Sistemas Complexos, Associatividade, Processos Mentais e a Simbolização

Roseli S. Wedemann[1]

Raul Donangelo[2,3]

Luís Alfredo V. de Carvalho[3]

[1]State University of Rio de Janeiro

[2]Universidad de la República - Uruguay

[3]Federal University of Rio de Janeiro

Motivation

- Develop schematic, self-organizing, neural-network models to describe mechanisms associated with mental processes as described by Freud (neurosis, working-through, conscious / unconscious associations).

Neurocomputational Models

- Understand the importance of the capacity for operating on symbols in the psychic aparatus and in therapy.

- Understand cognitive functions involved in consciousness. ⟶ artificial consciousness

- Study the topological properties of these models. Concepts and methods from statistical mechanics and complex networks.

Mental Processes

- Creativity: Capacity of broadening attention to a wider range of elements, allowing the discovery of unusual associations of ideas (associationists).

- Delusions: Statements made in inappropriate contexts. Total and unquestionable certainty implies incorrigibility. A detachment from *reality* (Freud).

- Disorganized Thought: Excessively heterogeneous ideas are associated. Subject´s discourse becomes incoherent and unintelligible.

- In schizophrenia, disorganized thought, delusions and hallucinations are considered positive psychotic symptoms and respond well to neuroleptic treatment.

- Psychodynamical theories correlate creativity, psychopathology and unconsciousness. Aspects such as broader, distant or looser association making and unfocusing of attention are common in describing creativity, psychotic thinking and schizophrenia.

- Neuroses: Repressions and traumas causing a compulsion to repeat painful (neurotic) symptoms.

psychiatric drug therapy → **global (sub)network effect**

×

psychoanalytic working-through → **selective fine-tuning of individual synapses**

"Once before I ventured to tell you that you nourish a deeply rooted faith in undetermined psychical events and in free will, but that is quite unscientific and must yield to the demand of a determinism whose rule extends over mental life."

Freud, *Introductory Lectures on Psycho-Analysis*

Standard Edition, W. W. Norton and Co, 1966, first German Edition in 1917

Assumptions

- Mental states result from the global cooperation of the distributed neural cell activity in the brain. A global emergent state generates a bodily response, an *act*.

- Memory is encoded in the architecture of the neural net of the brain. Information is recorded by reconfiguring the net, learning.

- Memory traces are retrieved through an associative memory mechanism.

- Each brain state represents only one mental state. Each symbol is associated to only one meaning.

Freud and Neuroses

- Traumatic or repressed memories are knowledge which is present in the subject, but which is momentarily or permanently inaccessible to his consciousness: unconscious knowledge.

- Neurotic patients systematically repeat symptoms in the form of ideas and impulses: compulsion to repeat, related to the repressed memories.

- Neurotics have obtained relief and cure from strong neurotic symptoms through a mechanism called working-through: constructing conscious knowledge of the repressed and understanding and changing the compulsion to repeat through transference → creativity.

  Freely talking, analyzing dreams, etc...

Functional Model for Neuroses

Neuroses manifest themselves as an associative memory process: network returns a stored pattern, when it is shown another input pattern sufficiently similar to the stored one.

Compulsion to repeat: neurotic symptom is acted when the subject is presented with a stimulus which resembles, at least partially, a repressed or traumatic memory trace, $\hat{S}$.

stimulus → **net stabilizes on** → **neurotic act**

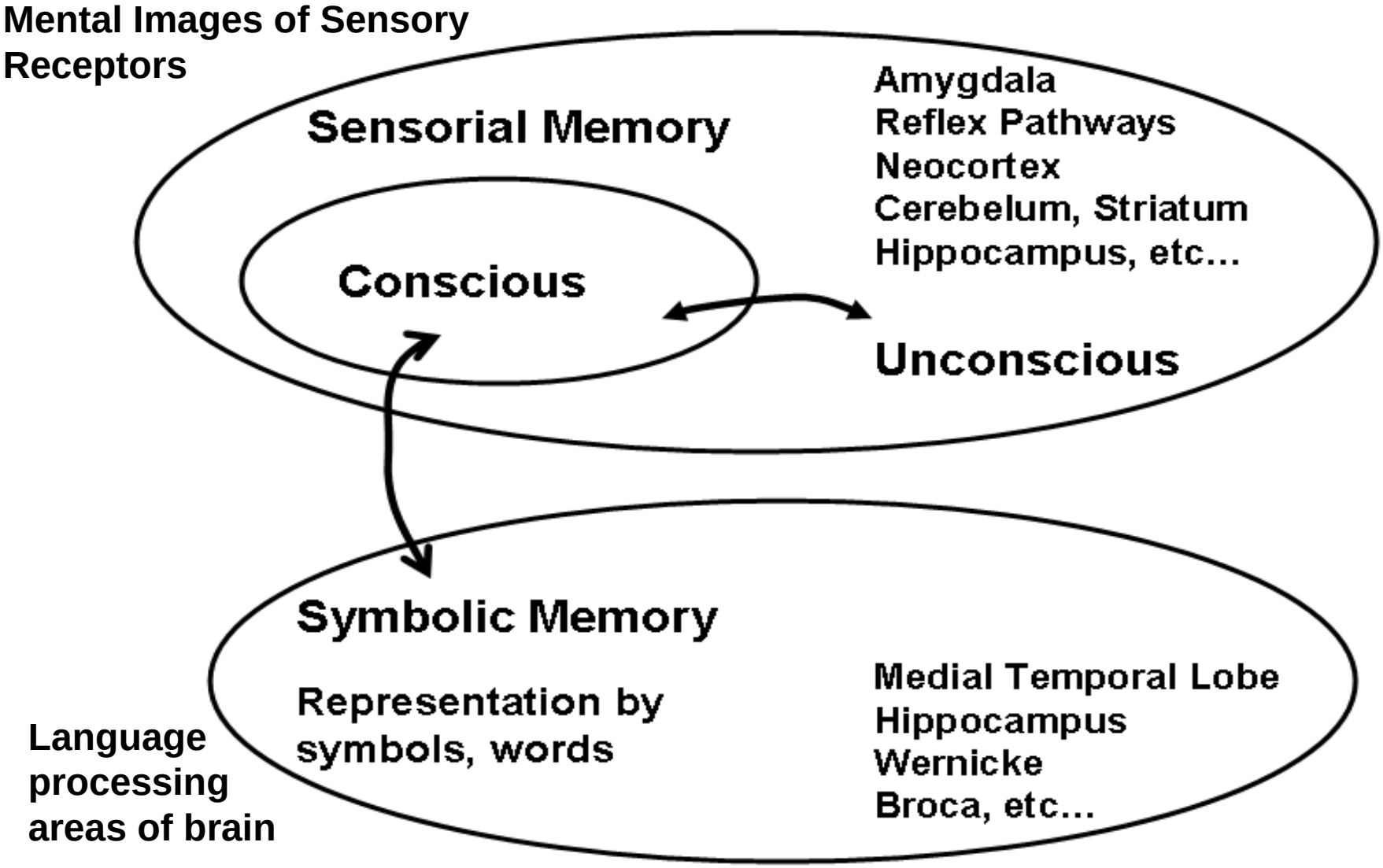
$\hat{S}$

Neurotic behavior: the act isn´t a result of the stimulus as a new situation, but a response to $\hat{S}$.

Psychoanalytic working-through:

linguistic, symbolic associative process, language → **reinforcing synapses among memory traces in brain (also declarative memory, consciousness)**

Conscious / Unconscious Processes



- A trace in sensorial memory may “become conscious” if associated to a pattern in symbolic memory.
- Symbolic memory areas associated with language → we can associate a word (symbol) such as “red” to the visual sensation of seeing a red object.
- Access to symbolic memory represents Freud’s concept of conscious / unconscious mental processes (preconscious) and role of language in psychoanalysis. Importance of representation, symbolization in mental phenomena.
- Similar to ideas and models obtained from neurophysiology and cognition (Changeux[1], Edelman[2], Baars[3]).

[1]J. P. Changeux, *The molecular biology of consciousness investigated with genetically modified mice*, Phil. Trans. R. Soc. B, 2006 361, 2239.

[2]G. M. Edelman, *Wider than the Sky, a Revolutionary View of Consciousness*, Penguin Books, London, 2005.

[3] B. J. Baars, In the Theatre of Consciousness: Global Workspace Theory, A Rigorous Scientific Theory of Consciousness. *Journal of Consciousness Studies*, **4**, No. 4, 1997, pp. 292.309

Computational Model

We developed **Algorithm Neuroses**[1] to ilustrate these ideas.

Memory simulated by Boltzmann Machine (**BM**): Pattern retrieval on net is achieved by a simulated annealing (**SA**) process, where temperature T is gradually lowered by an annealing schedule α.

Psychoanalytic working-through is simulated based on Hebbian learning mechanism.

[1] R. S. Wedemann, R. Donangelo, L. A. V. Carvalho, Lecture Notes in Computer Science, Vol 2329, pp 236 - 245, 2002.

Memory functioning: Boltzmann Machine (**BM**) with complete graph.

N nodes with states S_i in $\{-1, 1\}$, synaptic weights $\omega_{ij} = \omega_{ji}$

Energy:

$$E(\{S_i\}) = -\frac{1}{2}\sum_{ij}\omega_{ij}S_iS_j$$

Network state distribution function is Boltzmann-Gibbs (BG):

$$P_{BG}(\{S_i\}) = \frac{\exp\left[\frac{-E(\{S_i\})}{T}\right]}{\sum_{\{S_i\}}\exp\left[\frac{-E(\{S_i\})}{T}\right]}$$

T is network temperature

Real memory is not a complete graph.

We developed **Hierarquical Clustering Algorithm**[1,2] to generate a clustered hierarchical topology in memories, based on biological mechanisms: neural growth factors and Hebbian learning.

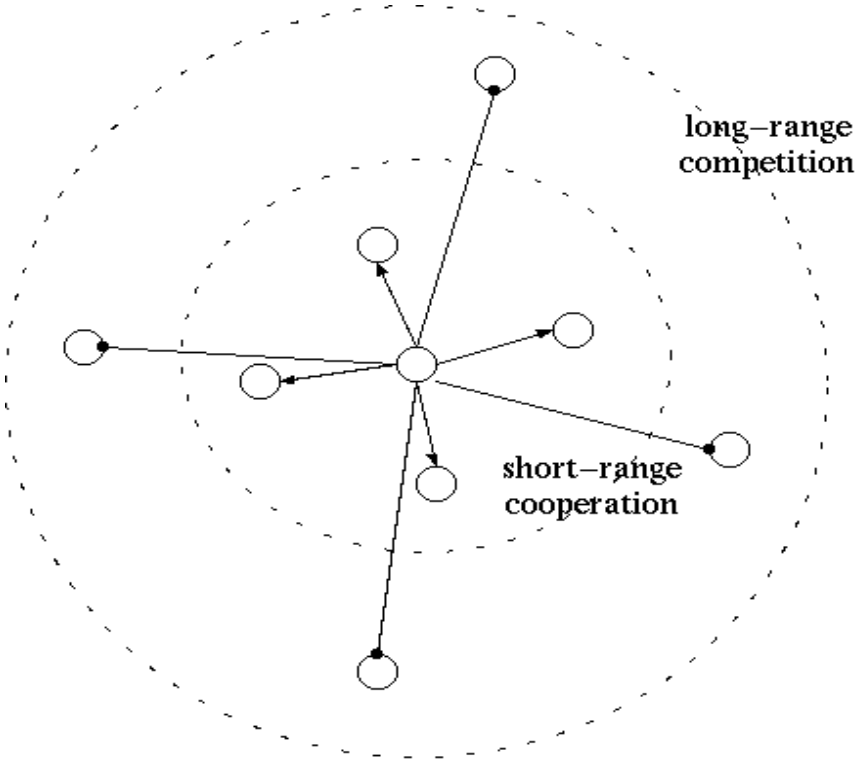
[1]R. S. Wedemann, R. Donangelo, and L. A. V. Carvalho, Chaos 19, 015116, 2009.

[2]R. S. Wedemann, L. A. V. Carvalho, and R. Donangelo, Neurocomputing, 2008, doi:10.1016/j.neucom.2008.02.023

Modeling structure of the topology of each memory

In many animals,
brain cells have
a structure called[1]
on-center / off-surround.

Cooperation / Competition



[1]H. Hartline, F. Ratcliff, "Inhibitory Interactions of Receptor Units in the Eye of Limulus", Journal of General Physiology, 40, 351-376, 1957.

- A signaling network is established to control development and plasticity of neuronal circuits.

- Competition is controlled by environmental stimulation

→ this is the way environment represents itself in the brain.

- Formation of neuronal organizations (biological circuits) called maps.

- **Hebbian learning**: synaptic growth among two neurons (or two regions representing memory traces) is promoted by simultaneous stimulation of the pair.

- Establish synapses among clusters (long range synapses) reflecting associations among representations, within and among memories.

  → LANGUAGE.

  We don´t know this distribution.

  Started with random and study to find something better...

- If long range synapse connects neurons in different memories, multiply by $\lambda \in (0, 1]$. → Neurotic network.

- Regulates synaptic *plasticity*, by strengthening synapses within a cluster and reducing synaptic strength between clusters (disconnects clusters).

- A kind of *preferential attachment* with conservation of total synaptic weights.

  → Complex Networks

- Neurons that have received stronger sensorial stimulation (are more strongly connected), will stimulate their neighborhoods and promote still stronger connections. Agreement with the known microscopic biological mechanisms.

- System is small. Simulations are slow in current processors. → Purpose is to illustrate basic concepts and mechanisms at semantic level.

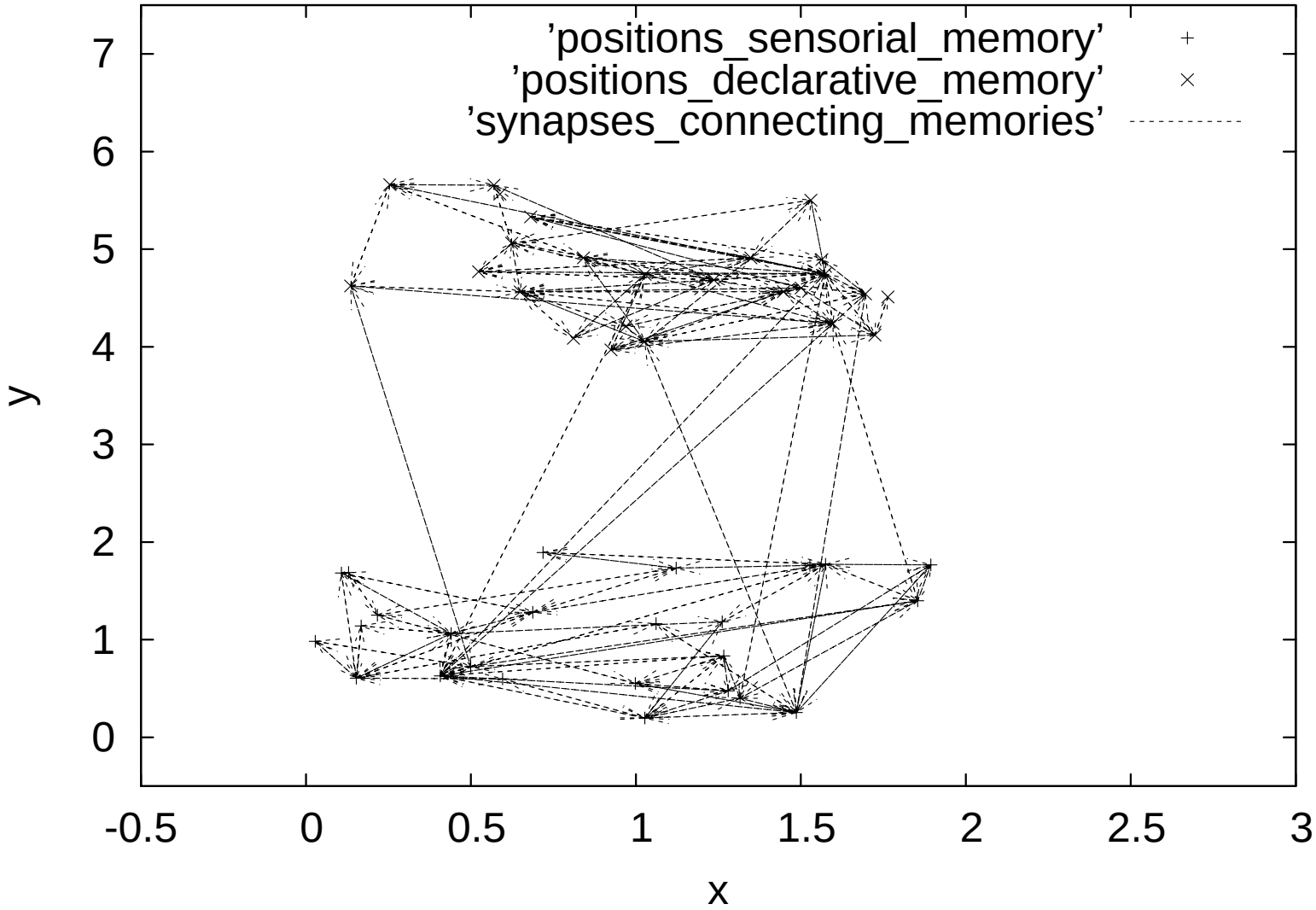
- Short range microscopic mechanisms are scalable.

  → Mapping to biological substratum.

- Parallelization of algorithms for larger systems. Future work.

Network Topology with Long Range Synapses:

N = 50, σ = 0.58



```
ERROR: invalidrestore
OFFENDING COMMAND: restore

STACK:

-savelevel-
-savelevel-
-dictionary-
```