

Neural Memory and Mentation

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Abstract

From time immemorial, philosophers and theologians struggled to describe how mental states emerge from the operations of the brain.

Our own efforts have been focused on memory and emotive states. We define the words: "Mentation", "sensation" or "feelings", "emotions", "memory" and "mind". In particular, we distinguish between computer memory and neural memory, the former being "demotive", the latter imbued with emotive qualities. Feelings are sensations linked to psychic states; Emotions are the recall of feelings.

The minimal cognitive unit of information (cuinfo) on which memory is based, is outlined by a tripartite mechanism (Marx and Gilon, 2012 - 2020). NTs ejected from neural vesicles, elicit a range of physiologic reactions linked to emotive states and encode these in conscious memory. Thus, emotions applying to all animals could be considered as remembered feelings. But "Mind" is a unique human quality, memory expressed through language.

Mentation and memory are merged qualities instigated by the neural net that transcends metabolic energy into a mental dimension. We suggest that the neural net integrates the cuinfo contributions of individual neurons and consolidates them into comprehensible recall, experienced as "memory". The neural net generates memory by melding physiologic processes with biochemical reactions. Effectively, mind emerges from the embodiment of memory.

Keywords: Mentation; Emotions; Memory; Brain

Background

Q: What are the processes that permit the neural net to generate a mental state such as memory?

From time immemorial, philosophers and theologians struggled to describe how mental states emerge from the workings in our heads. Descartes, a mathematician, was torn between Body and Mind [1,2]. Some offered concepts related to ghosts or spirits, though this was debunked by others [3]. Others, considered the brain as an evolved organ that instigates a talent for language, expressed as "mind" [4]. A literary critic's heroic attempt to unify the clinical, linguistic and psychological aspects of memory

was deficient in a number of respects [5]. There was no mention of key words, namely: Chemistry, molecule, neurotransmitter, signal, physiology, terms that could be used to credibly account for the emergence of a mental talent from an assembly of viable neurons.

Alternate efforts related to the "information theory" [6-9]. Biologists joined in this enterprise, linking it to evolution [10-12]. In particular, neurophysiologists focused on electrodynamic signaling between neurons, measured by various techniques (EEG, EKG, PET, fMRI). The literature is too vast to encapsulate here in a few paragraphs but can be accessed in Google.

One could consider that neural memory involves a phase change of metabolic energy into mental experience. One cannot easily calculate the energy cost of an individual cuinfo. It must be a fraction of the 340 cal/day expended by the active human brain (10^{10} neurons) which collectively remember (Note: 1 watt per day = 20,636.29 cal/d). Compared to a supercomputer which expends 4.04 megawatts (MW) of electricity to operate, the achievement of memory by the low-powered human brain speaks of a unique transformation of metabolic energy into mentality. Suffice it so say that comprehending this transformation this is an ongoing effort that engages a vast armada of academic scientists, witness the scientific literature and the many YouTube lectures.

Our own efforts have been focused on the physiologic basis of memory and emotive states. Rather than addressing the emergence of mental talents as a philosophical problem [12] and to avoid vagueness in language, we define and clarify commonly used terms.

Mentation

Synonyms - cognition, consciousness, awareness, thinking. Mentation involves conscious awareness associated with emotive memory.

Sensation or feeling

Devices, such as video cameras or audio microphones, can detect optical or sound stimuli and store them as information for subsequent replay. However, the decoded information is inherently “demotive”, bereft of psychic qualities.

By contrast, sensations or feelings detected by the neural net are coincident with psychic states.

Emotions

The recall of previously experienced psychic states. Emotive states render meaning to recalled stimuli. Consequently, emotions require a memory function. (More on the mechanism below).

Memory

The term memory is an example of polysemy, as it is applied both to computers and to neural nets. Computer memory is linked to algorithmic processing of information in binary format. It is ultimately physical [13], embodied by dopants distributed within an inorganic matrix (i.e. Si) [14]. The information stored in memory

chips as bits, is processed by algorithms that compute an “output”. The bit has no emotive quality. Each bit is like the other; none has inherent value/significance. Hence, the processed output is “demotive”, without meaning.

By contrast, neural memory is emotive, as it ultimately affects survival. But the process by which it is realized remains enigmatic. Most neuroscientists ascribe mental processes to electrodynamic signaling between neurons through synapses [15-17]. But objections have been raised as such a model ignores non-synaptic (ep-haptic) signaling [18,19]. Also, it does not explain how emotive states are instigated and remembered.

Mind

Refers to our psychological powers of thinking and remembering [20]. It may apply exclusively to humans as it involves the talent for language and logic.

Code

Q: What is the “neural code”?

The technique of coding as applied to computers [21-24], “has enriched conceptions of (neural) memory) processing and considerably broadened the scope of (neural) memory research” [25]. Of course, the physical (chemical) character of the encoding effectors [12] reflects the encoding process. To address the required physicality for the neural net, we have proposed that the minimal cognitive unit of information (cuinfo) of neural memory, is realized chemically, as outlined by the tripartite mechanism (Figure 1) [26-29].

Process

In the tripartite model of neural memory, the individual neuron is surrounded by cuinfo complexes which it “reads” [26-29]. The neural net integrates the contribution of the individual neurons into comprehensive recall. Thus, a working model of how the brain generates memory needs to describe read/write processes that meld physiologic aspects with biochemical processes [30] (Figure 2).

Operationally, the sensors (i.e. GPCR, K-channels, etc.) which laterally diffuse along the neural membrane ($D > 5 \times 10^{-3} \text{ um}^2 / \text{sec}$) [31,32] continuously peruse the exposed cuinfo to generate emotive memory (Figure 3).

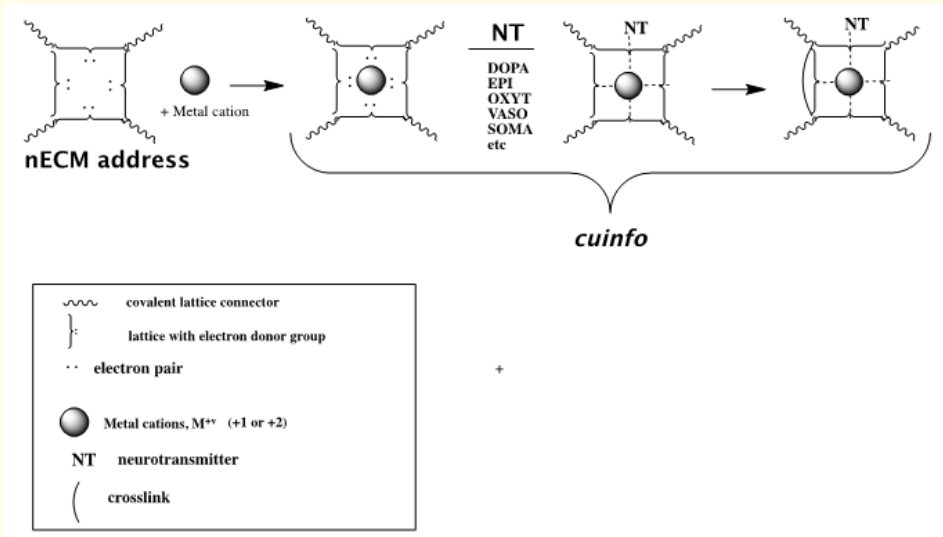


Figure 1: Formation of cuinfo complexes with different monovalent and polyvalent metal cations, as well as with different neurotransmitters (NTs), rendered more stable by crosslinking.

Figure 2: A chemographic schematic of neurons surrounded by cognitive units of information (cuinfo,) that the neural net integrates and consolidates into comprehensible memory (not to scale, as the cuinfo are much smaller).

Figure 3: A. Lateral view of GPCR mosaics [31] which diffuse along the neural membrane, on the order of 10^{-3} to 10^{-1} $\mu\text{m}^2/\text{sec}$ [32,33]. The moving sensors can glancingly recognize (resonate with) the cuinfo. In passing, they recognize the NT content which imposes emotive context to the decoded memory. B. Representation of a K2P channel sensor within membrane of the neuron, “perusing” different cationic moieties of metal-centered cuinfo with its S-S tip, as it traverses the neural membrane.

Emotive memory is an intrinsic facet of mentation. The example of biology indicates that a minimum of 300 neurons (i.e. *C. elegans*) are required to achieve the emergence of a mental talent, namely memory [34-36]. One could consider that the mental talent of emotive memory, evolved along with the increasing complexity of neural interactions [12] (Figure 4).

Figure 4: The emergence of ever more complex conscious mental states, such as emotions and memory, correlated with the evolving size and complexity of neural net signaling.

Discussion

Electrodynamic signaling is not causative of mentation. Rather, we opine that mentation is rendered operational by chemodynamic processes that occur during the neural net’s thinking activity. Effectively, we suggest that the chemo-dynamic resonant signaling process generates the phenomenon of mentation i.e. memory, as schematised in figure 5. The achievement of memory results from chemodynamic play between neurons and their nECM, as per the tripartite mechanism. The electrodynamic signals couple the chemodynamic mental state to the electrodynamic synaptic signaling system to actuate distal organs, muscles and glands.

We propose that the achievement of mental states in the brain results from two modes of neural signaling, the synaptic and the ephaptic mode. The synaptic electro-chemical signals are directed from senses to the brain and from the brain to the peripheral nervous system to actuate distal organs, muscles and glands. Mental states such as consciousness and memory emerge from the combined ephaptic and synaptic electro-chemical signaling that occurs between neurons comprising the brain.

Figure 5: A schema which illustrates the of electro-dynamic and chemo-dynamic signaling relevant to memory.

The neural surface is punctated by many varied sensors (GPCR, integrins, etc.), mosaics of proteins which are mobile and capable of sensing the cognitive information encoded within the nECM around the neurons [36-38]. Mood and memory are based on decoding the chemodynamic signals as outlined by the tripartite mechanism. The resonant state achieved by the neural net decoding of cuinfo

and its integration is experienced as a conscious (mental) state, of which emotive memory is an intrinsic aspect.

Conclusion

Like architects who acknowledge the brick with which they construct a house, we consider how emotive memory could be constructed from the resources available to the neural net.

Resources (substances)

- Neural net (>300 neurons)
- nECM - cuinfo
- Metal cations (~10)
- Neurotransmitters (NTs) (>80)

Mentality is inextricably linked to memory. It involves both “substance” and “process”. The neural circuit integrates and consolidates the ephaptic and synaptic signaling contributions of all neurons comprising the net [38-46], to experience memory. The NTs elicit physiologic reactions entangled with psychic states and encodes feelings into memory that are recalled as “emotions”. Effectively, mind as memory emerges from body.

Acknowledgements

By GM: In memorium to my late wife, the artist Georgette Batlle (1940-2009), my muse, the mother of my children, Danae and Jonathan. Thanks to my daughter Danae and to my companion Karine Ahouva Leopold (Jerusalem, Paris) for encouragement and cheers.

GM CG: We appreciate that Professor Gallistel's (Rutgers University) remarks on our early manuscripts drew our attention to “memory” as the proper focus of our speculations.

Conflict of Interest

GM is a founder of MX Biotech Ltd., with the commercial goal to develop new “memory materials” and devices.

CG is an emeritus professor at the Institute of Chemistry, The Hebrew University of Jerusalem. He is active in developing technologies for the conversion of peptides and active regions of proteins into orally available drugs.

Notwithstanding, the ideas forwarded here are scientifically genuine and presented in good faith, without commercial clouding of the concepts expressed therein.

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