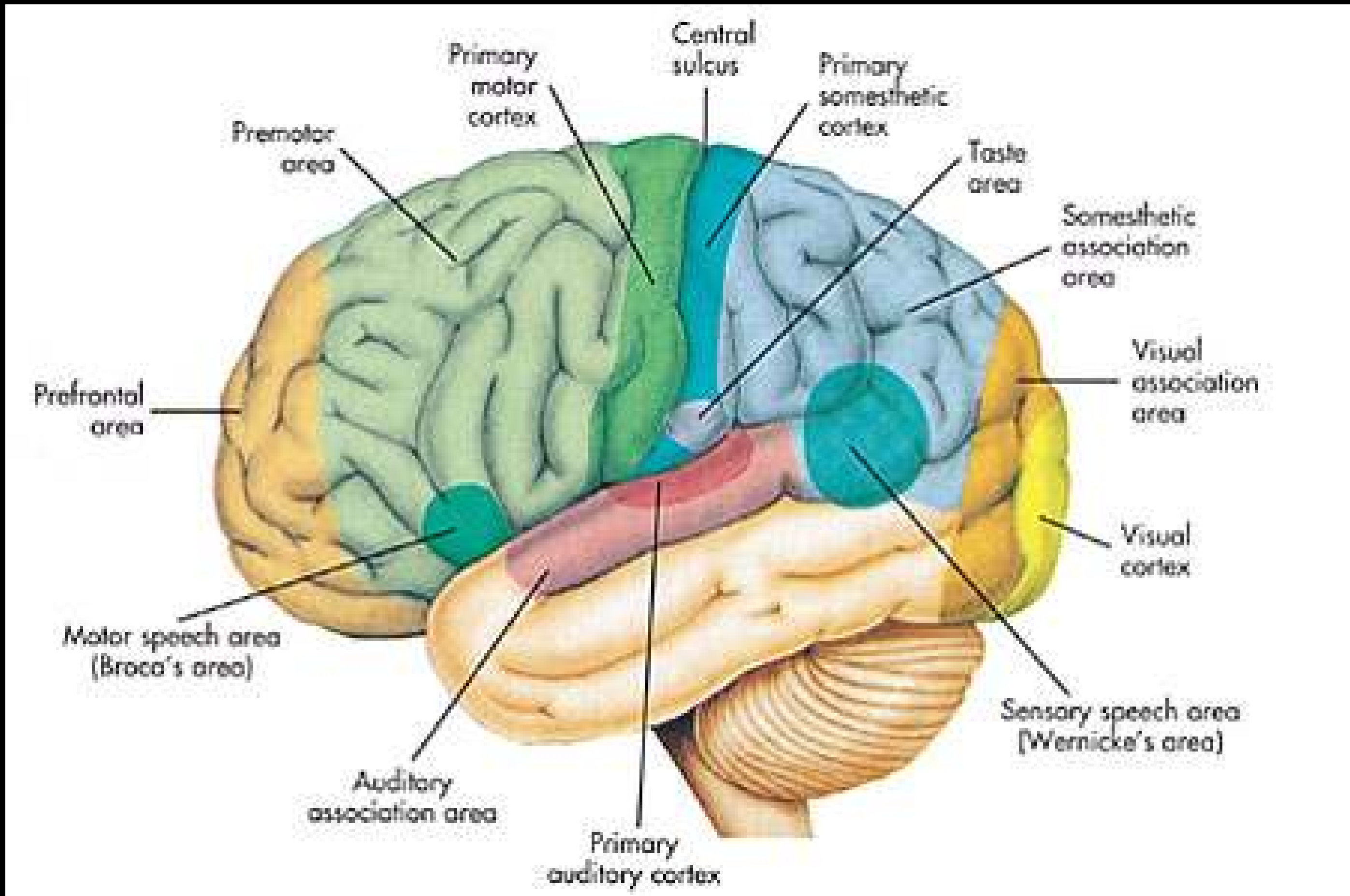
Theories of Cognition & Motor-Action

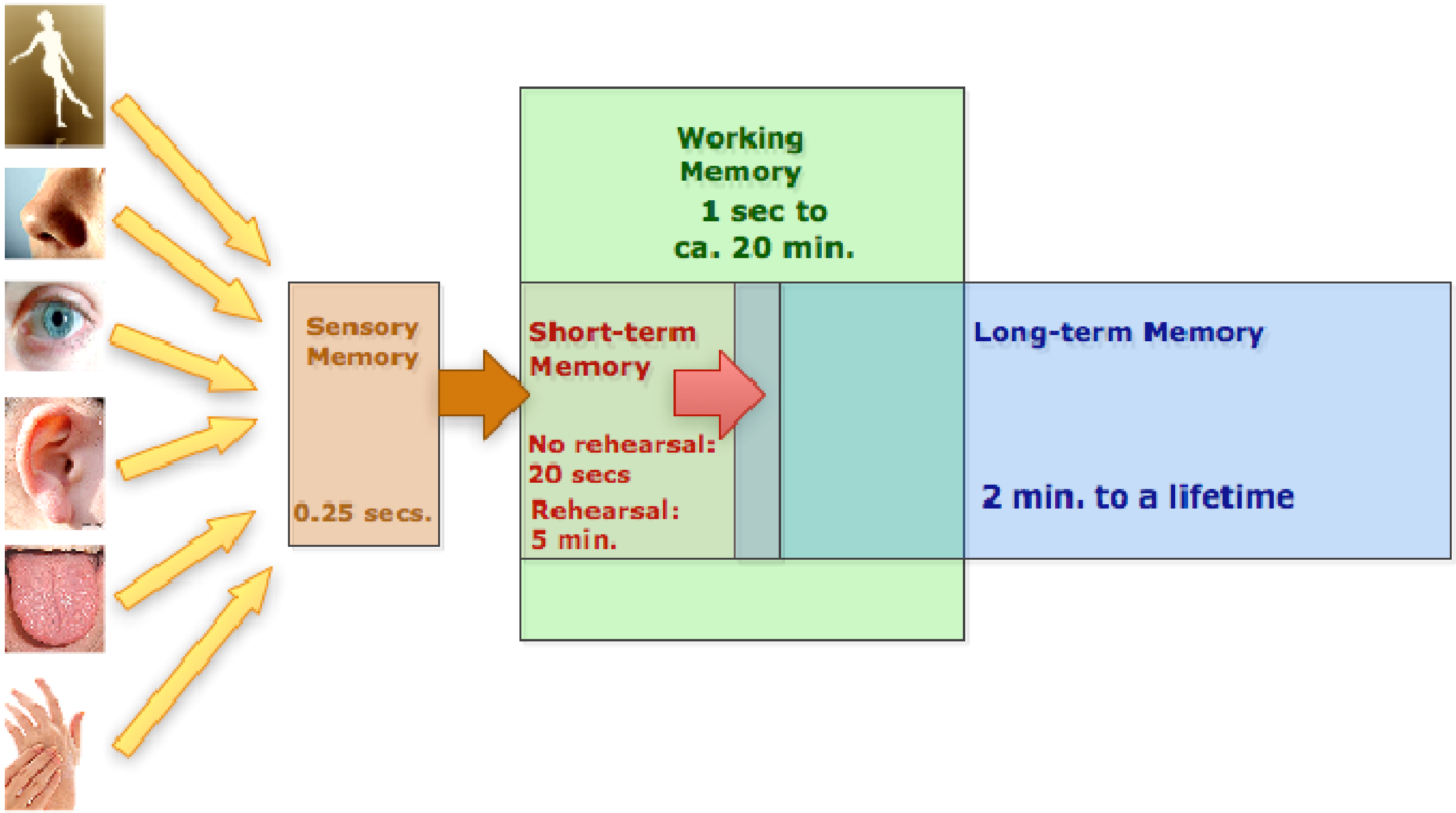
Dr Pradipta Biswas, PhD (Cantab)
Assistant Professor
Indian Institute of Science
https://cambum.net/

Cognition

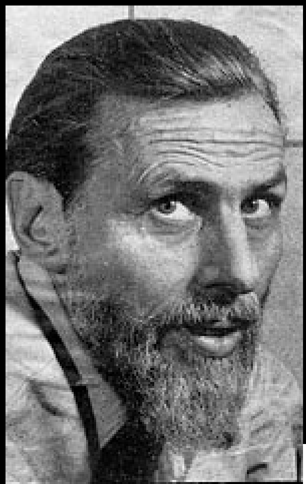
Brain



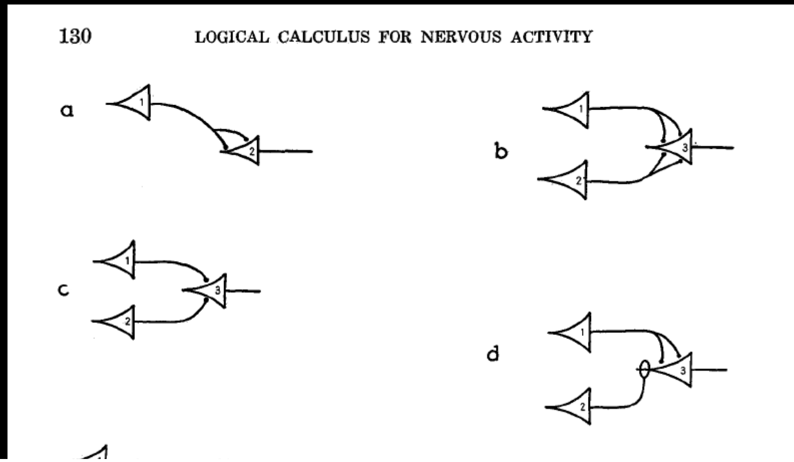
Central sulcus
Primary motor cortex
Primary somesthetic cortex
Premotor area
Taste area
Somesthetic association area
Prefrontal area
Visual association area
Visual cortex
Motor speech area (Broca's area)
Sensory speech area (Wernicke's area)
Auditory association area
Primary auditory cortex


Working Memory
1 sec to ca. 20 min.
Sensory Memory
0.25 secs.
Short-term Memory
No rehearsal: 20 secs
Rehearsal: 5 min.
Long-term Memory
2 min. to a lifetime

Early influential work



Warren McCulloch



Walter Pitts

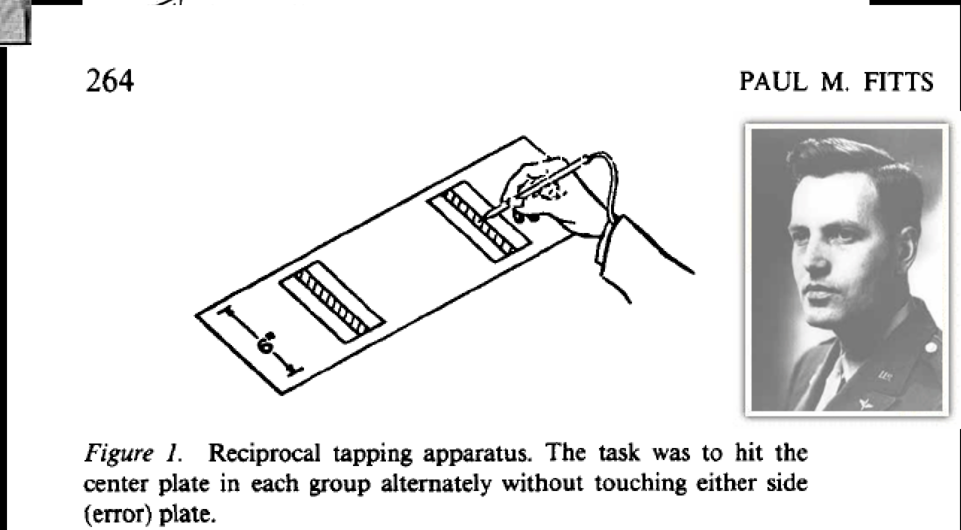


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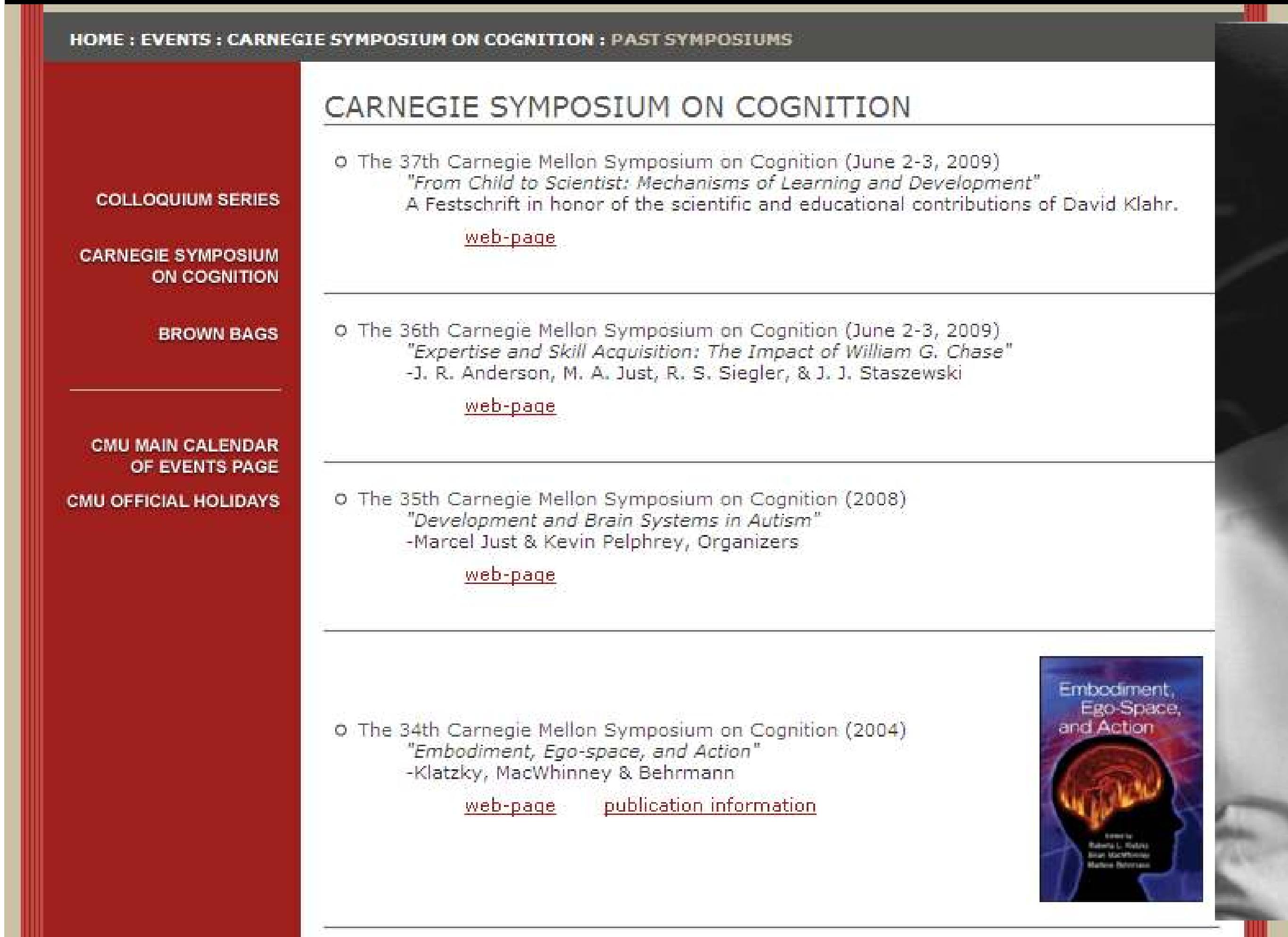
Figure 1. Reciprocal tapping apparatus. The task was to hit the center plate in each group alternately without touching either side (error) plate.

Problem

Holistic Picture



HOME : EVENTS : CARNEGIE SYMPOSIUM ON COGNITION : PAST SYMPOSIUMS

- COLLOQUIUM SERIES
- CARNEGIE SYMPOSIUM ON COGNITION
- BROWN BAGS
- CMU MAIN CALENDAR OF EVENTS PAGE
- CMU OFFICIAL HOLIDAYS

CARNEGIE SYMPOSIUM ON COGNITION

- The 37th Carnegie Mellon Symposium on Cognition (June 2-3, 2009)
  "From Child to Scientist: Mechanisms of Learning and Development"
  A Festschrift in honor of the scientific and educational contributions of David Klahr.
  web-page

- The 36th Carnegie Mellon Symposium on Cognition (June 2-3, 2009)
  "Expertise and Skill Acquisition: The Impact of William G. Chase"
  -J. R. Anderson, M. A. Just, R. S. Siegler, & J. J. Staszewski
  web-page

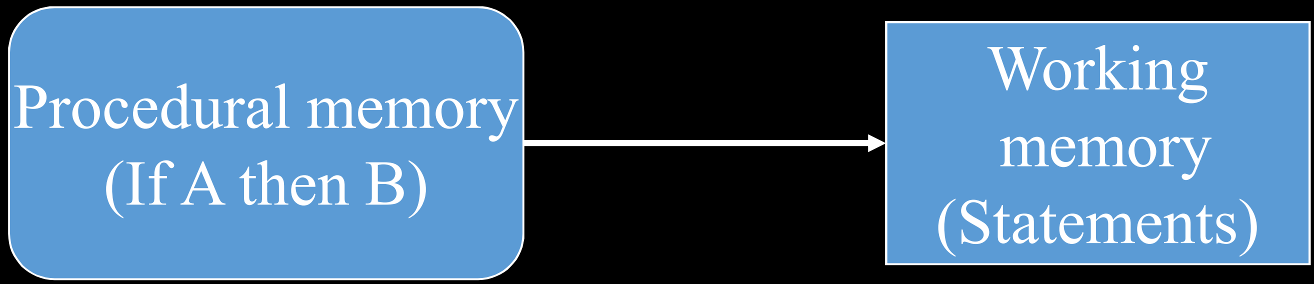
- The 35th Carnegie Mellon Symposium on Cognition (2008)
  "Development and Brain Systems in Autism"
  -Marcel Just & Kevin Pelphrey, Organizers
  web-page

- The 34th Carnegie Mellon Symposium on Cognition (2004)
  "Embodiment, Ego-space, and Action"
  -Klatzky, MacWhinney & Behrmann
  web-page publication information

Time scale of action

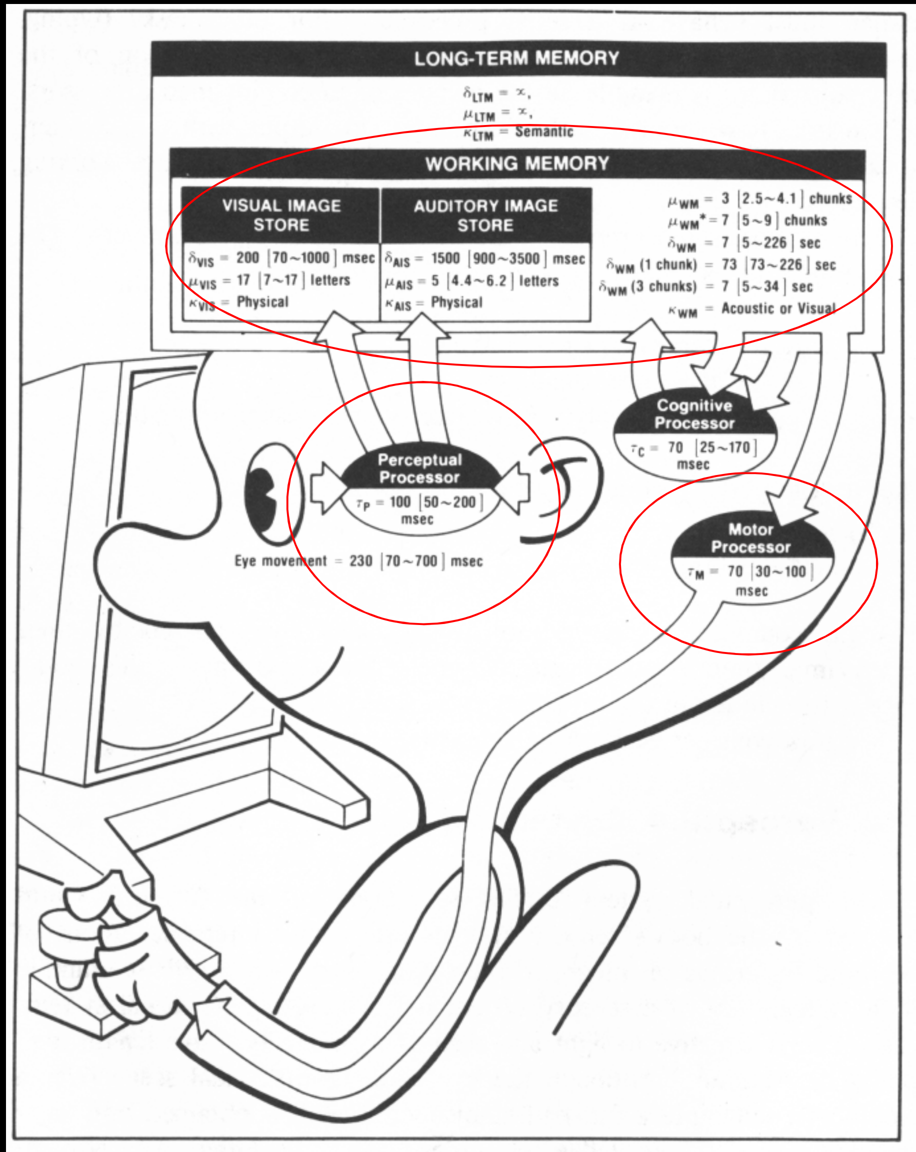
TIME SCALE OF HUMAN ACTION		
SCALE (sec)	SYSTEM	STRATUM
10^7 10^6 10^5		SOCIAL
10^4 10^3 10^2	Task Task Task	RATIONAL
10^1 10^0 10^{-1}	Unit Task Operations Deliberate Act	COGNITIVE
10^{-2} 10^{-3} 10^{-4}	Neural Circuit Neuron Organelle	BIOLOGICAL

SOAR - Symbolic system

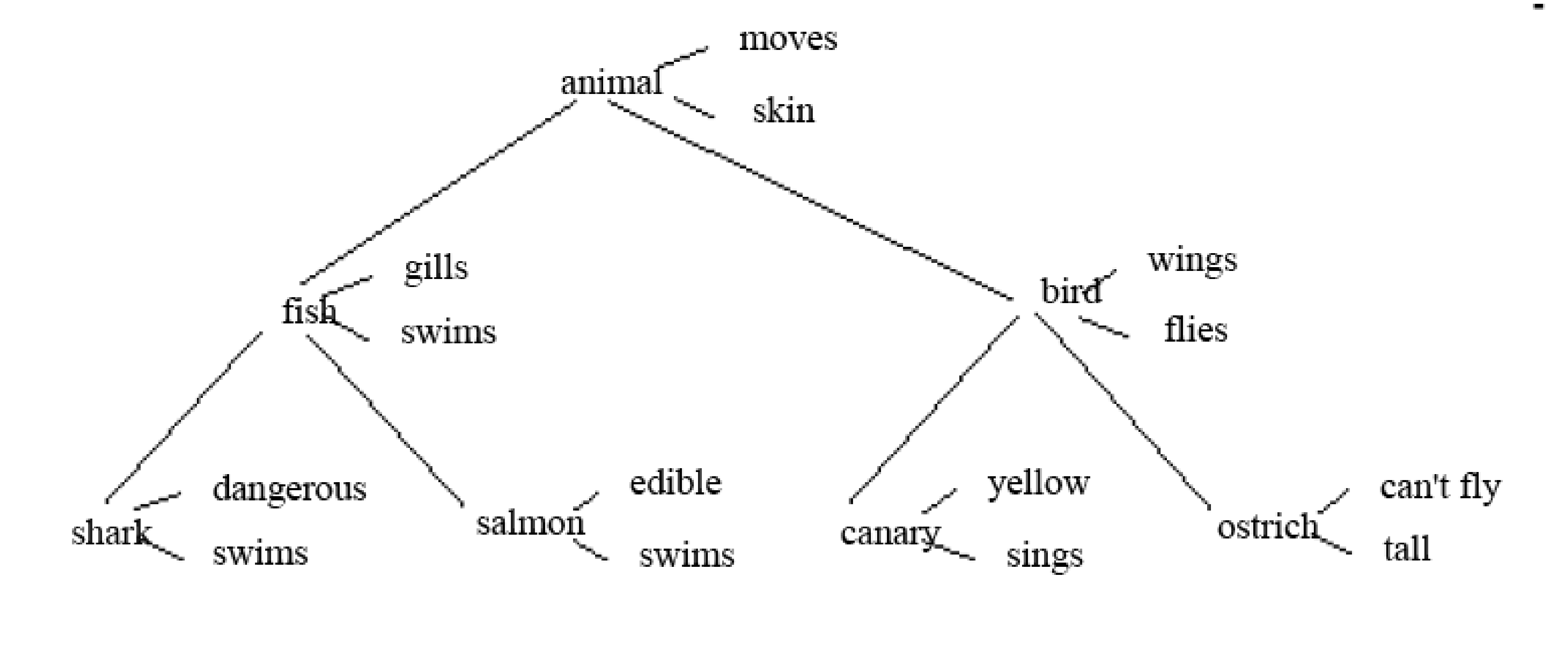


- State space model → Memory and problem definition
- Impasse → Can’t find a rule, decompose goal to sub-goals
- Chunking → Learning new situation

Model Human Processor



ACT-R



- Uses both symbolic and sub-symbolic processing

ACT - R

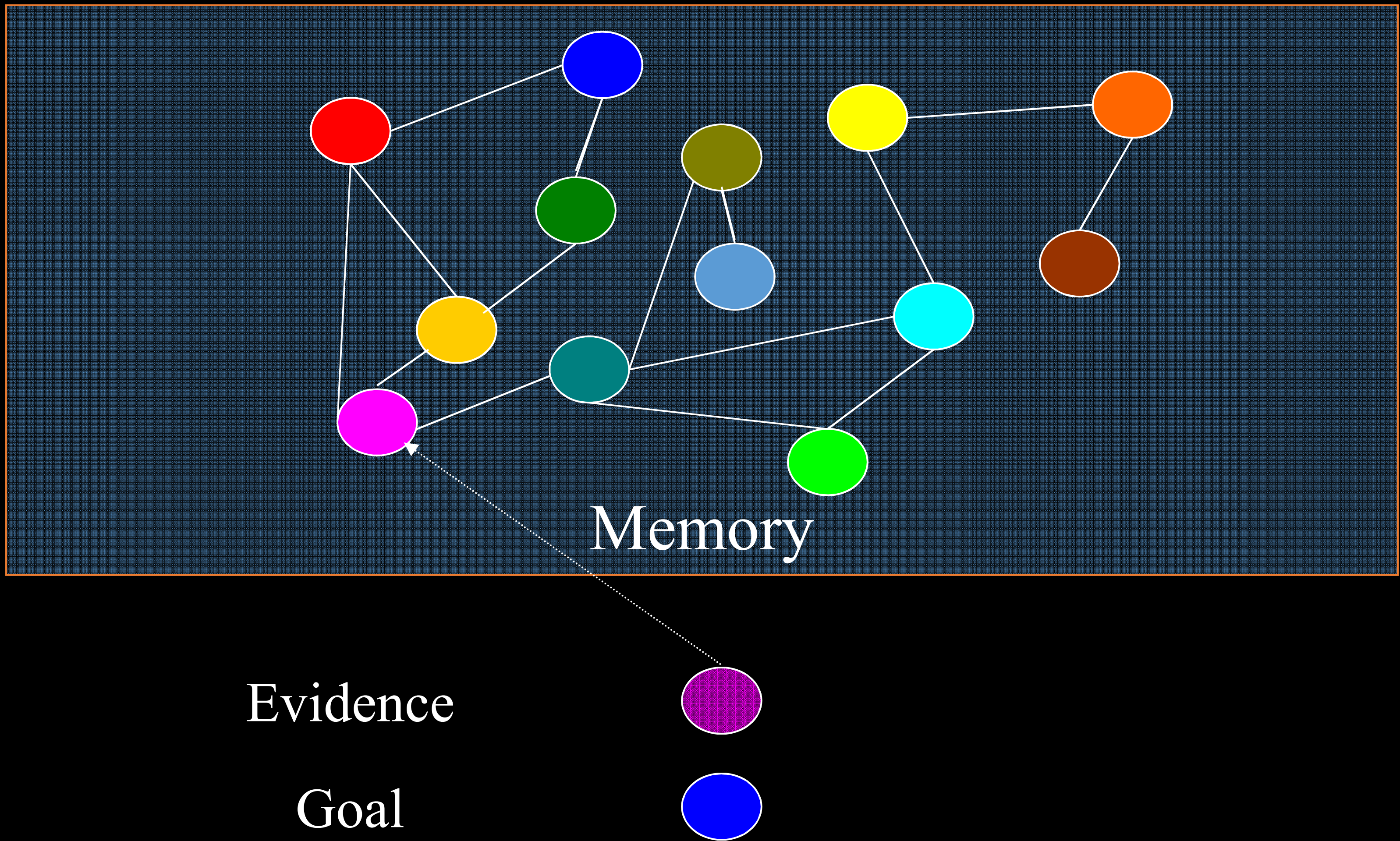
- Uses declarative and procedural memory like SOAR
- The subsymbolic structure is a set of parallel processes that can be summarized by a number of mathematical equations.
- The equations that make up the subsymbolic level are not static and change with experience.

ACT - R

- The subsymbolic learning allows the system to adapt to environment.

- Whether and how fast a memory element can be retrieved from declarative memory depends on the subsymbolic retrieval equations, which take into account the context and the history of usage of that fact.

Memory retrieval



A node with more connections will be retrieved quicker and with higher probability of retrieval

Errors

Table 8.2 A catalogue of errors

Skill-based performance	
Inattention	*Overattention*
Double-capture slips	Omissions
Omissions following interruptions	Repetitions
Reduced intentionality	Reversals
Perceptual confusions	
Interference errors	

Rule-based performance	
Misapplication of good rules	*Application of bad rules*
First exceptions	Encoding deficiencies
Countersigns and nonsigns	Action deficiencies
Informational overload	Wrong rules
Rule strength	Inelegant rules
General rules	Inadvisable rules
Redundancy	
Rigidity	

Knowledge-based performance
Selectivity
Workspace limitations
Out of sight out of mind
Confirmation bias
Overconfidence
Biased reviewing
Illusory correlation
Halo effects
Problems with causality
Problems with complexity
Problems with delayed feedback
Insufficient consideration of processes in time
Difficulties with exponential developments
Thinking in causal series not causal nets
Thematic vagabonding
Encysting

Source: Based on Reason, 1990

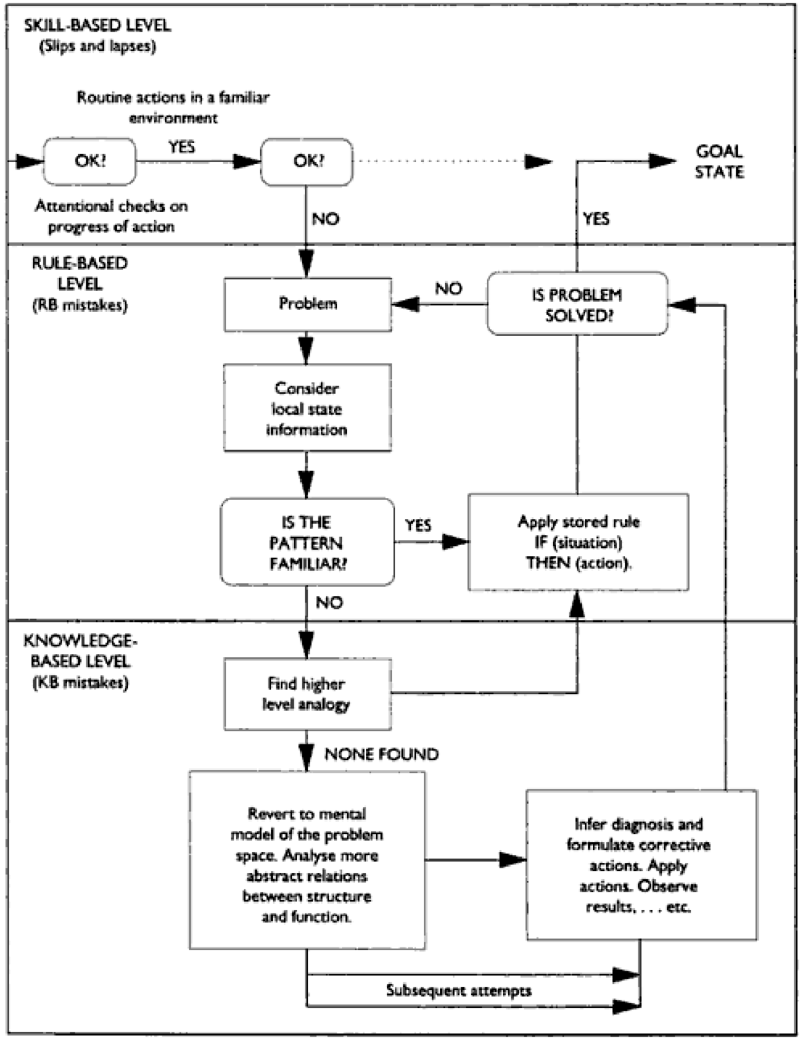


Figure 8.3 The Generic Error Modelling System (GEMS). (Based on figure 3.1, Reason, 1990)

Designers' points

- More connections → Easy retrieval
  - Try to make interface elements familiar to users
  - Use analogy to users' known objects, actions
- Identify and categorize prospective errors by end users
- Think about short term / working memory load while designing an interface
  - Restrict amount of items in a single screen

Motor action

Rapid Aiming Movements

Quick

Accurate

Preprogrammed

Woodworth’s study

Eye open – visual feedback

Error ∞ Speed

Eye close – no visual feedback

Accuracy does not depend on Speed

Two phases of movement

- Initial impulse

- Current control

Fitts' Law

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

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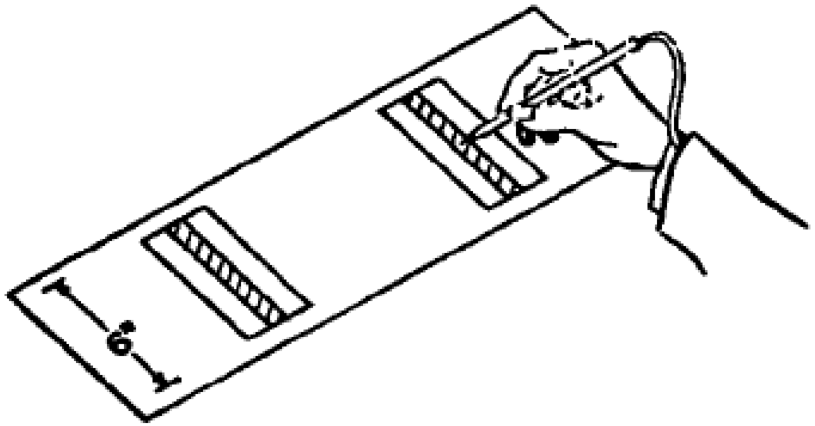


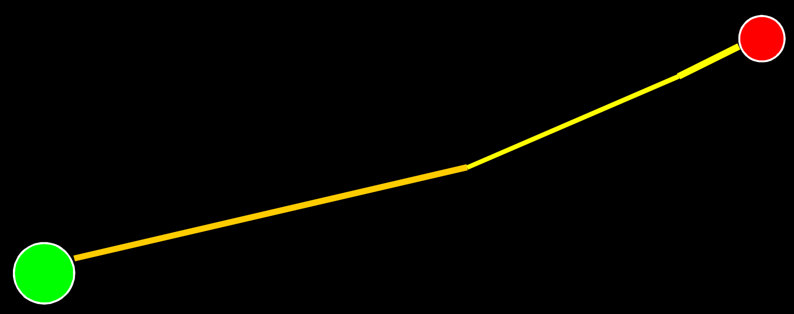
Figure 1. Reciprocal tapping apparatus. The task was to hit the center plate in each group alternately without touching either side (error) plate.

Applications

- Moving cursor in a screen using mouse or joystick
- Transferring pegs into hole
- Aiming movement under water
- Manipulating objects under a microscope

Explanations

- Iterative correction model [Crossman & Goodeve 1963/1983]



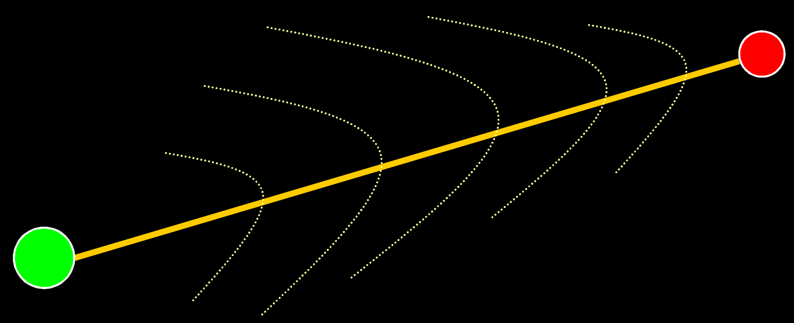
Problems in explanation

- Need of corrective movements
- Timing of corrective movements

Impulse variability model

- Neuro motor impulse -> burst of force towards target (Schimdt et al, 1979)

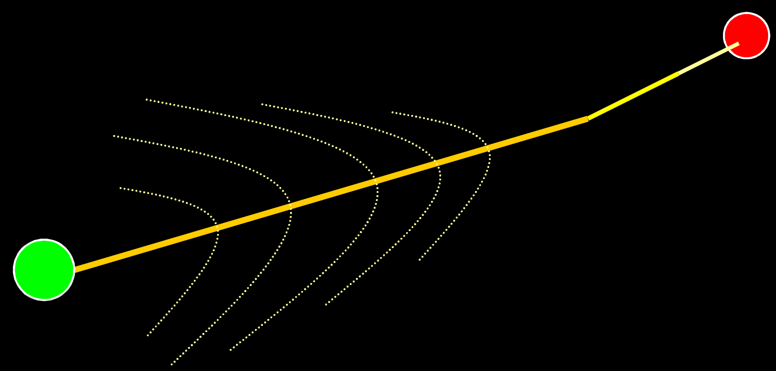
Distance ∞Amount of force ∞ Variability of force



Optimized initial impulse model

- Accommodates both Schimdt and Crossman's model (Meyer et al, 1988)

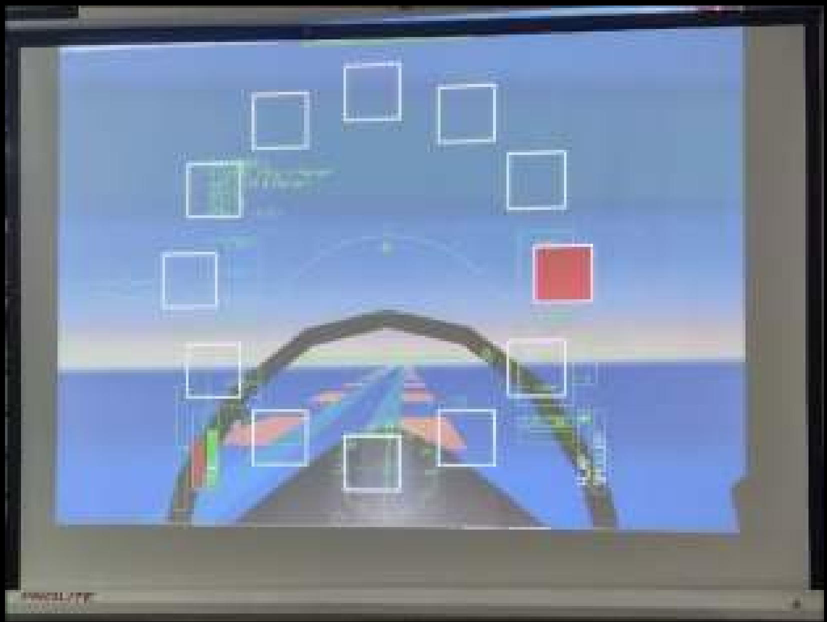
- Supports both initial impulse and current control

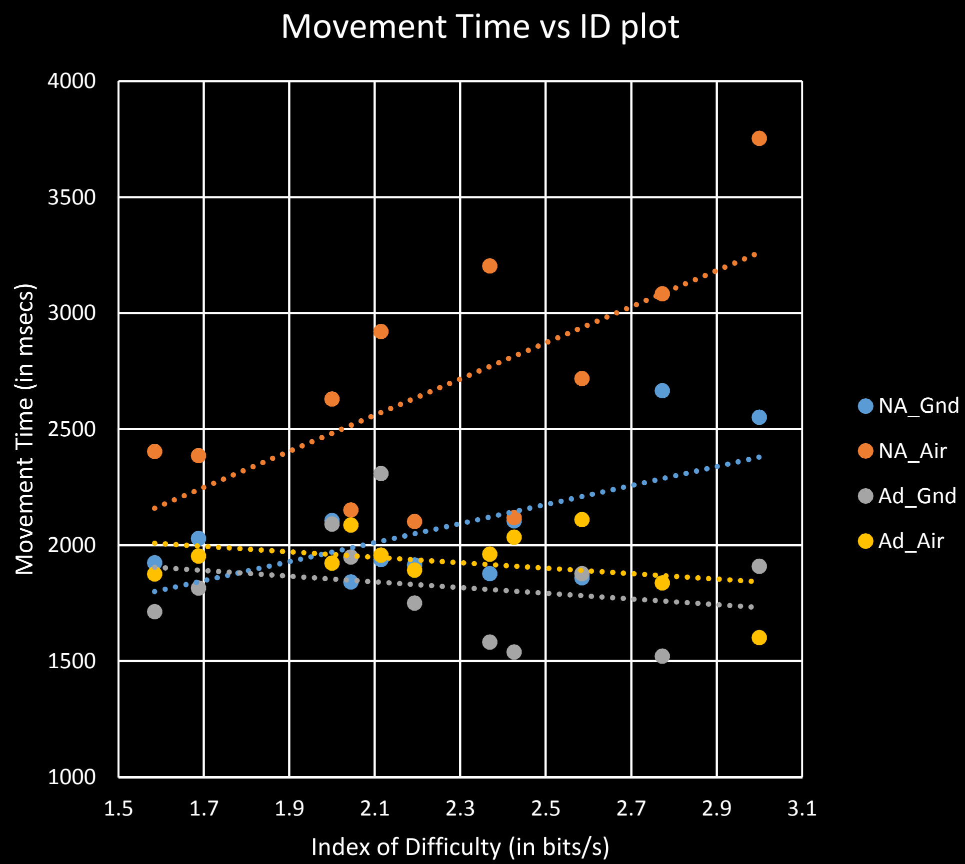


Computer input device

Card's first home run came when he used a then-little-known law called "Fitts' law" to examine input devices such as joy sticks, a head-motion detector, and a newfangled controller that hung by a cable from the computer called a "mouse." Fitts' law analyzes how easily a human can hit any given target - in this case, moving a cursor to a specific point on a screen - and Card measured the mouse to be almost as simple as if one could move the cursor around on the screen with one's hand. After Card's work, Xerox began manufacturing mice, Apple soon followed, and now they're practically de rigueur on all computers.

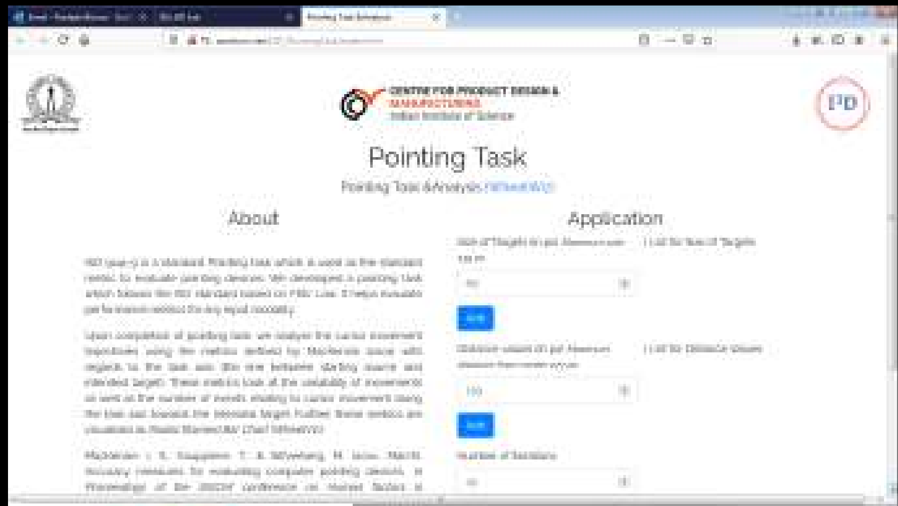
ISO Pointing Task

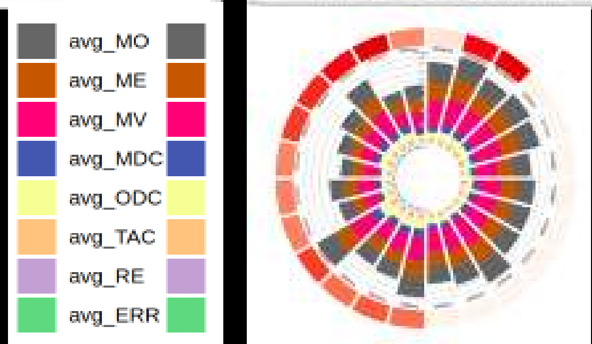




ISO Pointing Task - Software

http://cambum.net/I3D_PointingTask/index.html



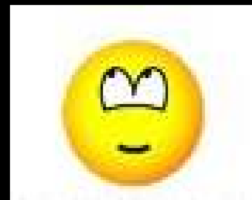


Motor impaired users

Fitts' Law

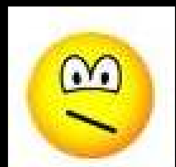
Smits-Engelsman [2007]

Gajos [2007]



Bravo [1993]

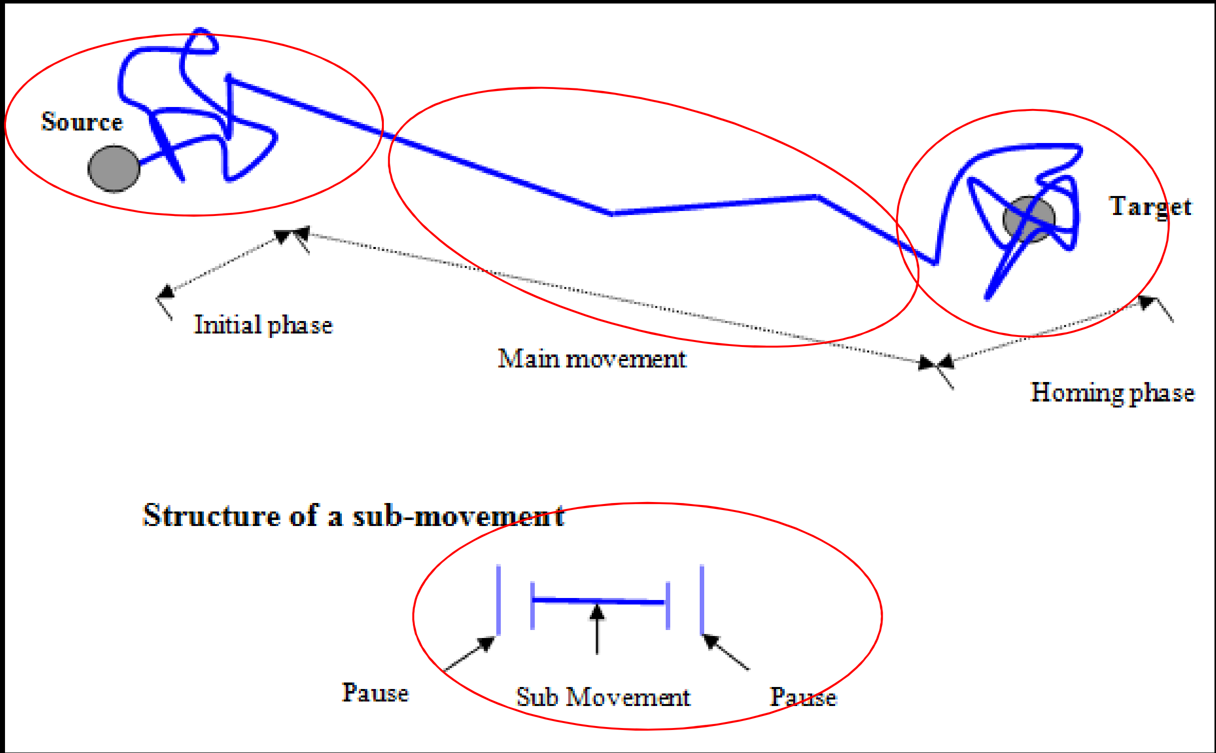
Gump [2002]



Trewin and Pain, 1999
Keates, Clarkson and Robinson, 2000
Keates and Trewin, 2005
Keates, Trewin and Paradise, 2005

Hand strength

Model



Linear regression model predicts number of sub-movements and movement time in each phase

Designers' points

- It takes more time to point if
  - Target is away from source
  - Target is small in size
- Movement occurs in multiple sub-movements
- Sub movements in homing phase may be random due to physical or situational impairment
  - Increase inter-button spacing to avoid wrong selection

Take away points

- Models of memory & cognition
- Introduction to Symbolic and Connectionist models
  - SOAR & ACT-R
- Fitts' Law analysis
- Movement patterns of motor impaired users