Neuroscience and Human Cognition

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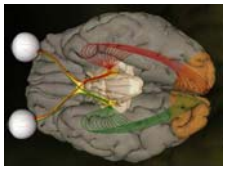
Human cognition

- *Neuropsychology* is the science of study the relationship between brain function and behavior
- *Cognitive psychology* deals with how people perceive, learn, remember, and thinking about information
- *Engineering psychology* is to specify the capacities and limitations of the human cognition for the purpose of guiding a better design

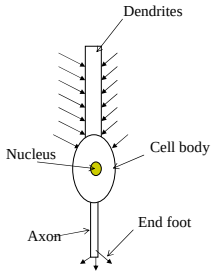
The structure of the brain

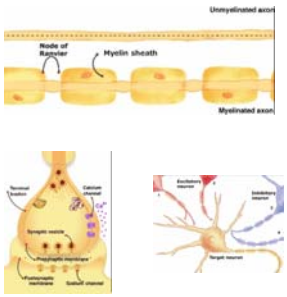


The large part is the cerebrum. It Consists of two cerebral hemispheres

The smaller part is the cerebellum.

Neuroscience





Nervous system

- central (CNS):
  - The CNS is comprised of the brain and spinal cord
  - the CNS receives input from the senses, processes this information in the context of past experience and inherent proclivities and initiates actions upon the external world
- peripheral (PNS).
  - somatic and autonomic.
  - the autonomic system is divided into the sympathetic and parasympathetic.
  - The PNS provides the sensory input and carries out the actions initiated by the CNS.

Three assumptions

- There are many relatively independent modules in the cognitive system. Each module can function to some extent in isolation from the rest of the processing system.
- There are certain reasons between how the physical brain is organized with that of the mind.
- Investigation of cognition in brain-damaged patient can tell us much about cognitive processes in normal individuals.

Methodologies

- Electroencephalogram (EEG)
- Event-related potential (ERP)
- Magnetonencephalogram (MEG)
- Positron emission tomography (PET)
- Magnetic resonance imaging (MRI)

Advantages & disadvantages

- they provide the opportunities to study the brain functions, to locate the respect function center in the brain without damage the brain
- the measurement equipment is huge and expansive, and the measurement has to be taken place in the advanced laboratory

The sensors on human body

On muscles:
• Muscle and tendon receptors

On the head
•Vision
•Hearing
•Balance
•Taste
•Smell

On joints:
•Changes in joint position
•Speed of movement
•Position of the joint
•Pain sensation

On the skin:
•Head-cold
•Pain
•Touch-Pressure

Receptors

- are specialized part of cells
- different in each sensory system
- perceive different kind of energy.
- act as a filter.
- They are designed to respond only to a narrow band of energy within the relevant energy spectrum.
- receptive fields of individual receptors are overlapping
- It can detect locations
- Detection of stimulus is often determined by receptor density and overlap
- rapidly adapting receptors: they react quickly to the changes of the stimulated energy
- slow adapting receptors: provide the information as the stimulated energy is still there

Sensory system

- Each sensory system requires three to four neurons, connected in sequence, to get information from the receptor cells to the cortex. There are changes in the code from level to level and it is not a straight through, or point-to-point correspondence
  - A motor respond can be produced
  - The message can be modified
  - Systems can interact with one another

Perception

- Perception is a process of receiving the outside world information by the receptors and transfers the information to the brain
- The only message the brain receives is the discharge passed along the neurons in the various sensory pathways
- Everything we know comes to us through our senses.
- Our sense sometimes can deceive us, so we must have some innate knowledge about the world to be able to distinguish between real and imaginary sensations

Sensory system

- How does action potential in the neuron cells code the differences in sensations, and how do they code the features of particular sensation? (we still not clear)
- The increase or decrease of the discharge rate of a neuron is correlated to the presence of the stimulus

Theories

- neural areas that process these sensations in the cortex are distinct;
- we learn through experience to distinguish them;
- each sensory system has a preferred link with certain kinds of movements, which ensures that the systems remain distinct at all levels of neural organization

Sensory modality

- Cortex is fundamentally an organ of sensory perception and related processes
- The recognition is happened in cortex

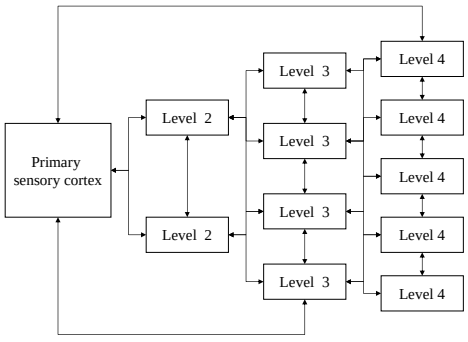
Multimodal cortex

- some areas in the cortex were identified that had functions in more than one modality, for example the vision and touch are in the same area.
- presumably function to combine characteristics of stimuli across different modalities
- there is probably more than one process that requires multimodal information, although it is not know exactly what is processes might be

Cortical connection

- There is no a single area in the cortex that could represent entire perceptual or mental states.
- All cortical areas have internal connections that connect units with similar properties.
- There is a re-entry of the connection, which means that when a given area A sends information to area B, area B reciprocates and sends a return message to area A.

distributed hierarchical system



Learning and memory

- Learning is a process that results in a relatively permanent change in behavior.
- Memory is the ability to recall or recognize previous experience;
- certain neural structures and circuits are associated with different types of learning and memory
- every part of nervous system is able to learn

Learning theory

- a learning theory contains five components
  - *Experiences*: The sensation-perception continuum forms the basis of the experience
  - *Schemata*: A schema is a mental framework or model that we use to understand and interact with the world. Experiences use sensation-perception to either create a new schema or modify an existing one
  - *Habits*: connections between symbols and their corresponding actions
  - *Reinforcement*: It is the process of using events or behaviors to produce learning. There are both positive and negative reinforcers
  - *Interference*: Old habit families interfere with new leaning

Memory

- *Short-term memory*: memory for things that are retained only for a short period of time.
- *Long-term memory*: memory for things that are remembered for a long period of time.
- *Implicit memory*: is an unconscious, no intentional form of memory.
- *Explicit memory*: Which involves conscious recollection of previous experiences.
- *Reference memory*: it refers to knowledge of the rules of a task
- *Working memory*: refers to events that can happen on a trial

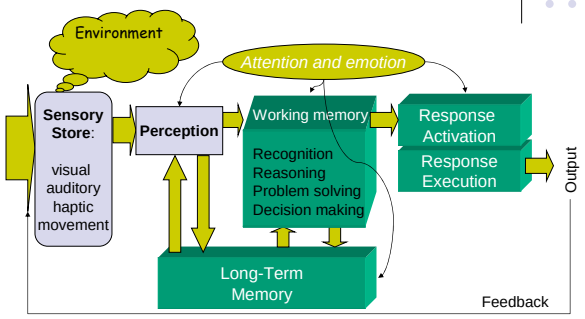
The mechanism of memory

- There is no specific brain location that holds one specific type of memory
- Hebb's (Hebb 1949) *cell assembly theory* has been almost the only theory from neuron level to explain the mechanism of the memory
  - each psychologically important event – whether a sensation, percept, memory, thought, or emotion – can be conceived as the flow of activity in a given neuronal loop
  - if two neurons (A and B) are excited together, they become linked functionally
  - one cell could become more capable of firing another because synaptic knobs grew or became more functional increasing the area of contact between the afferent axon and the efferent cell body and dendrites
  - there are qualitative changes in the synapses

Problems with Hebb's *cell assembly theory*

- If sensory experiences change sensory systems, thus permitting memories of the events, how do we remember ideas or thought?
- If experiences result in widespread changes in synapses, how do we find specific memories?

Information processing



Assumption

- Performance limitations arise as a result of constraints imposed on the processing of information by the mind's internal mechanisms
  - Still held today:

    "Errors result from physiological and psychological limitations of humans. Causes of error include fatigue, workload, and fear, as well as cognitive overload, poor interpersonal communications, imperfect information processing, and flawed decision making"

    (Helmreich, 2000, p. 781)

Performance limitations

- Performance problems related to processing limitations in any of the stages:
  - Data-limited
    - Input degraded (e.g. visual stimulus briefly flashed)
  - Resource-limited
    - system not powerful enough (e.g. working memory)
  - Structurally limited
    - system cannot perform simultaneous operations
      - e.g. limbs, but also perceptual focus

Attention in perception and display space (1)

- Selective attention
  - Visual sampling
    - Pursuit – eye follows a target moving at a constant speed across the visual field
    - Saccadic – jumped view
    - Location
    - Supervisory
    - Target search
  - Optimality of selective attention
    - Select the relevant stimuli to attend at the appropriate times

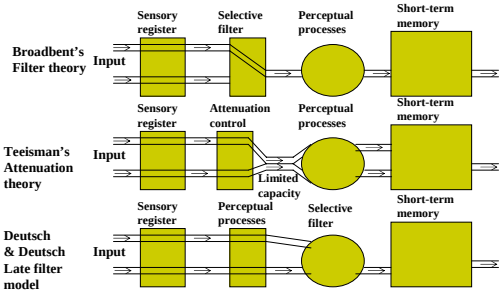
Attention in perception and display space (2)

- Paralle processing and divided attention
  - Several items within the view field might be processed together
- Focus attention

Attention in perception and display space (3)

- Auditory divided attention
- Focus auditory attention
- Cross-modality attention

Bottleneck theories



Emotion

- Various theories of how emotion works
- Emotion clearly involves both cognitive and physical responses to stimuli
- The biological response to physical stimuli is called *affect*
- Affect influences how we respond to situations
- Implication for interface design

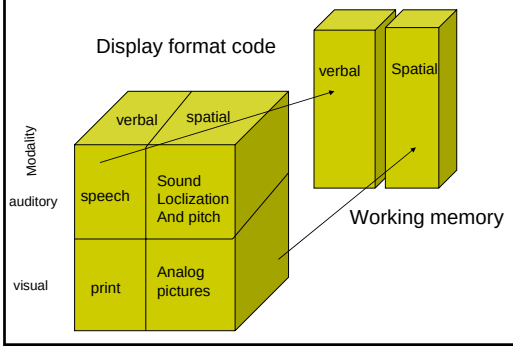
How emotions are manifested/measured

- Physiological response
  - Heart rate
  - Respiration
  - Skin response
  - Blood pressure
- Questionnaire
- Facial expression
- Voice
- Brain activity
- Gestures and actions

Modality compatibility

- Reaction time depends in part on compatibility between stimulus and response modality
  - If stimulus visual, then quicker pointing response
  - If stimulus aural, then quicker voice response
  - Tasks using verbal working memory served best by auditory inputs and vocal outputs
  - Spatial tasks best served by visual inputs and vocal outputs

Display modality and working memory code



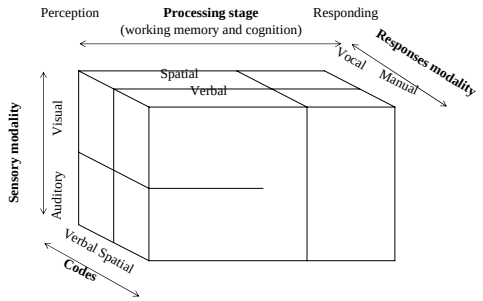
Performance-resource function

- If two tasks do in fact interfere with one another (are performed less well) because they are sharing resources to which each previously had exclusive access, there must be some underlying function that relates the quality of performance to the quantity of resources invested in a task

Multple resources theory

- Any two tasks demand separate rather than common resources on any of the three dimensions, three phenomena will occur
  - Time-sharing will be more efficient
  - Changes in the difficulty of one task will be less likely to influence performance of the other
  - The resources are not interchangable.

Multple resources theory



Hick-Hyman Law

- More complex decisions or choices require longer to initiate
- $RT=a+bH_s$

Skills, Rules, Knowledge

Performance Level	Characteristics
Skill based performance	Automatic, unconscious, parallel with other activities
Rule based performance	Recognizing situations and following applicable procedures
Knowledge based performance	Conscious problem solving

Not always all stages