Biological Inspiration - Neurodynamics

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1. Abstract

- **Neurons Make Up the Brain**
  billions of neurons organized with the populations

- **Two Kinds of Neurons**
  projection neuron - long range connections up to a meter, and
  local neuron - short range connections

- **Brain States**
  neural population activity forms the multiple basins of chaotic attractors - brain states
  states jump between each other

- **Tools to Analyze Neurons**
  brain imaging and
  nonlinear brain dynamics

- **Neurons in Brain as Humans in Societies?**
  If the neurons create the intentional behavior, do societies and economies have intentionality, also?

2. Neurons Make Up the Brains

2.1. Introduction

- neurons interact with the synapses that are attached to the dendrites

- view of neurons
  mesoscopic - view through the populations
  microscopic - view of a neuron as a single cell

- neurons can either inhibit or excite

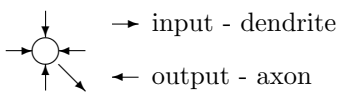

Figure 1: A schematic view of a very simplified neuron. The dendrites collect input. An axon sends output.

2.2. Conceptual Description of Neuron

- input or electric potential comes through dendrites
- output leaves through an axon, see [1]
- two main types of neurons:
  projection neuron (like interstate roads)
  local neuron or interneuron (like local streets)

2.3. Neural Connections

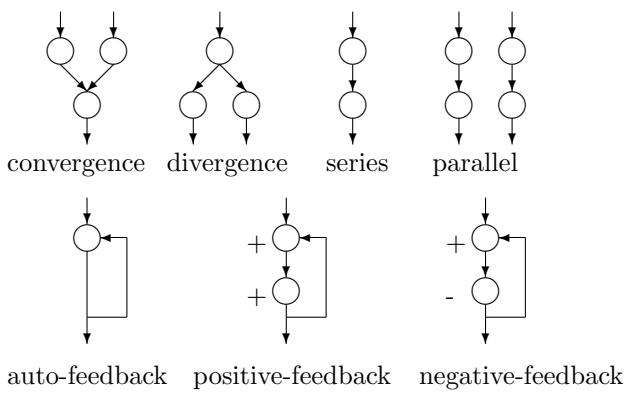

Figure 2: Possible connections among the neurons and the populations of neurons. +/- indicates excitation/inhibition. Figure is redrawn from [1].

3. Activities of Neurons

3.1. Single Neuron States

- axon expresses its state in the frequency of its action potentials or pulse rate

- dendrite expresses its states with the intensity of its synaptic current or wave amplitude

3.2. Microscopic vs. Mesoscopic

- single neuron activation is intracellular - microscopic view

- collective neural activities - mesoscopic view

4. Building Blocks of Chaotic Neurodynamics

4.1. Short Description of Building Block of Neurodynamics

- described in detail in [1]

- couple building blocks of neurodynamics:

  neurons start to participate in a group collectively

  oscillations of population activity due to inhibitory connections

  prolonged oscillations by the modifications of the neural connections

  chaos as the background activity with coupled populations oscillating with different frequencies

4.2. Figures of Couple Building Blocks of Neurodynamics

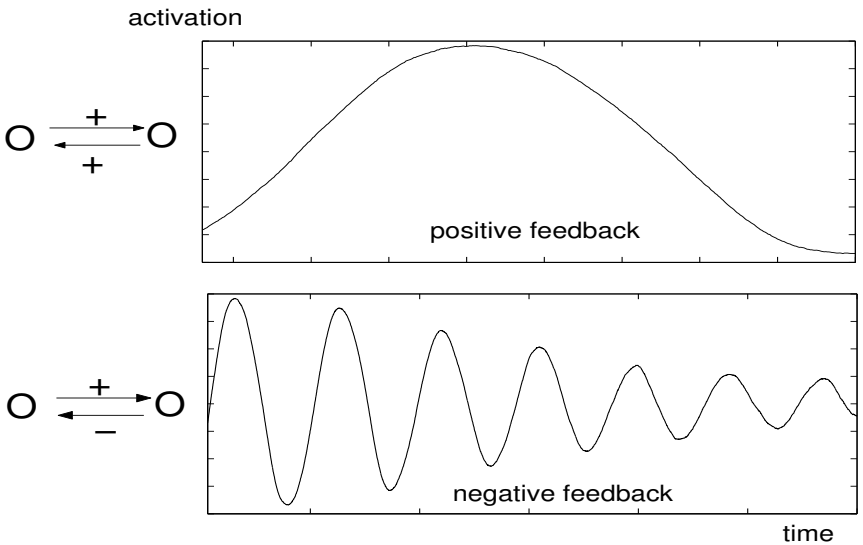

Figure 3: The first two building blocks of neurodynamics redrawn from [1]. A positive feedback prolongs an activation (top). A negative feedback creates the oscillation (bottom). + is for the excitatory influences and − is for the inhibitory.

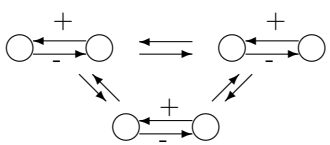

Figure 4: Schematic view of three coupled oscillating system, which can produce chaotic activity. The fourth building block of neurodynamics.

5. State Space of a Cortex

5.1. Itinerancy of Brain States

- state space of a brain comprises attractor landscape

  with several adjoining basins of attraction: one for each class of stimuli

- Kaneko, Tsuda and Freeman

  described the activity of a brain with an itinerant trajectory in [1] and [3]

- states jump between each other by the state transitions

6. Intentionality and Meaning Created by Brain

6.1. Tools to Study the Brain

- brain imaging and nonlinear brain dynamics

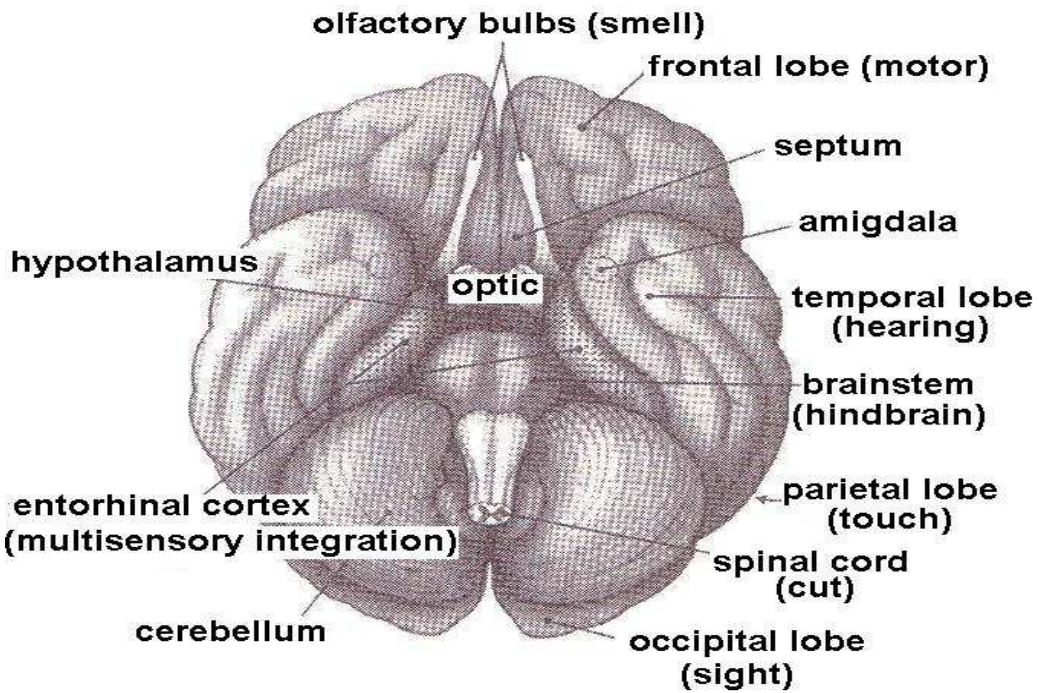

Figure 5: A schematic view of a human brain redrawn from [1]. Different modules are associated to different functions.

6.2. Intentionality and Meaning

- three main properties of intentionality; unity, wholeness, and purpose

unity: unifies the brains and bodies, which are entirely committed to the action

wholeness: whole life's experience to each moment of choice

purpose: all the actions to some end

7. Brains and Societies

7.1. Brains are Small Words

- neurons across all remote brain areas rapidly enter into a cooperative state

7.2. Relationship between Neural and Social Networks

- entities mutually influence each other
- possible negative influences
- making the new relationship connections
- grow and divide their relationships, connecting or disconnecting with others
- success in finding and maintaining a connection depends on the relationships being active

7.3. Changes Due to Learning

- successful cooperation is reinforced with stronger ties (Donald O. Hebb [5])

7.4. Questions

- Under which conditions the populations of asynchronous individual components do start to synchronize or cooperate?
- Do the principles of dynamically interacting neural populations, which create intelligent behavior, apply in social networks, also?

References

[1] W. J. Freeman, *"How Brains Make Up Their Minds,"* Columbia University Press, New York (1999)

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[4] D. J. Watts, *"Small Worlds: The Dynamics of Networks between Order and Randomness (Princeton Studies in Complexity),"* Princeton University Press, Princeton (1999)

[5] D. O. Hebb, *"The Organization of Behaviour,"* John Wiley & Sons, New York (1949)