Human-Computer Interaction: 1B. Model Human Processor and Time Scales

9th October 2025

HCI Introduction

- Humans as Information Processors
- The "Model Human Processor"
- Time Scales of Human Action

Learning Objectives: be able to …

- Describe how humans can be viewed as information processors
- Explain the MHP Model
- Reason about human interaction time based on the MHP Model
- Identify and illustrate time scales of human action

Humans as Information Processors

- In cognitive science, humans are viewed in terms of information processing
- Perception
  - We gain information from the world through sensors
- Cognition
  - We process information based on existing knowledge
  - We gain new knowledge, and make decisions
- Motor action
  - We have ‘information output’ into the world
  - Speaking, gesturing, writing, drawing, navigating the world, manipulating objects, …

Cognitive model by Robert Fludd (1619), Wikipedia

Information processing performance

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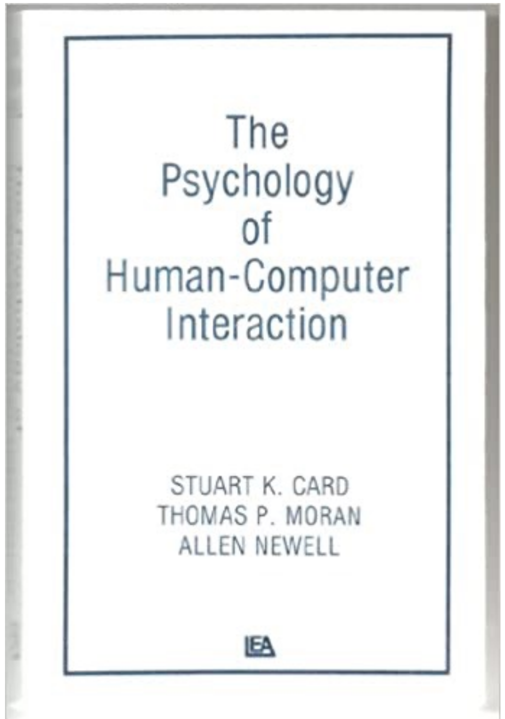
- In computer science, we have models that let us describe the performance of computers, at a systems level:
  - Types of processors, and their clock speed
  - Types of memory, and their capacity
  - How everything is connected
- This enables (rough) prediction of how long it takes to process information
- **Can we do the same for humans?**

Model Human Processor

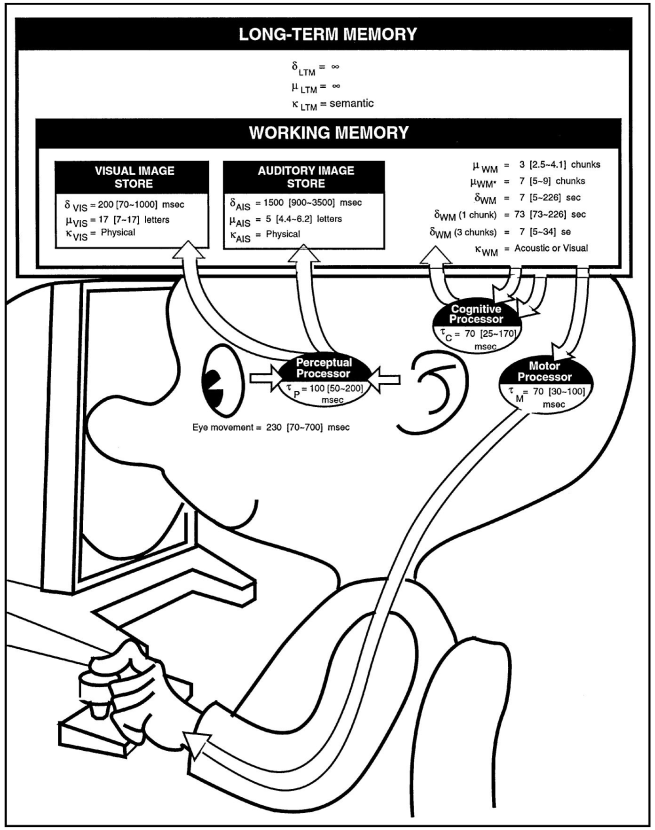
- A model to describe human performance as it relates to human-computer interaction
- Introduced in a 1983 book on Psychology applied to HCI
- Known for short as MHP model, or CMN model (after the authors)
- Bridges Psychology and Computer Science
  - Modelling human behaviour in information processing terms
  - Captures facts about human behaviour for application in HCI



Model Human Processor

A model user of a computer

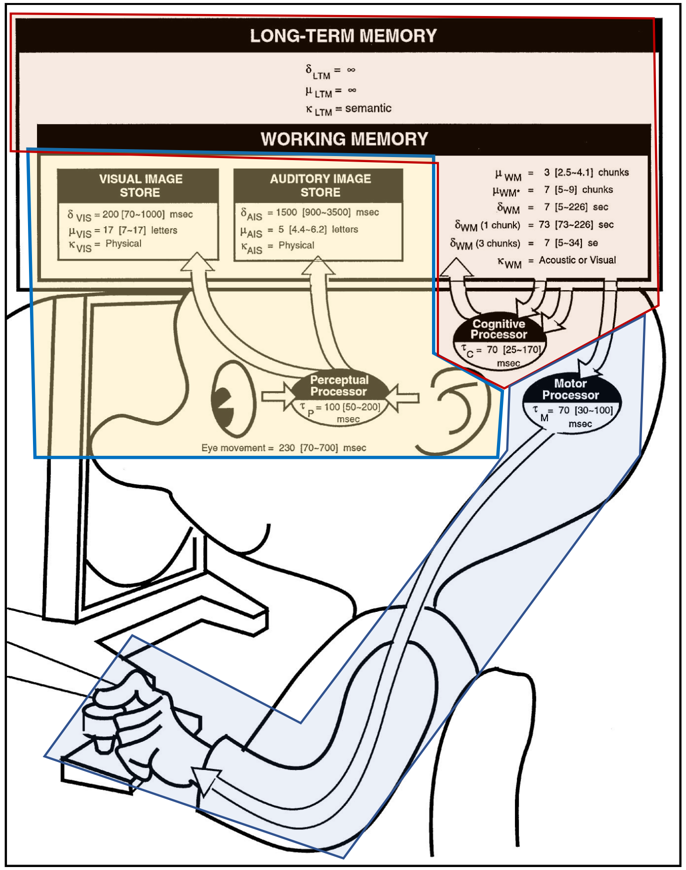
- Eyes and ears for input
- Arm-hand-finger for output
- Brain with processors and memories
    - each with performance parameters and connections



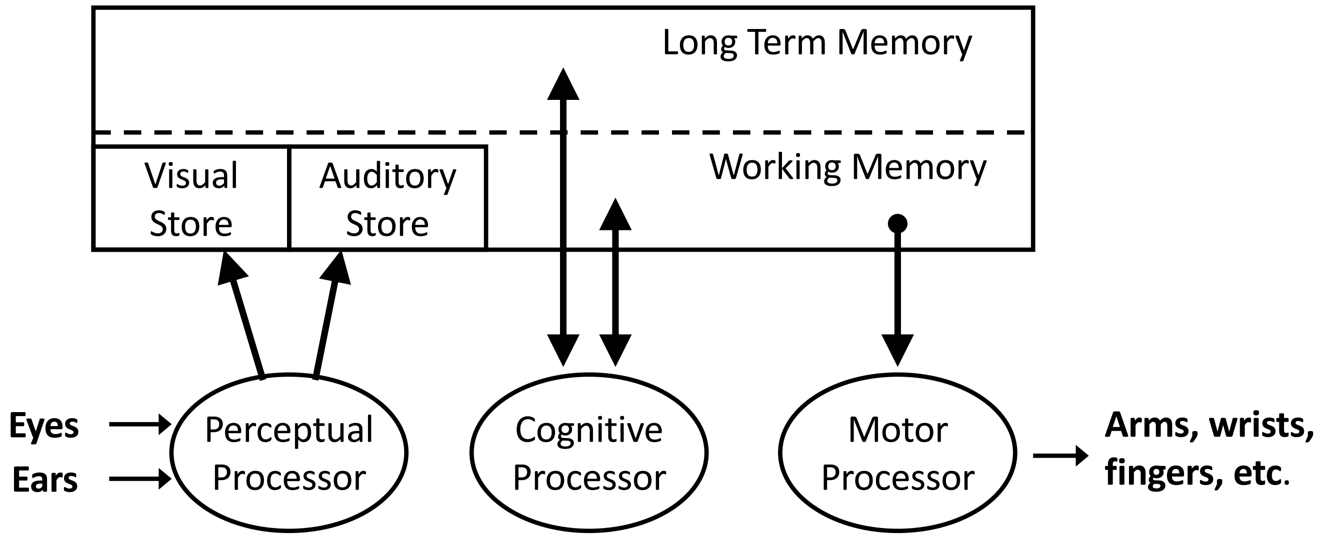
Model Human Processor

Three interacting subsystems

- Perceptual system
- Motor system
- Cognitive system

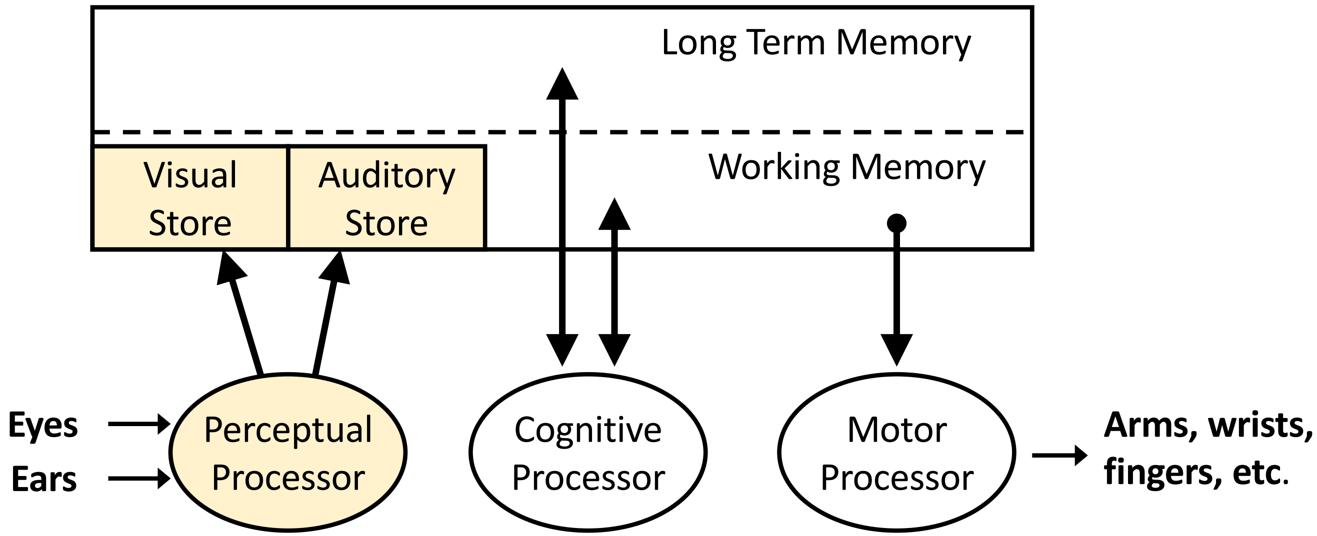


Processors and Memories



Perceptual System

- Composed of *perceptual memory* and *processor*
- Responsible for transforming external events into a form that the cognitive system can process



Perceptual Memory

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Perceptual memory is like a buffer for sensor data

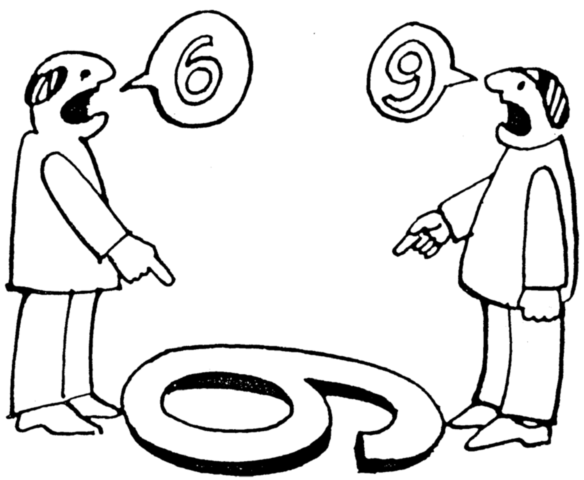
- For each sensor, incoming stimuli are stored for a short time
    - Visual image store: ~200ms
    - Audio store: ~1500ms
- The incoming data is represented as ‘raw data’
    - Low-level features of images, sound, …

- Why is the data buffered?
- Why over different time windows?

Perceptual Processor

Content in perceptual memory is processed to be symbolically encoded.

- Coding takes time!
- Cycle time: T_P = 100ms
- Variable rate, shorter for features that "pop out" or are more intense
- When multiple similar events occur in the same cycle, then they are integrated
  - Bloch's Law: R = I x t
  - e.g. perceiving two short stimuli as one of twice the intensity



Question Time …

1. If 20 clicks per second are played for 5 seconds, about how many clicks could a person hear?
2. If 30 clicks per second are played for 5 seconds, about how many clicks could a person hear?
3. How many frames per second must a video be played to give illusion of motion?
4. In a talking head video, how far off can the audio and video be before a person perceives the video as unsynchronized?

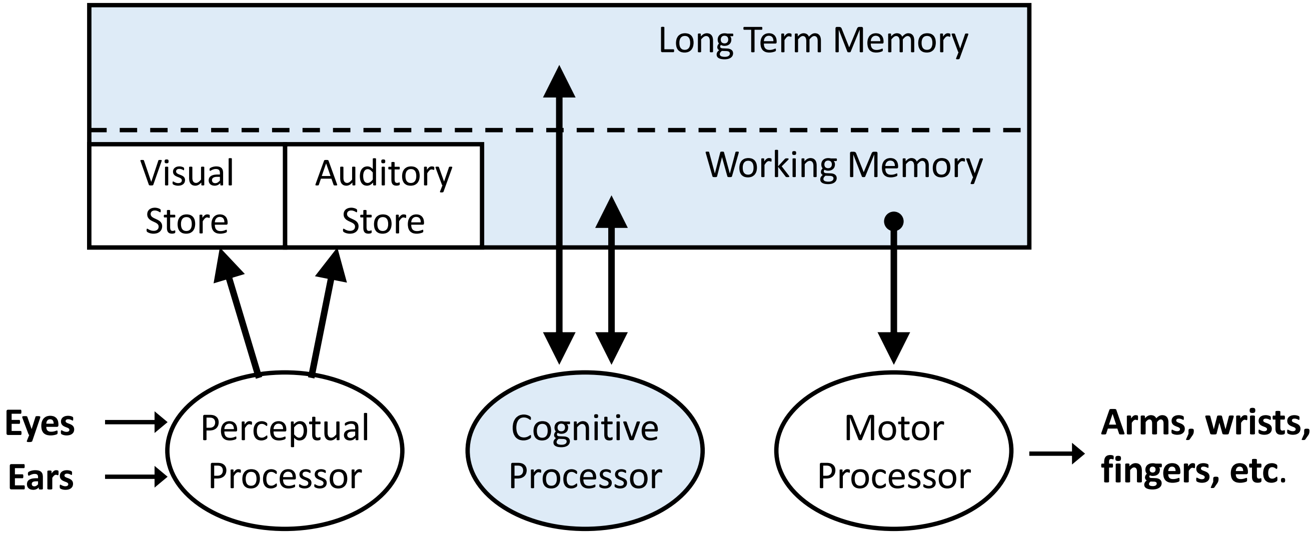
Perceptual Processor

The processor cannot code all information before the next stimulus arrives.

- There is more buffered in Perceptual Memory than can be coded before it is replaced by new sensations
- Order of coding is influenced by attention:
  - What we focus on, what we are looking for, what draws our attention
- Type of coding is influenced by
  - Gestalt perception of patterns, shapes and structure
  - Associations triggered (e.g. faces seen before)
- The way something is encoded impacts on how it is stored in memory and how it can be retrieved from memory

Cognitive System

- Composed of *working memory, long-term memory* and the *cognitive processor*
- Responsible for processing perceived information and deciding how to act upon it

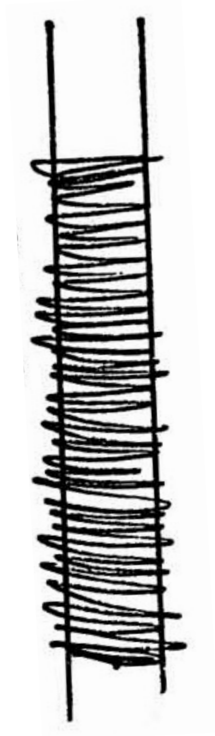


Cognitive Processor

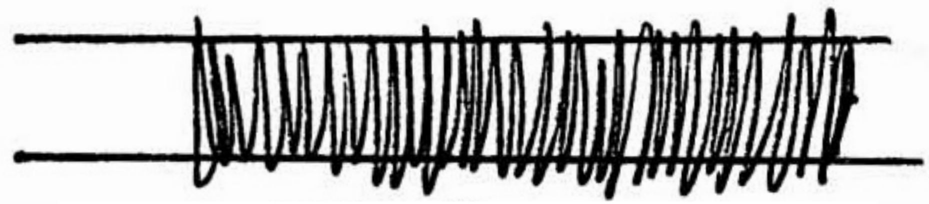
- The cognitive processor works on *symbolic* information that is available in working memory, as a result of perceptual coding
- Cognitive processing is based on a recognize-act cycle:
  - **Recognize**: activate associations stored in long-term memory
  - **Act**: decide what to do next, modifying working memory ("loading" the next task)
  - Recognition is highly parallel, but Acting is serial: one decision at a time
  - Cycle time: T_C = 70ms
- Uncertainty Principle: decision time increases with the uncertainty about the judgment to be made, requires more cognitive cycles
- Cycle time can be shorter when greater effort is induced by the task
- Cycle time also diminishes with practice

Experiment that you can do in pairs

- One time-keeper with stopwatch, one ’participant’
- On a piece of paper, draw two parallel lines, ~3 cm apart, not too thick
- When the time-keeper gives you the start signal, your task is to draw back and forth between the two lines
  - **As fast as possible!**
  - Also **as accurately as possible**
- Time-keeper stops the task after 5 seconds



Analyse your data



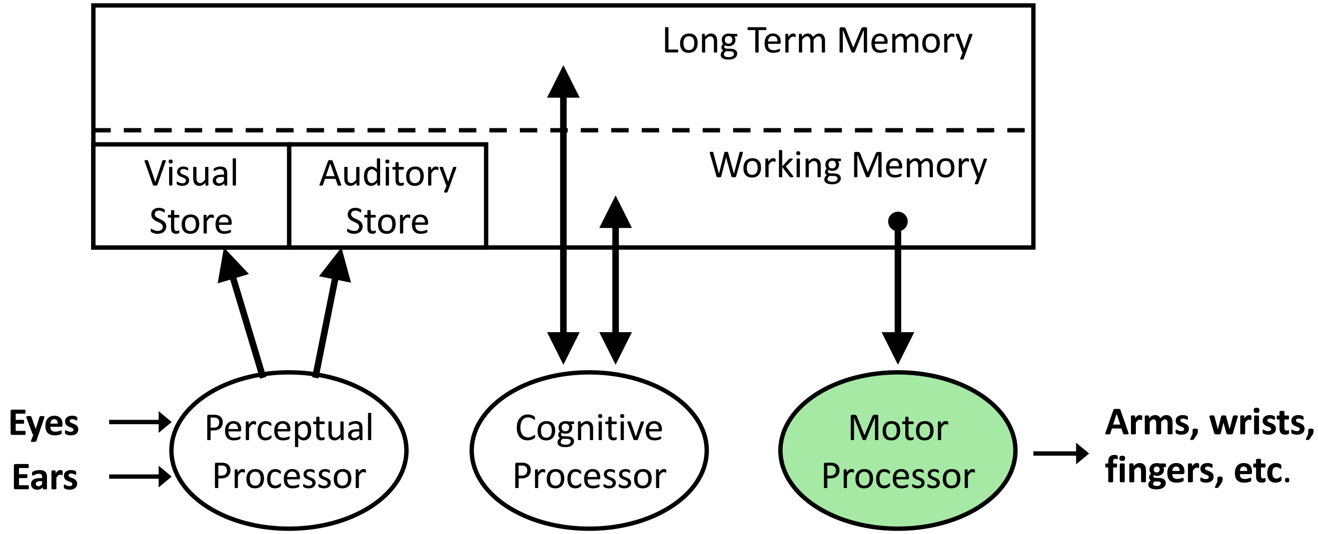
- Count each individual stroke
  - Each pen reversal / change in direction
- Calculate strokes/second
- This indicates the rate at which the brain can program actions

Example: about 50 strokes

- 10 strokes per second
- 100ms for each stroke
- Composed of:
  - Time to program the action
  - Covering the distance (minimal in the experiment)

Motor System

- Translating thought into action
- Cycle time: T_M = 70ms, time required to issue a motor command
  - Between 30-100ms depending on task

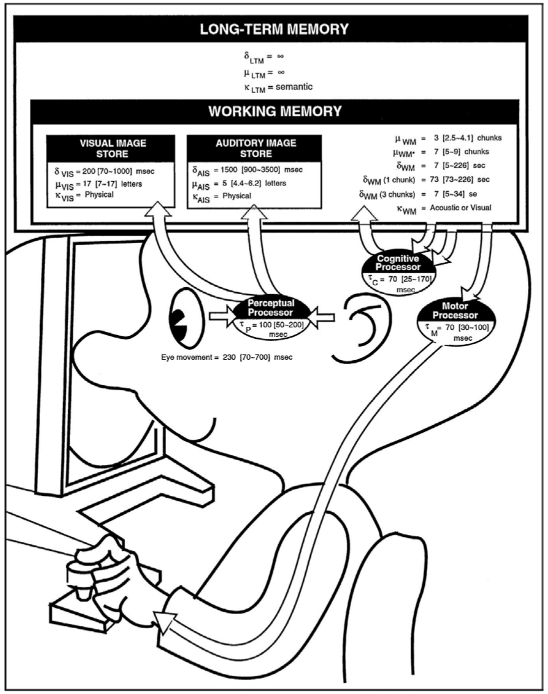


Motor system

- Rate of repetitive movement
- Typing
  - Advanced professional 120 wpm -> 2 words / sec.
  - 4.7 characters/word -> 9.4 characters/sec
  - 106 ms per character
  - 53 ms for finger-down / finger-up

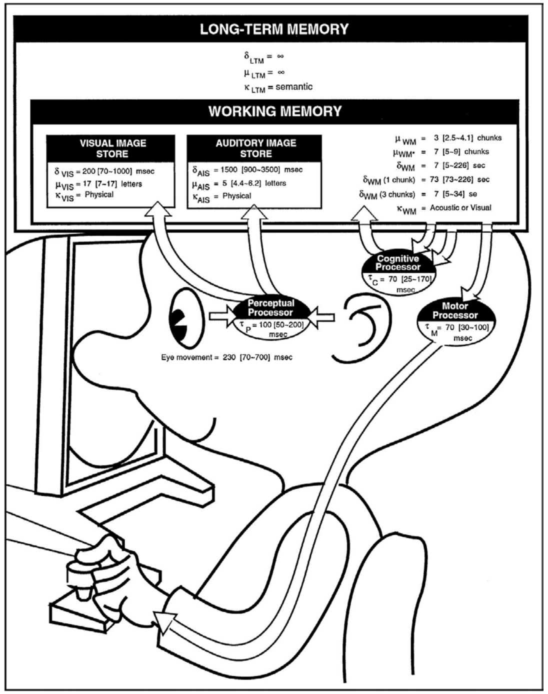
Applying the MHP model to HCI

- User sits in front of a screen, finger on button
- Whenever a prompt appears, they must press the button
- What is the reaction time?
  - Perception of stimulus
  - Recognition of stimulus as trigger for action
  - Executing the motor command



Discussion

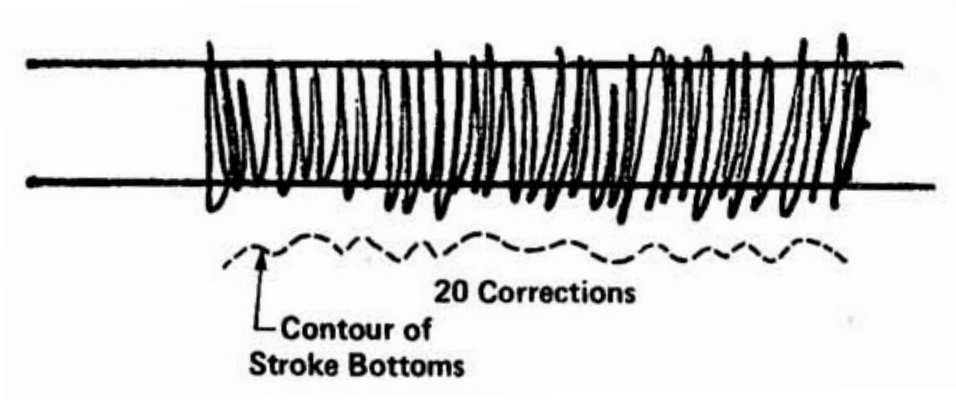
- The MHP is a model of human performance
- How accurate is the MHP for actual reaction time?
- Do you expect much variation from user to user?
- Collect data in your homework (Exercises E1)!



Pen Stroke Analysis, cont.

- Draw a contour line that shows the changes in stroke length
- Count each direction change in the contour
- This indicates corrections made when strokes were over- under shooting
- 250ms per correction
  - 5/20 = 0.25S (250ms)

- **Why?**
- **100 (perceptual) + 70 (cognitive) + 70 (motor)**



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- **Time Scales of Human Action**

Time Scales of Human Action

- Model of human action
- Time on a logarithmic scale
- From the time it takes for neurons to fire … to life-spanning activities

Scale (sec)	Time Units	System	World (theory)
10^7	Months		SOCIAL BAND
10^6	Weeks		
10^5	Days		
10^4	Hours	Task	RATIONAL BAND
10^3	10 min	Task	
10^2	Minutes	Task	
10^1	10 sec	Unit task	COGNITIVE BAND
10^0	1 sec	Operations	
10^{-1}	100 ms	Deliberate act	
10^{-2}	10 ms	Neural circuit	BIOLOGICAL BAND
10^{-3}	1 ms	Neuron	
10^{-4}	100 µs	Organelle	

From Newell, A. (1990). *Unified theories of cognition.* Harvard University Press.

Time Scales in HCI and User Interfaces

Scale (sec)	Time Units	System	World (theory)
10^7	Months		**SOCIAL BAND**
10^6	Weeks		
10^5	Days		
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- Information systems, media library/services, social media, activity trackers, …
- Productivity apps, games …
- Search, or looking up something
- Enter a keyword, make choice in menu, …
- Move cursor, press key, (double)-tap
- Perception and action (visuomotor processes, e.g. eye movement)

Human Response Time Requirements

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- Time is a critical factor in HCI
- For interaction to be successful, systems needs to responsive
- A system is perceived as responsive if it complies with human time requirements
  - <0.01S controlling in real time
  - <1S computer under our control
  - >=10S frustration and memory decay

Deadline	Perceptual and Cognitive Function	Design Requirement (example)
0.001 sec.	Detect silent audio gap	Max. drop-out time in audio feedback
0.01 sec.	Notice pen-ink lag	Max. lag time in stylus interfaces
0.1 sec.	Perceptual-motor feedback	Feedback for hand-eye coordination, (e.g. mouse pointer movement)
	Perceive cause-effect	Feedback for click on button or link Displaying “busy” indicators
1 sec.	Max. conversational gaps	Displaying progress indicators
	Reaction time for unexpected events	Wait time for users to react before presenting more (e.g., warnings)
10 sec.	Unbroken concentration on a task	Completing one step of a multi-step task (e.g. in a wizard)
100 sec.	Critical decision in emergency sitiuation	All info required for decision is provided or can be found in this time

MHP and Time Scales – Key points

- Humans can be modelled as information processors
  - A model of rationale processing (not accounting for emotion)
- Human performance can be predicted based on time needed for different stages of information processing (perception, cognition, action)
- Human action plays out at different time scales, from low-level neurological to high-level tasks and activity
- Interactive systems are perceived as responsive when they comply with human time requirements at different scales

Homework

- Complete the Javascript Tutorial by Monday
- Complete the exercises (E1) before your workshop
- Come with reaction time data to the workshop, for analysis in class

Lecture Revision

- Is there any parallel processing in the human perceptual system?
- What is the input to the Perceptual Processor and what is the output, and where is it stored?
- Identify the processors in the MHP model and their cycle times
- Think of a simple computer game you know and consider three ways in which it could be made harder: one that increases perception time, one that increases cognitive processing, and one that increases time to act.