Human Computer Interaction

UNIT-6
Lecture 3:
Cognitive Architecture

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Cognitive Architecture

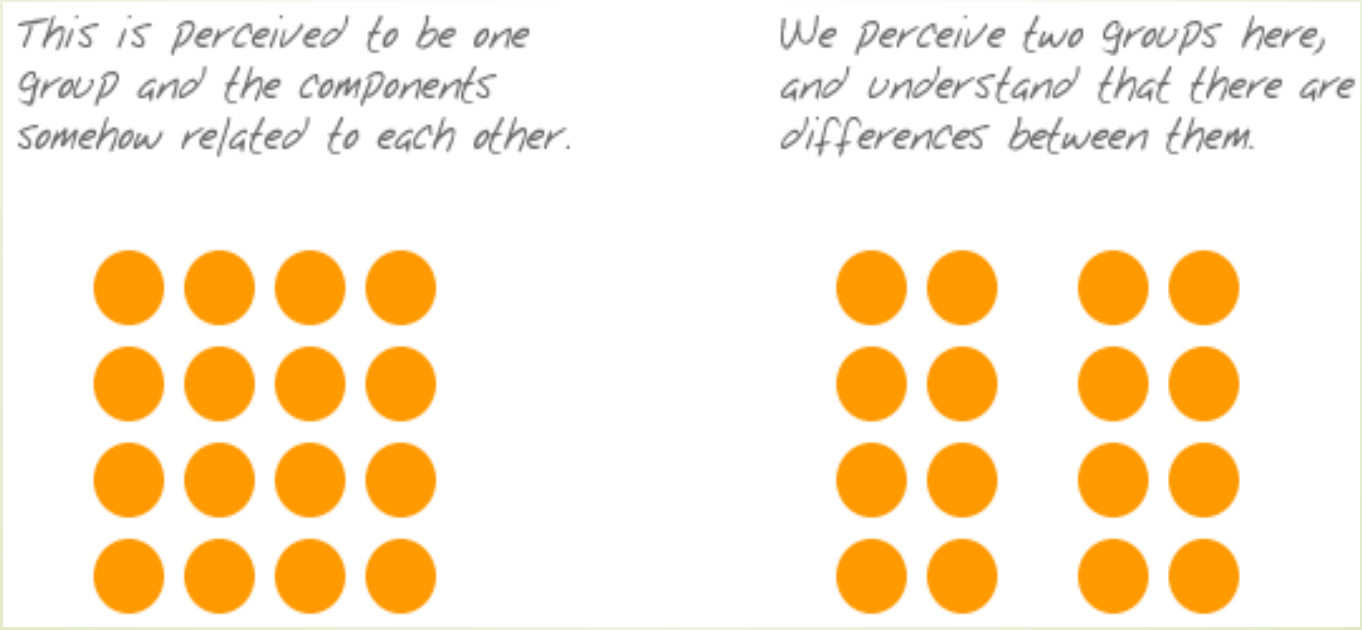
Model Human Processor - II

Gestalt Laws of Perception

- The organizing principles, which enables us to perceive the patterns of stimuli as meaningful wholes, are defined as
  - Proximity
  - Similarity
  - Closure
  - Continuity
  - Symmetry
  - Simplicity

Proximity

- The principle of proximity states that things that are close together appear to be more related than things that are spaced farther apart.

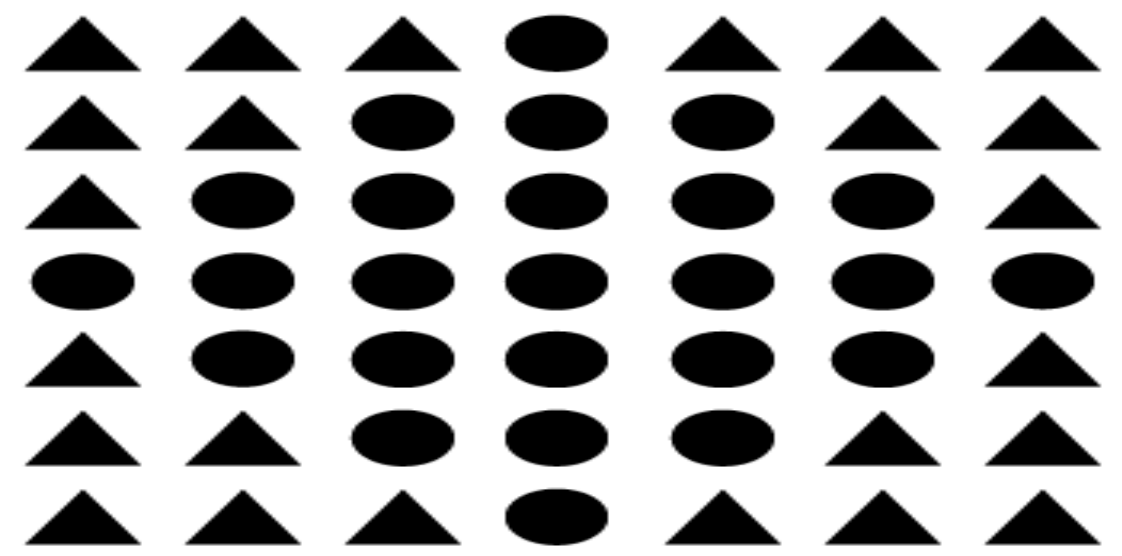


- Proximity is so powerful that it overrides similarity of color, shape, and other factors that might differentiate a group of objects.

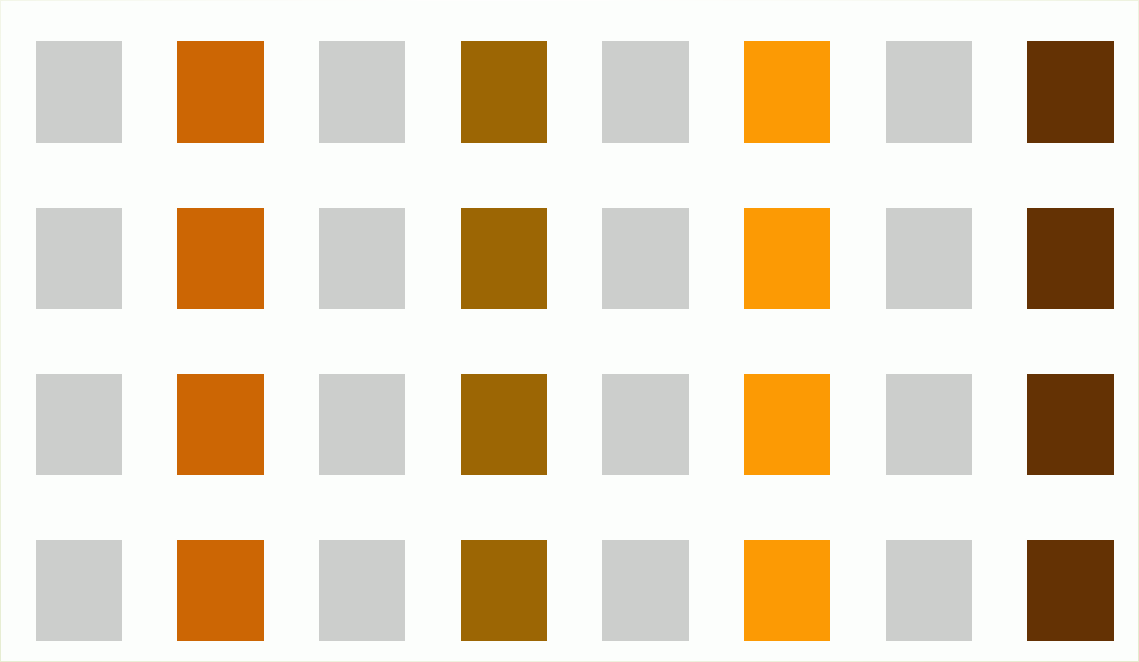
- Notice the three groups of black and red dots above? The relative nearness of the objects has an even stronger influence on grouping than color does.
- Here, the dots appear as groups rather than a random cluster of elements

Similarity

- The principle of similarity states that **when things appear to be similar to each other, we group them together. And we also tend to think they have the same function.**
- For instance, in this image, there appear to be two separate and distinct groups based on shape: the circles and the triangle.

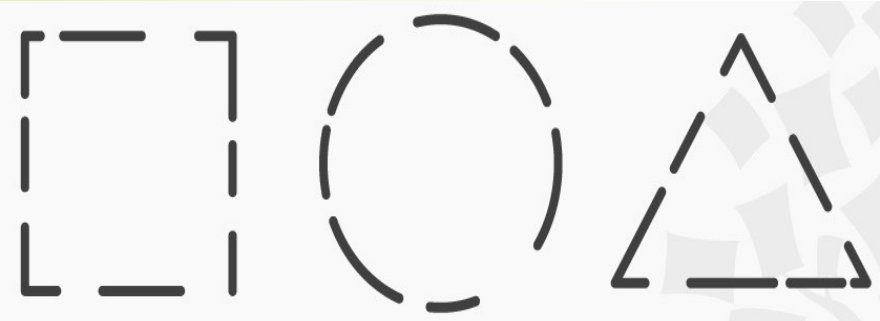


- A variety of design elements, like color and organization, can be used to establish similar groups. In the image below, for example, even though all of the shapes are the same, it's clear that each column represents a distinct group:



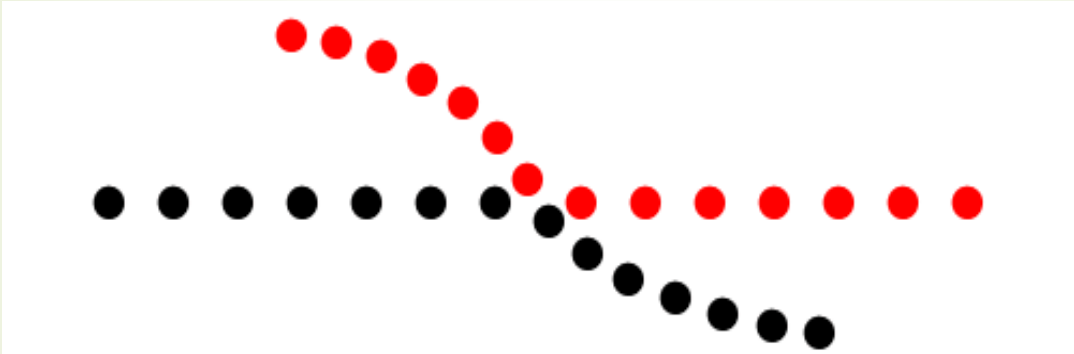
Closure

- The principle of closure states that **when we look at a complex arrangement of visual elements, we tend to look for a single, recognizable pattern.**
- In other words, when you see an image that has missing parts, your brain will fill in the blanks and make a complete image so you can still recognize the pattern.



Continuity

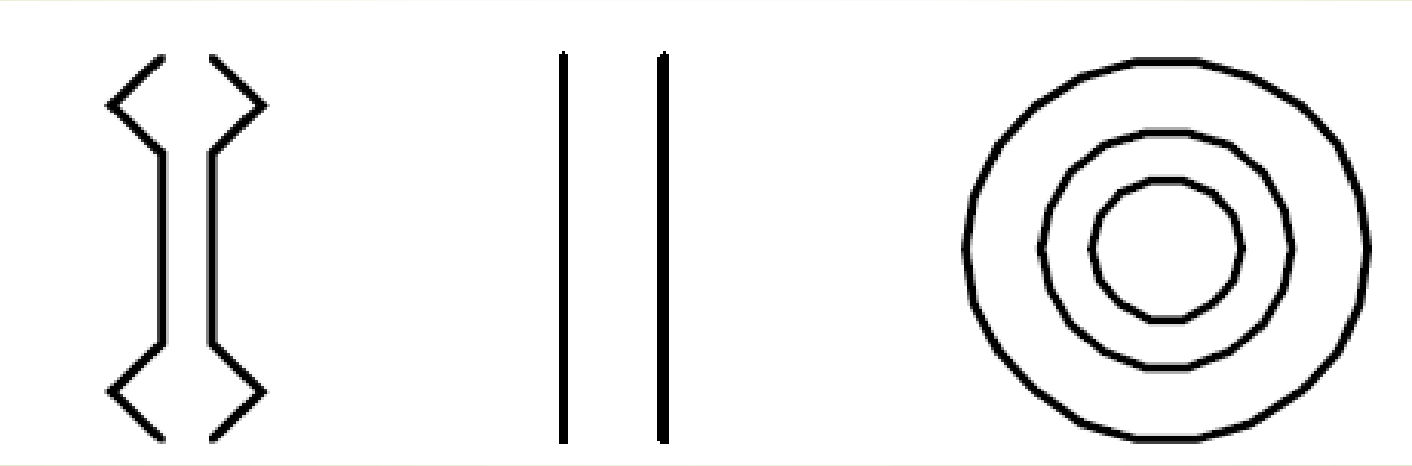
- The principle of continuity states that **elements that are arranged on a line or curve are perceived to be more related than elements not on the line or curve.**



- In the image above, for example, the red dots in the curved line seem to be more related to the black dots on the curved line than to the red dots on the straight horizontal line. That's because your eye naturally follows a line or a curve, making continuation a stronger signal of relatedness than the similarity of color.
- The stimulus appears to be made of two lines of dots, traversing each other, rather than a random set of dots

Symmetry

The Law of Symmetry is the gestalt grouping law that states that elements that are symmetrical to each other tend to be perceived as a unified group. Similar to the law of similarity, this rule suggests that objects that are symmetrical with each other will be more likely to be grouped together than objects not symmetrical with each other.



Simplicity (law of Pragnanz)

- The word *pragnanz* is a German term meaning "good figure." The law of Pragnanz is sometimes referred to as the law of good figure or the law of simplicity. This law holds that objects in the environment are seen in a way that makes them appear as simple as possible.

You see the image above as a series of overlapping circles rather than an assortment of curved, connected lines.

Principles of Perceptual System

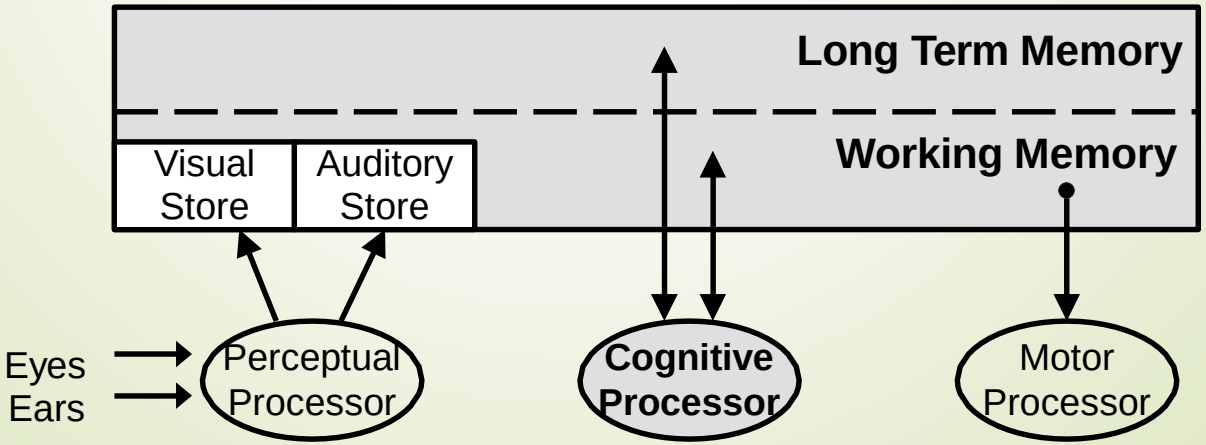
- There are two principles governing the working of the perceptual system
  - **Variable processor rate principle** - processor cycle time varies inversely with stimulus intensity (brighter screens need faster refresh rates)
  - **Encoding specificity principle** - encoding at the time of perception impacts (a) what and how information is stored and (b) what retrieval cues are effective at retrieving the stored information

Cognitive System

- The cognitive system in MHP is responsible for decision making
- It is a production system comprising of
  - A set of production (IF-THEN) rules (stored in the memory; working memory (WM) + long term memory (LTM))
  - A rule interpretation engine (cognitive processor)

Cognitive System

- It uses the contents of WM and LTM to make decisions and schedule actions with motor system
- Composed of a processor and the two memories (WM and LTM)



Working Memory

- Holds intermediate products of thinking and representations produced by perceptual system
- Comprised of activated sections of LTM called “chunks”
  - A chunk is a hierarchical symbol structure
  - 7 ± 2 chunks active at any given time (known as the the 7 ± 2 principle)

Working Memory

- The memory content gets decayed
- The decay is caused by:
  - Time: about 7s for three chunks, but high variance
  - Interference: more difficult to recall an item if there are other similar items (activated chunks) in memory
- **Discrimination principle**
  - Difficulty of retrieval determined by candidates that exist in memory relative to retrieval cues

Long-Term Memory

There are two types of long-term memory: *episodic memory* and *semantic memory*.

- **Episodic memory** represents our memory of events and experiences in a serial form. It is from this memory that we can reconstruct the actual events that took place at a given point in our lives.

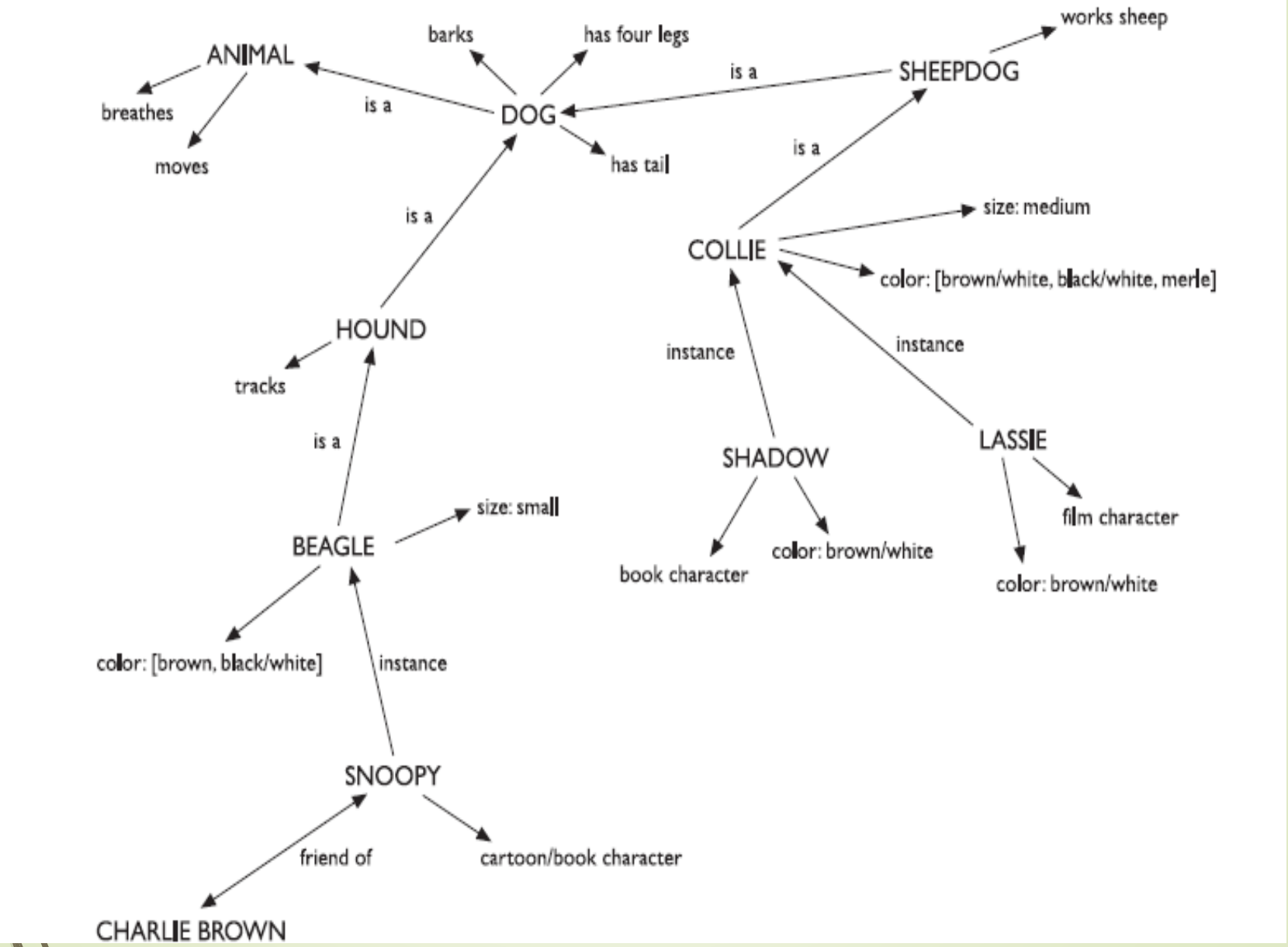
- **Semantic memory**, on the other hand, is a structured record of facts, concepts and skills that we have acquired. The information in semantic memory is derived from that in our episodic memory, such that we can learn new facts or concepts from our experiences.

- Semantic memory is structured in some way to allow access to information, representation of relationships between pieces of information, and inference. One model for the way in which semantic memory is structured is as a network. Items are associated to each other in classes, and may inherit attributes from parent classes. This model is known as a ***semantic network***. As an example, our knowledge about dogs may be stored in a network such as that shown in Figure.

Long-Term Memory

- Holds mass of knowledge; facts, procedures, history
- Two types
  - Procedural – IF-THEN rules
  - Declarative – facts
- Declarative memory consists of a network of related chunks where edge in the network is an association (semantic network)

LTM - Semantic Network Example



Long-Term Memory

- Fast read, slow write
- Infinite storage capacity, but you may forget because:
  - Cannot find effective retrieval cues
  - Similar associations to other chunks interfere with retrieval of the target chunk (**discrimination principle**)

Cognitive Processor

- Implements “cognition”
- Operation called cognitive/production/decision cycles - A pattern matching process
  - IF side tests for a particular pattern in declarative memory
  - When IF side matches, THEN side is executed (called *rule firing*)

Cognitive Processor

- A cycle completes when no more firing is possible
- A firing can
  - Activate motor component (ACT)
  - Fire another rule
  - Change WM/declarative memory (thus helping in other cycles)

Cognitive Processor Principle

- **Principle of recognize-act cycle**
  - **Recognize:** activate associatively-linked chunks in LTM
  - **Act:** modify contents of WM
- Cycle time = ~70ms

Cognitive System Principles

- **Uncertainty principle**

  Decision time increases with the uncertainty about the judgment to be made, requires more cognitive cycles

- **Variable rate principle**

  Cycle time is shorter when greater effort is induced by increased task demands or information loads; it also diminishes with practice

Cognitive System Principles

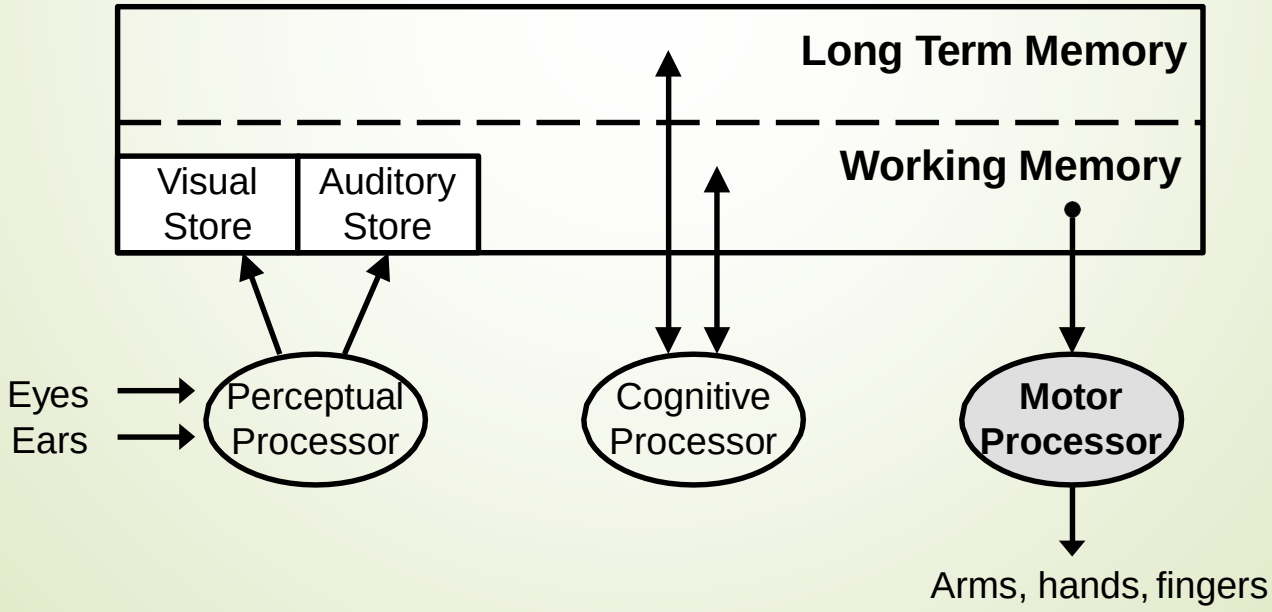
- **Power law of practice**

$$T_n = T_1 * n^{-\alpha}$$

Here, Tn is the task completion time at the n-th trial, T1 is the task completion time in the first attempt and α is *learning constant* (usually taken as 0.4)

Motor System

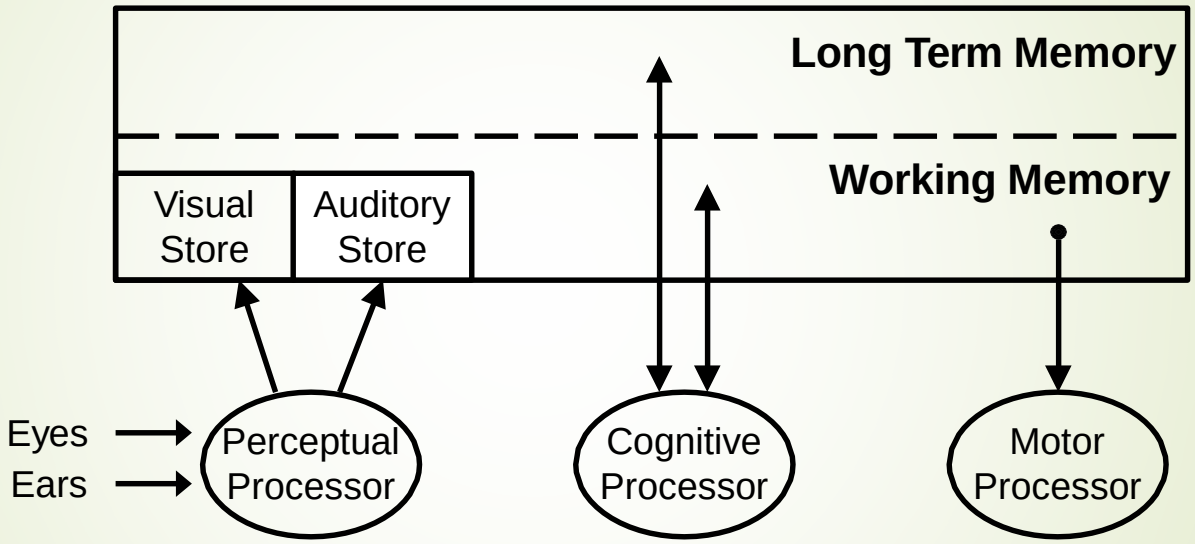
- Translates thoughts into actions
  - Head-neck and arm-hand-finger actions



Motor Processor

- Controls movements of body
  - Movement composed of discrete micro-movements
  - Micro-movement lasts about 70ms
  - Cycle time of motor processor is about 70ms
- Principle: Fitts' law (we already encountered)

Putting It All Together



Cycle Times 100 ms 70 ms 70 ms

Perceive-Recognize-Act cycle ~= 240 ms

Principles - Summary

- Basis of the model
  - P0: Recognize-Act cycle of the cognitive processor
  - P8: Rationality principle
  - P9: Problem space principle

Principles - Summary

- **Other 7 principles tend to describe ways of estimating duration of operators;**
  - P1 -- Variable perceptual processor rate
  - P2 -- Encoding specificity principle
  - P3 -- Discrimination principle
  - P4 -- Variable cognitive processor rate principle
  - P5 -- Fitts's law
  - P6 -- Power law of practice
  - P7 -- Uncertainty principle

Example 1

- A user sits before a computer terminal. Whenever a symbol appears, s/he must press the space bar. What is the time between stimulus and response?

Tp (perceive the symbol) + Tc (recognize the symbol) + Tm (press key) = 240 ms

Tp = perceptual cycle time (100ms)

Tc = cognitive cycle time(70 ms)

Tm = motor cycle time(70ms)

Example 2

Two symbols appear on the computer terminal. If the second symbol matches the first, the user presses “Y” and presses “N” otherwise. What is the time between the second signal and response?

- **Tp + 2Tc (compare + decide) + Tm = 310 ms**

100 + 2(70) + 70= 310 ms