Intellectual functions of the brain: Learning, Memory and higher order functions

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Learning:
- Neural mechanisms that modifies behavior according to life experiences.
- An ability of the brain to acquire information and to process them in neural circuits.

Memory:
- Ability to store and recall information or experiences.
Learning

- Non-associative
  - Habituation
  - Sensitization
- Associative
  - Classical conditioning
    - *(reflexive)*
  - Operant conditioning
    - *Reward & Punishment*
Aplysia and Learning Research

- “Seaslug” (or rabbit)
- 20,000 large neurons
- Observable gill withdraw response when the siphon is stimulated
Non-associative Learning - Habituation

- **Habituation**
  - Getting used to it...
  - A neutral stimulus delivered repeatedly
  - Repeated stimuli decreases the response; stimulus gradually becomes “unimportant”
  - Examples?
Non-associative Learning - Habituation

• Neural basis of habituation:
  • Repetitive stimulation of a single synapse:
    • In presynaptic terminal:
      • Decreased $\text{Ca}^{2+}$ influx (repetitive stimuli decreases the number of $\text{Ca}^{2+}$ channels)
      • Decreased amount of secreted transmitters
    • Long-term effects: Number of active zones and synaptic endings decrease
Non-associative Learning-Habituation
Non-associative Learning-Sensitization

- **Sensitization**
  - “Becoming more sensitive”
  - If the repeated stimuli are accompanied by a **noxious stimulus**; sensitization occurs...
Neural basis of sensitization:

- **Presynaptic facilitation**: Presynaptic neuron prolongs the action potentials (*by closing K channels*)
Presynaptic Facilitation
• Theory: Storage of information via the permanent alteration of the synaptic sensitivity.

• New or facilitated pathways: *Memory traces* (engrams?)
Stages of memory formation

• Coding
• Storage
• Retrieval
Storing memory

- Synaptic changes associated with memory
  - Hypertrophy of existing synapses
  - Increase in dendritic size
  - Increase in nerve conduction velocity
  - Formation of new synapses
Types of Memory

- According to the storage duration:
  1. Primary (short term) memory
  2. Secondary (intermittent) memory
  3. Tertiary (long-term) memory
Short-Term Memory

- Lasts seconds after learning...
- Maximum “nine items” can be stored
  - “reading the phone number and dial”
- Related to hippocampus and parahippocampal regions
- Presynaptic facilitation/inhibition or postsynaptic potentiation
- Reverberating circuits?
Working Memory

• Ability of **prefrontal areas** to select proper information among simultaneous and different kinds of information perceived by the brain; *transient memory*.

• Working memory enables us to:
  • Foresee what’s coming...
  • Planning the next movement or decision
  • Buy time to process sensory information
  • Foresee the consequences of the motor actions
  • Solving complicated problems
Consolidation

• Transformation of the short-term memory to permanent records (from working memory to reference memory)
  • Depends on “repetition”
• Related to: Gene expression, protein synthesis and hypertrophy of synaptic plates.
Intermittent (secondary) memory

- Require 30 min to 3 hours to generate...
- Information can be stored for minutes or weeks; but retrieval is not easy.
- Store generalizations rather than details...
- Needs repetition (consolidation)
- Includes *habituation* and *sensitization*. 
Long-Term Memory

- Needs at least 4 hours to form
- Depends on frequent repetition
- Stored in different areas of Neocortex but always interconnected
- Thalamocortical reverberation circuits
- Micro-structure changes! Increases the number of connection between neurons...
- Virtually unlimited!
Long-Term Potentiation (LTP)

- Hippocampus, neocortex and other areas
- Repetitive excitatory signals enhance the single response to a preceding excitation.
- “Retrograde messengers” are involved...
Long-Term Potentiation (LTP)

NMDA Glutamate Receptor
Types of memory

- Declarative (explicit)
- Nondeclarative (implicit) = reflex memory
Declarative (explicit) Memory

- Memory of conscious awareness
- Stored generally in the hippocampus and the medial temporal lobe
- Dense interaction between memory items.
- Also includes the *working memory* (in frontal lobes).
Nondeclarative (implicit) Memory

- Sum of various skills
- Unconscious
- Reflexive and closely related to “habits”
- “Experiences unconsciously alter behavior”
- Includes skills, habits, etc.
- Related to cerebellum, basal ganglia, amygdala and certain regions of neocortex.
Some Memory Impairments

- **Retrograde Amnesia:** May occur following brain trauma or electroshock... Long-term memory formation is generally intact.

- **Anterograde Amnesia:** May occur following a lesion in temporal structures (esp. in Hippocampus). New memory formation is impaired...
Higher Functions: Thalamocortical System

Areas of the cerebral cortex that connect with specific portions of the thalamus.
Higher Functions: Thalamocortical System

Functional specialization of some major cortical areas connected to thalamus
Association areas of the cortex

- Parieto-occipito-temporal
- Prefrontal
- Limbic
- Anterior
- Posterior parietal (stereognosis)
- Inferior temporal (face recognition)
Association areas of the cortex

- Parieto-occipitotemporal a.a.
  - Analysis of spatial coordinates of the body
  - Language comprehension
  - Visual language (reading)
  - Naming objects
Association areas of the cortex

- Broca’s Area: Planning complex movements and elaboration of thoughts
- Limbic Association Area: Behavior, emotions, motivation
- Wernicke’s Area: Naming of objects
- Word formation
- Language comprehension intelligence
- Somatosensory: Spatial coordinates of body and surroundings
- Motor: Visual processing of words
- Auditory: Vision
Association areas of the cortex
Association areas of the cortex

- Facial recognition area
- Temporal lobe
- Frontal lobe
Association areas of the cortex

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Jennifer Aniston strikes a nerve

Single brain cells show selective response to specific celebrity photos.

Roxanne Khamsi

Is a single cell in your brain devoted to Jennifer Aniston or Bill Clinton? Maybe so, according to new research.

A recent experiment showed that single neurons in people’s brains react to the faces of specific people. Researchers see the findings as evidence that our brains use fewer cells to decode a given image than previously thought.

The subject of visual processing has sparked much scientific speculation in the past. Exactly how our brains extract meaning from an image remains unclear. At one end of the spectrum of possibilities, a network of cells would process various bits of information in a scene and piece it all together to form an understandable picture.

At the other extreme, the brain would contain a separate neuron to...
Language and Personality

(a) Speaking a written word
- Motor cortex
- Wernicke’s area
- Broca’s area

Words read → Visual cortex

(b) Speaking a heard word
- Motor cortex
- Wernicke’s area
- Broca’s area

Spoken words → Auditory cortex
Other topics…

- “Plasticity”…
- Epilepsy…
- Feed-forward reflexes
- Consciousness?
- “Voluntary” movements and free-will?