

A Critique of the Atkinson-Shiffrin (As) Mathematical Model of Human Memory

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“Today's scientists have substituted mathematics for experiments; they wander off through equation after equation and eventually build a structure, which is not related to reality.”

Nikola Tesla

Emotions are the anchoring experiences on which psychology is aimed. The challenge of neuroscientists is to clarify how neural nets generate mental states, such as emotive memory. To that end, Atkinson-Shiffrin (AS) (1950) proposed mathematical algorithms and formulae to describe memory. Our critique of their approach is based on 3 issues: Evolution, Physiology and Emotions. What is missing in the AS mathematical model is a physiologically relevant process for encoding emotive memory.

“Meta-physics” is the branch of philosophy that examines the fundamental nature of reality i.e. the relationship between energy and matter. “Meta-chemistry” (“Psycho-chemistry”) could be considered to be the branch of chemistry that deals with mental states emerging from neuro-chemical processes. However, what does “Meta-mathematics” imply? Does mathematics delve into matters of Mind as well as Logic? Neuro-math?

Neither the metrics of physics nor the mathematics of Atkinson-Shiffrin can credibly characterize the process of recalling Emotive states. Only chemistry can pierce the veil of neurophysiology. For example, emotive states can be instigated by chemical entities, such as “neurotransmitters” (NTs) and recreational drugs.

In consideration of this, we propose a biochemical tripartite mechanism involving neurons interacting with their surrounding extracellular matrix (nECM) which serve as “memory material”. Incoming perceptions are encoded with trace metals + neurotransmitters (NTs) ejected by neurons, to form metal-centered cognitive units of information (cuinfo) from which memory is consolidated. The NTs can be considered the effectors and encoders of emotive mental states achieved by the neural net. Regarding the Atkinson-Shiffrin approach, we opine: Emotions exceed the grasp of mathematics.

Keywords

Neurotransmitter, Cognitive information, Emotive memory, Mentality.

Background

Memory remains enigmatic. In spite of more than 200 years of concerted efforts by modern scientists, its causative processes in the brain remain mysterious. It is not surprising that in this computer age, many cognitive scientists consider the brain as a type of computer and often refer to a “neural code”, which however has remained cryptic.

For computers, “memory” is physical [1], related to the disposition of spins, holes or dopants in a matrix, in a manner that translates into a “demotive” (lacking emotions) binary code of information. By contrast, neural “memory relates to the recall of past experience saturated with emotive overtones, whose code we cannot fathom.

One cannot employ the metrics of physics or the Information Theory of computers to formulate emotions [2-5]. McCulloch–Pitts presented [6] a mathematical model of a lone neuron (Equation 1), where N_i and N_{ic} are non-afferent neurons, Σ and Π are syntactical symbols for disjunctions and conjunctions, which are finite in each case [1].

Equ. 1.

$$N_i(z_1) \equiv S \left\{ \prod_{m=1}^q N_{jm}(z_1) \cdot \sum_{\alpha \in K_i} \prod_{\alpha \in K_i} N_{ie}(z_1) \right\}$$

However, such a formulation says little regarding the physiology of emotive states achieved by neurons, though it inspired John von Neuman to theorize the circuits and processors, which underlie

modern computer chips [7]. This approach set the stage for the conceptualization of brain functions by Atkinson-Shiffrin (AS) (1950) [8]. Their mathematical model of human memory (Figure 1) exerted great influence on subsequent generations of cognitive scientists [8-10].

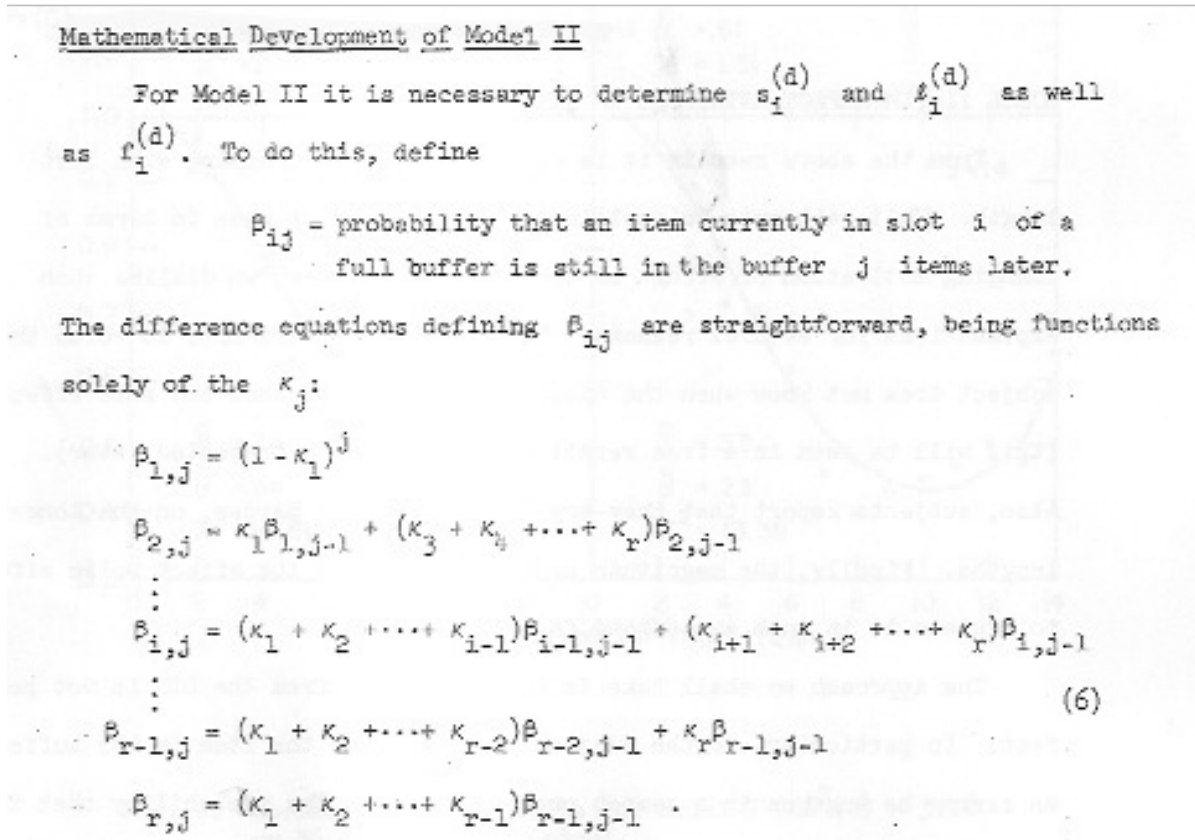


Figure 1: Some equations of the Atkinson-Shiffrin (AS) mathematical model of human memory [8].

The AS model was subsequently expanded into sub-groups:

- Retrieving Effectively from Memory (REM), a model of word “recognition memory”.
- SAM theory (Search of Associative Memory) in 1978.

Critiques and Specific comments

We have reviewed these and companion papers and have penned some general critiques of the AS mathematical approach, as follows:

- 1. Evolution:** The AS approach to memory is not universal; is not applicable to all animals. However, *H. sapien* is a creature whose entire physiology evolved from processes already operational in slime molds, bacteria and worms [11-14]. One could expect that a mechanism of human memory would be rooted in its evolution with neural creatures. However, no such mention appears in AS.
- 2. Physiology:** We note that the words “neuron”, “physiology” and “metabolism” do not appear in the AS papers, though

the word “element” appears numerous times, but never in its literal as referring to a chemical element [15,16]. Thus, the AS mathematical model is far removed from the workings of neural circuits operating in a biochemical context, exhibiting the talent of memory.

- 3. Emotions:** The AS model of memory is “demotive”, is totally lacking in any reference to emotive states. Human and animal memory has emotive qualities that cannot be ignored or reduced to mathematical formulae. It seems that: *Emotions, the essence of psychology, exceed the grasp of mathematics.*
- 4. Terms employed by AS:** memory types, “buffer model (properties)”, “coding format”, “spaces (slots)”, etc. are verbal categories that are not defined materially or biologically. AS avoid mechanistic descriptions of processes causative of memory, but simply verbalize them.
- 5. The AS technique** is to name a “state” (or a putative buffer), assign it as a function, which is algebraically serialized (k_j or k_i) (Figure 1), then worked into enigmatic algorithms (Figure 1). AS admit to “uncertainty” in the equations, but plough on with more.

Discussion

In spite of the “demotive” quality of computer memory, attempts have been made to imbue algorithms with affective qualities [17-24]. Notwithstanding, emotions still evade logical formulations. What is missing in the AS model is a physiologically relevant mechanism of memory that addresses:

- o **Emotions:** A mathematical model of electrodynamic neural signaling misses the mark and cannot formulate emotive states. Neural “memory relates to the recall of past experience saturated with emotive overtones.
- o **Persistence:** Rationalize the temporal characteristics of “short term memory (STM)”, “long term memory (LTM)”, “working memory” in a manner consonant with physiologic constraints and biochemical possibilities.
- o **Forgetting:** Describe a physiologic process that permits of forgetting as well as remembering.

Tripartite Mechanism [25-32]

We have proposed a biochemical approach that permits a connection of neural signaling to emotive states. For example, the tripartite mechanism, describes neurons interacting with their surrounding extracellular matrix (nECM), by deploying dopants (metal cations and neurotransmitters (NTs)) to encode cognitive units of information (*cuinfo*). Each NT elicits a unique set of physiologic responses entangled with psychic states, which it also encodes as memory (Table 1).

Table 1: Neurotransmitters (NTs), Which Elicit both Physiologic Reactions and Psychic States.

Neurotransmitter (NT)	Physiologic reactions * (perceptions, feelings)	Emotive states!
Biogenic amines (8) Amino acids (>10) Neuropeptides (>70) Acetylcholine (1) NO (1) Endocannabinoids (>10) (trace metals; >10)	Breathing Blinking Blood pressure Blood coagulation Cold (feel) Contraction of muscles Coughing Cramps Crying Defecation Dilation of muscles Dilation of pupil Drooling Erection Evacuation Fever Goose bumps Heart beat Heat (feel) Hunger (feel) Immune reactions Itching Pain Retching Seeing Shivering Smelling Thirst (feel) Touching Vomiting	Anxiety Aggression Awareness Craving Curiosity Depression Desire Dread Dreams Fantasy Fear Hate Joy Love Paranoia Sadness Sex drive Sociability
	* No memory required.	! Emotions requiring memory

Feelings are sensations that are accompanied by psychic states but do not require memory.

Emotions are the recall of previous psychic states, thus require a memory function.

The chemo graphic notation of the tripartite mechanism of memory represents the nECM binding pocket (address), metal cations and NTs capable of interacting with the many electron-rich “addresses” around neurons (Figure 2).

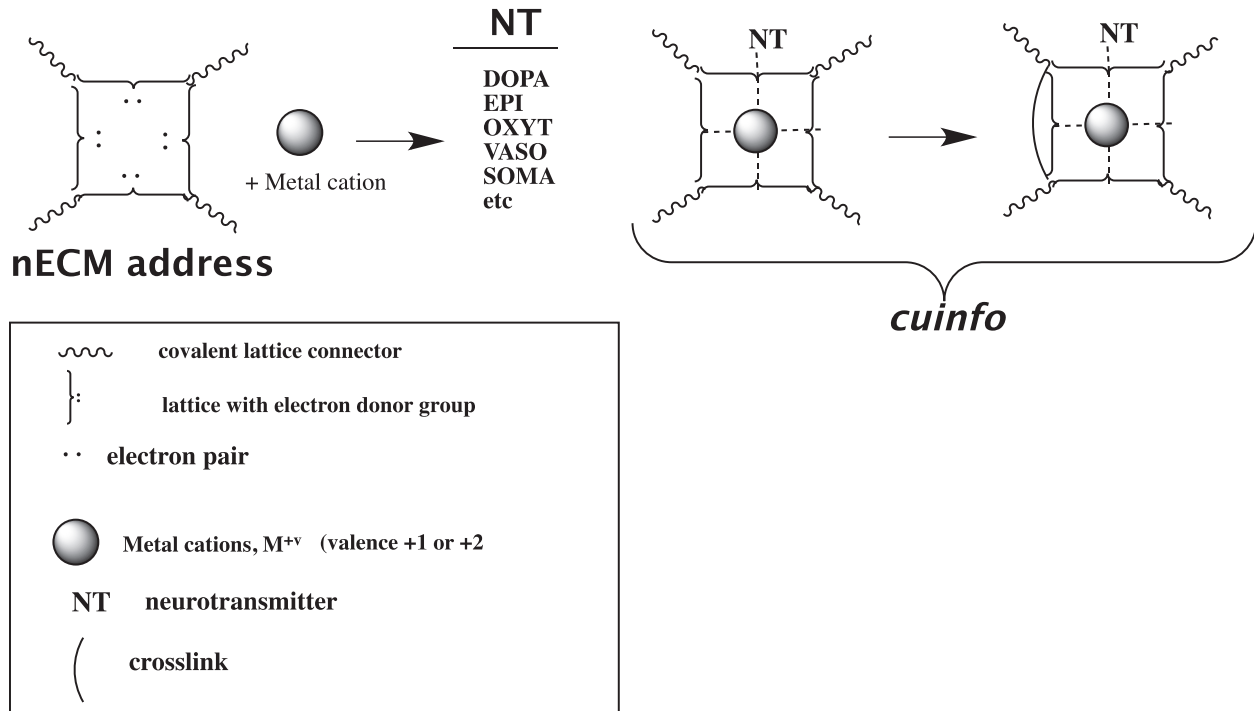


Figure 2: Chemographic representations of the reaction of a nECM (electron rich site) binding site for a metal cation, an “address”. The additional binding of an electron-rich neurotransmitter (NT) to *cuinfo* confers emotive context.

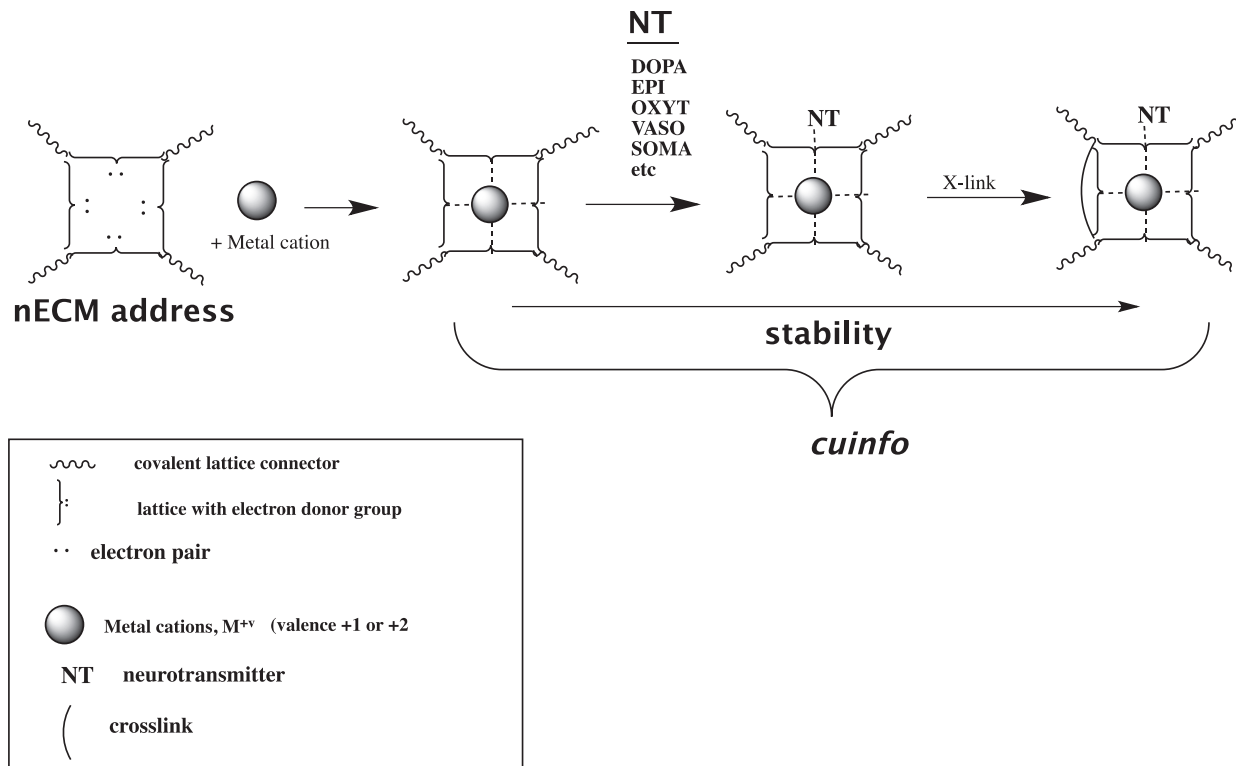


Figure 3: Chemographic representations of the reaction of a nECM (site) binding a metal cation, at a nECM electron rich “address”. The subsequent binding of a neurotransmitter (NT) to *cuinfo* confers emotive context and subsequent crosslinking, all which improve the stability of the *cuinfo* complex.

The stability of these memory units reflects the affinity of the metal cations to the nECM address. Emotive states are encoded by complexation with NTs. Final persistence is rendered by covalent crosslinking reactions. This graphic shorthand helps neuroscientists grapple with the biochemical processes underlying neural memory and emotions.

Conclusion

“Metaphysics” is the branch of philosophy that examines the fundamental nature of reality i.e. the relationship between energy and matter. “Meta-chemistry”, alternately termed “Psycho-chemistry”, is that branch of chemistry that deals with mental states emerging from chemical processes harnessed by neurons. However, what does “met mathematics” imply? Does mathematics delve into matters of Mind as well as Logic?

The tripartite mechanism suggests a biologically credible neural code from which memory could be consolidated. Moreover, it identifies, in molecular form, elicitors and encoders of emotive states (i.e. NTs). The experience of memory is a process whereby communicating neurons instigate a new unique dimension, mentality manifest as emotive memory. Neither the metrics of physics nor the formulae of mathematics characterize an emotive state. Ergo, the mathematical equations proposed by AS cannot encompass the mental dimensions of emotive memory.

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