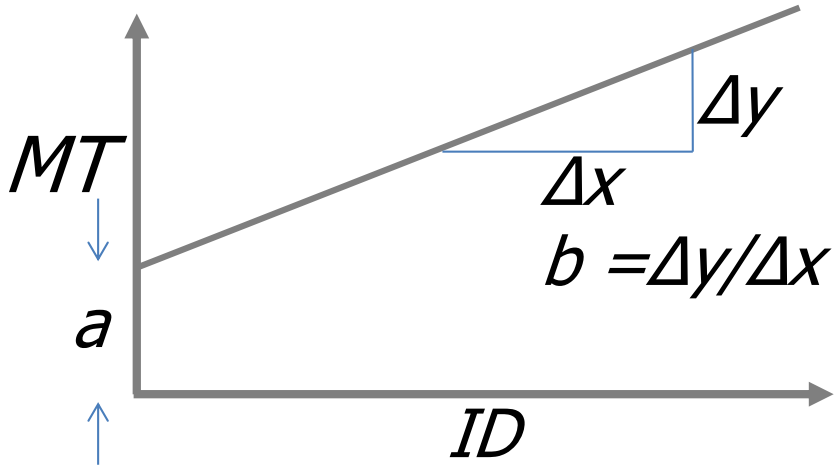
- 'Index of difficulty' (ID) measures difficulty of rapid aimed movement:
  - $ID = log_2 (A/W + 1)$
  - Measured in 'bits'




  - ID = $log_2 (1000/5 + 1) = 7.651$ *bits*

# Human Output: Fitts' Law

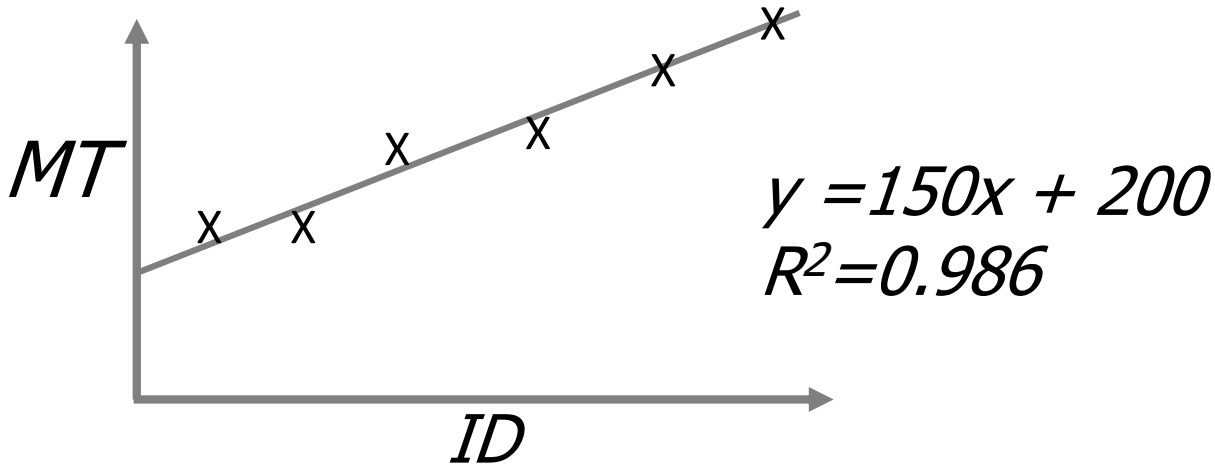
- Fitts' Law: movement time (*MT)* is linear with *ID*
  - $MT = a + b\ ID$ or $MT = a + b\ log_2\ (A/W + 1)$




  - Reciprocal of slope (*1/b)* also called 'throughput' or 'bandwidth' of device; in bits/second

# Human Output: Fitts' Law

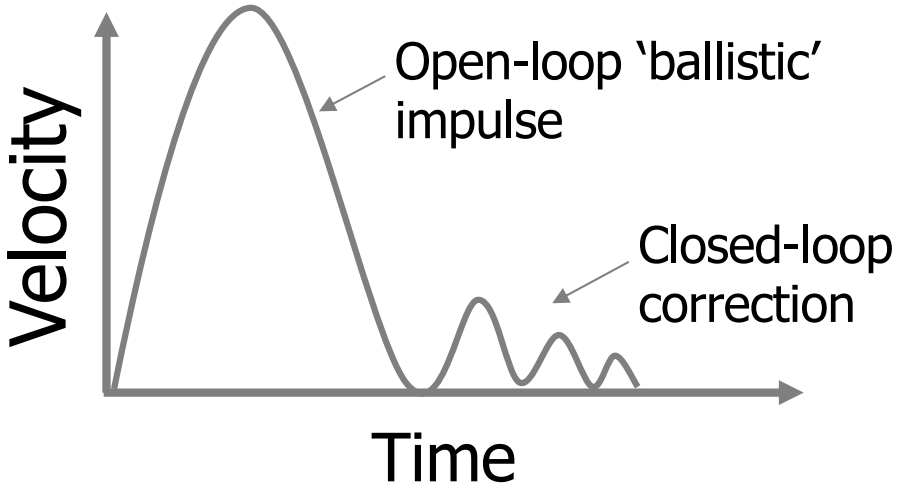
- *a* and *b* empirically determined (regression)




- For a mouse:
  - *a* typically 200-500 ms
  - *b typically* 100-300 ms/bit

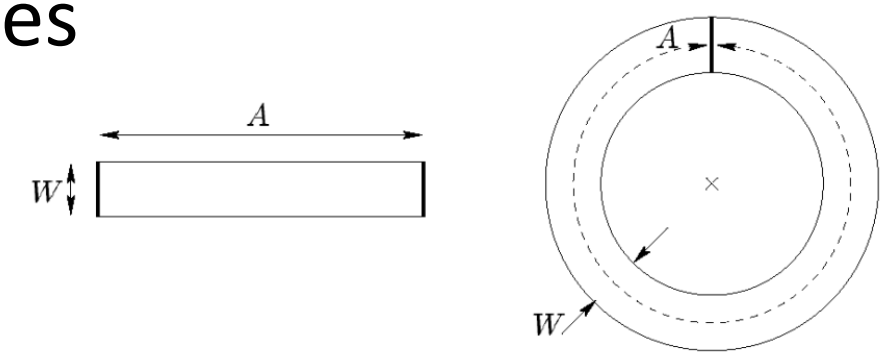
# Human Output: Fitts' Law

- Accurate and extensively validated for many types of aimed pointing
  - Consider velocity profile



# Human Output: Steering Law

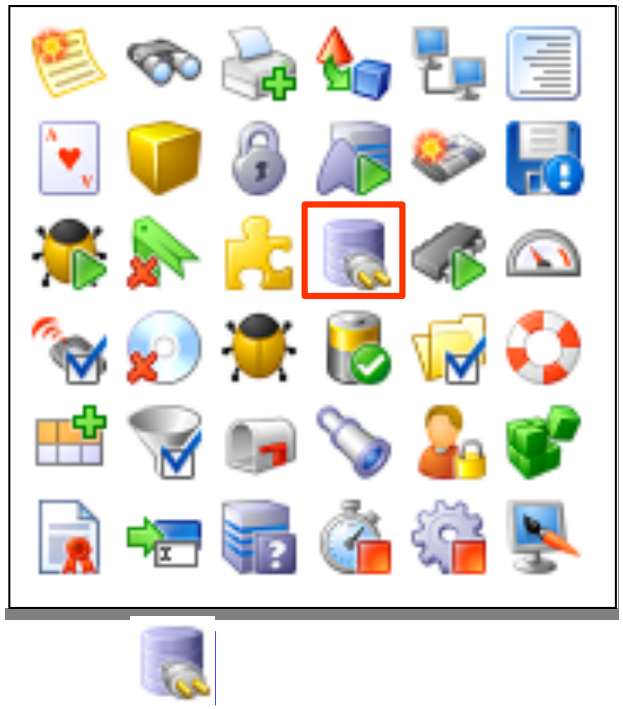
- A model of continuously controlled 'steering'
  - *MT = a + b ID* or *MT = a + b (A/W)*
  - *A* is the tunnel length; *W* is tunnel width
  - *(A/W)* still called 'index of difficulty'
- Also works when W varies

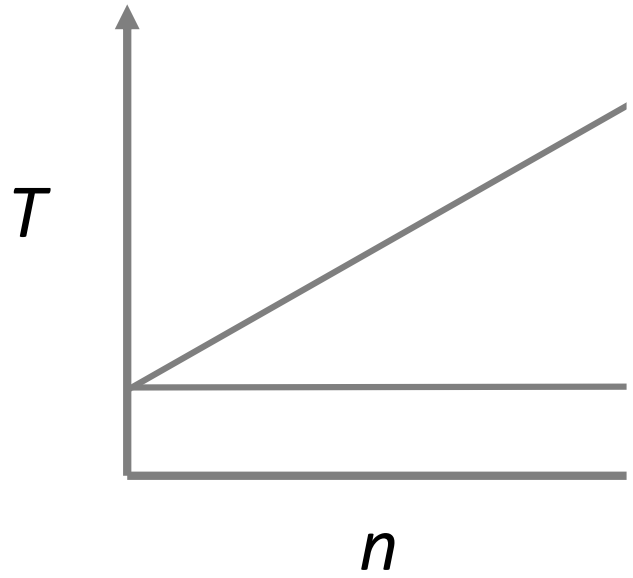


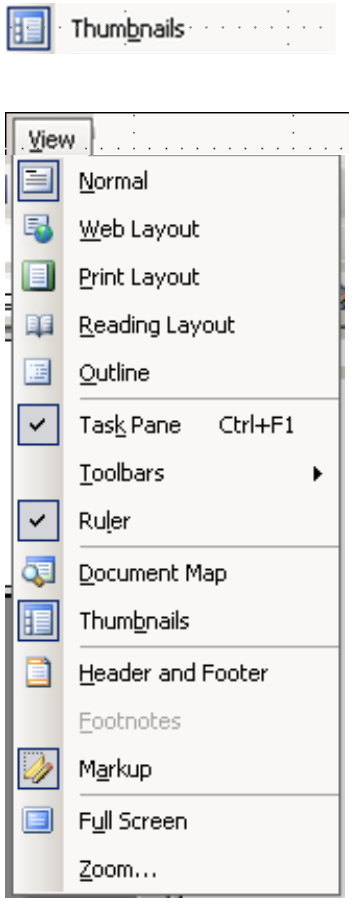

(a) Linear tunnel (b) Circular tunnel

# Human Processing: Visual Search Time

- Extensively researched in psychology






Findlater, et al. CHI'09

# Human Processing: Visual Search Time

- Extensively researched in psychology
- Visual search time is a linear function of the number of candidate items: O(n) , i.e., $T = a+b \times n$
- BUT, pop-out effects can reduce that to O(1)

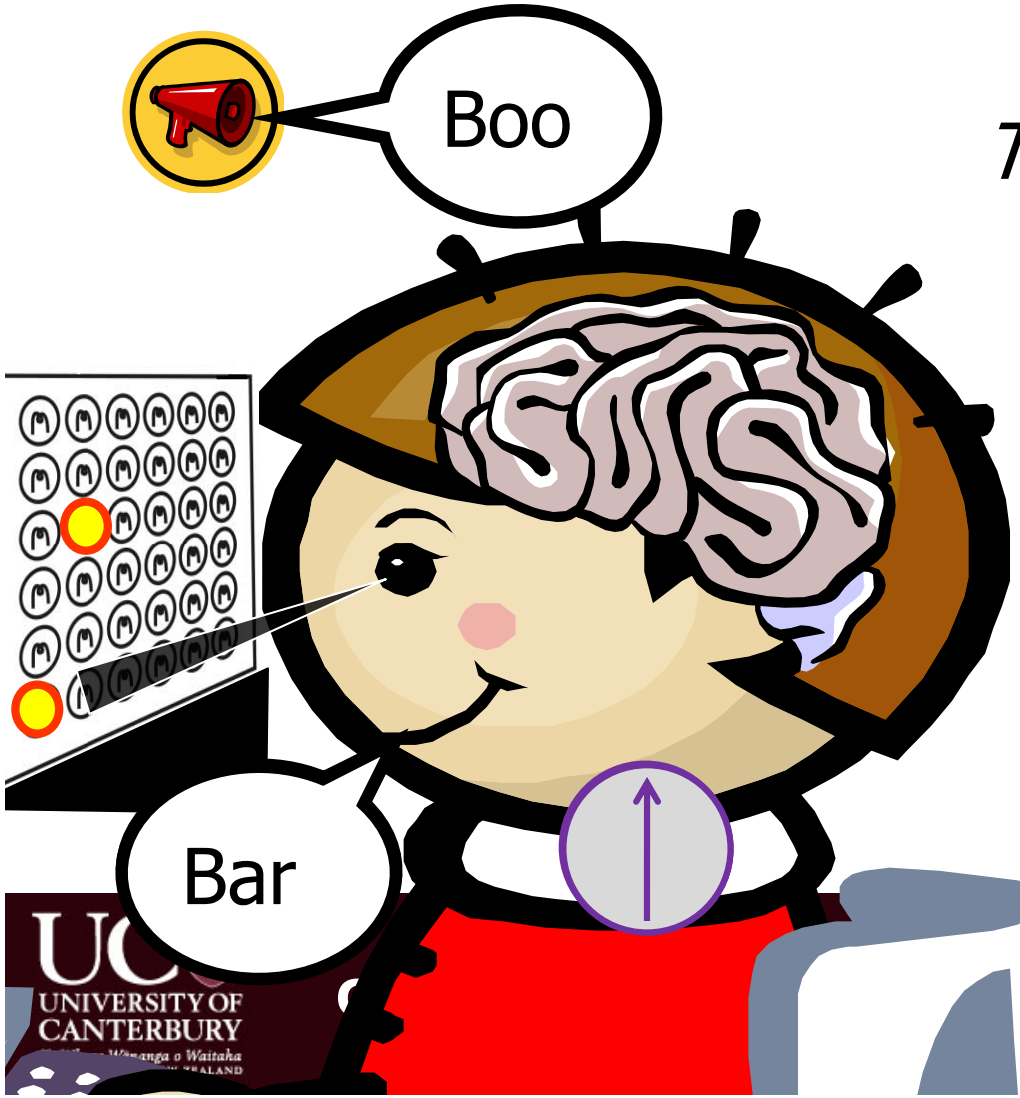
- Visual search is essential when novice, but ideally unnecessary with experience (more soon)

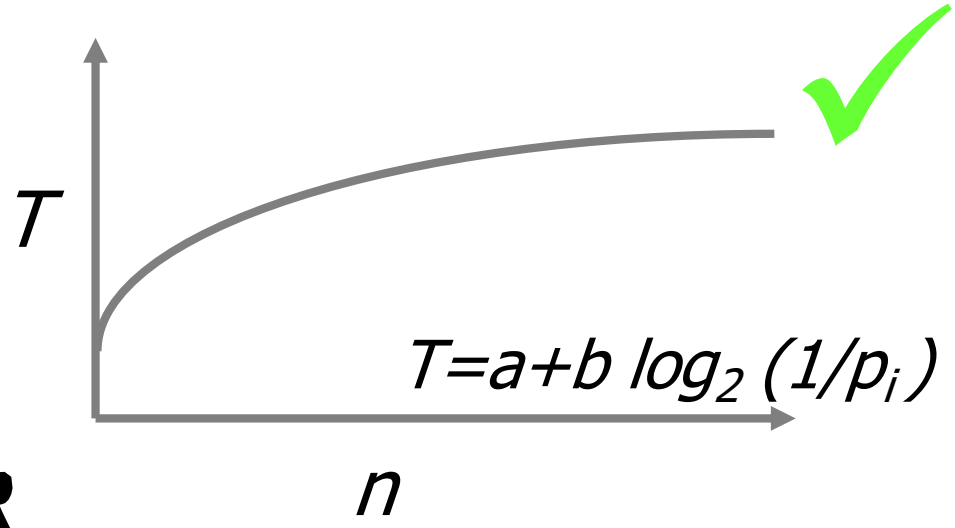
# Human Processing: Hick/Hyman Law of Decision Time

- Choice reaction time when optimally prepared
  - $T = a + b \times H$
  - H is 'information entropy'
  - For item *i,* with probability $p_i$, $H_i = log_2(1/p_i)$
  - For *n* equally probable items, $H = log_2(n)$

- We make frequent decisions quickly!

# Human Processing: Hick/Hyman Law of Decision Time



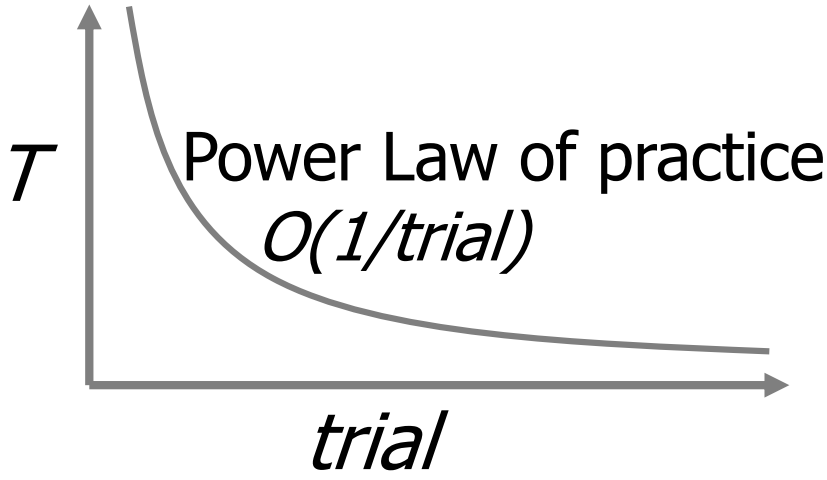

In our menu experiments,
*a*=240ms, *b*=80ms/bit

# Human Processing: Implications of Hick/Hyman Law

- Decisions are fast: O(log n)
- Applies to name retrieval (commands) and location retrieval
- In GUIs, replace visual search (O(n)) with decision through spatial stability

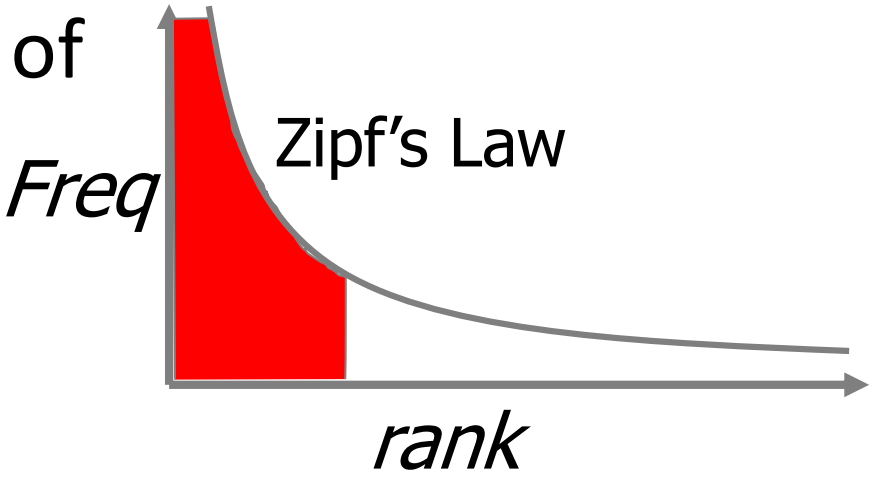
# Human Processing: Power Law of Practice

- Performance rapidly speeds up with practice
  - $T_n = Cn^{-\alpha}$ or $log(T_n) = C - \alpha log(n)$
  - $T_n$ is time on trial n
  - $C$ is time on trial 1
  - $\alpha$ is learning curve
- Applies to simple and complex tasks

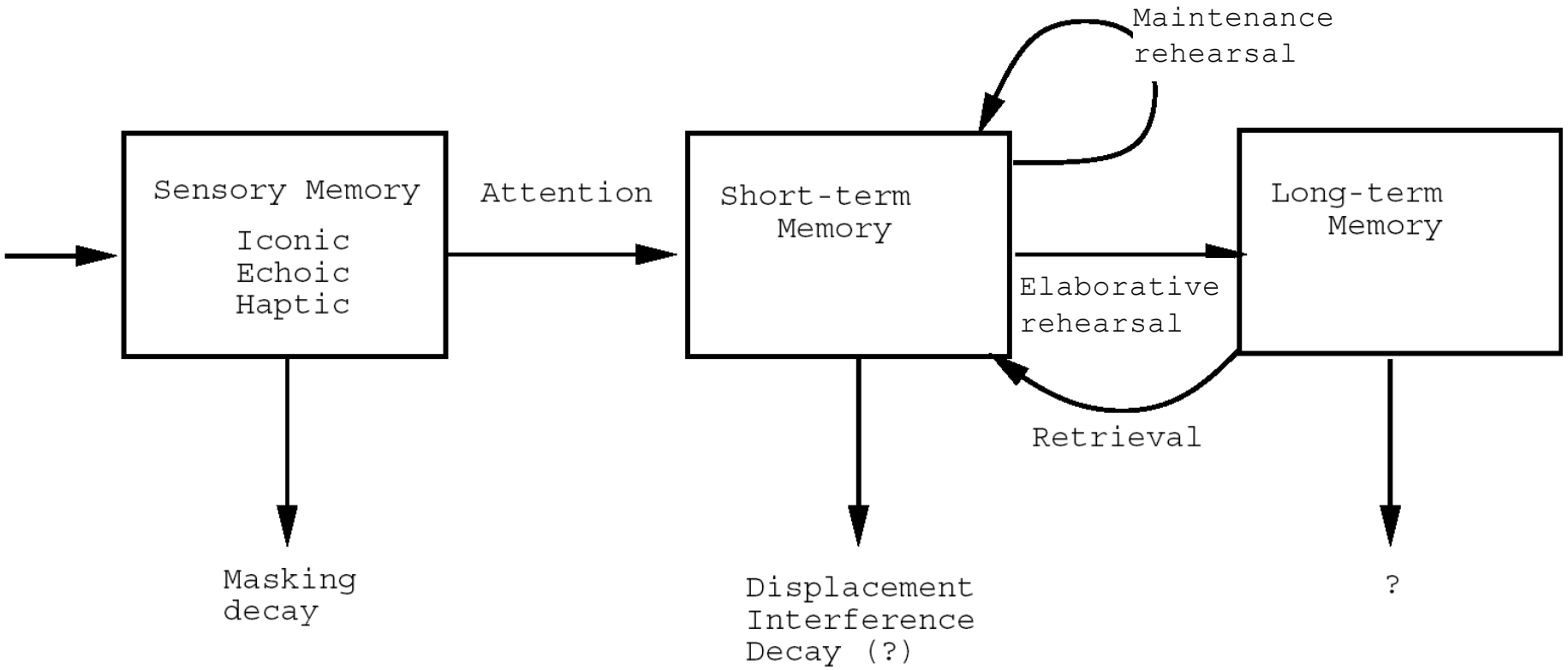


# Human Pattern of Behaviour: Zipf's Law, Pareto Principle, 80-20 rule

- Frequency of words (Zipf 1932)
  - $P_n \approx n^{-\alpha}$
  - $P_n$ is scaling factor of frequency of $n^{th}$ ranked word
  - $\alpha \approx 1$
- Also applies to frequency of commands, URLs, apps, windows, ...
- 80% of time using 20%



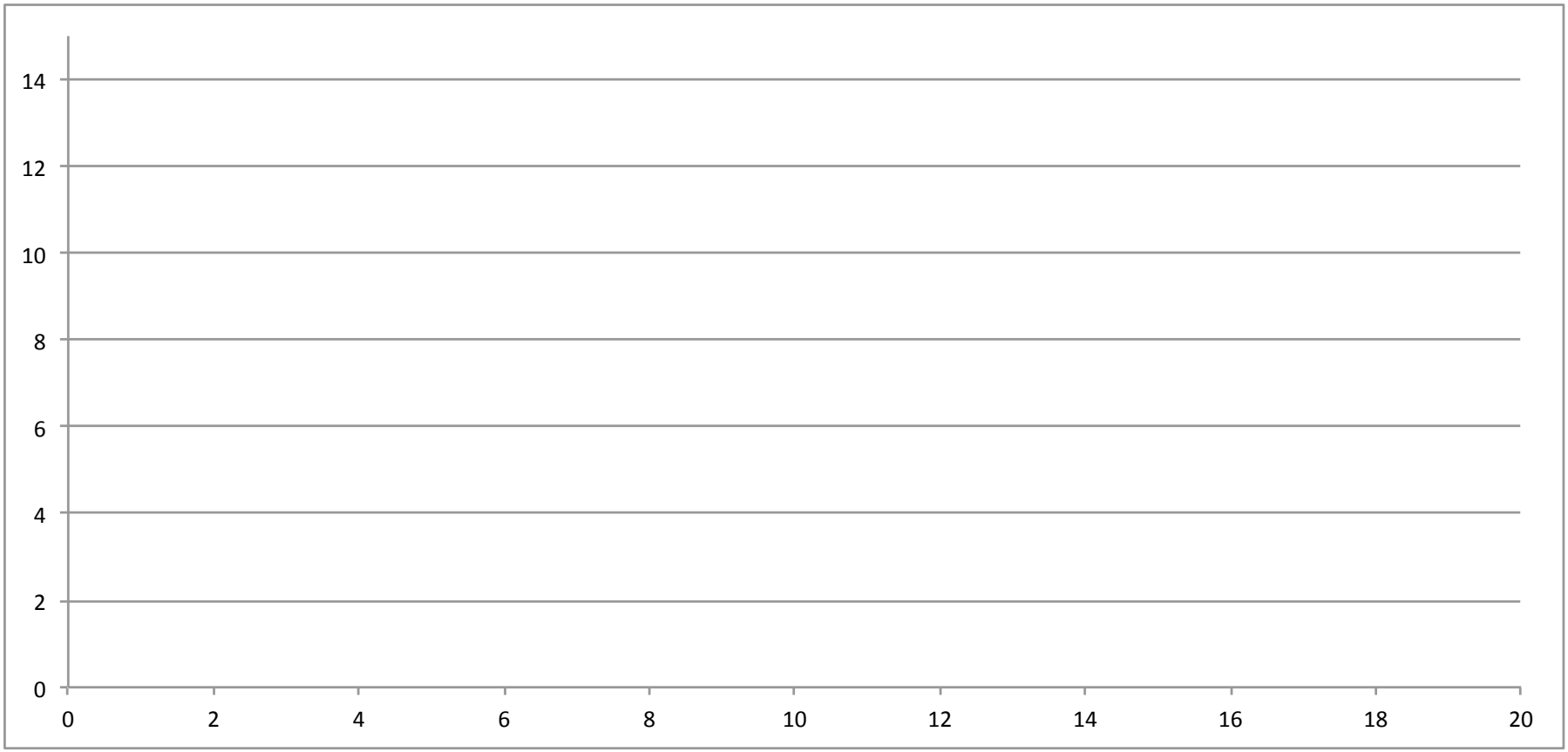
# Human Memory: Simplified Model



# Short-Term Memory

- Input from sensory or long-term memory
- Capacity up to 7±2 ‘chunks’ (abstractions)
- Chunks used to aid storage and reconstruction
- Fast access (≈70ms); rapid decay (≈200ms)
- Constant update and interference
- Maintenance rehearsal

# Test of 7±2



# Long-Term Memory

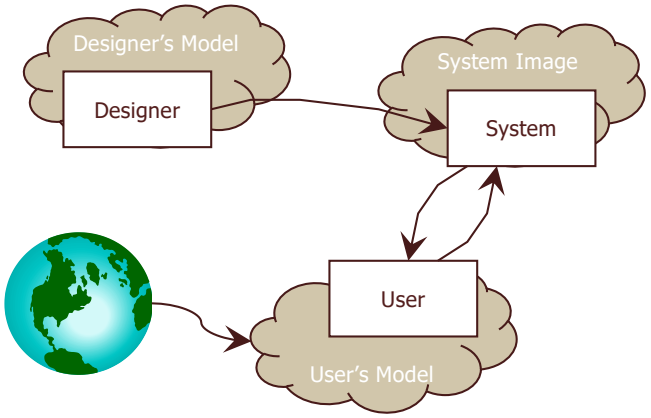
- Input through elaborative rehearsal and extensive repetition
- Slow access (>100ms)
- Decay?

## Lessons

- Support recognition; don't demand recall
- Support spatial processing

# Human Error: Mistakes

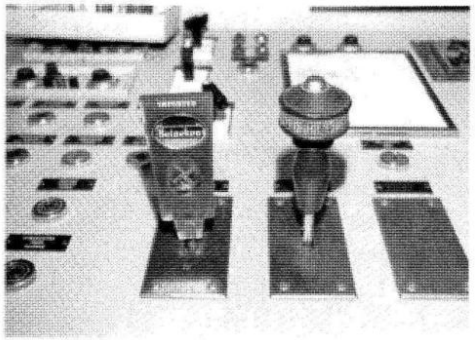
- Errors of conscious decision
- Due to incorrect or incomplete model of system
- Only detected with feedback



# Human Error: Slips

Errors of automatic and skilled behaviour

- Capture error
  - Two action sequences with common starting point(s)
  - Captured into wrong path (usually the more frequent one)
- Description error
  - More than one object allowing the same/similar action
  - Execute right action on wrong object



- Data-driven error
  - External data interferes with STM
- Associative activation error

# Stroop Effect

(Data-Driven Error)

| | | |
|---|---|---|
| Red |  | Blue |
| Blue | | Red |
| Yellow | | Green |
| Green | | Orange |
| Orange | | Yellow |
| Purple | | Red |
| Red | | Green |
| Green | | Purple |
| Yellow | | Green |
| Blue | | Yellow |
| Green | | Blue |

# Human Error: Slips (continued)

- Loss-of-activation error
  - Goal displaced/decayed from STM completed
- Mode error
  - Right action, wrong system state
- Motor slip
  - Pointing/steering/keying error
- Premature closure error
  - 'Dangling' UI actions required after perceived goal completion

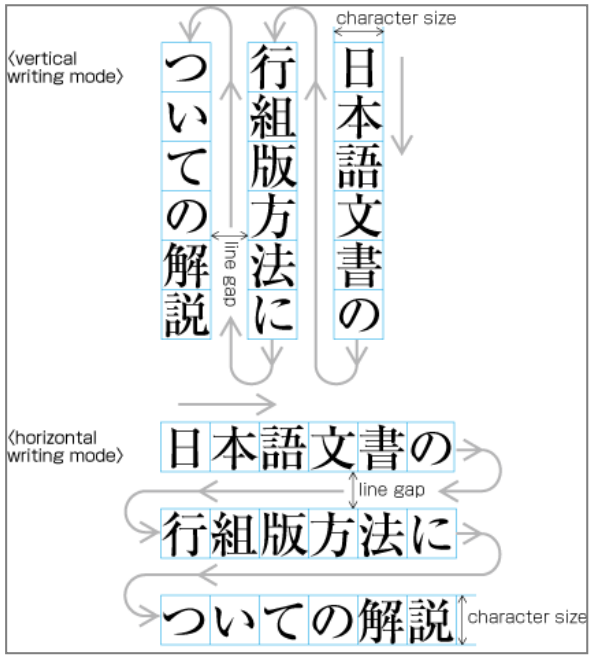
# Aside: What is a mode?

- System **partition**
  - Different set of commands available
  - Different interpretation of same commands/actions
  - Different display method
- Modal dialog
  - Grabs focus for application/desktop and must be dismissed to proceed
- Ensure modes are visible/noticeable

# Human Phenomena

But people don't conform to simple models

- International/cultural differences




Source: w3.org

On or off?

# Human Phenomena

- Sapir-Whorf Hypothesis
  - Language influences the way we think
  - More generally, "Law of the instrument" or "Maslow's hammer"
  - Our language/tools influence how we think about design/interaction

# Human Phenomena

- Cognitive Dissonance
  - Inconsistent cognitions are uncomfortable
  - Therefore rationalise beliefs
  - Festinger experiments with dull tasks: https://www.youtube.com/watch?v=1kmVy1QPXn0
  - "I spent 5 years learning to use this software"
  - "This software is slow and really hard to use"
  - *"I like this software and I can use it well"*

# Human Phenomena

- Homeostasis
  - People maintain equilibrium
  - If a system makes things easier, it'll be used to do more difficult things
  - If a system makes things safer, it'll be used to do more dangerous things

# Human Phenomena

- Satisficing
  - People make do rather than optimise
  - E.g., ‘hunt-and-peck’ typing for decades because too busy right now to learn touch typing
  - How many keyboard shortcuts do you know and use?

# Human Phenomena

- Hawthorne Effect
  - People like being involved
  - Complicates evaluations

# Human Phenomena

- Explaining away errors
  - In hindsight, it's often easiest to blame the user

# Human Phenomena

- Fixation
  - Tendency to repeatedly reuse the same solution method rather than think of new/better methods

# Human Phenomena

- Perception versus reality
  - People's perception often differs from reality
  - E.g., perceived duration varies for filled versus unfilled time

# Human Phenomena

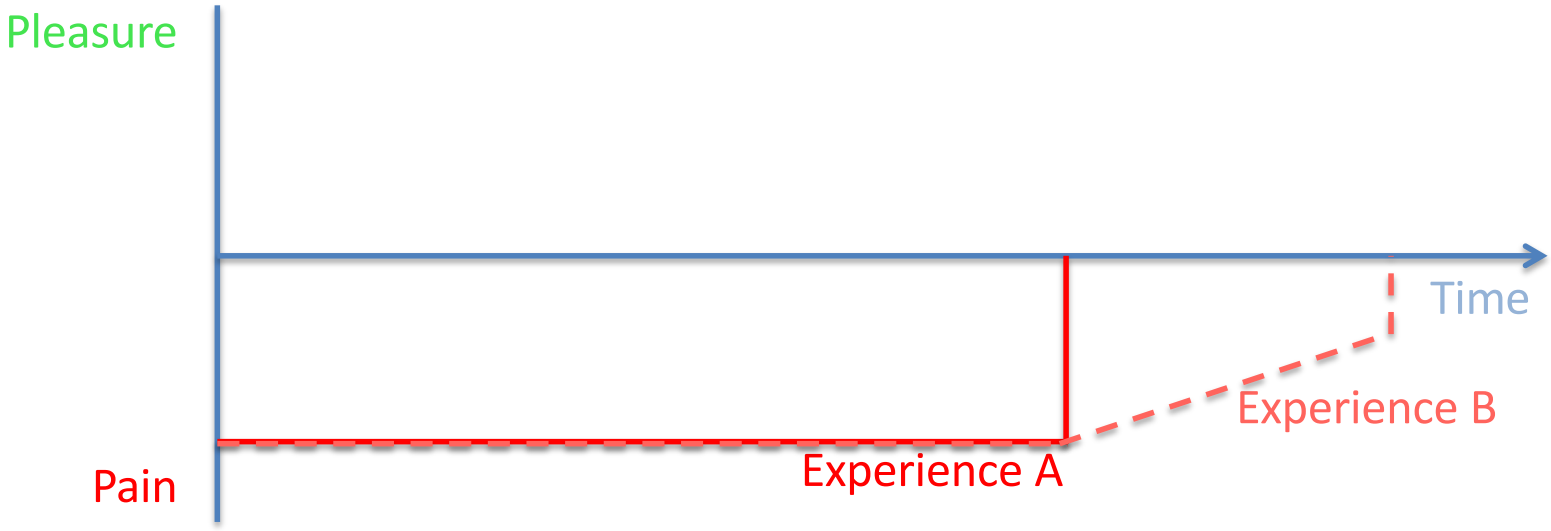
- Peak-End Effects

# Human Phenomena

- Peak-End Effects

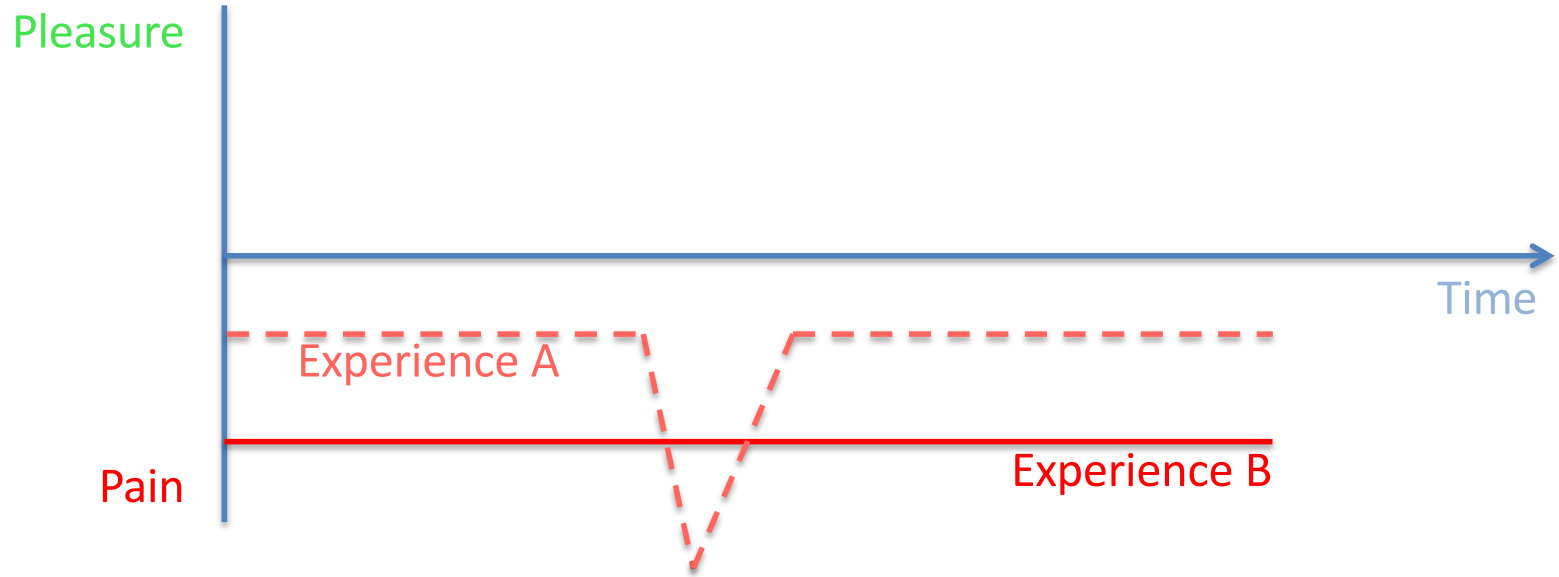
# Human Phenomena

- Peak-End Effects



# Human Phenomena

- Peak-End Effects



# Human Phenomena

- Peak-End Effects
  - People's retrospective assessment of experience is heavily influenced by moments of peak and end intensity
  - (People prefer more pain to less, if it finishes better)

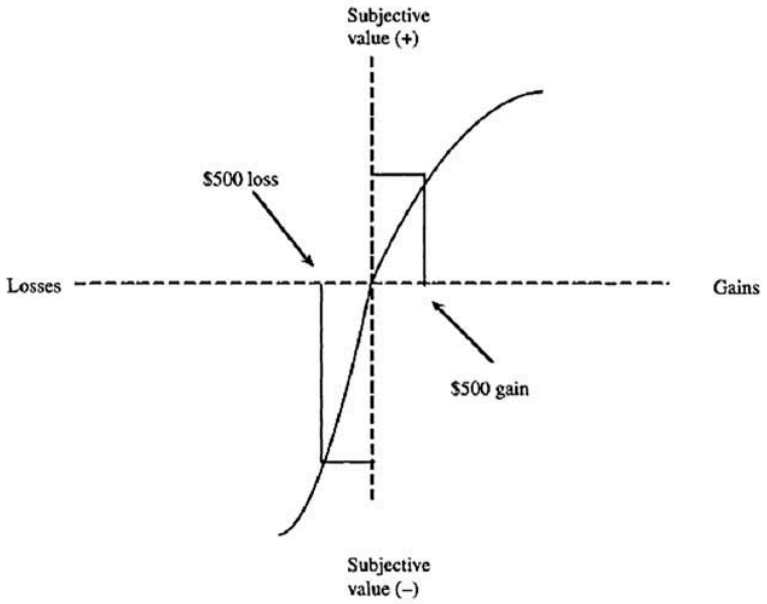
# Human Phenomena

- Negativity bias
  - One coin toss: win $110 on heads; lose $100 on tails will you take it?

# Human Phenomena

- Negativity bias
  - One coin toss: win $110 on heads; lose $100 on tails will you take it?

- Bad is stronger than good



# Modeling Performance

# Keyboard Level Model (KLM)

Card, Moran, Newell 1983

- Given:
  - A low level task (i.e., a simple command or action)
  - The command language of a system
  - The motor skill parameter of the user
  - The response time parameters of the system

- Predict:
  - Time for error free expert performance

# Keyboard Level Model (KLM)

Card, Moran, Newell 1983

- KLM is comprised of:
  - Operators
  - Encoding methods
  - Heuristics for the placement of mental **(M)** operators

# KLM - *Operators*

- Operators
  - **K** Press a key or button ≈ 0.2s (0.12 – 1.2)
  - **P** Point with mouse ≈ 1.1s or Fitts' Law
  - **H** Home hands ≈ 0.4s
  - **D** Draw line segments
  - **M** Mental preparation ≈ 1.35s or Hick's Law
  - **R** System response
- $T_{execute} = T_K + T_P + T_H + T_D + T_M + T_R$

# KLM – *Encoding Methods*

- Encoding methods define how operators are written

**MK[i] K[p] K[c] K[o] K[n] K[f] K[i] K[g] K[RETURN]**

Or

**M 8K [ipconfig RETURN]**

This results in a timing of 1.35 +8 *0.20 =2.95 seconds for an average skilled typist.

# KLM – *Heuristics for M Placement*

Use Rule 0 to place all Ms. Then apply rules 1 to 4 for each M to determine if it should be deleted.

**Ms are a pain!**

| | |
|---|---|
| Rule 0 | Insert an M before all Ks that are not part of argument strings and before all Ps that select commands |
| Rule 1 | If an operator following an M is fully anticipated in an operator previous to the M, then delete the M (e.g., PMK → PK) |
| Rule 2 | If a string of MKs belong to a cognitive unit (e.g., name of command), then delete all Ms but the first |
| Rule 3 | If a K is a redundant terminator (e.g., terminator of a command immediately following the terminator of its argument), then delete the M in front of it. |
| Rule 4 | If a K terminates a constant string (e.g., a command name), then delete the M in front of it. If the K terminates a variable string (e.g., an argument), then keep the M in front of it. |

# KLM Does Not Do…

- Errors
- Learning
- Functionality
- Recall
- Concentration
- Fatigue
- Acceptability

# GOMS

Card, Moran, Newell 1983

- KLM predicts low level operation times
- GOMS is higher level, including selection between alternative methods
  - **G**oals: what the user wants to achieve
  - **O**perators: specific actions (KLM style)
  - **M**ethods: sets of steps to complete a goal (hierarchical GOMS)
  - **S**election rules: select between alternative methods
- Time predictions and memory load can be calculated from GOMS

# GOMS Example

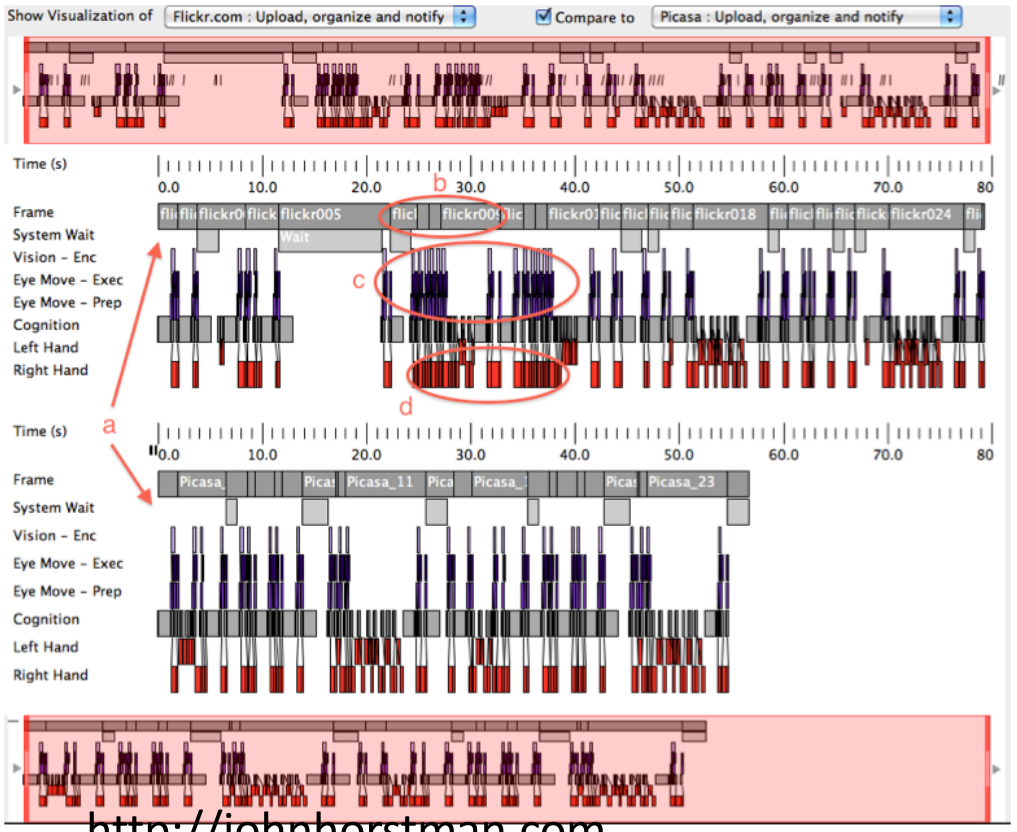
## Card, Moran, Newell 1983

```
GOAL: Iconise-Window
  [select
      GOAL: Use-Close-Method
         Move-Mouse-To-Window-Header
         Pop-Up-Menu
         Click-Over-Close-Option
      GOAL: Use-L7-Method
         Press-L7-Key]

For user Barney:
  Rule 1: Select Use-Close-Method unless
           another rule applies
  Rule 2: If the application is GAME, Select
           L7-Method
```

Source: Dix et al. “Human-Computer Interaction”

# CogTool




http://johnhorstman.com