

Questioning Tononi's "Information Integration" Theory of Consciousness

Gerard Marx^{1*} and Chaim Gilon²¹*MX Biotech Ltd., Jerusalem, Israel*²*Institute of Chemistry, Hebrew University, Jerusalem, Israel****Corresponding Author:** Gerard Marx, MX Biotech Ltd., Jerusalem, Israel.**DOI:** 10.31080/ASNE.2023.06.0632**Received:** February 08, 2023**Published:** May 16, 2023© All rights are reserved by **Gerard Marx and Chaim Gilon.****Abstract**

The ambition of modern neuroscientists is to analyze natural phenomena with testable/observable descriptions. But the biologic phenomenon of "consciousness" is overlooked by physicists as it cannot be objectively measured/observed. Computer scientists suggest "demotive" binary algorithms, that are inadequate to code for emotive states. Tononi, a psychiatrist and neuroscientist, presents a Manifesto that consciousness corresponds to the capacity of a system to integrate information.

Consciousness is characterized here as a disposition or potentiality - in this case as the potential differentiation of a system's responses to all possible perturbations.

We are puzzled by Tononi's lack of definitions and pose 4 questions:

Q 1: What does "effective information" mean?

Q 2: What defines "Quality"?

Q 3: What is the physicality of Tononi's "neural substrate"?

Q 4: How is the "quality" of information determined?

Mind and body are a complex unity where psyche emerges from the physiology and chemistry of an ensemble of specialized cells. In line with Tononi's Manifesto, we agree that consciousness is an integrated process where sensate information is merged into experience, remembered as memory. But we modify the vagary of Tononi's Manifesto by re-casting "information" as "cognitive information", imbued with emotive qualities encoded by neurotransmitters (NTs). We refer the reader to our previously published description of the tripartite mechanism of emotive memory [1-7].

Bottom Line: Causative explanations of memory and consciousness are not served by simply calling on an "integration" process. Rather, they require a recognition of the interplay between the physiology of neural circuits and entangled biochemical processes.

Keywords: Cognitive Information; Memory; Emotion; Metal Complex; Neurotransmitter

Background

The phenomenon of consciousness has puzzled thinkers throughout history. It has fueled the ponderings of theologians and philosophers, and in recent times, neurophysiologists. Sleeping is a normal process whereby neural creatures become unconscious for a period of time, thereby becoming refreshed to meet life's challenges. Modern surgical procedures are performed by rendering the patient unconscious with drugs [9]. Not to mention mind-altering drugs. But what is consciousness?

The ambition of modern neuroscientists is to analyze natural phenomena with testable descriptions. The biologic phenomenon of "mentality is overlooked by physicists as it cannot be objectively measured. The physicists' approach to consciousness is blinkered by their concepts of the 4 basic forces of nature (gravity, electromagnetism, weak and strong nuclear attractions), which along with mass and space-time, constitute their entire "reality" [10,11]. Those physicists who call upon quantum mechanics to crack the neural memory code [12-14] are stuck by its inability to formulate emotive

states. From the perspective of scientific testing, consciousness is measured indirectly by observing a neural creature's pulse, blood pressure, or with electrodynamic devices (i.e. EEG, PET fMRI) which detect metabolic states.

The linguistic, introspective approach has resulted in frustration resulting from the inability to provide a credible metric system based on natural language [15,16].

Computer scientists preferred binary algorithms to describe neural memory, hoping that processes performed by chips mimic those by neural ensembles [17-20]. But they have not been able to describe the transformation of metabolic energy into the mental dimension (also referred to as "cognition", "thinking", "awareness" or "consciousness") characterized by "emotions" and "memory". With the exception of pharmacologists who focus on psycho-active drugs, few biologically inclined chemists have ventured into the field of mentality [21,22].

Tononi, a psychiatrist and neuroscientist, presents a manifesto about what consciousness is and how it can be measured [23]. According to his hypothesis, consciousness corresponds to the capacity of a system to integrate information.

"Consciousness is characterized here as a disposition or potentiality – in this case as the potential differentiation of a system's responses to all possible perturbations".

He presents a simple diagram of a photodiode (i.e. Figure 1) to illustrate his concept of, "effective information, minimum information, bipartition, and complexes".

Questions

We are puzzled by Tononi's descriptions and lack of definitions.

Q 1: What does "effective information" mean? Does it relate to "value" or "meaning" for a neural creature, implying an emotive context (i.e. affective)?

"Information" has a physical aspect with a thermodynamic cost [20,24-26]. Tononi invokes "entropy" along with hypothetical measurements and subjects these to algebraic "analysis" (i.e. effective information for this bipartition is

$$EI(A B) = EI(A \rightarrow B) + EI(B \rightarrow A).$$

He presents abtuse mathematical notations (i.e. connection matrix $CON(X)$, normalized so that the absolute value of the sum of the "afferent synaptic weights per element corresponded to a constant value $w < 1$ (here $w = 0.5$), vector X of random variables that represents the activity of the elements of X , subject to independent Gaussian noise R of magnitude c . When the elements settle under stationary conditions, $X = X * CON(X) + cR$. By defining $Q = (1 - CON(X))^{-1}$ and averaging over the states produced by successive values of R , we obtain the covariance matrix $COV(X) = \langle X * X \rangle = \langle Q * R * R * Q \rangle = Q * Q$ ".

Tononi analyzes his hypothetical system "to identify its complexes – those subsets of elements that can integrate information, and each complex will have an associated value of Φ – the amount of information it can integrate".

He rephrases his theory that "the quality of consciousness associated with a complex is determined by its effective information matrix".

Q 2: What defines "Quality"? What does the "matrix" mean for the neural creature?

Tononi calls upon neuroanatomical experience where a "neural substrate of consciousness is a distributed thalamocortical network, and that there is no single cortical area where it all comes together".

It has been suggested that consciousness is a distributed effect of many emotive memories that are consolidated from various anatomical regions of the brain, as hypothesized by way of a Global Neuronal Network (GNW) (i.e. "brain cloud") [27-29]. But we are left with questions:

Q 3: What is the physicality of Tononi's "neural substrate"?

Tononi makes two claims:

- "A first claim is that the neural substrate of consciousness as we know it is a complex of high Φ that is capable of integrating a large amount of information".
- "A second claim of the theory is that the quality of consciousness is determined by the informational relationships within the main complex".

Q 4: How is the quality of information determined?

Tononi concludes that “consciousness depends exclusively on the ability of a system to integrate information, whether or not it has a strong sense of self, language, emotion, a body, or is immersed in an environment”.

He posits that consciousness is a fundamental quantity, that consciousness has a physical substrate and that it should be possible to build conscious artifacts. Unhappily, he does not propose a structure for the “physical substrate” or detail how it can serve as “information”.

Tripartite Mechanism of Emotive Memory

We address many of the vagaries of Tononi’s Manifesto by redefining “information”. The neural net deals with “cognitive information”, that is, information imbued with emotive qualities.

Physiologically, neural/glial cells are enshrouded in a web of glyco-aminoglycans (sic. nECM) which serves as their “memory

material”. Our proposed tripartite mechanism involves the interactions of neural/glial cells with their nECM, ejecting a “dopant code” of trace metals + neurotransmitters (NTs) to form metal-centered cognitive units of information (*cuinfo*) (Figure 1). The NTs are the effectors and codifiers of emotive states for the stimulated neural nets [30,31]. Alternatively phrased, the NTs are the coding “alphabet” of emotive states and the associated nECM reactions are the “syntax” which provide logical sequence and permanence to the remembered experience. We refer the reader to our published work for more detailed treatment [1-8].

Neural signaling is based on molecular interactions of neural cells with their surrounding nECM to form *cuinfo* (Figure 2). The *cuinfo* are the molecular correlates of memory units hypothesized by Semon as “engrams” [32-34], the physical aspects of memory that render synaptic connections operative.

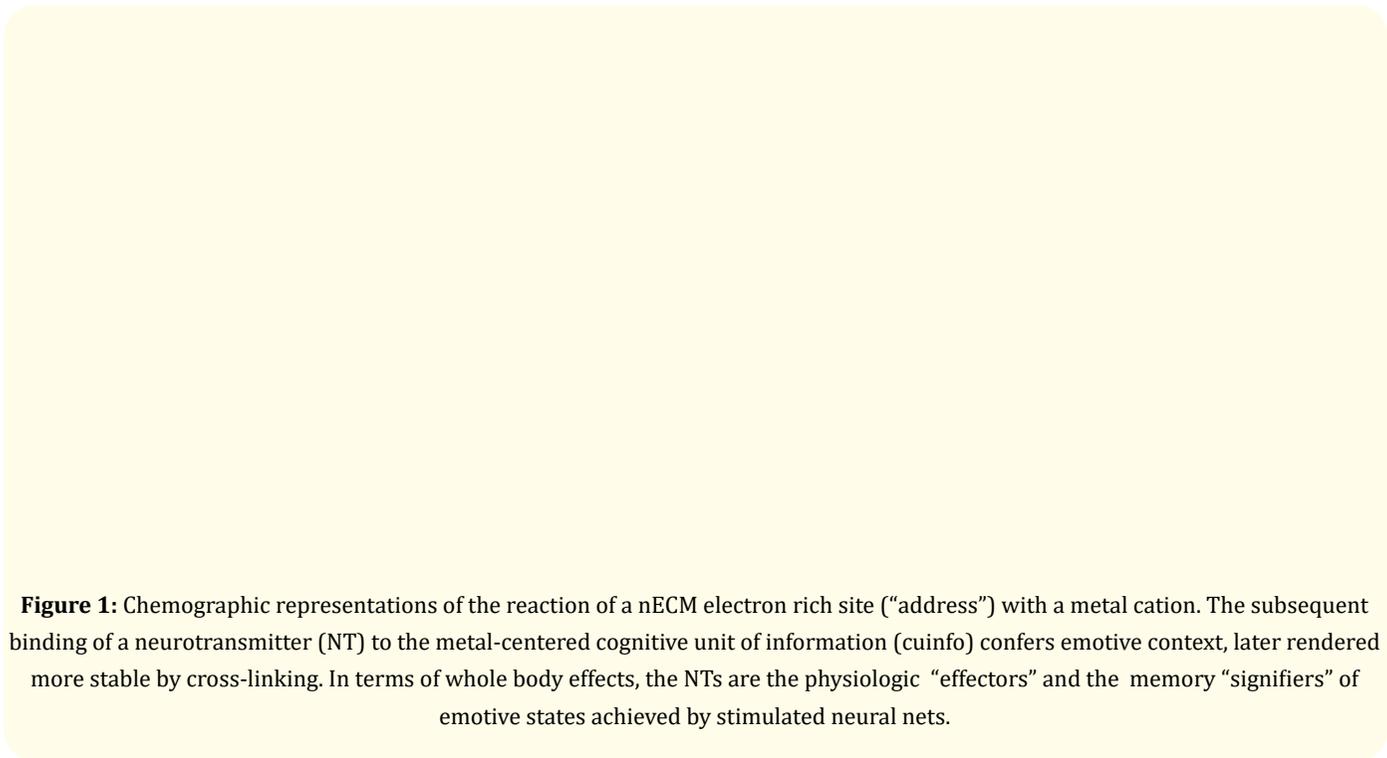


Figure 1: Chemographic representations of the reaction of a nECM electron rich site (“address”) with a metal cation. The subsequent binding of a neurotransmitter (NT) to the metal-centered cognitive unit of information (*cuinfo*) confers emotive context, later rendered more stable by cross-linking. In terms of whole body effects, the NTs are the physiologic “effectors” and the memory “signifiers” of emotive states achieved by stimulated neural nets.

Figure 2: A neuron draw as surrounded by cuinfo ([C]) embedded in the surrounding nECM (not shown).

Conclusion

We have posed four questions relating to how Tononi enunciated his conception of processes underlying "consciousness".

In line with the broad outline of Tononi's Manifesto, we agree that consciousness is defined as "integrated" emotive information generated by the complex physiology of the neural creature. However, we are acutely aware that a causative explanation of "information" must incorporate physiologic as well as biochemical levels of description, as is common in clinical medicine. One does not go to a hospital for a quantum mechanical physicist's diagnosis of one's aches and pains [35]. Particularly for mental phenomena, one cannot ignore the emotive aspects of experience, on which quantum mechanics is mum.

Memory is the central feature of consciousness, While we agree that the ability to integrate "information" is crucial to achieving a state of consciousness, we need to clarify the chemical code of the cognitive information and elaborate on the mechanism whereby integration occurs. Thus, we forward a tripartite mechanism which defines "cognitive information" as encoded by metal-centered complexes adducted with NTs which provide emotive context to units of memory (Figure 1). After all, without emotive memory, consciousness is a will o' wisp.

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(By GM). A memorium to my late wife, the artist Georgette Batlle (1940-2009). Thanks to my daughter Danae (Jerusalem) and son Jonathan (Weehawken, NJ), for warm encouragement and practical support.

Conflict of Interest

GM is a founder of MX Biotech Ltd., with the commercial goal of developing new classes of "memory materials" and "memory devices".

CG is emeritus professor at the Institute of Chemistry, The Hebrew University of Jerusalem. He is active in developing technologies for the synthesis and conversion of peptide analogues of 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 here.

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