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Quantum-Like Compression in Human Vision: Discrete Level Amplification and Gamma Phase Locking in the Default Mode Network

Ravinder Jerath[1*] and Varsha Malani[2]

[1]Charitable Medical Organization, Mind-Body and Technology Research, Augusta, GA, USA
[2]Masters Student Northeastern University, Boston, MA, USA

***Corresponding author:** Dr. Ravinder Jerath, Charitable Medical Organization, Mind-Body and Technology Research Augusta, GA, USA

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Abstract

One of the most remarkable functions within humans is vision. With the complex mechanisms behind the operation of human visual systems, humans can compress the vast amounts of information available to them. This article explores the complex processes behind this compression ability at a discrete level of amplification like quantum amplitude amplification algorithms, gamma phase locking, and the default mode network (DMN) or default space. This paper will discuss these mechanisms, review the evidence that supports these mechanisms, discuss the implications of this research, and discuss potential future research that can take place on this topic.

Keywords

Human Vision; Quantum-Like Compression; Amplification and Gamma Phase.

Introduction

The human brain's ability to process an enormous amount of data recognized from the visual component of the environment compels scientists to find that the human brain has some compression mechanisms for visual data. Studies have proven that the human brain has mechanisms responsible for processing visual data, such as discrete level amplification, gamma phase locking, and default space, attributable to the DMN [1]. These mechanisms can be explained further by research on quantum-like models in relation

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to discrete visual processing [2]. The following research paper analyzes the human brain's quantum-like compression of vision through discrete level amplification, gamma phase locking, and default space's role concerning the DMN.

Some of the quantum-like models that have been used to explain the discrete processing of vision relate closely to quantum mechanics principles [2]. However, not all quantum-like models relate to biological processes. For example, research has shown that in binary image compression, the quantum image compression algorithm substantially reduces the quantum circuit's gate count to encode classical images into quantum states without sacrificing the image quality [3].

Quantum-Like Compression in Visual Processing

Similar to qubits in quantum computing, the photoreceptors in the human eye encode information and initiate image compression. Quantum-inspired tensor network algorithms perform dimensionality reduction for substantial image compression [4]. The human visual system’s perceptual grouping principle discards redundant image data [5], much like quantum amplitude estimation approximates significant computational results [6]. Further, research studies have demonstrated that quantum correlations in human vision perform such alignment of single-photon detections with perceptual outputs [7]. Other research studies demonstrate the efficacy of quantum image compression with advanced DCT-EFRQI models that demonstrate efficient encoding in quantum gates [8]. By using quantum-like superposition techniques to represent images, the human eye performs image compression to reduce redundant processing loads on the brain.

Discrete Level Amplification: A Quantum-Inspired Mechanism

Another feature that could relate directly to visual compression mechanisms within the brain is discrete level amplification, based on quantum amplitude amplification (QAA), which amplifies states to increase probability. This process can also be seen in the amplification of signals at retinal receptors in the face of thermal noise [9]. Another facet of this amplification phenomenon in quantum models is Floquet amplification, which can amplify weak fields by several orders of magnitude.

This demonstrates that once a signal is received, it can be increased substantially in strength to a statistically significant level [10]. Furthermore, another mechanism within this phenomenon of discrete levels corresponding with hierarchical layers is quantum-inspired pruning in neural networks. This causes a drastic latency reduction without losing accuracy. Lastly, a related phenomenon in cortical processing is visual evoked potentials, which vastly amplify phase-locked responses at specific latencies [11]. This mechanism of discrete amplification could also be helpful for optimizing visual compression mechanisms in the brain.

Gamma Phase Locking in Visual Perception

Some of the roles of neural oscillations in the gamma range are visual perception and consciousness [12]. For instance, the modulation of neuronal gamma oscillations in area V1 facilitates orientation selectivity to communicate visual information with other brain areas [13]. Synchronization in a phase-locked manner between gamma oscillations enhances perceptual resolution beyond optical diffraction limits via

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synchronization with eye tremors [14]. Relatedly, the phase of gamma-band oscillation amplitude coupling predicts visual stimulus visibility or the strength of gamma oscillation amplitude locking to lower theta or alpha oscillation phases in visual tasks [15]. Additionally, increased gamma-band oscillations in frontal brain regions are associated with consciously induced perceptual destabilization in multistable perception tasks [16]. The phase locking of gamma oscillations is involved in compressing visual information [17].

The Default Mode Network as Default Space

Other functional networks display phase-locking dynamics that influence perception. For example, the default mode network (DMN) is a neural system that is not associated with external stimuli but is instead activated for introspective thoughts [18]. The DMN's alpha phase coupling with ventral visual areas of the brain decouples from visual perception during periods of mind-wandering [19]. Phase-locking within the DMN modulates perceptual biasing in theta frequencies [20]. Quantum-like models compare neural function in the DMN to probabilistic computations occurring in phase spaces. According to these models, slow brain waves below 4 Hz phase-lock to maintain baseline coherence in the DMN [21]. The DMN is a "default space" for integrating sensory data and internal feedback [22].

Integration and Implications

Beyond the amplification at discrete levels, the phase locking phenomenon of gamma frequencies, and the modulation of that phase locking that is performed via the DMN, these processes also potentially involve the discrete amplification of certain visual signals and inputs in order to gain a more detailed and holistic understanding of the visual inputs that are being received. At its most basic level, the phenomenon of quantum-like compression in vision allows a human to focus on certain types of visual inputs in order to gain a better understanding of those inputs that are being observed; yet, rather than focusing on every single aspect of those inputs, though, the visual system can instead focus on amplifying certain aspects of those features. Still, phase locking is a necessary feature of the process of quantum-like compression, in that it helps to create that holistic understanding of those amplified signals and features – a holistic understanding that can only be achieved when the signals are bound together as a whole [14]. In that way, the role of gamma phase locking is similar to those involved in other algorithms, like iterative quantum searches [9]. Even more broadly, though, this concept allows for an understanding of the processes that might be involved in the experience of perceptual illusions; those illusions are more likely caused by disruptions to the DMN's modulation of that default space, or disruptions to the gamma phase locking within that default space, which leads to an inability or inefficiency in performing the process of quantum-like compression within vision. The same could also be said for attentional blinks, another well-studied phenomenon related to visual attention [15]. Beyond that, however, this understanding also means that the processes of quantum-like compression can directly relate to quantum-inspired algorithms like those seen in quantum image processing [23].

Ultimately, though, these concepts and understandings have many implications for a variety of fields of study, as well. For instance, with respect to the field of cognitive science, this information creates new avenues for the understanding of disorders related to perception, and could motivate and aid in therapeutic interventions regarding those disorders. For instance, conditions like schizophrenia have been related to disruptions in the oscillations involved in gamma phase locking and modulation within that default space [24]. Thus, restoring and normalizing those oscillations may be one potential therapeutic option for treating those who experience symptoms like disrupted visual experiences. Furthermore, those interested in the use of quantum-inspired computing or technologies can also make use of this information as a potential means of powering certain bio-mimetic algorithms in visual AI systems. For instance, it is already known that vision-based systems that are specifically designed for performing tasks like object recognition require advanced compression techniques, like those seen with discrete amplification Given these various examples, therefore, it seems highly likely that this theory has enabled, or could enable, a variety of applications in various fields and contexts.

Conclusion

In conclusion, the capabilities of the human brain to compress visual information can be explained through a quantum-like visual compression model that incorporates the phenomena of discrete level amplification, gamma phase locking, and DMN dynamics. This model explains the brain's remarkable ability to significantly compress the vast quantity of information received by the eyes in such a short time and enhances it in such a way that allows for meaningful perception and understanding of the world around us. This model is supported by extensive evidence, and it sheds light on the efficiency and vulnerability of human vision. Furthermore, given the extensive implications of such a model, this model has the potential to significantly impact related fields, such as AI and quantum computing. As for the research done in this article, further research is needed to provide insights into other areas of human cognition and consciousness or to solidify the claims of this model through experimental investigation. Overall, this quantum-like visual compression model advances knowledge in neuroscience, paving the way for a more holistic understanding of human consciousness and cognition.

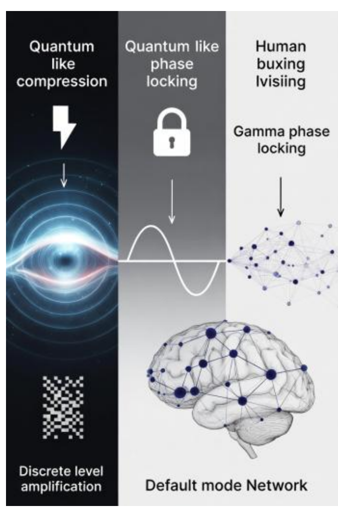

Figure 1: Conceptual illustration of quantum-like neural dynamics and large-scale brain network synchronization.

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