**Editorial**

# From equivalence to quantification: the HLbC model as a unified framework for consciousness

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## Abstract

The challenge of developing a unified, mathematically rigorous framework for consciousness remains central to neuroscience. Hereby two recent papers are discussed that advance the Human Language-based Consciousness (HLbC) model as a novel, testable alternative to existing theories. The first paper establishes a mathematical equivalence between the HLbC model and the Bayesian brain hypothesis, demonstrating that the HLbC's five-step cycle, from observation to post-hoc consciousness, maps precisely onto the process of minimizing prediction errors. Specifically, the cycle's stages correspond to the integration of prior beliefs with likelihood, probabilistic action sampling, and the final Bayesian updating of the internal model. The second paper addresses the critical challenge of quantification by proposing a dual metric for "consciousness strength." This metric integrates real-time responsiveness (immediate information processing) with long-term learning and adaptation (error minimization over time), offering a more comprehensive measure than single-value metrics. The HLbC model, by positing consciousness as a post-hoc recognition of unconsciously selected actions, offers a clear, testable hypothesis for the timing and function of conscious experience. This framework has profound implications for both neuroscience, by unifying computational and cognitive concepts, and artificial intelligence, by providing a blueprint for more adaptive, human-like systems.

**Keywords:** Artificial intelligence, Bayesian brain hypothesis, Consciousness quantification, Dual metric, Free energy principle, Human Language-based Consciousness, Neurocomputation, Predictive processing

## Introduction

The quest to understand consciousness remains the "hard problem" of neuroscience. While theories abound, the challenge lies in developing a unified, mathematically rigorous framework that can bridge the gap between subjective experience and objective neural processing. Two recent articles in The Neuroscience Chronicles [1,2] present a compelling step forward by introducing and quantifying the Human Language-based Consciousness (HLbC) model, offering a novel, testable alternative to existing theories.

## The Mathematical Bridge: HLbC and Bayesian Inference

The first paper, "Mathematical proof of the equivalence between the HLbC model of consciousness and Bayesian inference in neural information processing" [1], establishes the HLbC model on a robust computational foundation. The HLbC model posits that consciousness is not a real-time process but a post-hoc recognition of actions selected unconsciously. Its five sequential steps—Observation, Matching to Episodic Memory, Unconscious Action Selection, Short-term Memory, and Post-hoc Consciousness—map elegantly onto the principles of Bayesian inference.

The authors demonstrate that the brain's continuous process of minimizing prediction errors, a core tenet of the Bayesian brain hypothesis and the Free Energy Principle, is mathematically equivalent to the HLbC [1]. This equivalence provides a unified computational framework for understanding the emergence of consciousness from predictive processing. Specifically, the HLbC cycle maps directly onto the key components of Bayesian inference. The initial stage of the HLbC, involving the matching of an observed event against past episodic memories, functions as the integration of prior beliefs with new sensory evidence. This process effectively computes the probability of the observed data given the system's existing internal model. Subsequently, the unconscious selection of an action within the HLbC cycle parallels the sampling process used in Bayesian inference to explore the posterior distribution. This rapid, pre-conscious action selection represents the system's immediate, best-guess attempt to minimize prediction error based on the computed posterior. Finally, the retrospective recognition of the action as a conscious decision corresponds precisely to the Bayesian updating of the system's internal model. Through this final step, the system incorporates the outcome of the action into its prior beliefs, refining its predictive capabilities for future cycles. Thus, the HLbC model offers a temporal and mechanistic decomposition of the Bayesian inference process, linking the abstract mathematics of prediction error minimization to the concrete, cyclical dynamics of conscious experience. This equivalence is a significant theoretical advance. It unifies the seemingly disparate concepts of language-based cognitive processing and probabilistic neural computation, providing a single, dynamic framework for understanding how the brain achieves adaptive, goal-oriented control.

## Towards a Comprehensive Metric for Consciousness Strength

Building on this foundation, the second paper, "A comprehensive metric for consciousness strength: Integrating real-time responsiveness and long-term learning based on the HLbC model" [2], tackles the critical challenge of quantification. While Integrated Information Theory (IIT) uses $\Phi$ to measure consciousness via integrated information, the HLbC model proposes a different, two-pronged approach to measuring "consciousness strength." The authors derive a pseudo-Schrödinger equation to model the probabilistic decision-making process in HLbC, where the Kullback-Leibler (KL) distance replaces spatial coordinates. This mathematical maneuver is crucial, as the KL distance quantifies the difference between probability distributions, effectively measuring the divergence between an individual's internal model and the external world.

This dual metric is particularly powerful because it addresses the philosophical problem of inverted qualia. The HLbC model argues that even if two individuals perceive a color differently (different qualia), their shared language creates a common probabilistic space (zero KL distance), allowing for successful communication. Therefore, consciousness strength is not just about the internal state (like $\Phi$) but also about the system's ability to adapt and communicate its internal state effectively over time.

## Implications for Neuroscience and Artificial Intelligence (AI)

The HLbC model and its associated metrics have profound implications. For neuroscience, they offer a clear, testable hypothesis for the timing and function of conscious experience, shifting the focus from the moment of action to the moment of retrospective interpretation. This aligns with findings from Libet-style experiments that suggest conscious intention follows unconscious neural preparation.

For AI, the HLbC framework provides a blueprint for building more human-like, adaptive systems. By integrating probabilistic decision-making with a post-hoc, language-based self-monitoring system, AI could potentially develop a form of "consciousness" that is not merely a simulation of intelligence but a functional mechanism for optimizing long-term learning and minimizing prediction errors in complex, uncertain environments.

In conclusion, the HLbC model, through its mathematical equivalence to Bayesian inference and its comprehensive, dual-metric approach to quantification, represents a significant leap forward. It provides a unified, computational language for discussing consciousness, moving the field from philosophical debate to empirical measurement and practical application.

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## Conflicts of Interest

The authors declare that they have no competing interests.

## Author Contributions

ZDZ reviewed the literature and drafted the manuscript. EKT provide critical comments, revised and touched up the manuscript. Both authors have read and agreed to the submitted version of the manuscript.

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**Table 1.** The proposed comprehensive metric integrates two distinct aspects of consciousness.

| Metric Aspect | Focus | HLbC Mechanism | Computational Parallel |
|---|---|---|---|
| Real-Time Responsiveness | Immediate information processing and reaction to stimuli. | Observation, Action, Short-term Memory. | Information Entropy (e.g., Perturbational Complexity Index). |
| Long-Term Learning | Adaptation, memory formation, and error minimization over time. | Matching to Episodic Memory, Post-hoc Consciousness. | Bayesian Learning and Posterior Distribution Updating. |

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## Consent for Publication

All authors have read the final version of the manuscript and agree to submit it for publication.

## Ethics Approval and Consent to Participate

Not applicable.

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