HUMAN BRAIN VERSUS ARTIFICIAL INTELLIGENCE: A PHYSIOLOGICAL PERSPECTIVE ON COGNITION, LEARNING AND INFORMATION PROCESSING

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ABSTRACT

INTRODUCTION

Artificial intelligence (AI) is an interdisciplinary field of computer science, integrating insights from various fields including mathematics, neurophysiology, psychology, linguistics and philosophy. AI's primary goal is to mimic some aspects of human cognition, such as pattern recognition, judgment, and even original problem-solving.

MATERIAL AND METHODS

In this article review and analysis of the available literature was dove. Literature was searched from Google Scholar, ScienceDirect and PubMed using keywords Artificial Intelligence, Human Intelligence, Human Al collaboration and neuroplasticity.

RESULTS

This conceptual review found that human brain and the artificial intelligence have different capabilities. The brain is powerful because of its creativity, cognitive flexibility, inherent awareness, and ethical reasoning, whereas AI is powerful because of its incredible speed, data processing precision, and scalability. Because of this, they are not rivals but ideal partners, and their synergistic collaboration is the demand of future.

CONCLUSION

With their distinct capabilities, human brain and AI should complement each other. This collaboration will allow us to combine the deep holistic understanding and ethical reasoning of humans with the computational power and data-processing capabilities of machines.

KEYWORDS

Artificial Intelligence, Human Intelligence, Neuroplasticity, Human-AI collaboration

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INTRODUCTION

Artificial Intelligence (AI) developed to mimic human brain learning, has evolved as a significant educational technology that enhances capabilities across various domains in diverse users.[1] Recent advance in AI and information technology have enable better integration of humans with machines. While the human brain, shaped by evolution, exhibits creativity, intuition, and abstract thinking, AI is a modern tool designed for rapid data processing and problem-solving. Despite its impressive computational abilities, AI lacks the capacity for human-like processing of thought, perception, and emotional intuition, which are essential for creativity and inspiration that have historically propelled civilization.[2]

The different parts of the human brain work together to create ideas, memories, and emotions, much like a finely tuned orchestra. The frontal lobe, the command center for creativity and abstract cognition is the center for planning, decision-making, and creativity. This is the sheet where the concepts are developed, theories are conceived, and the effects decisions are closely examined. Similarly, another region of the brain the parietal lobe provides the brain with a dynamic image of the physical world. Simultaneously, the temporal lobe facilitates the formation of new associations and connects diverse concepts by storing memories and interpreting sounds. The brain's specialized region for processing visual input is the occipital lobe, which converts light into the vibrant pictures. Together with our memories and abstract thought, these images lay the foundation for our capacity for imagination and creativity. Any masterpiece must be emotionally charged, and the limbic system serves as the brain' emotional center. This area deepens our thinking, boosts motivation, and enhances creativity, enabling us to create connections that guide and motivate our choices.[3] The brain is human's most amazing resource- a living example of the power of biological evolution from comprehending a fleeting expression to creating whole new universes. Even if the brain has evolved into a remarkable machine, artificial intelligence offers a different perspective and provides up-to-date processing and creative solutions.[4]

Importance for understanding limits and potential of both systems

AI's primary goal is to mimic some aspects of human cognition, such as pattern recognition, judgment, and even original problem-solving. We shall compare the human brain and artificial intelligence using key criteria to better comprehend the benefits and limitations of each system.[5]

Table 1. Significance for comprehending the capabilities and limitations of both systems (AI and the human brain).[4]

Parameter	Human Brain	Artificial Intelligence
Power Efficiency	~20 watts (Light bulb equivalent)	Dozens to thousands of kilowatts/ hour
Neural capacity	~ 86 billion neurons	Model-dependent (e.g.,GPT-4 has ~ 175 billion parameters)
Interconnectivity	~100 trillion synapse	Billions of mathematical weights
Learning	Continuous adaptive	Requires large labeled datasets
Creativity	Emotion-and Association drive	Mimic creativity by combining data
Intuition	Experience-based often irrational	No intuition; decisions are purely rational
Flexibility	Adapts quickly to new situations	Limited; requires retraining
Scalability	Limited by physiology	Easily scalable

This analogy highlights how the brain and AI are interconnected; the former is skilled at intuition and flexibility, while the latter is skilled at speed and scalability. When taken as a whole, they show the possibility of a partnership that capitalizes on each organization's advantages.[6] Artificial intelligence relies on preset algorithms and large datasets, whereas the human brain excels in flexibility, intuition, and experiential knowledge. It differs from human cognation in that it is unable to process ambiguity, comprehend context, or access emotions. By analyzing the similarities and difference, we can understand the uniqueness of each system.[7] This perspective allows us to envision a collaborative model where human cognation and artificial intelligence complement each other rather than compete, ultimately enhancing the outcomes that humanity as a whole.[8]

Neuroanatomical & Structural Organization

The human brain, with its intricate neuronal framework, makes a foundation for cognation, behavioral activities and survival.[9] The cerebrum, brainstem, and cerebellum are the three main structural divisions of the brain. Stretching from the upper cervical spinal cord to the diencephalon of the cerebrum, the brainstem is situated at the base of the brain. It is separated into the midbrain, pons, and medulla. Positioned behind the brainstem is the cerebellum. White matter (myelinated axons) and gray matter (neuronal cell bodies) make the basic configuration of the brain. Gray matter is involved in processing information, while white matter facilitates its transmission. Moreover, non-neuronal glial cells, such as astrocytes, microglia, and myelin-forming oligodendrocytes, are just as important for functioning brain as neurons. These cells are involved in the regulation of neuroinflammatory processes, both beneficial and detrimental; they are also involved in the formation, maturation, and removal of synapses, which contributes to the formation of neural circuits essential for maintaining proper neural processing and function in the central nervous system (CNS).[10]

Plasticity and structural reorganization

The process known as neuroplasticity describes how various stimuli can alter the amount of brain cells and synaptic remodeling that takes place in the brain.[11] Our brain is a dynamic neural network that can develop significantly under the right circumstances, not just a static collection of cells, as demonstrated by current research on neuroplasticity. Two main mechanisms can be used to classify neuroplasticity: Collateral sprouting and neuronal regeneration include concepts such as neurogenesis and synaptic plasticity. Concepts like equipotentiality, vicariation, and diaschisis are all part of functional restructuring. The brain has the ability to rearrange itself in reaction to novel situations, learning, and experiences.[12]

Artificial Intelligence (AI)

The connectionist neural networks, which are biologically inspired models with fundamental units called "artificial neurons," are among the most well-known types of cognitive geometric models.[13] With connections that can send and receive impulses, neurons function as simple linear integrators. The neuron sends out a signal along its outgoing connections if the activation impulse from incoming connections hits or exceeds a specific threshold. Artificial neurons are the interconnected nodes in artificial neural networks that mimic the activity of biological neurons in the human or animal brain by transmitting signals, usually in the form of real numbers, through their connections.[14] After processing input signals, they produce outputs according to a nonlinear function and specific weights. Artificial neurons work together to solve a problem in an artificial neural network. Artificial neural networks are software applications or algorithms that essentially use computing systems to carry out mathematical computations, whereas artificial neurons are software components, also known as nodes.[15] Three layers of interconnected artificial neurons[16] make up a basic neural network:

Input Layer: Through the input layer, the artificial neural network receives data from the outside world. Before sending the data to the next layer, the input nodes process it, either classifying or analyzing it.

Hidden Layer: The intermediate layers between the input and output layers are called the hidden layers. There can be many hidden layers in artificial neural networks. After analyzing and further processing the output from the previous layer, each hidden layer moves on to the next.

Output Layer: The output layer is the last layer of a neural network model. It generates the final results, such as probabilities for classification tasks or a numeric value for regression tasks.

The outcome of all the data processing done by the artificial neural network is provided by the output layer. It may include one or more nodes. A binary (yes/no) classification problem, for example, will have a single output node in the output layer, producing a result of either 1 or 0. However, the output layer may have multiple output nodes if the problem involves multi-class categorization. Weighting occurs as inputs go across synapses to the cell. After applying an activation function to the "summation of weighted inputs" from every incoming synapse, the neuron sends the outcome to every other neuron in the subsequent layer.[17] The weight associated with each input's synapse to the current neuron is used to scale it. In the case when the previous layer has three inputs or neurons, each neuron in the current layer will have three distinct weights, one for each synapse. Neural network layers depend on activation functions, which modify the input they receive before sending it to the next layer. Neural networks are empowered by these functions, which allow them to depict complex non-linear interaction.

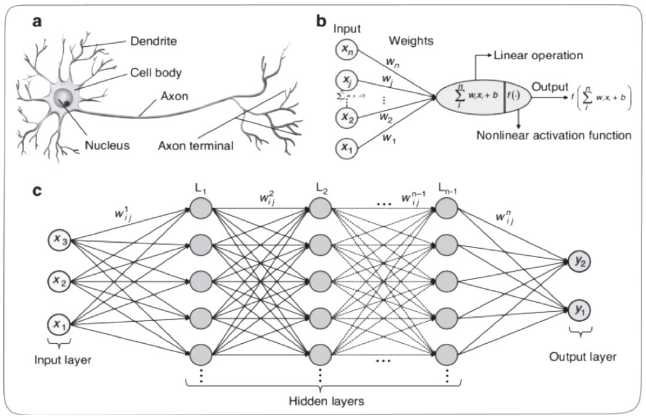

Figure 1. Neuron structure and artificial neural network

a. structure of biological neurons.
b. mathematical inferring process of artificial neurons in multi-layer perception,including the input, weights, summation, activation function, and output.
c. Multi-layer perception artificial neural network.[18]

When AI systems make mistakes, they typically need outside help—like software updates or human input—to correct the problems.[19] They lack the capacity to recognize and fix issues on their own, a task that biological systems carry out through neuroplasticity or immunological responses.

Neurophysiology & Signal Processing

Electrically excitable neurons generate electrical impulses in response to inputs, which spread throughout the cell and its axons as action potentials.[20] Changes in the cationic gradient across their plasma membranes, primarily involving sodium and potassium, produce and transmit these action potentials. Ultimately, through synapses, these action potentials go to the axonal terminal and cause depolarization in nearby cells. Through the process of synaptic transmission, this activity demonstrates how these cells communicate with one another, specifically at synapses.

Numerous neurotransmitter molecules constantly work to keep our brains functioning, controlling everything from our heartbeat and breathing to our ability to learn and focus. They can also affect a variety of psychological factors, including enjoyment, pleasure, mood, and terror. Common neurotransmitters that are present in the body and brain include serotonin, dopamine, glutamate, adrenaline, nor-adrenaline, and endorphins.[21] An individual's mood, activity levels, sleep patterns, and even hunger can all be impacted by these neurotransmitters. In order to keep the brain's excitatory and inhibitory processes in balance, neurotransmitters are essential. Both emotional reactions and cognitive capacities depend on this equilibrium.[22]

In biological neurons, information arrives by the dendrites, is processed by the soma, and is sent via the axon. An artificial neuron receives information through weighted inputs. The artificial neuron's body then aggregates the weighted inputs, biases them, and applies a transfer function to the sum. Finally, the processed information is transferred via the output(s).

To compute the weighted sum, each input is multiplied by its weight, and the resulting products are added together. Additionally, a bias component is included in the weighted total. This term alters the activation function, allowing the neuron to fire even when all inputs are zero. The activation function performs a nonlinear change of the weighted sum. This transformation is critical because it allows the network to understand the non-linear correlations contained in the data.[23] Without activation functions, the network would only be capable of simulating linear relationships. The network supports a variety of activation functions, including ReLU, sigmoid, and softmax, allowing it to handle a variety of problems (both regression and classification). The mathematical explanation[24] below demonstrates the benefit of the artificial neuron model's simplicity.

$$y(k) = F\sum_{i=0}^{m} w\,i(k)\,.\,xi(k) + b$$

Where,
xi (k) is input value in discrete time k where i goes from 0 to m.
wi (k) is weight value in discrete time k where i goes from 0 to m.
b is bias
F is transfer function
y (k) is output value in discrete time k.

The word "clock cycles"[25] is used to describe a steady, synchronized pace for information processing, but "dynamic neuronal firing rates" more accurately describes organic neurons' asynchronous, event-driven features. Biological neurons convey messages via spikes, and their firing rates (the rate at which these spikes occur) vary dynamically depending on both input and internal circumstances, in contrast to the constant clock-driven technique seen in many artificial systems.[26]

Learning Mechanisms

The synaptic mechanism known as Hebbian learning[27] is described as strengthening synaptic connections based on optimum temporal contingency. This helps with synaptic predictive processing and strengthens connections that show frequent prediction-outcome links.

As cellular models for information retention in the central nervous system, long-term protection and long-term depression permanent changes in synaptic strength brought on by different patterns of synaptic activity have drawn a lot of attention. Research in several brain regions, from the spinal cord to the cerebral cortex and in a variety of animal species, including humans and invertebrates, has demonstrated a consistent ability for chemical synapses to experience long-lasting variations in effectiveness in response to different induction protocols.[28]

Sleep has profound role in the creation of long-term memories. Slow-wave sleep causes the hippocampus's representations to be repeatedly replayed by neurons, which gradually transforms and integrates them into neocortical networks. Three noteworthy aspects of this procedure are highly emphasized. (i) Hippocampus replay, which enhances local synaptic plasticity[29] and captures elements of episodic memory; (ii) brain oscillations that define slow-wave and rapid-eye movement sleep, which offer mechanisms for controlling information flow across distant brain networks; and (iii) qualitative changes in memories during system consolidation that result in abstracted, gist-like representations.

Human cognitive functions, including perception, attention, learning, memory, reasoning, and problem-solving, are all greatly impacted by emotions. They have a special impact on attention, affecting its selectivity and motivating activities. Since our limited attentional resources are better focused on relevant information, learning is intimately related to this control over attention and executive processes. Emotions also improve knowledge encoding and facilitate effective retrieval.[30]
Similarly, in AI the term "Back Propagation" (BP)[31] indicates a broad family of Artificial Neural Networks (ANN), which are designed with several linked layers. With a learning method based on the Deepest-Descent approach, the BP ANNs constitute a unique kind of ANN. One well-liked optimization method for training neural networks and machine learning models is gradient descent. By gradually lowering errors through parameter adjustments, gradient descent enhances model performance. Gradients, loss functions, and learning rates are key components of leading models. Mini-batch, batch, and stochastic (SGD) gradient descent all balance efficiency and data usage. In natural language processing (NLP), they are essential for training and improving large language models (LLMs). Rate scheduling and regularization are used to solve problems like over fitting and disappearing or bursting gradients.[32]

By providing insights from data and customized learning experiences, artificial intelligence (AI) improves decision-making. However, it also raises concerns about the possible deterioration of human judgment and critical thinking. Furthermore, there is concern that AI tools may increase reliance on technology and decrease intrinsic motivation, even while they can increase student motivation through personalized learning routes and interesting material. Predictive analytics and AI-powered monitoring may greatly enhance students' safety and well-being.[33]

Sleep is essential for preserving both our physical and mental well-being, and getting enough sleep helps humans to concentrate better on our everyday tasks.[34] Despite the fact that sleep is known to be essential for memory consolidation in human systems, current AI systems lack a direct analog of this process. In order to solve catastrophic forgetting in AI, several researchers have looked into offline processing, sometimes referred to as "sleep-like replay"; however, this idea is far different from the sleep-dependent restructuring seen in humans.[35]

Strengths & Weaknesses

The human brain contains exceptional qualities, including flexibility, creativity, moral thinking, and contextual comprehension. Multiple neural networks dynamically interact to originate these cognitive activities, not limited to particular brain areas. Key areas like the frontal lobes and prefrontal cortex play key roles in these processes, although their activities are intertwined with other brain regions.

Scalability guarantees that the AI system can preserve speed and accuracy as it expands and takes on increasingly challenging jobs, even though these attributes are crucial in specialized fields. Scalable AI systems sometimes entail deploying models in resource-constrained situations and optimizing them for efficiency. Methods such as "scaling out" concentrate on developing distributed AI ecosystems in which specialized models communicate and work together to improve overall flexibility and scalability.[36] AI's benefits are essentially its speed and accuracy in certain fields, and its scalability guarantees that these advantages can be capitalized upon and preserved as AI systems develop and expand.[37]

Decision-Making and Adaptation

The brain functions as a network of interrelated areas that coordinate actions and reactions. Communication between sensory data, emotional reactions, and logical thought is made possible by neural pathways. For instance, when confronted with a difficult decision, the limbic system evaluates emotional relevance while the prefrontal cortex takes rational thinking into account. Effective decision-making and adaptive behavior are ensured by this cooperation between different brain areas. The brain's capacity to change its structure by creating new neural connections is known as neuroplasticity.[38] Learning, memory formation, and injury healing are all aided by this flexibility. People may recover from brain damage, pick up new abilities, and adjust to changing surroundings because of neuroplasticity. Engaging in activities like learning a new language, playing an instrument, or solving problems helps strengthen neuronal connections, highlight the brain's remarkable development potential and dynamic nature.[39]

Pattern recognition is one of the most fundamental aspects of AI. It plays a pivotal role in tasks such as classification, clustering, regression, and anomaly detection.[40] The ability to detect patterns and regularities from large datasets is critical for decision making processes, automation, and developing intelligent systems. It also examines the diverse applications of pattern recognition across industries such as healthcare, finance, and robotics,[41] emphasizing its role in the future of AI.

While algorithmic rigidity offers efficiency and consistency in activities that are well-defined, neural flexibility promotes adaptability and learning in dynamic contexts. Using the benefits of human and machine intelligence, the optimal approach typically requires balancing these two concepts. According to some academics, understanding this equilibrium is essential for developing efficient systems that can handle complex and uncertain situations.

Future Directions

A cutting-edge technology called the brain-computer interface (BCI)[42] was developed to provide a direct line of communication between the human brain and outside technologies. Using brain activity to control external devices or interact with virtual worlds is one of the main objectives of BCI. BCI have the potential to improve human computer interaction, restore movement to paralyzed individuals, and create new opportunities in a variety of fields, including communication, gaming, and medicine, by decoding brain signals and translating them into commands.

A key cognitive ability required for academic success, professional efficacy and responsible citizenship is critical thinking, which is the ability to evaluate, integrate and analyze data to reach logical conclusions. One of the main areas of current study has been the dual nature of AI's impact on cognitive growth. By providing personalized advice and immediate feedback, AI applications can improve learning outcomes,[43] which in turn promotes skill acquisition and information retention. Nevertheless, there is mounting evidence that cognitive offloading may results from an over-reliance on these technologies. The process known as cognitive offloading occurs when people delegate cognitive duties to outside resources, reducing their capacity for deep reflective thinking.[44] According to Paas et al,[45] cognitive load on an individual's working memory can free up brain resources, but it may also reduce cognitive engagement and make learning new skills more difficult. Because AI technologies are so widely available and offer prepackaged information and rapid responses, users may be discouraged from engaging in the cognitive processes required for critical thinking. A future in which human and AI develop simultaneously, influencing and enhancing one another's skill, envisions the co-development of human competences and AI functionality.[46,47] In order to achieve this synergistic connection, humans must adapt to use AI efficiently while also guiding its development through their particular needs and abilities. This co-evolutionary process includes both AI's assistance to humans and the requirement that humans learn how to interact with and use AI as a cooperative partner.[48]

CONCLUSION

The human brain and AI both possess unique strengths that, when combined, can create powerful synergy. The brain has excellent flexibility, creativity, and ethical reasoning enabling adaptation in various contexts. In contrast, AI contains enormous computational speed, precision in data processing and scalability, but lacks the emotional intelligence and contextual understanding inherent to human cognition. Therefore, a complementary relationship is required between the human and AI, where the data driven capabilities of AI enhances human decision-making, while human intelligence guide the ethical development of AI. To potentiate this collaboration, a deeper understanding of both biological and artificial intelligence is needed. The development of educational curricula with new, targeted, and easily configurable training forms and learning environments for Human-AI systems are therefore recommended. By integrating human adaptability with the efficiency of AI, we can develop the systems that are not only intelligent but also ethical and aligned with human values, paving the way for a future where human-AI collaboration brings new innovations for the society.

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