Designing Interactive Systems I
Lecture 01: Introduction to HCI, CMN Model, and Fitts' Law

Prof. Dr. Jan Borchers
Media Computing Group
RWTH Aachen University

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http://hci.rwth-aachen.de/dis

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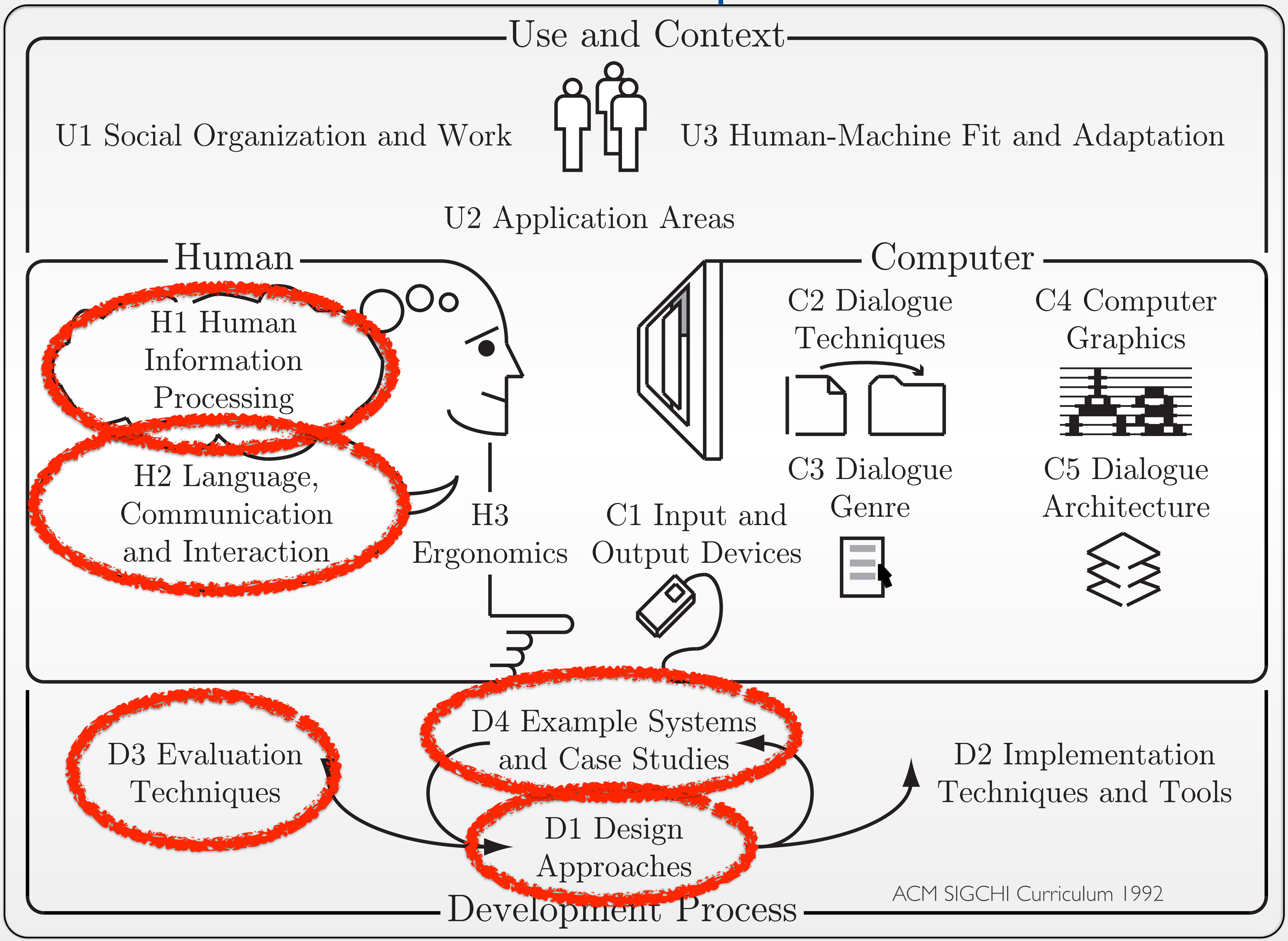
What's Human-Computer Interaction?



Class Topics

Cognition

- Performance
- Models of interaction
    - Affordances
    - Mappings
    - Constraints
    - Types of knowledge
    - Errors
- Design principles

History

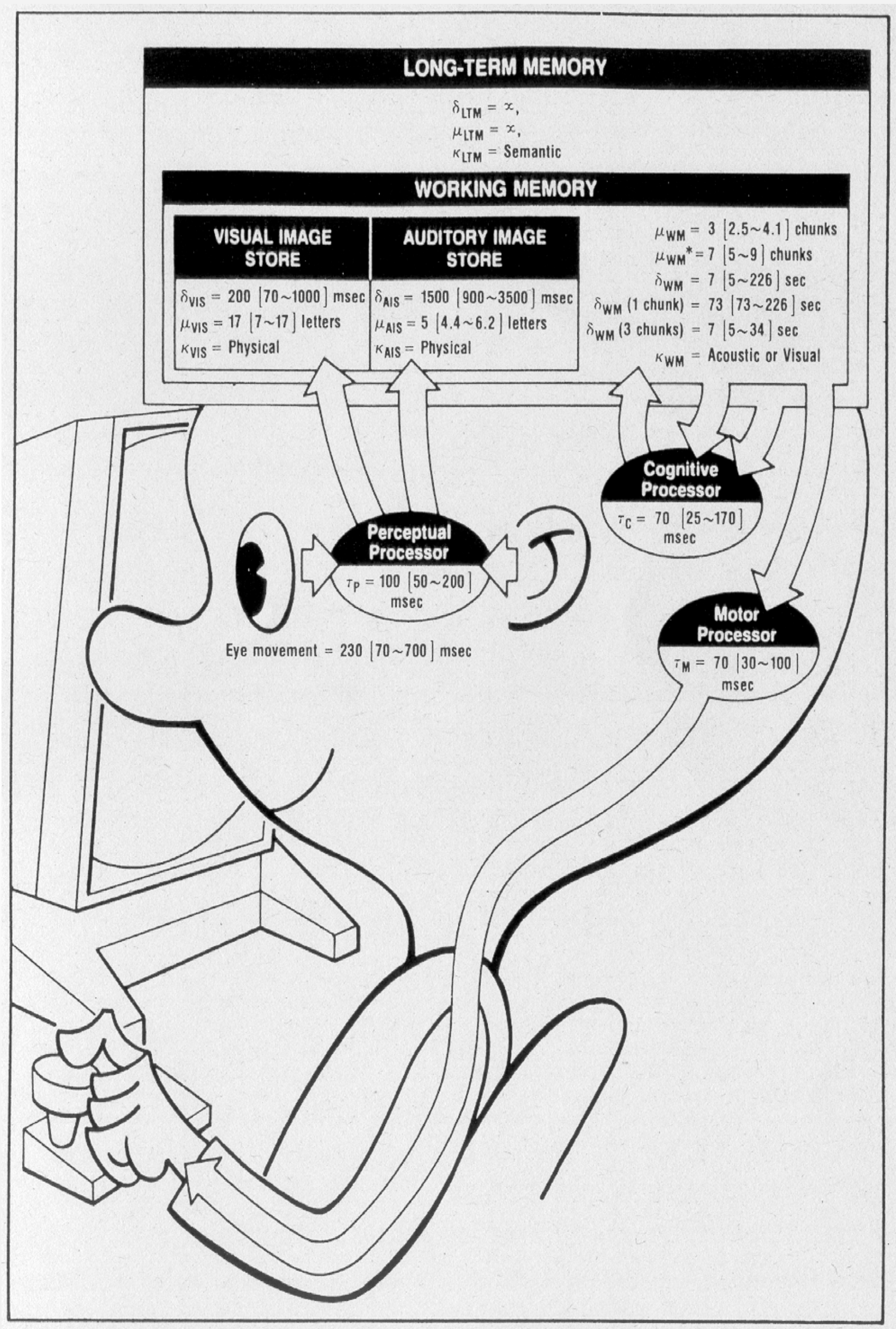
- History of HCI
- Visions
- Phases of Technology

Design Process

- Iterative design
- User observation
- Ideation
- Prototyping
- User studies and evaluation
- Interaction design notation

Model Human Processor

- By Stuart Card, Tom Moran, Allen Newell (CMN Model)
  - The Psychology of Human-Computer Interaction (1983)
- Basic model for perception, memory, and motor system
- Goal: estimate execution time, error rates, and training effects for simple input/output events



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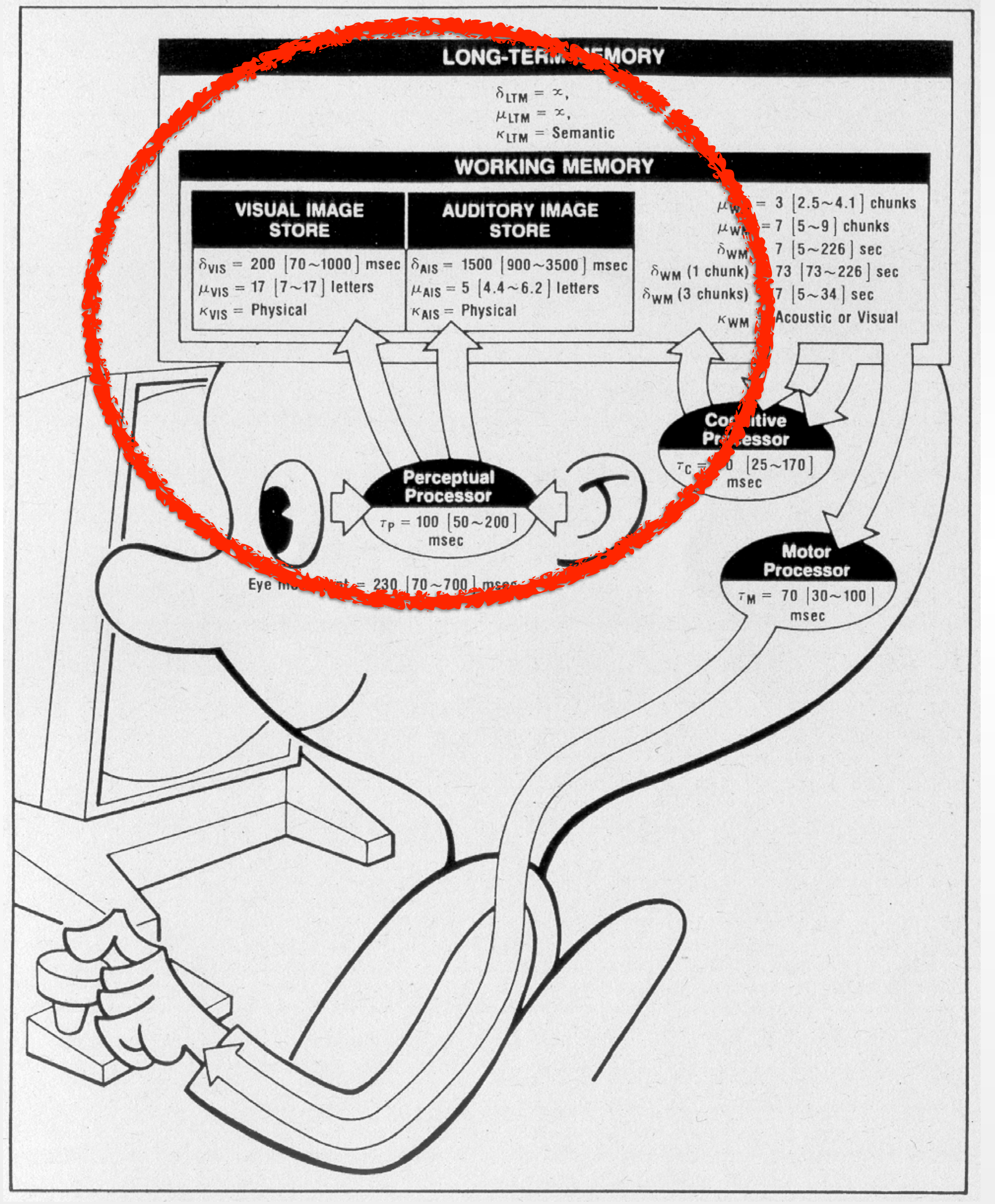
Model Human Processor

- 3 processors with associated memory
- Slow, middle, fast performers

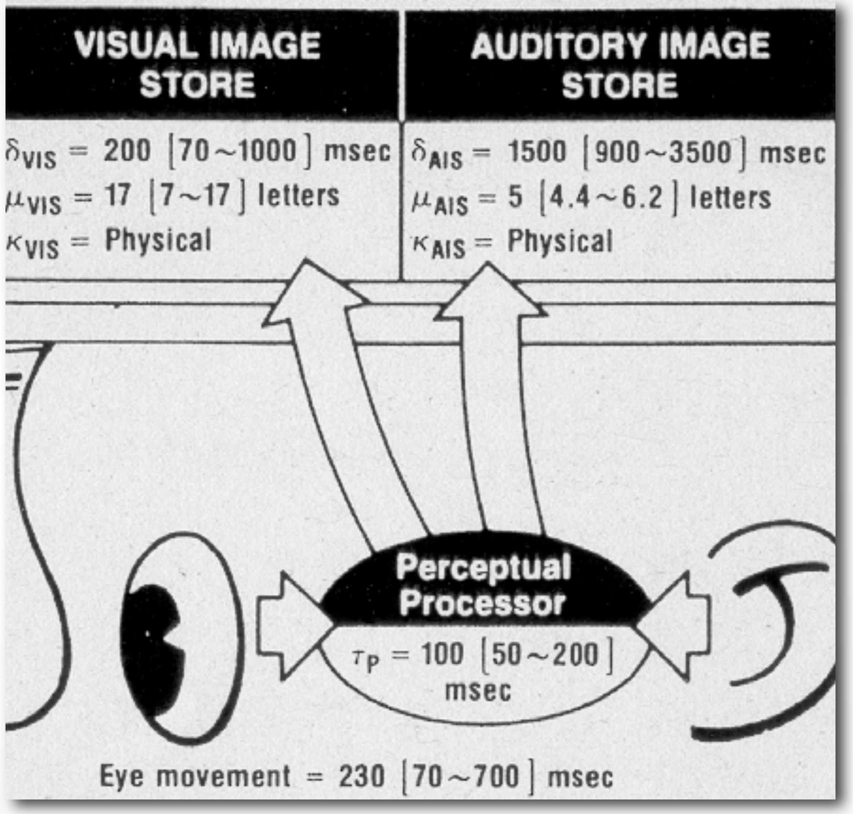


Experiment I

- Work in pairs of 2
  - Read the paragraph handed out
  - Have your friend observe your eye movements while you're reading

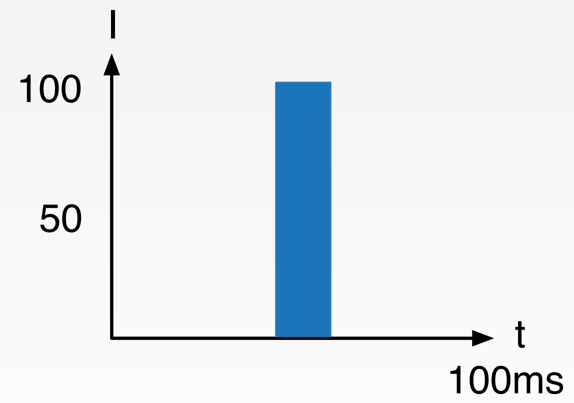
Perception

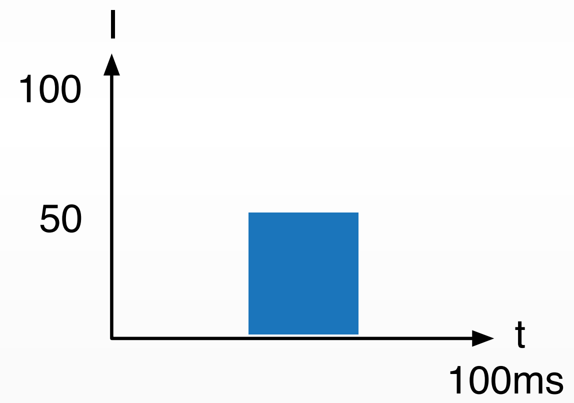
- Eye saccades: 230 ms
- Explains reading rates
  - Maximum: 13 characters/saccade ⇒ 652 words/minute

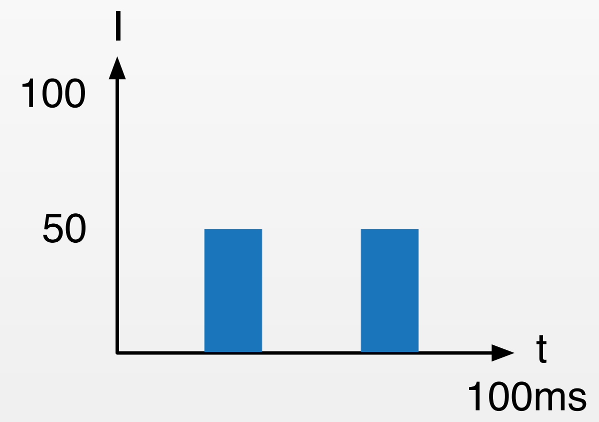


Perceptual Processor

- Stores sensor signals in visual & auditory stores
- Perception time: $\tau_P \approx 100$ ms
  - Explains Bloch's Law
    - $R = I \times t$
    - R is response
    - I is intensity,
    - t is exposure time
  - Constant response for $t < 100$ms

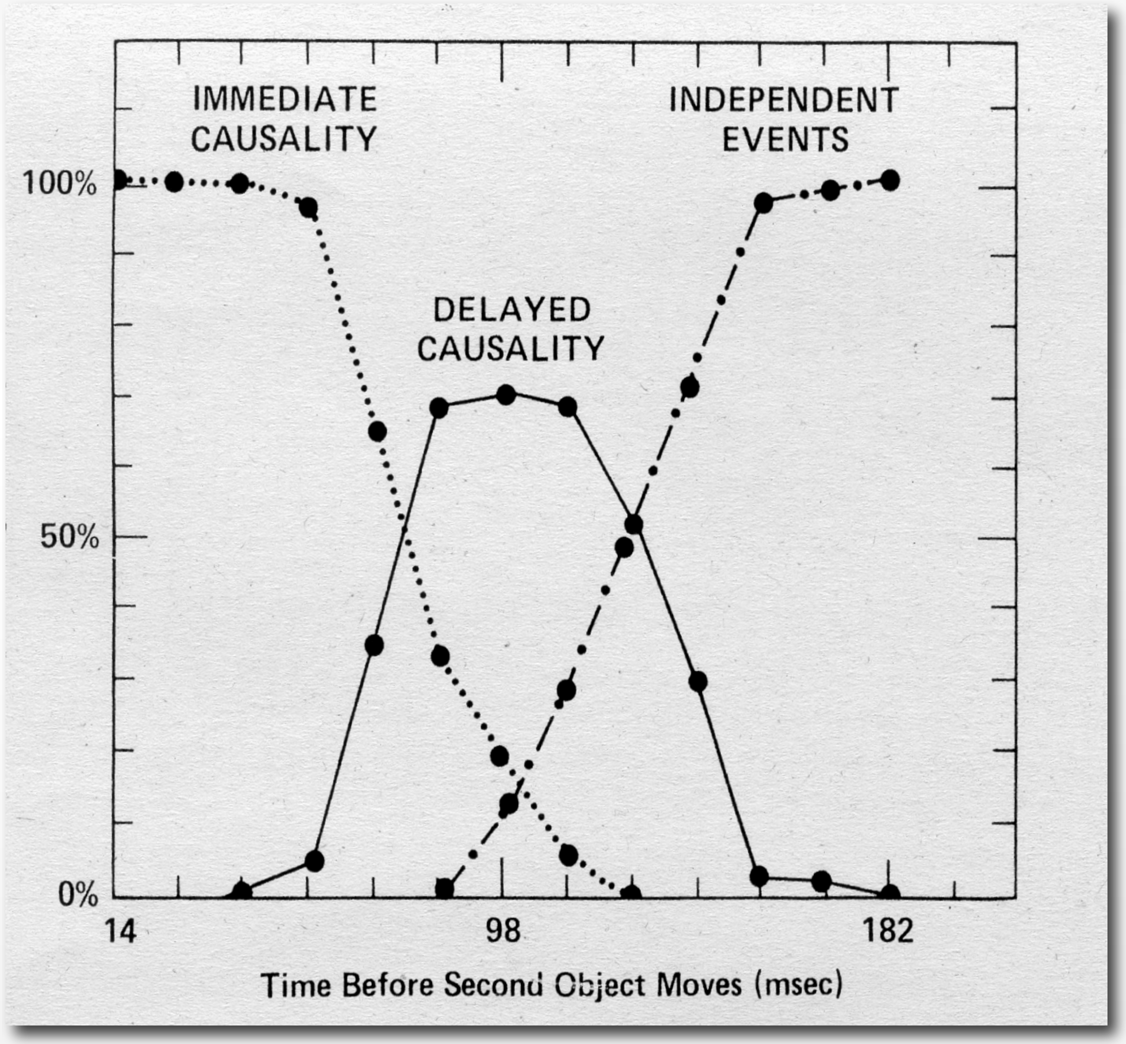






Perceptual Processor

- Perception time: $\tau_P \approx 100$ ms
  - Explains animation rates (10 fps for MiddleMan)
  - Explains max. delay before causality breaks down
  - Shortens with intensity



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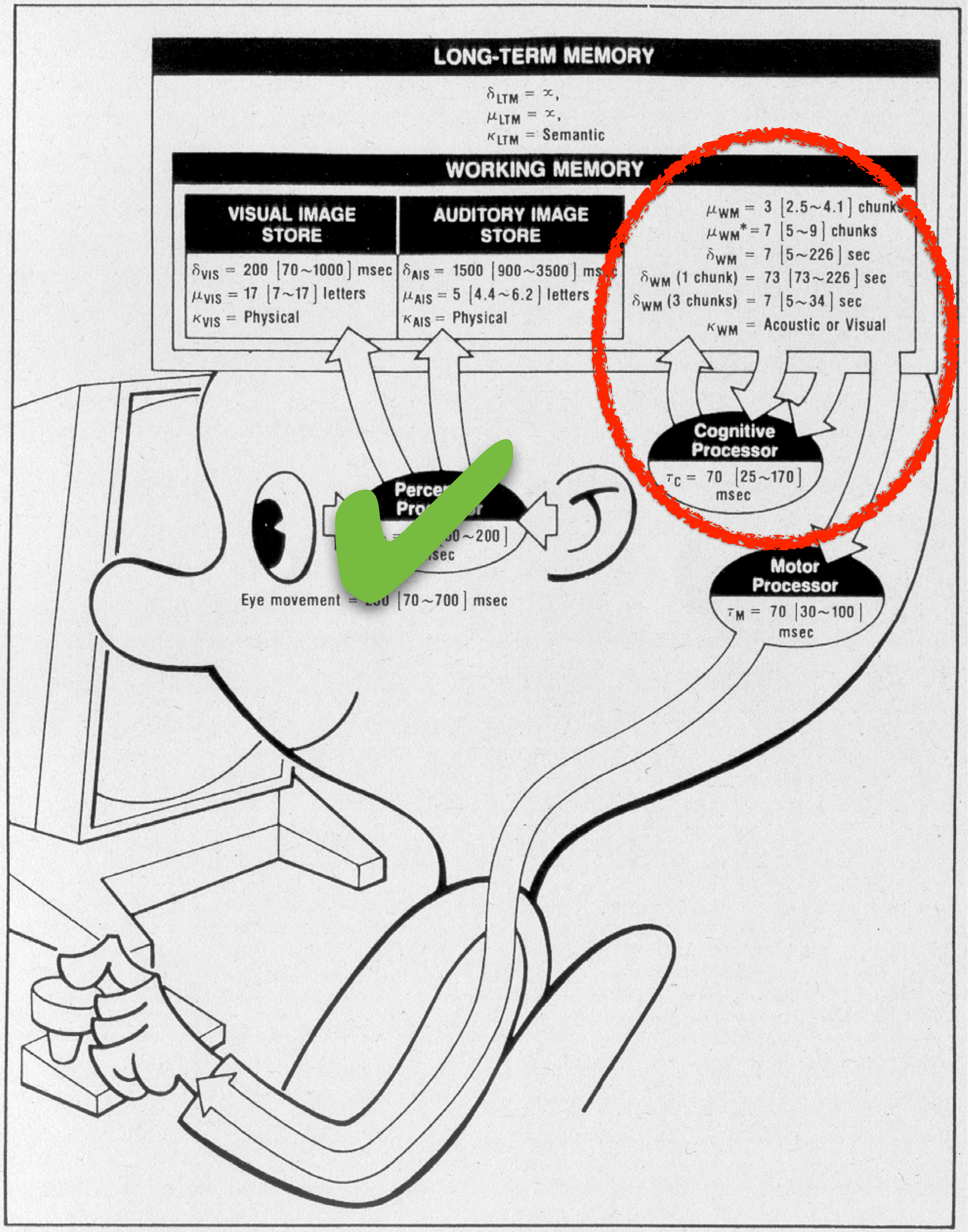


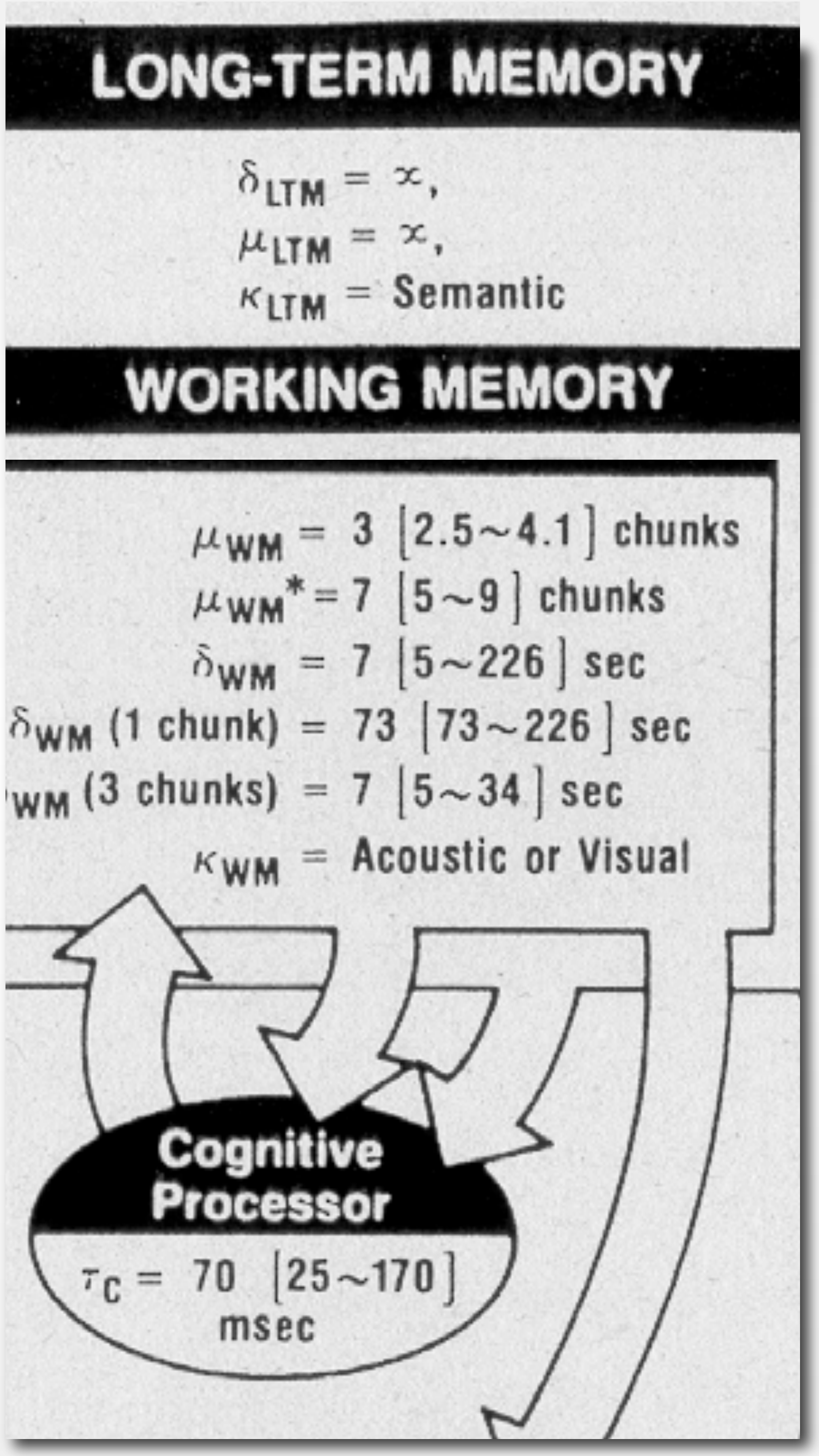
LONG-TERM MEMORY
δLTM = ∞,
μLTM = ∞,
κLTM = Semantic
WORKING MEMORY
VISUAL IMAGE STORE
δVIS = 200 [70~1000] msec
μVIS = 17 [7~17] letters
κVIS = Physical
AUDITORY IMAGE STORE
δAIS = 1500 [900~3500] msec
μAIS = 5 [4.4~6.2] letters
κAIS = Physical
μWM = 3 [2.5~4.1] chunks
μWM* = 7 [5~9] chunks
δWM = 7 [5~226] sec
δWM (1 chunk) = 73 [73~226] sec
δWM (3 chunks) = 7 [5~34] sec
κWM = Acoustic or Visual
Cognitive Processor
τC = 70 [25~170] msec
Eye movement
[70~700] msec
Motor Processor
τM = 70 [30~100] msec

Experiment 2

- Digit experiment
  - Choose 5 digits secretly from your sheet, then read them to your neighbor.
  - Have him count backwards aloud from 50.
  - Have him answer some other question (like what he had for dinner 3 days ago).
  - Does he still remember the entire 5-digit sequence correctly?
- Switch roles, repeat with 9 digits.
- Finally, switching roles again, read the long sequence of numbers to your neighbor, stopping somewhere suddenly. See how many of the last numbers he can repeat immediately.

Cognitive System

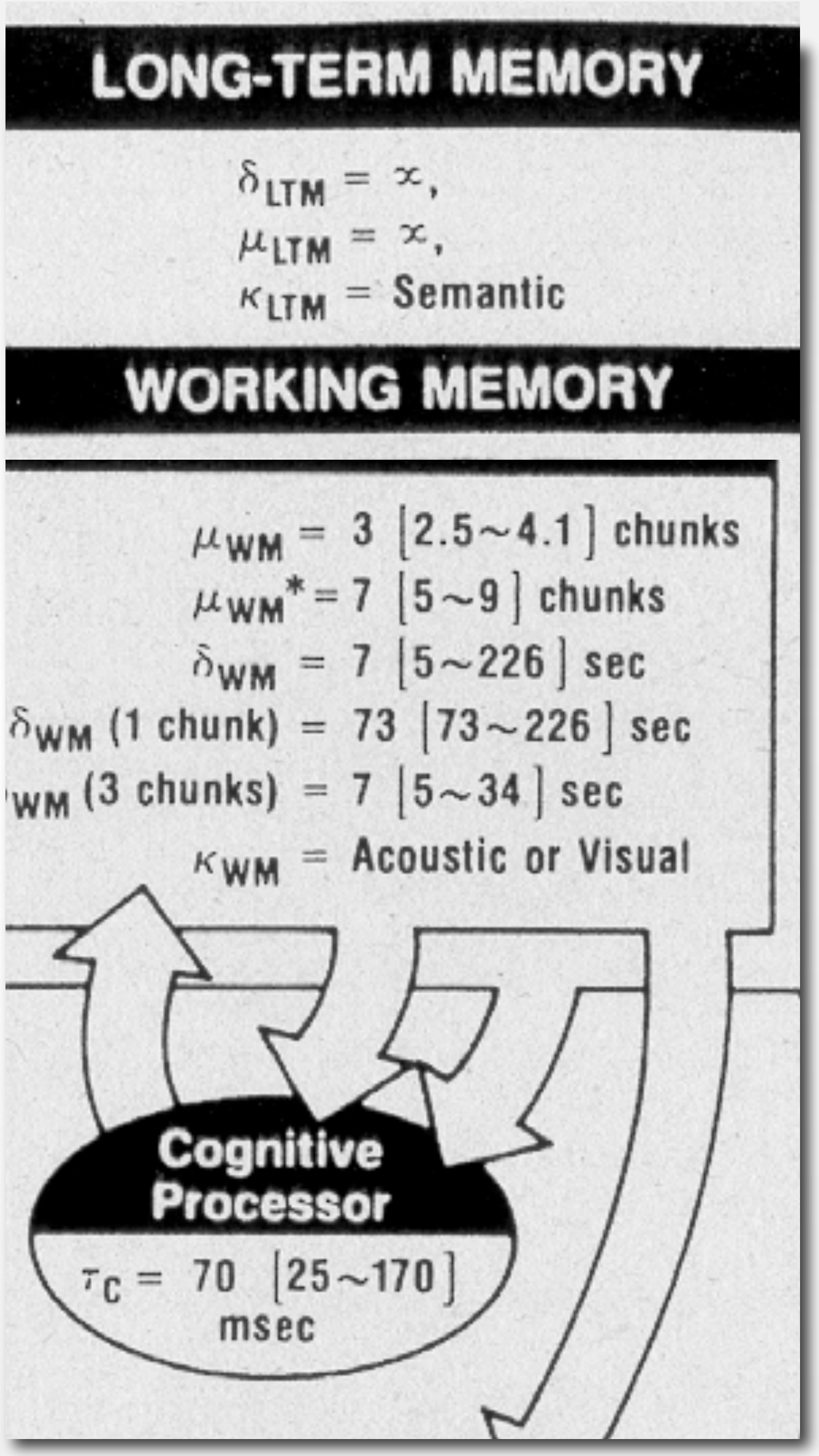
- Chunks depend on user & task
- Working memory:
  - Capacity: μ_{WM} = 7 ± 2 chunks (Miller '56)
  - Half life: $\delta_{1,WM}$ = 73 s (1 chunk)
    $\delta_{3,WM}$ = 7 s (3 chunk)
  - Visual/acoustic encoding

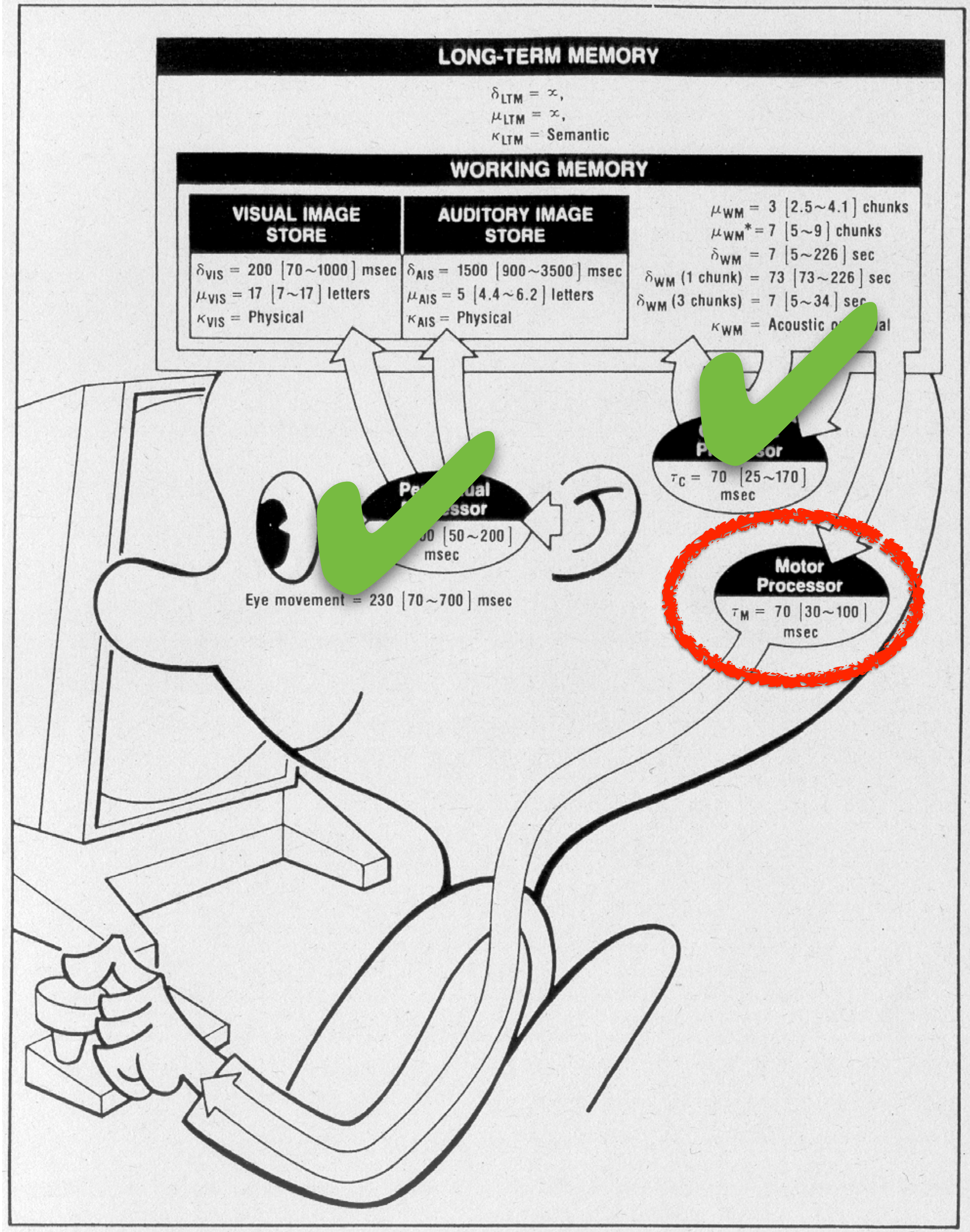


Cognitive System

- Cognitive processor:
  - Processing time $\tau_C = 70$ ms
- Long-term memory:
  - Infinite capacity and half life
  - Semantic encoding (associations)
  - Fast read, slow write

⇒ Remembering items maxes out at 7 s/chunk learning speed (1 pass)

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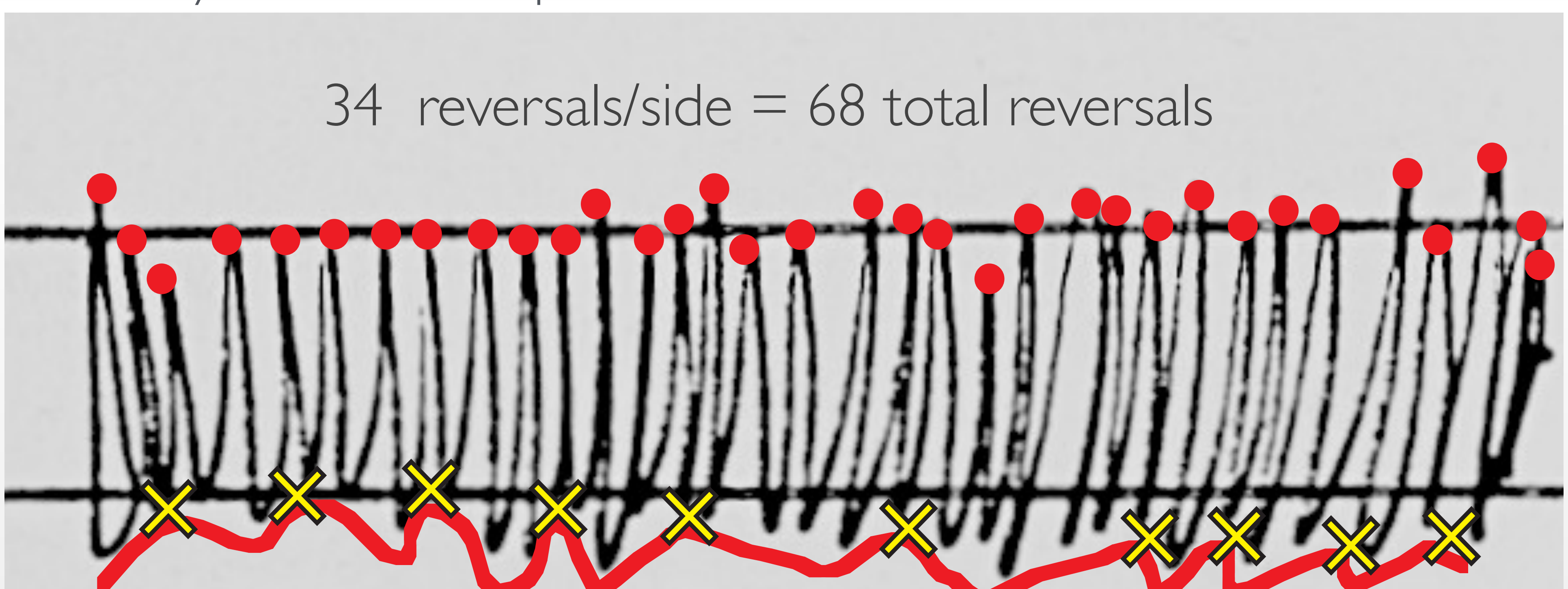
δ_{WM} = 7 [5~226] sec
δ_{WM} (1 chunk) = 73 [73~226] sec
δ_{WM} (3 chunks) = 7 [5~34] sec
τ_C = 70 [25~170] msec
[50~200] msec
Eye movement = 230 [70~700] msec
Motor Processor
τ_M = 70 [30~100] msec

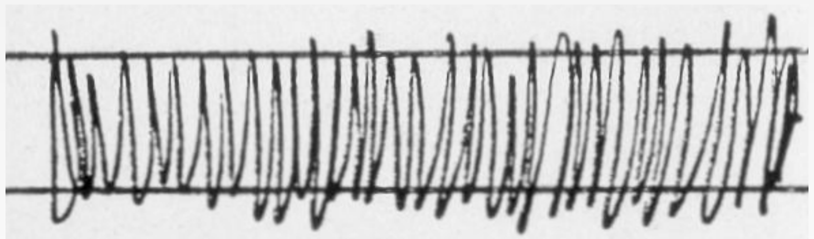
Experiment 3

- Experiment: draw strokes between lines for 5s. Try to reach both lines.
- Count number of reversals
  - How many milliseconds per reversal?
- Create a contour of stroke bottoms, count number of corrections
  - How many milliseconds per correction?

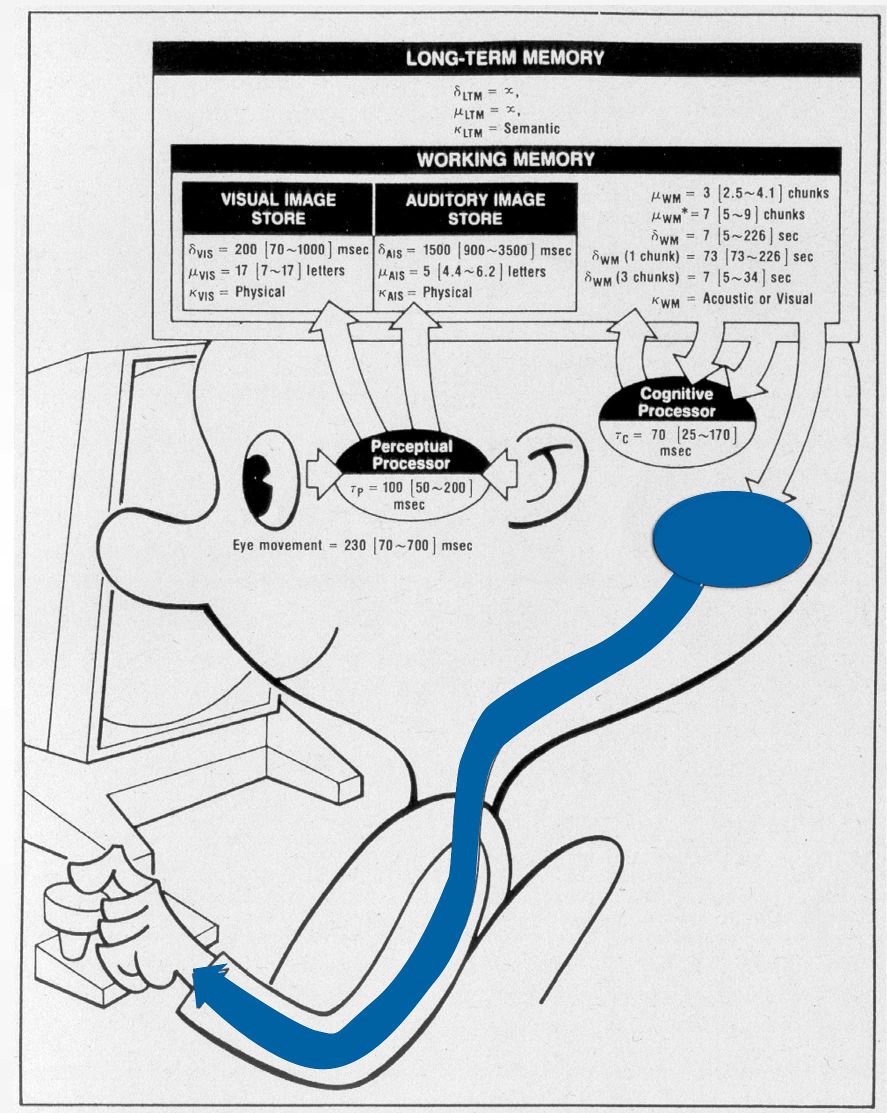


10 corrections/side = 20 total corrections

Motor System

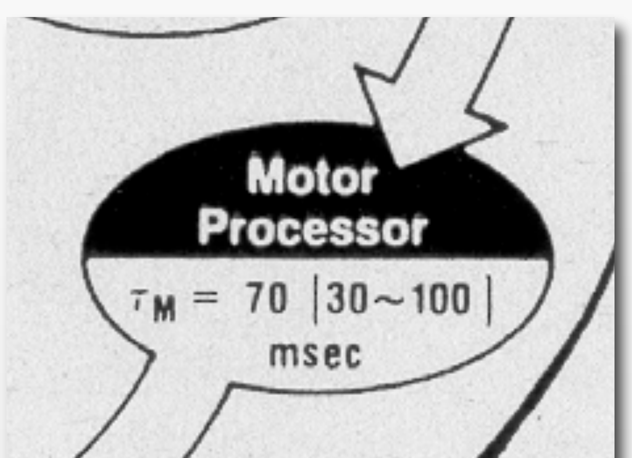


74 ms/reversal
250 ms/correction

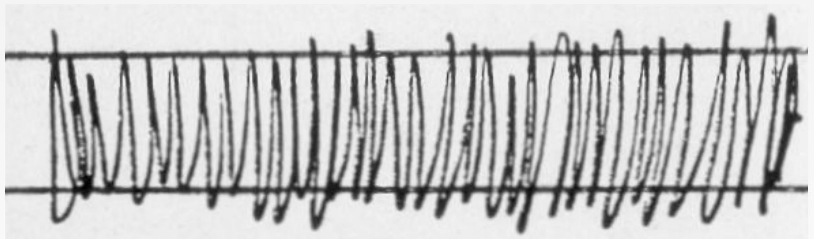


- Motor processor (open loop)
  - τ_M = 70 ms

  ⇒ Average time between each reversal



Motor System



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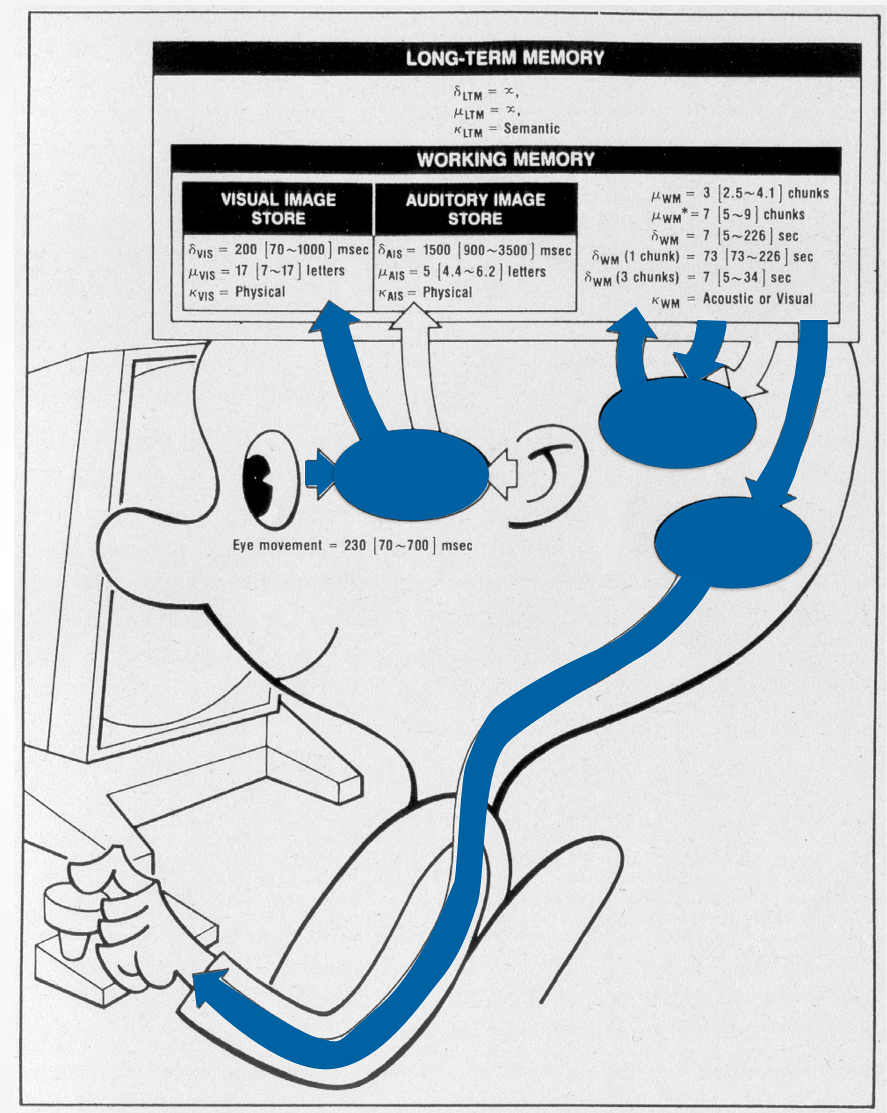


- Closed loop:
  - $\tau_P + \tau_C + \tau_M = 240$ ms

  $\Rightarrow$ Average time between each correction

Fitts' Law

Experiment 4

1cm

4cm

Same for 0.5cm and 2cm wide strips
Tap for 10s, count taps afterwards

8cm

16cm

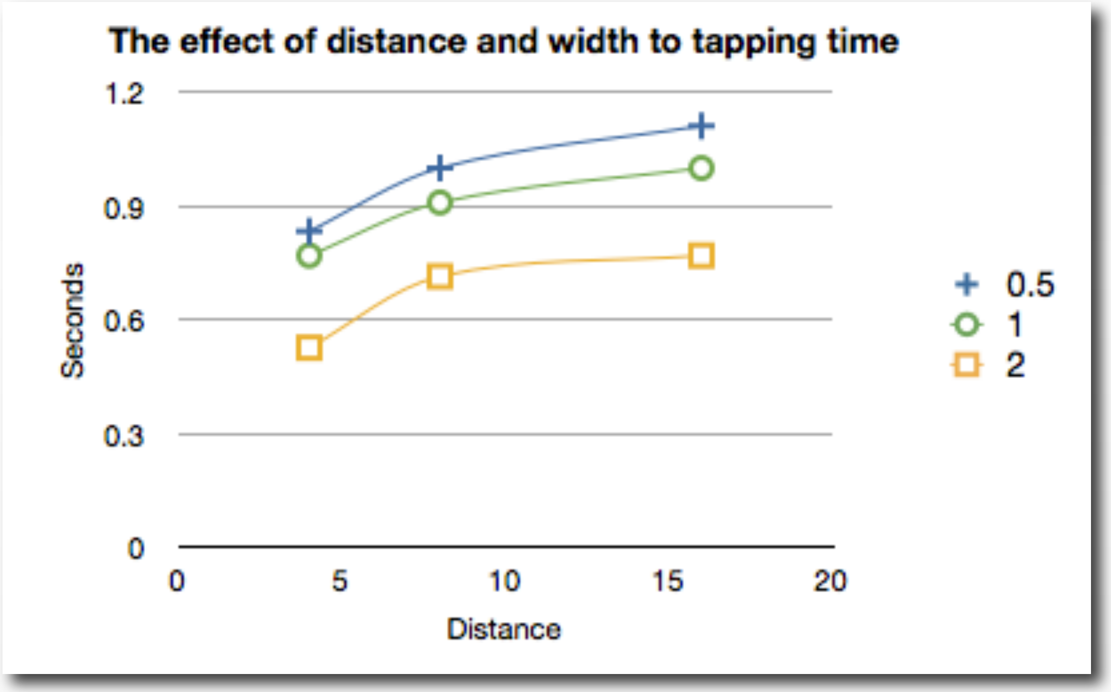
Tapping Task Results

- Doubling the distance adds roughly a constant to execution time

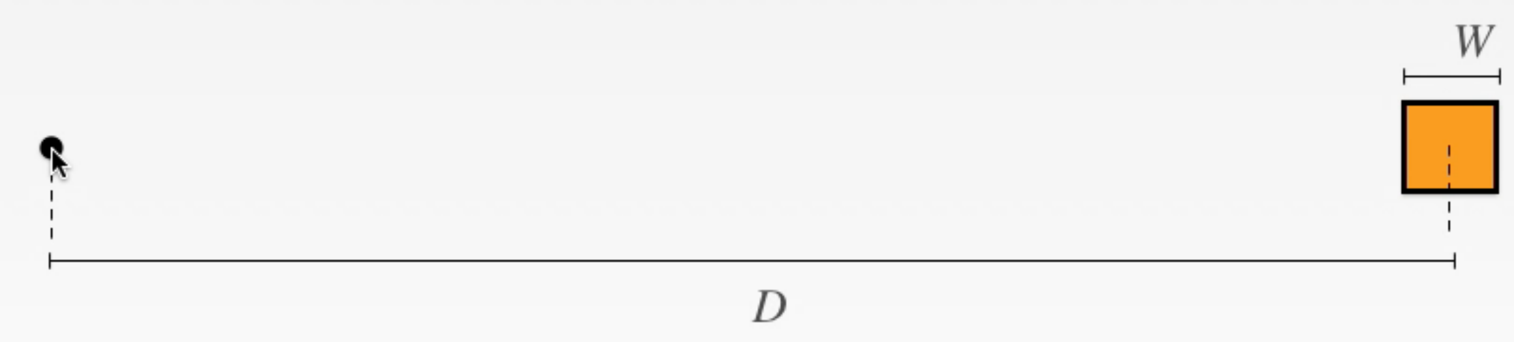
  ⇒ indicates logarithmic nature

- Doubling the target width gives about same results as halving the distance

  ⇒ indicates connection of D/W in formula



Motor System: Fitts' Law



- Goal: Predict time to press buttons (physical or on-screen) as function of distance and size
- Result (Fitts, 1954): $T_{pos} = I_M \times I_D$
  - T_{pos} time to reach button
  - I_M = 100 ms/bit index of movement, constant
  - $I_D = \log_2(2D / W)$ index of difficulty, in bits
- Fitts' law can be derived from CMN model

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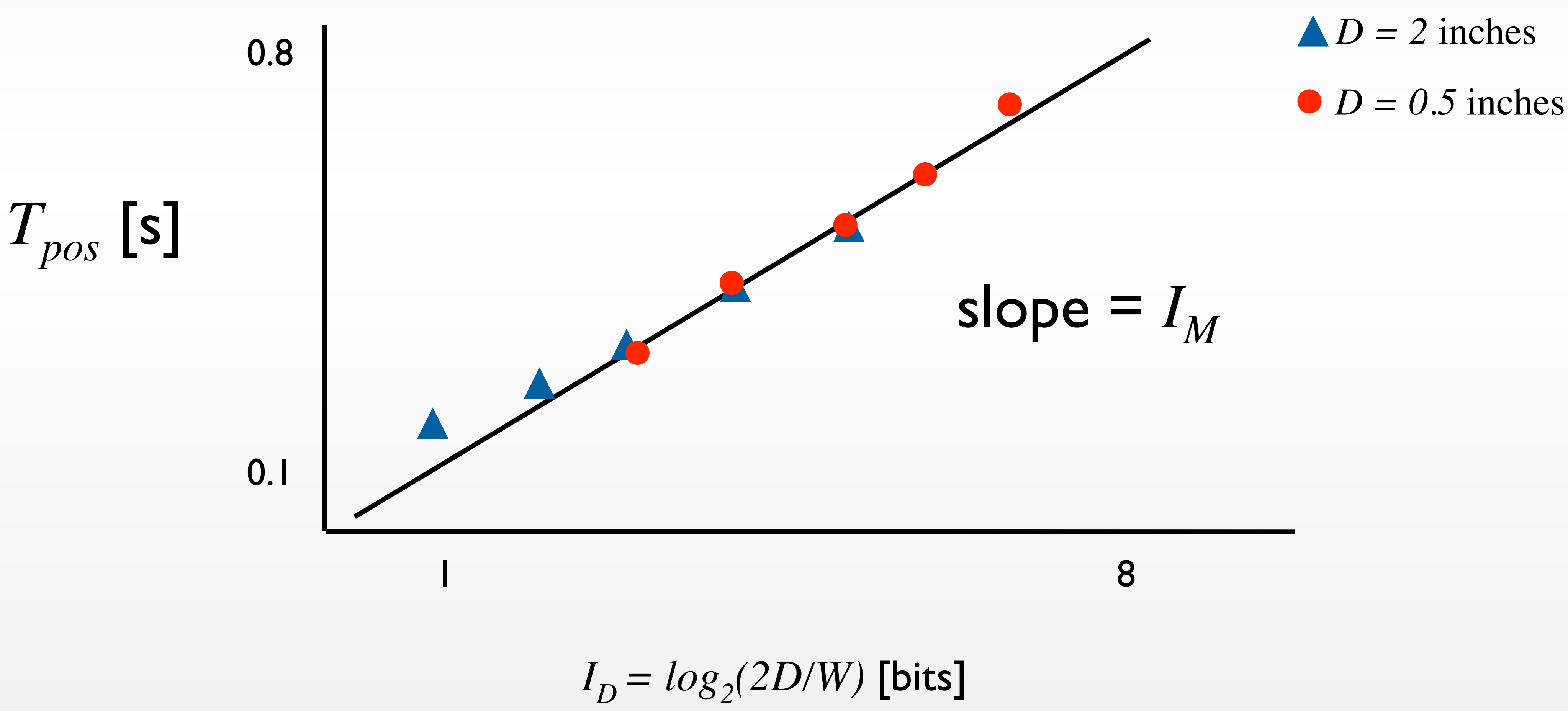
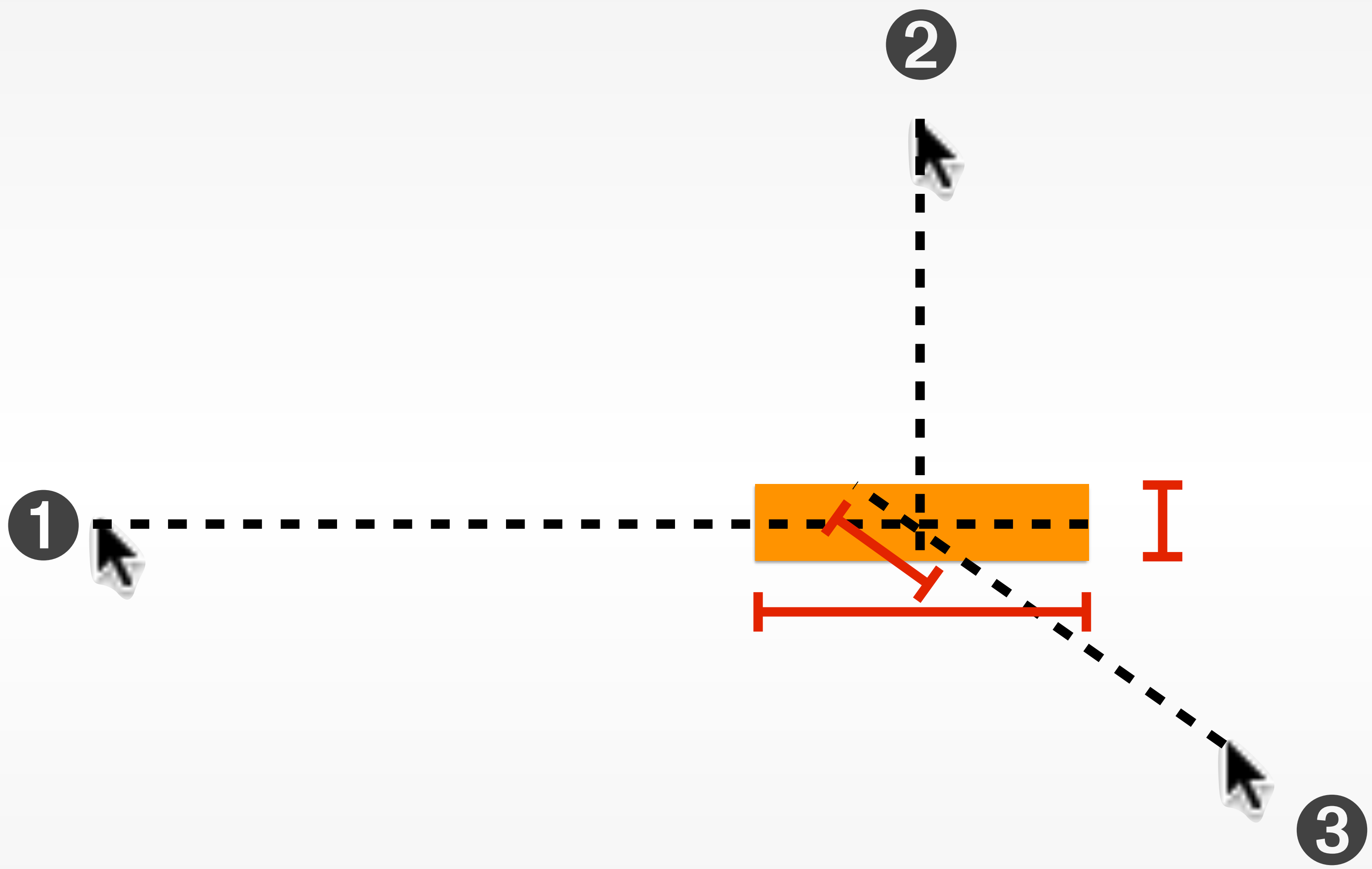
Visualizing Fitts' Law

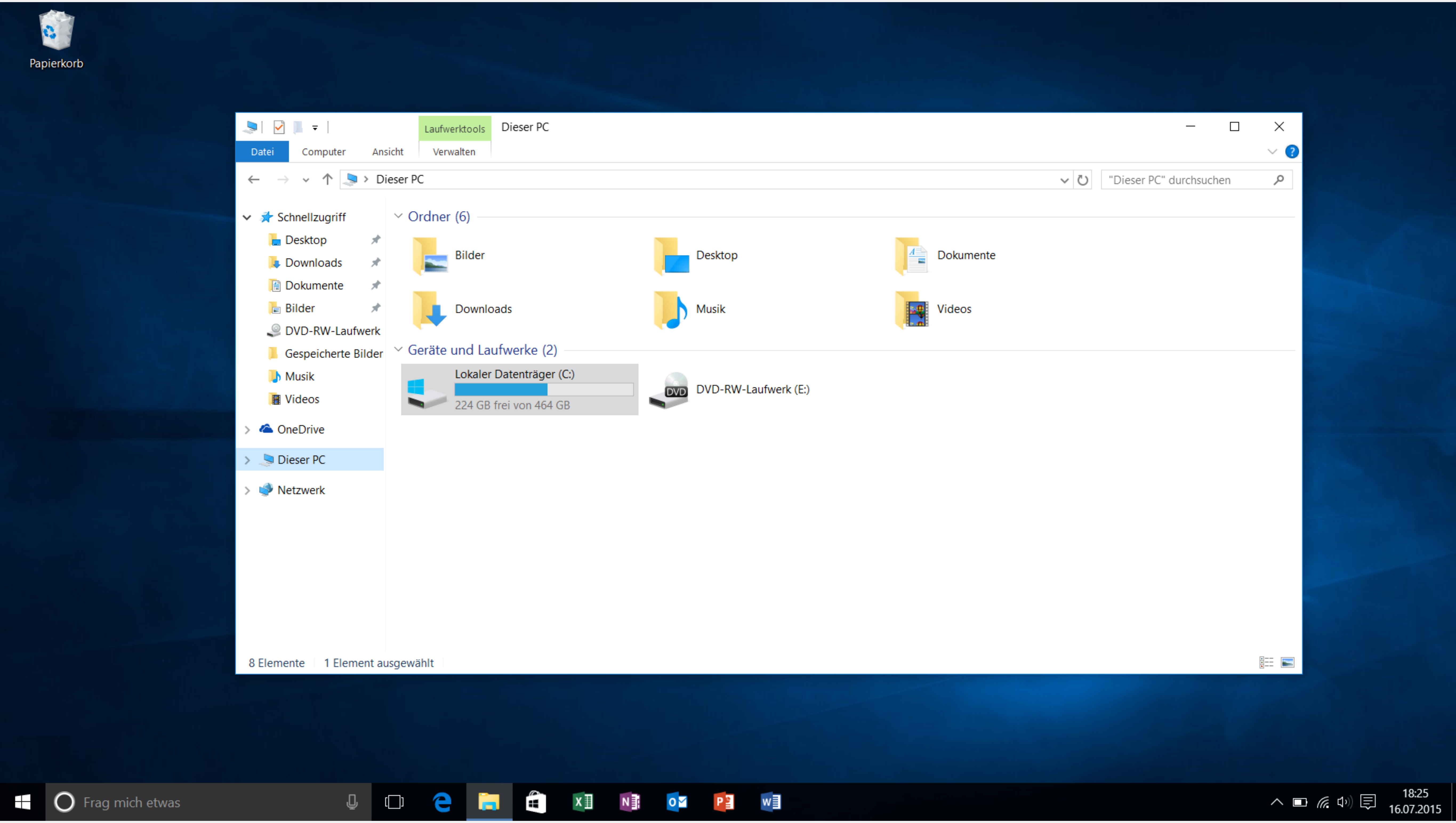
Experiment: fixed distance D, varying width W



Target Width



✳ Alternative measures are compared by [MacKenzie & Buxton, CHI'92]


Papierkorb
Laufwerktools
Dieser PC
Datei
Computer
Ansicht
Verwalten
Dieser PC
"Dieser PC" durchsuchen
Schnellzugriff
Desktop
Downloads
Dokumente
Bilder
DVD-RW-Laufwerk
Gespeicherte Bilder
Musik
Videos
OneDrive
Dieser PC
Netzwerk
Ordner (6)
Bilder
Desktop
Dokumente
Downloads
Musik
Videos
Geräte und Laufwerke (2)
Lokaler Datenträger (C:)
224 GB frei von 464 GB
DVD-RW-Laufwerk (E:)
8 Elemente
1 Element ausgewählt
Frag mich etwas
18:25
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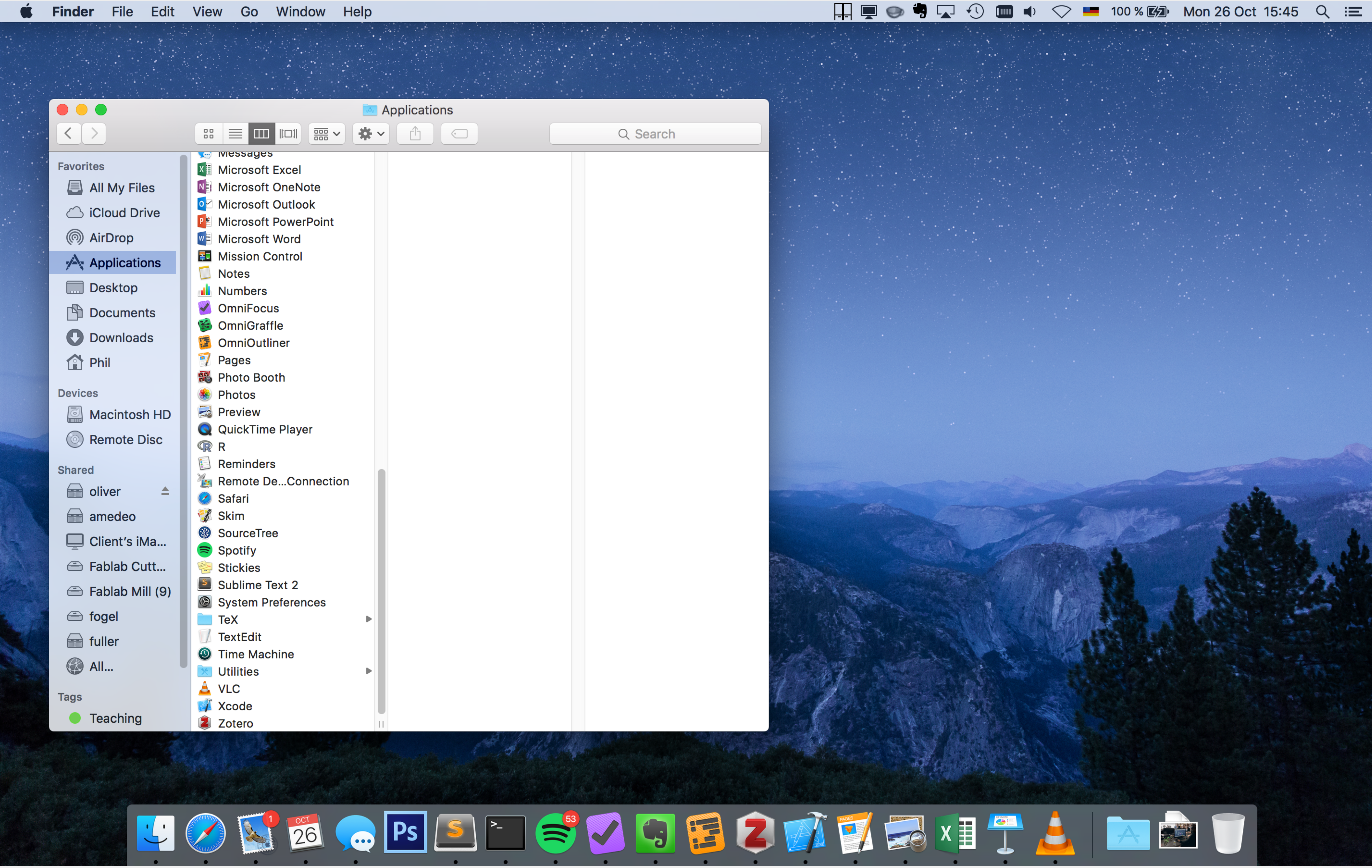
Windows 10



OS X El Capitan

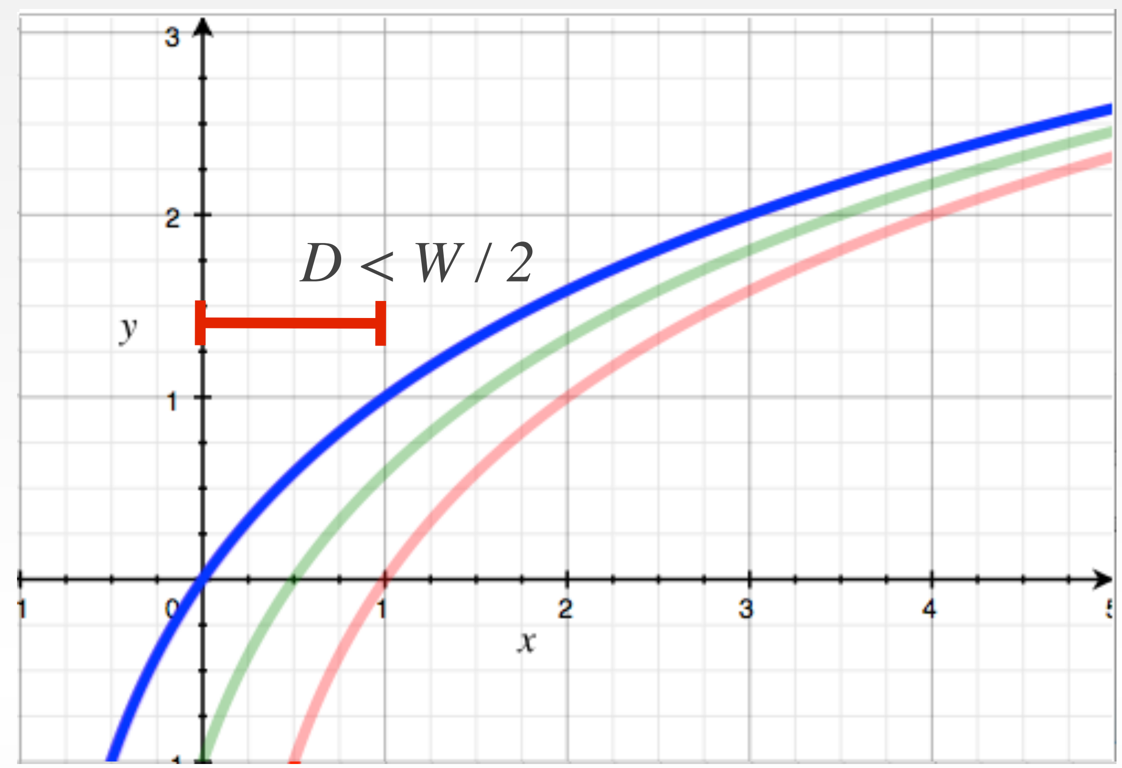
Improvements

- Welford's Formulation, 1968:
  - $$T_{pos} = I_M \cdot \log_2\left(\frac{D}{W} + \frac{1}{2}\right)$$
- Shannon's Formulation, ISO, 80's:
  - $$T_{pos} = a + b \cdot \log_2\left(\frac{D}{W} + 1\right)$$

  a, b depend on device, determine experimentally

  Use a = 0 ms, b = I_M = 100 ms for quick and dirty estimates

  Improved curve fit, no negative times for infinite-size targets



$$T_{pos} = I_M \cdot \log_2\left(\frac{2D}{W}\right)$$

$$T_{pos} = I_M \cdot \log_2\left(\frac{D}{W} + \frac{1}{2}\right)$$

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

Summary

- The Media Computing Group does cool stuff.
- HCI is about humans, computers, the design process, and the social context.
- The CMN model allows estimating reaction times and memory performance.
- Fitts' Law allows estimating times for typing, pointing, and similar tasks.
- **Assignment**: Read "*Human-Computer Interaction*"

  (Dix, et al.) chapter "*The Human*" (pp. 11-59)
- Start reading "*The Design of Everyday Things*", by Donald Norman.