

“Consciousness” as a Fusion of the Global Neuronal Network (GNW) Hypothesis and the Tripartite Mechanism of Memory

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ABSTRACT

Many scholars consider that the gap in our understanding of consciousness to be unbridgeable. In our view, memory is the central phenomenon of consciousness. In that we have technical mastery of the memory of computers, many look to computers and its Information Theory as possible models for neural memory.

We point out that the “cognitive information” of neurons is distinct from the binary “information” used in computers; the former represents emotive states that escape binary-formatted formulations. Emotive “cognitive information” is the basis of neural memory, without which consciousness has no meaning. But the core enigma remains:

Keywords

Global neuronal network, Consciousness, Enigma.

How does the chemical composition of the brain generate experiential memory?

A “Global Neuronal Network” (GNW) hypothesis has been forwarded as a central tenet of consciousness. It was proposed that widely distributed “Information” flows between various anatomical regions of the brain by way of a “global workspace” (i.e. “brain cloud”). We have previously described a tripartite mechanism of neural memory in which neurons encode cognitive information within the surrounding extracellular matrix (nECM), using trace metal cations and neurotransmitters to encode emotive states [1-11].

We propose a fusion of the GNW hypothesis with the tripartite mechanism of emotive memory to describe how the brain achieves mental states of memory and emotions to experience consciousness. The unique electro-chemical performance of many individual neurons is consolidated by the anatomic units of the brain comprising the GNW, to achieve mental states based on the “tripartite encoded” emotive memory.

Background

Leaving aside the question of “origin of life”, “consciousness” is the “great enigma” of our existence. How does it work? *What instigates the psychic experiences of our brains?*

Memory and emotive states also beg clarification. Possibly, memory and emotions are mere facets of the “great enigma” of “consciousness”. Schooled as we are in the thermodynamic tenets of information and entropy [12,13], which describe the relation between energy and work, we can pose a secondary question: *How is the metabolic energy of the neural net transformed into the dimension of conscious experience?*

In that science provides technical mastery of the memory of computers, many look to computers and its Information Theory as possible models for neural memory. Many scholars consider that the gap in our understanding of brain processes generating consciousness to be unbridgeable. Philosophers and theologians conjured up concepts related to consciousness in terms of spirits, souls, ghosts and the like [14-17]. Physicists and logicians have attempted to parse conscious mentality into bite-size pieces of “information” modeled after computer algorithms [18-25].

Psychologists invented “psycho-speak” to refer to Id, Ego and Superego (Freud, Jung etc.) to refer to “consciousness” and its converse, “unconsciousness” [26,27]. In our view, memory is the central phenomenon of both consciousness and unconsciousness.

Information (info)

One could say that while “data” is a quantifiable unit of knowledge, “info” is vague. The single datum, the smallest unit of knowledge (input), is materially represented in the chip as dopants distributed in a matrix [13,28,29]. By itself, an individual binary datum or a “bit”, is meaningless. But a set of binary bits can integrate into a meaningful pattern, termed “information” (info). Thus, “info” derives from a material pattern of encoded “data”, recognized by an algorithm or an observing programmer. With respect to neurobiology however, the term “info” is inadequate as it cannot encompass the emotive mentality achieved by the neural/glia network comprising the conscious the brain [1-11].

We adopt the term “cognitive information” (cog-info) to expand the term “info” to encompass emotive states. The molecular correlates of such states are the neuro-glio-transmitters (NTs/GTs), molecules which elicit both physiologic reactions and mental states. More on this later.

Computers and the Internet “Cloud”

Synthetic devices such as computers provide a compelling model for a process termed “memory”. “Reading” the stored signals by the microprocessor defines operational “memory”. The micro processing chips which make up the functioning core of the computer, are capable of encoding binary signals and storing them in their Si matrix which serves as their “memory material” [13,28,29,30].

Today, many computers are linked to the internet, which serves to connect one to the other. The stored memory of many computers has been termed “cloud memory” and can be readily accessed on demand (<https://en.wikipedia.org/wiki/Cloudcomputing>, Figure 1).

The Enigma of Consciousness

Some scientists have attempted to model brain activity as an analogue to computer processing. They call up the “Information Theory” of Turing, von Neumann and others [18-20] to propose that neural signaling of “info” is effectively an electrodynamic process whose code is transformed by the neural net into mentality [31,32]. Thus, computer scientists have served up an amalgam of zeros and ones (0 1) to formulate algorithms termed “artificial intelligence” (AI) [33-35].

However, consciousness and the mental talents associated with viable neural nets cannot be mimicked by “demotive” electronic devices or binary-formatted algorithms which cannot encode emotive states. Even entangled quantum processors with many indeterminate states cannot achieve the mentality described as emotions. By contrast, neural nets powered by the Life Force of metabolism are inherently emotive, their sensorium sensitized by molecular mosaics which instigate cellular responses [36-38].

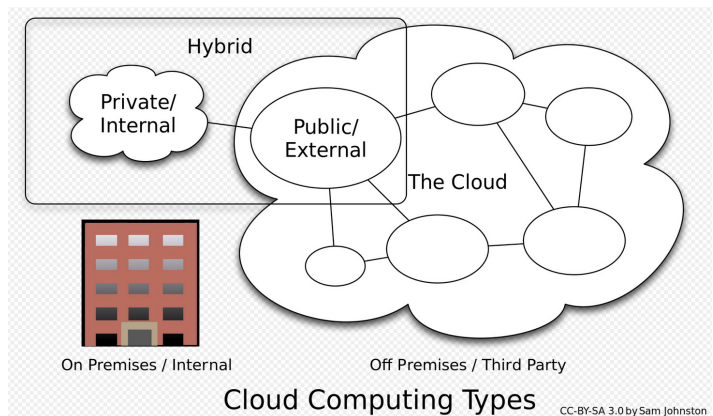


Figure 1: Cloud computing metaphor: the group of networked elements providing services need not be individually addressed or managed by users; instead, the entire provider-managed suite of hardware and software can be thought of as “Cloud computing”, being the on-demand availability of computer system resources (memory storage) and computing power, without direct active management by the user. Large “clouds” often have functions distributed over multiple locations (i.e. data centers). Essentially, “cloud computing” relies on the sharing of resources to achieve coherence (Wikipedia).

Consciousness is a biological phenomenon of all neural creatures, whose process we have not quite figured out. An explanatory account should explain how mental characteristics are linked to biological processes such as metabolism and follow the evolution of neural beings with ever more complex neural nets.

GNW Hypothesis of Consciousness

Some neuroscientists have forwarded a “Global Neuronal Network” (GNW) hypothesis as a central tenet of consciousness [40-42]. It was proposed that widely distributed “Information” flows between various anatomical regions of the brain by way of a “global workspace” (i.e. “brain cloud”). This hypothesis suggests that the GNW acts as a router whereby “information” is amplified and distributed. The global availability of “information” is what one subjectively experiences as consciousness.

Critique

While the GNW hypothesis is attractive as a model based on the anatomy of the brain, it is lacking in that it does not define “information” or elucidate how emotive states are achieved. It assumes a memory function but does not clarify how memory is represented or actuated. Also, it is vague regarding the emotive states that are the hallmark of consciousness and memory. These “holes” in the GNW hypothesis are addressed by the tripartite mechanism of emotive memory, as described below and in the cited references.

Information vs Cognitive information (info vs cog-info)

Neural “cognitive information” is distinct from the binary “info” used in computers, in that it represents emotive states that escape binary-formatted formulations.

Attempts to describe cognitive information by enlisting quantum mechanics and arcane “Hilbert space” mathematical formulae as:

$$\text{Lim } n, h, v = \text{consciousness}$$

$$v \rightarrow \infty$$

where n represents the dimensionality of Hilbert spaces, v the vibration and h the Planck constant, are futile. The authors themselves admit that consciousness is “beyond logic and therefore, beyond mathematics [43].

Nonetheless, we plough on and attempt to describe consciousness by using the tools and concepts acceptable to biochemists and biologists. From a physiologic perspective, the molecular correlates of emotive states are the neuro-glio-transmitters (NTs/GTs) which elicit both physiologic reactions and psychic states which are remembered (Tables 1, 2).

Table 1: Neuro-transmitters (NTs) and glio-transmitters (GTs) that elicit physiologic feelings and psychic emotions.

NTs	GTs
Acetylcholine (ACh)	amino-3 hydroxy-5-methyl-4 isoxazole-propionic acid
Amino acids (AA) (>5).	N-methyl D-aspartic acid (NMDAR)
cAMP	ATP, cAMP
Dopamine (DA)	D-Serine (D-Se)
Epinephrine (EPI)	Glutamate (Glu)
Glutamine (Gln)	Somatostatin
Histamine (HIS)	Taurine
Norepinephrine (NE)	GABA
Oxytocin (OT)	
Serotonin (SER)	
NO	trace metal cations

Definitions: The term "elicit" is defined as an experimentally observable reaction to the injection or application of a NT into a cell culture, an animal or human. For example, injecting adrenaline (epinephrine) "elicits" altered heart beat, vascular pressure and visceral reactions as well as changes in mental attitude, aggression, fight/flight reactions, all which impact on the memory/recall of those events.

Table 2: Neurotransmitters (NTs), which elicit both physiologic reactions and psychic states.

Neurotransmitter (NT)	Physiologic reactions* (Sensations, feelings)	Psychic states!
Biogenic amines (6)	Breathing	Anxiety
Amino acids (>10)	Blinking	Aggression
Neuropeptides (>70)	Blood pressure	Awareness
NO (1)	Blood coagulation	Craving
Endocannabinoids (>10)	Cold (feel)	Curiosity
	Contraction of muscles	Depression
	Coughing	Desire
	Cramps	Dreads
	Crying	Dreams
	Defecation	Fantasy

	Dilation of muscles	Fear
	Dilation of pupil	Hate
	Drizzling	Joy
	Erection	Love
	Fever	Paranoia
	Goose bumps	Sadness
	Heart beat	Sex drive
	Heat (fell)	Sociability
	Hunger (feel)	
	Immune reactions	
	Itching	
	Pain	
	Retching	
	Seeing	
	Shivering	
	Smelling	
	Thirst (feel)	
	Touching	
	Vomiting	
	*No memory required.	! Emotions requiring memory

Evolving Memory Mechanism

We take as a given that the neural circuit is the biological entity that senses the stimulus provided by the environment and reacts appropriately. Neural sensing evolved from the signaling processes pioneered by bacterial colonies which employed modulating molecules (bio-modulators later called neurotransmitters (NTs)) to control the movement (tropism) of the colony to or away from a stimulus source. Biologic evolution continued with the development of the earliest neural creatures, worms (*C. elegans*) from which all other neural creatures evolved. The evolved neurons and their immediate environment (see tripartite & nECM/PNN below) employed the same bacterial signaling molecules (i.e. biogenic amines, amino acids as well as new peptides, Table 2) to instigate favorable or unfavorable reactions (i.e. "feelings") to the environment. Moreover, the neurons developed a process for encoding and recalling "feelings" as memory, the recall of such could be termed "emotions".

Tripartite Mechanism of Emotive Memory

For the neural emotive memory, we proposed that the cognitive unit of information (*cuinfo*) is realized materially (sic. chemically [13,28,29]. Thus, a chemically based code permits the achievement of an emotive state instigated by neurotransmitters (NTs) released by neurons/glia cells and the recall of such [1-11]. The proposed tripartite mechanism for encoding memory involves the interactions of neurons with their surrounding extracellular matrix (nECM/PNN). It has been experimentally verified that neurons are not “naked”, but are enshrouded in a web of glycoaminoglycans [44-49] which we propose serves as a “memory material” [13,28,29]. Incoming perceptions are encoded with trace metals + neurotransmitters (NTs) to form metal-centered cognitive units of information (*cuinfo*). We have developed a chemographic notation for the tripartite mechanism which captures the essence of this regarding emotive memory (Figure 2).

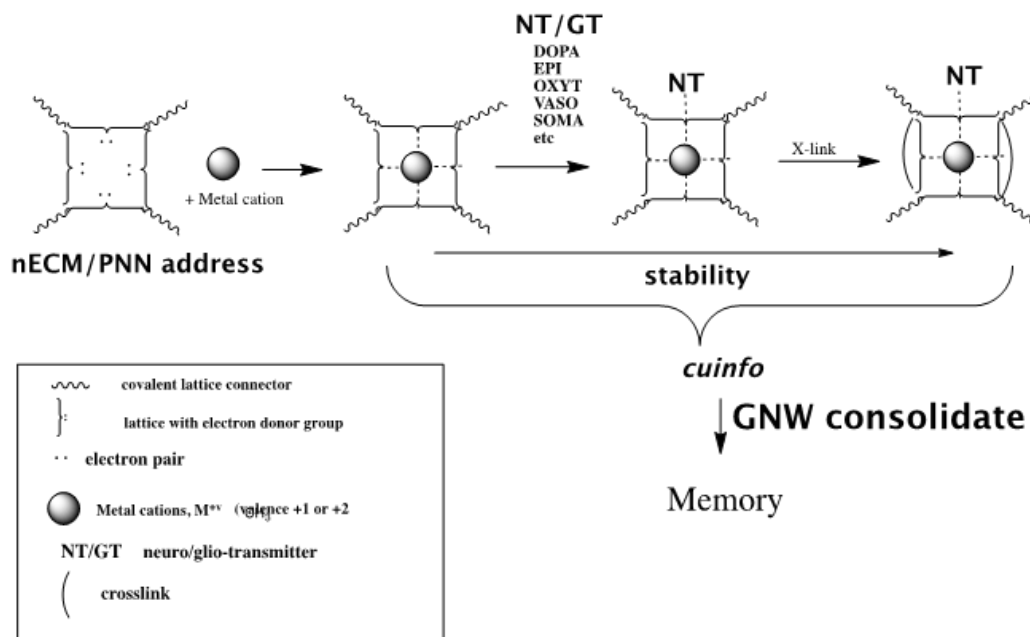


Figure 2: Chemographic representation of an “address” within the nECM surrounding the neuron and glial cells. The “address” is shown as an electron-rich square that can chelate a metal cation and subsequently entrap a signaling molecule such as a neurotransmitter (NT) or a gliotransmitter (GT), to form a metal-centered ternary complex equivalent to a cognitive unit of information (*cuinfo*). The *cuinfo* is the basic memory unit, the biochemical realization of the molecular unit of memory (MMM) proposed by Zeltzer et al., 2022 [1-11].

Fusion of GNW with Tripartite Mechanism

The notion that the basis for memory is due to external stimuli which produce enduring physical changes in the brain, was first proposed by Richard Semon, a German psychoanalyst, who invented the term “engram” to refer to a physical “trace” of sensorial stimuli embodied within the brain and available for recall [51]. The *cuinfo* are the molecular correlates of a memory engram. Essentially, the entire “edifice” of memory rests on the proper functioning of such a molecular encoding process. The tripartite mechanism of emotive memory is focused on the individual (quantal) memory units (*cuinfo*) that can be processed by the individual neuron.

In a binary-formatted computer memory, the individual bits (or bytes) are stored in a matrix. But comprehensive memory results from the collective activity of a group of neurons, not only from the *cuinfo* of an individual neuron. Thus, a working model of how the brain generates emotive memory needs to meld physiologic effects with electro-biochemical processes. The GNW hypothesis suggests a “brain cloud” that permits the neural net to consolidate the contribution of individual neurons in different anatomic compartments into comprehensive recall, effectively an integration of units of dispersed units of cognitive information [52].

Conclusion

The connection between extracellular matrix, neurotransmitter, essential metal cations and the expression of memory derived from bacterial signaling processes which evolved to ever more complex organisms. It is from this perspective that we propose a mechanism of neural memory from which one can synthesize a concept consciousness, Without memory, consciousness has no meaning. A fusion of the GNW hypothesis with the tripartite mechanism

of emotive memory describes how the brain achieves mental states of memory and emotions to experience consciousness. The unique biochemical performance of many individual neurons is consolidated by the anatomic units of the brain comprising the GNW to achieve mental states and emotive memory, schematically presented in Figure 3.

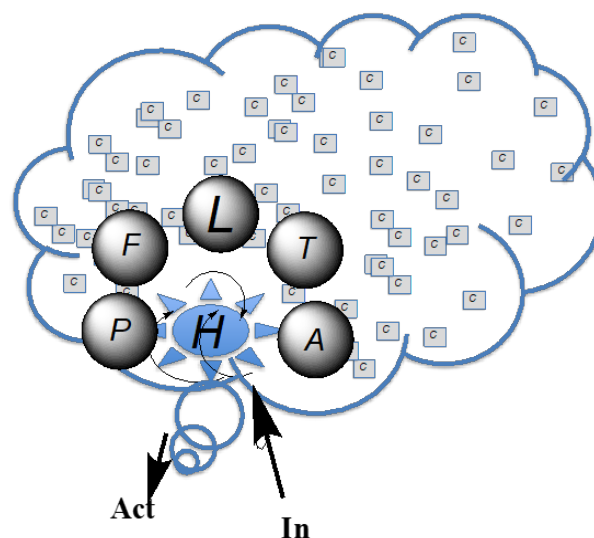


Figure 3: Conceptual schema whereby memory units (i.e. *cuinfo* ([C]) are encoded within the nECM throughout the brain (i.e. “nECM cloud”). Different anatomic regions of the brain are indicated by letters (i.e. amygdala, occipital lobe, parietal lobe, hippocampus, etc.) which comprise the brain’s GNW, which integrates and consolidates the many dispersed but entangled *cuinfo*, to enable the recall experience.

We avoid here a consideration of the “origin of life”, but focus on a possible biochemical mechanism whereby life was rendered conscious through memory. Clearly, the computer and its associated binary-coded algorithms are not up to the task of encoding an emotive state. Our physico-chemical rationalization begins with bacterial chemical signaling with biogenic amines (Table 1) [36]. Through the evolution of neural-net signaling, this emerged as the memory and consciousness of primates (Figure 3), which still employ identical bacterial signaling molecules (Tables 1,2).

While this schema has none of the pictorial elegance of Fritz Kahn’s metaphorical depiction of bodily processes [53], it serves to conceptualize the “brain cloud” of memory involved in the conversion of sensory input into a mental process by the hypothesized GNW model of consciousness.

Acknowledgement

(GM) To the memory of my wife, the artist Georgette Batlle (1940-2009), whose graphic skills helped me refine my models of blood coagulation and my epiphany of cognition. My daughter Danae and son Jonathan continue Georgette’s approach, by helping their father to cope.

(CG and GM): Our collaboration exemplifies the sage proverb: *"Iron sharpens iron, and one man sharpens the face of his neighbor"* to mean that in a good collaboration, one mind sharpens the abilities of the other. (Mishlei, Proverbs 27:17).

Conflict of Interest

GM is a founder of MX Biotech Ltd., with a commercial goal to develop biotechnology for wound healing and biomimetic sensors.

CG is emeritus professor of Hebrew University, but is active in developing and patenting peptide-based tools for surgery and pharmacology.

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

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