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COULD COMPUTER MEMORY SIMULATE THE COGNITIVE FUNCTIONS OF THE HUMAN MEMORY?

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ABSTRACT

Human brains contain a "nerve mesh" referred to as memory that performs cognitive functions.

This cognition is tantamount to acquiring knowledge and understanding through thought, experience, and senses. Cognitive processes start with thinking and knowing and go all the way to remembering, judging, and problem-solving. They involve higher-level functions of the brain such as language, imagination, perception, and planning. Basic cognitive processes of perception, attention, and memory could lead to creativity.

Could the amalgam of integrated circuits and derived software that we call computer memories ever simulate human cognitive functions induced by the memory organ of the brain. Functions like those demonstrated by biological memories.

This is the focus of the following article.

The article starts with an identification of the structure of human brain memories. It proceeds to explore the structure and role of brain memory within the human cognitive mix. It then analyses the memory element of the computer and its "cognitive" competencies and contrasts those with those of brain memories.

Tentative and conditional conclusions are then derived.

The article relies on works on neurology, electronics, data science and psychology.

KEYWORDS: Cognitive functions. Computer memories. Human brain memories.

1.0 BIOLOGICAL MEMORY

1.1 The human brain

Brain regulates most functions of the human body, including the vital, the basic and the complex. The human brain processes sensory information. One trillion neurons, work together over electrical compulsions to organize brain's physical activities and mental processes.

Brains "organs" perform distinct functions. The frontal lobe is involved in reasoning, motor control, emotion, and language. It's motor cortex, does the planning and coordinating of movement; the prefrontal cortex, is responsible for higher-level cognitive functioning; and the Broca's area, which is essential for language production.

Three brain areas do play significant roles in the processing and storage of diverse types of memories: cerebellum, hippocampus, and amygdala. The cerebellum's processes procedural memories: the hippocampus encodes new memories; the amygdala performs the storage function i.e. it plays a part in determining where the memories are stored based on the level of emotional response to the event. (Parts of the Brain Involved with Memory Copyright © 2014 by OpenStax College Psychology Copyright © 2014 by OSCRiceUniversity)

1.2 Human brain memory structure

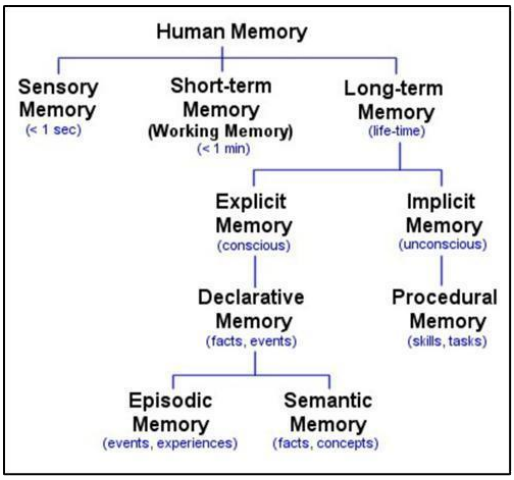
Memory is the process by which knowledge is encoded, stored, and retrieved. It could be short term, working memory or long term. Short-term memory and working memory terms are often used interchangeably. There are scholars who claim that some kind of manipulation of remembered information is needed to qualify the task as one of working memory. (R.C. Atkinson et al 1968)

Senses are involved too. Visual memory involves the ability to store and retrieve previously experienced visual sensations and perceptions when the stimuli that originally evoked them, are no longer present. Auditory memory, on the other hand, involves the skills of attending, listening, processing, storing, and recalling. Sequential memory requires items to be recalled in a specific order. Visual sequential memory is the ability to remember things seen in sequence, while auditory sequential memory is the ability to remember things heard in sequence.

Sensory memory is the shortest-term element of memory. It is the ability to retain impressions of sensory information after the original stimuli has ended. It acts as a kind of buffer for stimuli received through the five senses of sight, hearing, smell, taste, and touch, which are retained accurately. (L. Brooks et al, 2019).

Functionally, memory could be explicit or implicit. Explicit (declarative) memory includes semantics (words) and episodic (events) memory. Implicit (non-declarative) memory includes, primarily, nonverbal and motor memory.

Figure (1) The structure of the human brain memory



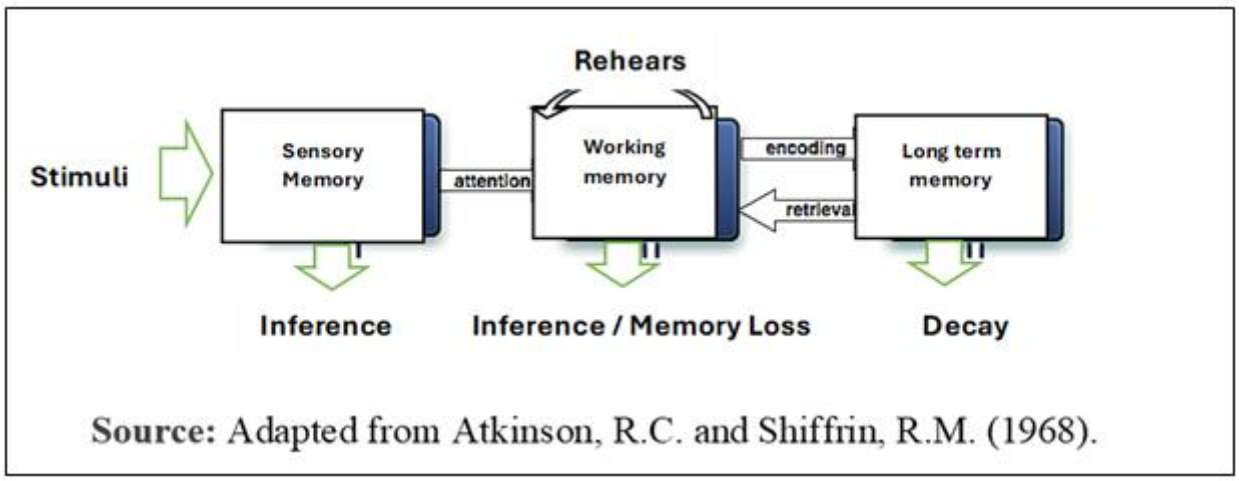
Source: L. Brooks, "Memory and Brain Mechanisms," Hubpages, Nov 20, 2019

1.3 Human brain memory functions

Human memory is an essential cognitive function that permits individuals to acquire, retain, and recover data that defines a person's identity (Zlotnik and Vansintjan, 2019). It is a multifaceted cognitive process that involves various stages: encoding, consolidation, recovery, and reconsolidation. The information can be acquired through various channels, such as visual, auditory, olfactory, or tactile inputs. The acquired sensory stimuli are converted into a format the brain can process and retain. Varied factors such as attention, emotional significance, and repetition can influence the encoding process and determine the strength and durability of the resulting memo. (Esin, C., Fathi, M., Squire, C., & Flick, U. (Ed.) (2014).

There exists a variety of definitions for cognition, but they all boil down to being the mental process of acquiring knowledge and understanding it through thought, experience, and the senses. Putting differently, it is the mental process involved in gaining knowledge and comprehension. Cognitive processes include thinking, knowing, remembering, judging, and problem-solving. They involve higher-level functions of the brain such as language, imagination, perception, and planning.

Figure (2) Memory segments.



Source: Adapted from Atkinson, R.C. and Shiffrin, R.M. (1968).

2.0 COMPUTER MEMORY

2.1 The Computer

A computer is a programmable device that stores, retrieves, and processes data. As an electronic device employing integrated circuits (IC) it receives data (input), processes this data, produces output, and stores results (IPOS). It can also be programmed to automatically carry out sequences of arithmetic or logical operations and perform generic sets of a variety of tasks. Digital computer is a type of personal computer that integrates the computer components. A laptop computer is portable computer (PC) that features all these components.

Competencies demonstrated in this process go all the way from receiving an input, storing this input, analysing stored inputs, and delivering an output. Input data is received from input devices, a program is used to process the data, and a processed data is displayed as output.

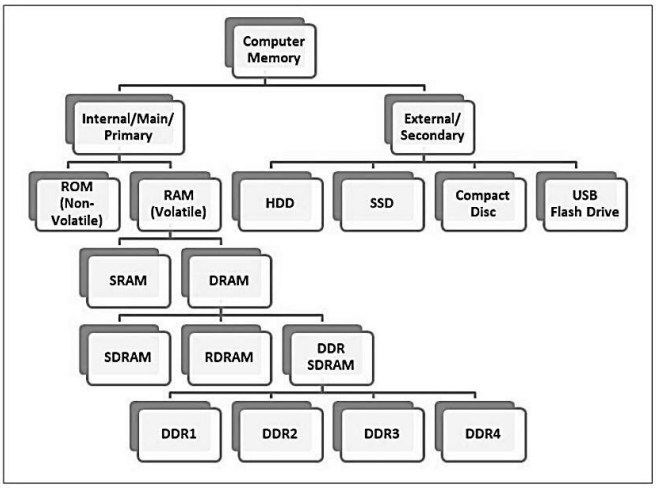
2.2 Computer memory structure.

Computers operations rely on four types of memories, a main memory, a secondary memory, a CPU registers and a Cache memory. It is a hierarchy of memories that enables the fastest speed and largest capacity of memory.

Main memory is the computer's data storage locus. It is a chip stored in a way that allows fast access by the processor. It has a Random Access Memory (RAM) and a Read Only Memory (ROM).

Secondary memory is a secondary storage device to save data after it has been saved by the primary storage device. It is used primarily to store large volume of data on permanent basis. It includes Hard Disk, • Floppy Disk, Zip Disk, Optical Disk and Magnetic Disk.

Figure(3) Computer memory structure



2.3 Computer memory functions.

Computer memory operates like the human brain. It stores s data and instructions. It is a data storage device where data is processed, and instructions required for processing are stored. It can store both the input and the output. Computer memory does not remember or forget things, it either knows something, or it does not. And it does not forget.

A typical computer has two distinct kinds of memory as well. There is a built-in main memory (sometimes called internal memory), made up of silicon chips It can store and retrieve data. Computers also have auxiliary memory (or storage), which remembers things even when the power is disconnected.

RAM has the name random access because it is as quick for the computer to read or write information from any one part of a RAM memory chip as from any other. Hard drives are also, broadly speaking, random-access devices, because it takes the same time to read information from any point on the drive. Auxiliary memory includes solid-state drives (SSDs), which are like hard drives only they store information on a flash memory instead of spinning magnetic discs.

Human brain memory versus computer memory

• How does computer memory compare to human brain memory?

Figure:

Element	Brain	Computer
Construction	Neurons and synapses	ICs, transistors, diodes, capacitors, transistors,
Memory growth	Increases each time by connecting synaptic links	Increases by adding more. memory chips

Backup systems	Built-in backup system	Backup system is. constructed manually.
Memory power	One hundred tera ops (one hundred trillion calculations/seconds)	One hundred million megabytes
Information storage	Stored in electrochemical and electric impulses.	Stored in numeric and symbolic form (i.e. in binary bits).
Transmission of information	Uses chemicals to fire the action potential in the neurons.	Communication is achieved through electrical coded signals.
Structural organization	Self-organized	Pre-programmed
Info processing power	Low	High
Input/output	Sensory organs	Keyboards, mouse, web
Parallelism	Massive	Limited
Reliability and damageability properties	The brain is self organizing, self-maintaining and reliable.	Computers perform a monotonous job and cannot correct itself.

Source: 2025 • Tech Differences, Difference between Brain and Computer IV Could computer memories simulate the cognitive competencies of human memory?

Where does the computer fail?

• Inputs from sensory memory

Sensory memory in psychology is the memory process that stores information taken in by the senses. These sensory impressions might be stored very briefly—particularly in relation to other types of memory—as human memory generally relies on sensory information to create memories and increase understanding. However, it does not have to retain impressions of sensory input long-term to maintain memory stores or sort through information.

As there are five senses, there are five types of sensory memory that are regarded by the scientific community. However, all forms of sensory memory are thought to have some common characteristics. These characteristics can remain true regardless of which sense is being used, or whichever part of the brain is processing the memory. ("What Is Sensory Memory and Why Is It Important? | Better Help") For example, Sensory memory does not require attention. It is automatic. Computers do not possess perceptive recording of this wide range of occurrences or "managing" them.

• Plasticity

"Neuroplasticity, also called brain plasticity, refers to the capacity of the brain to change and adapt in structure and function in response to learning and experience." ("Brain Plasticity in Psychology | Neuroplasticity") Put differently it is the capacity of the nervous system to modify itself, functionally and structurally, in response to experience and injury.

Neuroplasticity significance lies in two driving forces, learning and memory. The first theoretical notions of neural plasticity were developed in the nineteenth century (The Principles of Psychology, William James, 1890). In the twentieth century others proposed that neurons in adults break down and rebuild (Fuchs & Flügge, 2014).

Scientists now think that neuroplasticity occurs throughout all life stages, from childhood onwards (Doidge, 2007). The brain can rearrange itself in terms of the functions it carries out, as well as in terms of the basic underlying structure (Zilles, 1992). ("Brain Plasticity.docx - Early Theories Early experimental... - Course Hero") Structural plasticity performs several memory related tasks. It can increase storage efficiency in sparsely connected neural networks, and it could also increase stability of long-term memories. ("Plasticity-Driven Decision Making - SpringerLink") (The rewiring brain, a computational approach to structural plasticity in the adult brain 2017, pages 361-386, Chapter 17 - Impact of Structural Plasticity on Memory Formation and Decline)

Computer memories do not possess any of the plasticity rooted cognitive premises of the biological memory. Nor the self-initiation, restructuring or re assignment of tasks or restatement of functions the biological memory has.

• Output recall and reuse.

It is a daily and hourly occurrence that individuals take in added information and store it in the brain, maintaining it and recalling it depending on need. This happens because human brain has the capability of learning new skills and experiences, storing what has been learned and reusing the stored knowledge. ("Memory retention and recall process - Edge Hill University")

These capabilities of storing and reusing experiences and skills are stored in brain memory are typical for the human brain but not computers. The nonstop activity receiving added information from senses, updating existing knowledge using focus and attention, retrieving the stored experiences and skills, and planning for future activities that have not occurred yet do not belong to computer functions. ("Memory retention and recall process - Edge Hill University")

Computer memories receive, store, and recall data upon instruction. It does not, without program rooted instructions, adjust contents, restructure those or update them,

• Self awareness

Computer memory self-awareness is the ability of the system to introspect, recognize patterns in its own behaviour, and adapt its actions accordingly.

The pursuit of self-aware computer memory constitutes a formidable challenge. Self-aware necessitates computer memories capable of perceiving their existence, comprehending their environment, and making self-awareness-driven decisions. Self-awareness signifies the ability to identify oneself as a discrete entity distinct from the environment and other individuals. Consciousness and self-awareness share a connection, as both necessitate cognizance of one's thoughts, emotions, and existence.

The human memory can perform these functions as part of an overall cognitive competency. Computer memories are unable to perform these functions because they lack the relevant cognitive competencies.

3.0 CONCLUSIVE OBSERVATIONS

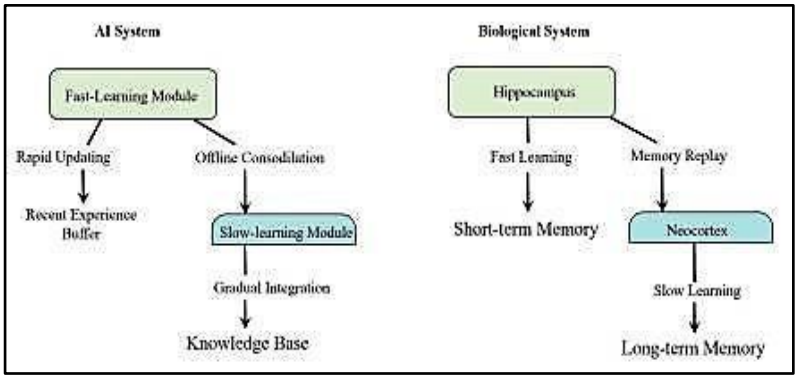
"Cognitive Technology is defined as technology that enables machines to possess mental abilities to mimic human behavior, learn from experiences, and make decisions, ultimately infusing intelligence into no intelligent machines." ("Cognitive Technology - an overview | Science Direct Topics") Cognitive technologies, or 'thinking' technologies, fall within a broad category that includes algorithms, robotic process automation, machine learning, natural language processing and …

The quest to create artificial intelligence (AI) systems demonstrating human brain plasticity as well as the capability of continuous learning while maintaining previously acquired knowledge constitute a prime challenge in machine learning. Stability–plasticity dilemma as this is defined lies at the heart of AI "learning." One of the many challenges is catastrophic forgetting, which relates to this stability–plasticity dilemma. This catastrophic forgetting occurs when artificial neural networks rapidly overwrite previously acquired knowledge when exposed to new data or tasks. ("Neuroplasticity Meets Artificial Intelligence: A Hippocampus-Inspired ...") Balancing rapid learning with stable knowledge retention lies at the heart of this dilemma.

Recent advances in AI, such as deep reinforcement learning and large language models, demonstrate the potential for brain simulated attempts. However, significant challenges remain in bridging the gap between biological and artificial neural networks. These include achieving the energy efficiency of biological systems implementing temporal dynamics or addressing ethical considerations.

The stability–plasticity dilemma remains a critical challenge in developing artificial intelligence (AI) systems capable of continuous learning
(https://pmc.ncbi.nlm.nih.gov/articles/PMC11591613/).

Figure (4): AI versus biological systems



Source: Rudroff T, Rainio O, Klén R. Neuroplasticity Meets Artificial Intelligence: A Hippocampus-Inspired Approach to the Stability-Plasticity Dilemma. Brain Sci. 2024 Oct

4.0 SUMMARY AND CONCLUSIONS

Cognition is the mental process of acquiring knowledge and understanding through thought, experience, and senses. Cognitive processes start with thinking and knowing and go all the way to remembering, judging, and problem-solving. They involve higher-level functions of the brain such as language, imagination, perception, and planning. Basic cognitive processes of perception, attention, and memory could lead to creativity.

Could the amalgam of integrated circuits and derived software that we call computers ever possess cognitive competencies?

This is the focus of the article.

The article starts with a definition of biological cognitive competencies. It explores their parameters and prime functions. It then proceeds to explore what we may refer to as the competencies of the computer or the amalgam of integrated circuits and their software capabilities. A comparison with biological cognitive functions follows and the similarities and gaps are identified.

Tentative and conditional conclusions are then derived.

The article relies on works on neurology, electronics, data science and psychology.

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