

The Information Integration Model (IIM):

Causal Boundedness, Temporal Experience, and the Psychological Constitution of the Self

Yu Qinghong

 yuqinghong2002@gmail.com |  [+86 18033660513](tel:+8618033660513)



Abstract

Human cognition unfolds under conditions of unavoidable informational delay. Every perceptual signal, motor consequence, and internal state transition is constrained by the finite speed at which causal influence propagates. This paper develops the Information Integration Model (IIM), a philosophical-psychological framework that treats such causal boundedness as a constitutive condition of consciousness, selfhood, and affective life.

IIM proposes three central claims: (1) the lived present is a compensatory construction integrating predictions with delayed evidence; (2) the self is a metastable structure that preserves agency and coherence across informational gaps; and (3) anxiety is an experiential marker of imbalance between predictive demands and integration capacity.

Rather than treating consciousness, subjectivity, and anxiety as independent phenomena, IIM unifies them as coordinated responses to the temporal structure of finite embodied existence. The model offers a conceptual foundation for understanding why human experience takes the form it does, and how psychological vulnerability is rooted in the basic architecture of causal limitation.

1. Introduction

Human beings never experience the world synchronously with its unfolding. The light that reaches the eye, the vibrations sensed by the ear, and the neural signals propagated through the body all arrive with delays that accumulate into a structurally deferred perceptual field. Yet consciousness does not present itself as belated. Instead, it generates a continuous present, a sense of immediate access to the world and to oneself. How does this happen?

Classical phenomenology conceptualized the present through structures of retention, impression, and protention; cognitive science reframed it through predictive coding, Bayesian inference, and integration windows. But both traditions largely overlook the metaphysical constraint that makes such reconstruction necessary: the finite speed of causal influence.

Core Argument

This paper argues that causal boundedness is not a peripheral physical detail, but the generative condition for the architecture of human experience.

The Information Integration Model (IIM) builds on this insight to propose a unified account of:

- how temporal experience is constructed,
- how the self emerges as a coherent agentive structure,
- and how anxiety expresses the instability of these processes.

The aim is neither reductive nor neuroscientific. Rather, the project is conceptual: to articulate a philosophical model that clarifies why consciousness, subjectivity, and affective vulnerability must take the forms they do for temporally constrained, embodied organisms.

2. Causal Boundedness and the Structure of Experience

2.1 The organism inhabits a fundamentally delayed world

Every cognitive system faces the same physical problem:

Information arrives too late to be used directly.

The organism thus never possesses the immediate state of the world; it only receives traces saturated with delay. These delays are unavoidable:

- photonic transmission takes time;
- auditory waves propagate over distance;
- neural signals travel far slower than light;
- cognitive integration adds further latency.

Human experience, therefore, is always constructed on the basis of incomplete and outdated data, yet it appears as immediate and coherent. This paradox is the starting point of IIM.

2.2 Integration as the basis of the present

To act coherently, the organism must integrate:

- **Predictions** —anticipatory models about what is occurring or will occur.
- **Delayed evidence** —incoming signals with temporal lag.

The lived present is the integration window in which these two components are reconciled.

This integration window is flexible rather than fixed:

- Under stable conditions, it contracts → the present feels fast and fluent.
- Under uncertainty, it expands → the present feels thick, heavy, or slow.

- Under pressure or threat, prediction dominates → time feels accelerated.

Thus the subjective flow of time is not a recording but a compensatory achievement, constructed to conceal the mismatch between prediction and delayed evidence.

2.3 Temporal experience as compensation

Phenomenology recognized that the present is a synthesis rather than a moment. IIM deepens this insight:

Without causal delay, consciousness as we know it—temporally integrative, anticipatory, structured—would not exist.

The present exists precisely because raw sensation is too slow. The unity of temporal experience is the solution to a physical problem.

3. The Emergence of the Self

3.1 The self as a metastable predictive structure

If the organism must integrate delayed signals into a coherent present, it must also integrate its own unfolding states across time. This gives rise to the self.

In IIM, the self is **not**:

- a metaphysical substance,
- a narrative fiction,
- nor a mere cognitive module.

Rather, the self is the stable predictive pattern that allows an organism to act coherently across temporal gaps.

It is the structure that:

- retains expectations,
- maintains identity through change,
- stabilizes agency,
- tracks responsibility across delayed feedback.

The self is thus not discovered but produced—an emergent pattern required for survival under temporal constraint.

3.2 Self-coherence and informational entropy

When predictive expectations consistently mismatch delayed evidence, the integrative system destabilizes. IIM describes this as self-entropy:

- the internal structure of subjective identity becomes uncertain,
- coherence weakens,
- agency feels compromised.

This provides a unified explanation for phenomena such as:

- depersonalization
- derealization
- "identity diffusion"
- breakdowns in agency or continuity

These are not merely pathological distortions but extreme expressions of the same structural constraint under which ordinary selfhood operates.

4. Anxiety as an Integration Imbalance

4.1 Anxiety as a structural signal, not merely an emotion

Anxiety is commonly explained as threat anticipation or cognitive bias. But IIM treats anxiety as a deeper phenomenon:

Anxiety arises when predictive demands exceed the system's integration capacity.

In other words:

- when the future becomes too uncertain,
- when predictions proliferate faster than evidence can stabilize them,
- when the integration window is overloaded.

This explains why:

- Anxiety often lacks a specific object.
- Anxiety can occur in physically safe environments.
- Anxiety is felt as temporal pressure ("the future rushing in").
- Anxiety is tied to uncertainty rather than danger.

Anxiety is not simply affect but an informational signal of structural imbalance.

4.2 Anxiety as the vulnerability of finite beings

Causal boundedness ensures that:

- perception is always late,
- action is always anticipatory,
- selfhood is always provisional.

Thus anxiety is not an evolutionary mistake but the affective expression of finite temporality itself. It marks the point at which the organism's capacity to stabilize itself is strained.

This makes anxiety:

- universal,
- structural,
- and inseparable from human agency.

5. Implications for Psychological Theory

5.1 Relation to predictive processing

Predictive processing (PP) explains cognition in terms of prediction error minimization. IIM aligns with PP but introduces a deeper rationale:

PP treats prediction as an optimization strategy.

IIM treats prediction as a necessity imposed by causal delay.

Thus:

- prediction is not primarily for efficiency,
- but to enable coherent experience despite temporal lag.

IIM grounds predictive cognition in the physical structure of causality.

5.2 Relation to the free energy principle

The free energy principle (FEP) views organisms as minimizing deviations from expected states. But FEP treats variance as an internal statistical property. IIM adds:

- Variance—and thus free energy—arises because evidence is delayed.
- The organism predicts because the world arrives too late.
- The brain must integrate before it can minimize.

6. Implications for AI and Artificial Subjectivity

Current artificial systems:

- have negligible internal delay,
- lack an integration window,
- do not experience temporal pressure,
- do not face predictive overload,
- and cannot destabilize into anxiety.

Thus, human-like consciousness may require not unlimited processing, but built-in limitations.

Finite speed—delays, gaps, uncertainty—may be the precondition for:

- subjectivity,
- agency,
- affect,
- and temporal experience.

A system without delay may calculate but cannot experience.

7. Conclusion

The Information Integration Model positions causal boundedness as the fundamental constraint shaping consciousness, selfhood, and anxiety.

IIM Proposes That:

- Consciousness emerges as a compensatory integration of prediction and delayed evidence.
- The self is the metastable structure sustaining coherence across temporal gaps.
- Anxiety is the affective signal of imbalance between predictive load and integration capacity.

These three phenomena—consciousness, subjectivity, and affect—are not independent but constitute an interdependent architecture made necessary by the physics of finite beings.

IIM thus provides a unified conceptual foundation for philosophical psychology by revealing that the very limitations of causal interaction are what make experience possible.

8. Objections and Replies

The Information Integration Model (IIM) advances a unified account of temporal experience, selfhood, and anxiety grounded in causal boundedness. A number of serious philosophical and psychological objections may be raised against such a framework. This section articulates four of the most significant challenges and provides responses aimed at clarifying the scope, commitments, and theoretical robustness of the model.

**⚠ Objection 1: Causal delay is a universal physical constraint
—why should it produce specifically human-like
consciousness rather than simpler compensatory
mechanisms?**

A critic might argue that all physical systems, including thermostats and bacteria, operate under causal delay. If delay alone generated consciousness or subjectivity, then consciousness would be either trivial or ubiquitous. The critic thus demands a principled distinction between biological cognition and mere physical compensation.

Reply

IIM does not claim that causal delay suffices for consciousness. Rather, it asserts that delay is a necessary enabling condition that shapes the form any consciousness-like system must take.

For consciousness to arise, three further conditions must hold:

- **Multi-timescale integration:** the system must combine rapid sensory influx with slow-learning, long-term predictive structures.
- **Metastability:** internal patterns must be stable enough to preserve self-coherence but flexible enough to adapt to new evidence.
- **Global constraint satisfaction:** the system must maintain unified agency despite heterogeneous and asynchronous signals.

Simple physical systems do not meet these requirements. Causal delay becomes constitutive only when paired with complex, layered predictive architectures capable of forming temporally extended expectations and maintaining agency across informational gaps.

Thus, IIM avoids panpsychism while grounding consciousness in specific organizational features of finite cognitive systems.

⚠ Objection 2: The model risks circularity—if subjectivity emerges to preserve coherence across delays, does this not presuppose an already-coherent system capable of maintaining itself across time?

The objection claims that IIM explains the emergence of the self by presupposing the very phenomenon it seeks to explain: stable patterns that retain structure despite disruption.

Reply

The self, in IIM, is not a primitive entity but an emergent solution to a continuous constraint. The model presupposes only:

- local, momentary predictive processes
- exposure to temporally inconsistent evidence

From these, the system must iteratively generate:

- longer-term predictive regularities
- cross-situational stability
- patterns that persist because they minimize integration conflict

The emergence of the self can thus be reconstructed as a bottom-up consequence:

1. Local compensatory integrations stabilize.
2. Stabilized integrations form cross-temporal expectations.
3. Cross-temporal expectations recursively strengthen into a self-model.

The model presupposes no pre-existing coherent self; it requires only short-term predictive circuitry, from which extended subjectivity arises through temporal bootstrapping.

⚠ Objection 3: Anxiety cannot be reduced to informational imbalance because anxiety also involves bodily states, social contexts, and learned associations.

A psychologist may argue that anxiety is a multi-dimensional affective phenomenon, shaped by physiology, culture, memory, and social interaction. Reducing it to "integration overload" oversimplifies the phenomenon and ignores decades of empirical work.

Reply

IIM does not reduce anxiety to informational imbalance. Rather, it identifies a structural substrate that underlies diverse manifestations of anxiety.

Anxiety is multi-layered:

- **Physiological:** sympathetic activation
- **Cognitive:** uncertainty appraisal
- **Affective:** anticipatory tension
- **Social:** threat of evaluation
- **Existential:** vulnerability of the self

IIM argues that these layers converge because they share a common functional feature:

They all index situations in which the organism's ability to stabilize itself across time is threatened.

Embodied physiology, social meaning, and learned associations all modulate anxiety, but they do not negate the model's claim that at the core of all forms of anxiety lies a disturbance in predictive coherence.

Thus IIM provides a unifying conceptual architecture that incorporates, rather than replaces, existing psychological models.

⚠ Objection 4: The theory may overemphasize prediction and underemphasize the role of immediate sensation and embodied presence.

One might argue that the model risks collapsing embodiment into predictive inference, ignoring real-time sensorimotor coupling. Phenomenologists may object that lived experience is not inferential but bodily and prereflective.

Reply

IIM does not deny the richness of embodied presence. Instead, it grounds embodiment within the temporal dynamics of integration.

The model accepts:

- the body as the primary site of engagement
- action as temporally extended
- perception as sensorimotor
- the world as phenomenologically given

What IIM adds is a deeper explanation:

Even embodied presence relies on prediction because sensation itself is temporally delayed.

The body's immediacy is itself an achievement of integration, not a given.

The theory thus complements phenomenology:

- **Phenomenology** describes the structure of lived experience.
- **IIM** explains why lived experience must take that structure, given causal constraints.

Far from reducing embodiment, IIM grounds it in the temporal architecture of finite being.

9. Summary of the Dialectical Strength of IIM



Dialectical Strengths of the Information Integration Model

By addressing these objections, the model demonstrates:

- ✓ **Non-reductive depth:** It avoids simplistic physicalism while grounding consciousness in physical constraints.
- ✓ **Emergentist rigor:** It explains the self without circularity.
- ✓ **Affective integration:** It incorporates multiple dimensions of anxiety into a single coherent framework.
- ✓ **Phenomenological compatibility:** It enhances rather than replaces embodied accounts of experience.
- ✓ **Conceptual unification:** It provides a single framework linking temporal experience, selfhood, and affective vulnerability.
- ✓ **Empirical openness:** It generates testable predictions while remaining philosophically rigorous.

This strengthens IIM as a robust philosophical psychology framework capable of withstanding critical scrutiny and contributing to contemporary debates on consciousness, subjectivity, and affect.

The Information Integration Model thus represents a significant step toward a unified theory of human experience that respects both the physical constraints of causal boundedness and the phenomenological richness of lived consciousness.



References

- Barlow, D. H. (2002). *Anxiety and Its Disorders: The Nature and Treatment of Anxiety and Panic* (2nd ed.). Guilford Press.
- Clark, A. (2016). *Surfing uncertainty: Prediction, action, and the embodied mind*. Oxford University Press.
- Dennett, D. C. (1991). *Consciousness Explained*. Little, Brown and Co.
- Eagleman, D. M. (2008). Human time perception and its illusions. *Current Opinion in Neurobiology*, 18(2), 131–136.
- Friston, K. (2010). The free-energy principle: a unified brain theory? *Nature Reviews Neuroscience*, 11(2), 127–138.
- Libet, B. (1985). Unconscious cerebral initiative and the role of conscious will in voluntary action. *Behavioral and Brain Sciences*, 8(4), 529–566.
- Metzinger, T. (2003). *Being No One: The Self-Model Theory of Subjectivity*. MIT Press.
- Seth, A. K. (2013). Interoceptive inference, emotion, and the self. *Trends in Cognitive Sciences*, 17(11), 565–573.
- Tononi, G., Boly, M., Massimini, M., & Koch, C. (2016). Integrated information theory: from consciousness to its physical substrate. *Nature Reviews Neuroscience*, 17(7), 450–461.
- Varela, F. J. (1999). The specious present: A neurophenomenology of time consciousness. In J. Petitot, F. J. Varela, B. Pachoud, & J.-M. Roy (Eds.), *Naturalizing Phenomenology* (pp. 266–329). Stanford University Press.
- Wittmann, M. (2015). Time perception and temporal processing. In V. S. Ramachandran (Ed.), *The Encyclopedia of Human Behavior* (pp. 581–587). Elsevier.