Biological Observers

Supplement to The Ignorant Observer Framework

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Abstract

This supplement explores whether the layered temporal structure of human perception—including delays in the range associated with Libet-style timing experiments—can be modeled using the bookkeeping principles of the Ignorant Observer Framework (IOF) when applied to biological systems. The analysis connects IOF to biological information processing, semantic filtering, and hierarchical observer architecture, asking whether finite capacity, umwelt partitioning, and dynamical self-opacity at multiple nested scales can generate timescales comparable to those reported in neuroscience.

The goal is not to expand IOF beyond its physical foundations, nor to claim that neuroscience validates the framework. All conclusions here are interpretative and exploratory; the core IOF remains unchanged.

Status of this supplement. This document is a biological interpretation of the model, not a neuroscience result. The numerical comparisons below should be read as plausibility checks and hypothesis generators, not as derivations of conscious timing or evidence for IOF. The capacity bookkeeping used throughout ($\kappa = h_{KS} - C_{\text{eff}} \ln 2$ and the timescales it sets) is the operational layer of IOF—classical information-theoretic tracking, observer-relative and recoverable, never a claimed departure from standard quantum mechanics.

1 Quick Dictionary (used throughout)

IOF uses one bookkeeping inequality:

$$\kappa \;=\; h_{KS} \;-\; C_{\text{eff}} \ln 2.$$

- h_{KS}: effective information-production / instability burden (nats/s).
  In chaotic dynamics, h_{KS} is the Kolmogorov–Sinai entropy rate; informally: "how fast the situation generates new information you would need to track."
- C_{eff}: effective tracking capacity available for world-representation (bits/s), after semantic filtering and internal budgeting.
- κ: self-ignorance rate (nats/s). $\kappa < 0$ = capacity-wins (textbook fixed-basis QM is operationally available); $\kappa > 0$ = chaos-wins (standard QM still holds, with an unstable/unresolved reference frame). These are control-law labels for the observer's tracking regime, never an effect or deviation beyond quantum mechanics.
- σ_θ^2: basis uncertainty (rad^2) in the observer's internal measurement frame.

Units note: if C_{eff} is in bits/s, then $C_{\text{eff}} \ln 2$ is in nats/s.

2 Introduction: Why This Supplement Exists

The main manuscript treats the empirical observer as a physical dynamical system with finite capacity, and therefore partial ignorance of its own internal basis.

The analysis here was inspired by the essay *Consciousness Across Three Worldviews* by Sarvapriyananda, Agüera y Arcas, and Rovelli,[1] which explores convergences between Vedantic, computational, and physical perspectives on consciousness, particularly regarding semantic information and umwelt filtering in biological systems.

This supplement serves three purposes:

1. To connect IOF to biological cognition, without burdening the main text.
2. To examine whether IOF-style capacity bookkeeping can reproduce order-of-magnitude timescales reported in neuroscience, including ∼20–70 ms tracking windows and ∼300–400 ms reportability delays.
3. To show how semantic filtering and hierarchical cortical architecture can be viewed as possible biological analogues of IOF principles.

All claims here are offered for exploration, not as definitive biological theory.

3 Semantic Information vs Raw Capacity

In IOF, C is the raw Shannon capacity: the maximal rate at which information can be processed or integrated.

[1] `https://www.noemamag.com/consciousness-across-three-worldviews/`

Biological observers do not devote their full Shannon capacity to world-representation. Most biological processing concerns:

- homeostasis,
- regulation,
- prediction of internal states,
- semantically relevant signals,
- avoidance of irrelevant data.

Therefore we introduce an **effective** capacity:

$$C_{\text{eff}} \leq C, \tag{1}$$

where C_{eff} is the **semantic / relevance-filtered capacity** actually available for tracking the world.

3.1 The Umwelt and Semantic Filtering

Gregory Bateson described a bit of information as *"a difference that makes a difference,"* emphasizing that salient information is not just statistical distinction, but one that matters functionally for the organism.

Following Jakob von Uexküll, we call this filtered information space the organism's **umwelt**—the perspective-dependent universe of behaviorally relevant information.

Every organism has both:

- **Internal umwelt**: hunger, pain, satiety, homeostatic signals
- **External umwelt**: predators, prey, mates, threats

Only semantically salient information consumes C_{eff}.

3.2 Why $C_{\text{eff}} < C$ in Biological Systems

The total Shannon capacity C must be partitioned:

$$C = C_{\text{homeostasis}} + C_{\text{internal}} + C_{\text{external}}, \tag{2}$$

where:

- $C_{\text{homeostasis}}$: metabolic regulation, immune response, etc.
- C_{internal}: tracking internal state (fatigue, arousal, interoception)
- C_{external}: bandwidth for world-modeling

The effective capacity for world representation is therefore:

$$C_{\text{eff}} = C_{\text{external}} < C. \tag{3}$$

3.3 Empirical Grounding of C_{eff}

Recent neuroscience provides direct measurements of conscious information processing rates. Zheng et al. (2024) analyzed data spanning nearly a century of cognitive experiments and found that human conscious cognition operates at approximately **10 bits per second**—with a range of 5–20 bits/s across tasks including reading, typing, and decision-making.[2]

This stands in stark contrast to sensory input rates ($\sim 10^9$ bits/s from the retina alone), implying a compression ratio of $\sim 10^8$. The bottleneck appears to be central rather than merely peripheral: conscious access to information is strongly limited.

This empirical value is compatible with the IOF parameter range $C_{\text{eff}} \sim 1$–30 bits/s used throughout this framework. In this supplement, the measured 10 bits/s is treated as a possible proxy for *conscious* world-modeling bandwidth—the semantic-filtered capacity relevant to IOF's tracking problem.

3.4 Empirical Grounding of h_{KS}

The instability burden h_{KS} corresponds to the rate at which internal dynamics generate unpredictable information. For neural systems, this can be estimated from Lyapunov exponents measured in EEG signals.

Studies of EEG nonlinear dynamics report largest Lyapunov exponents (LLE) in the range of 0.5–0.7 per sample during normal waking states.[3] At typical EEG sampling rates of 128–256 Hz, this corresponds to:

$$h_{KS} \sim 0.6 \times 128 \text{ Hz} \approx 50\text{–}80 \text{ s}^{-1}.$$

Direct measurements of short-term maximum Lyapunov exponents (STLmax) in intracranial EEG yield values of 4–6 bits/s during interictal periods, dropping to 1.5–2.5 bits/s during seizures (when the brain enters a more ordered state).[4]

The IOF parameter $h_{KS} \sim 20$–80 nats/s (equivalently $\sim$30–115 bits/s) is therefore in the same rough range as some measures of neural chaoticity, though the precise mapping between "raw EEG chaos" and "measurement-basis instability" is interpretative and not established.

3.5 The Resulting Timescale

With $C_{\text{eff}} \approx 10$ bits/s and $h_{KS} \approx 50$ nats/s:

$$\kappa = h_{KS} - C_{\text{eff}} \ln 2 \approx 50 - 7 = 43 \text{ nats/s},$$

giving a characteristic timescale $\tau \sim 1/\kappa \approx 23$ ms. Including the logarithmic threshold factor from the full t_{break} formula yields $\tau \approx 50$–70 ms—the order-of-magnitude biological tracking limit.

[2] J. Zheng et al., "The unbearable slowness of being: Why do we live at 10 bits/s?" *Neuron* **112**(24), 4066–4080 (2024). DOI: 10.1016/j.neuron.2024.11.008

[3] K. Natarajan et al., "Nonlinear analysis of EEG signals at different mental states," *BioMedical Engineering OnLine* **3**, 7 (2004). DOI: 10.1186/1475-925X-3-7

[4] L. D. Iasemidis et al., "An investigation of EEG dynamics in an animal model of temporal lobe epilepsy using the maximum Lyapunov exponent," *Experimental Neurology* **217**(1), 128–139 (2009). DOI: 10.1016/j.expneurol.2009.01.015

This is *not* a prediction from first principles; it is a consistency check showing that independently measured biological parameters yield timescales in the expected range.

4 The Layered Timescale Structure of Human Awareness

IOF predicts a limitation on self-knowledge due to finite C_{eff} and internal instability burden h_{KS}. When mapped onto biological observers with semantic filtering and hierarchical architecture, this can produce a cascade of characteristic timescales.

4.1 Layer 0—Fundamental Physical Tracking Limit (raw capacity)

From raw C versus h_{KS}, the IOF tracking timescale has the form:

$$\tau_{\text{raw}} = \frac{h_{KS}\,T_{\text{kick}}}{C\ln 2 - h_{KS}} \approx 23.2 \text{ ms.} \tag{4}$$

In this toy mapping, this is the shortest tracking timescale available for a finite observer with the assumed parameters.

This layer is not directly measurable in biology because organisms do not operate at raw Shannon capacity.

4.2 Layer 1—Biological Semantic-Filtered Tracking Limit

Because $C_{\text{eff}} < C$ due to umwelt filtering, the semantic layer sits in the chaos-wins regime ($C_{\text{eff}} \ln 2 < h_{KS}$): there is no convergence time, and the relevant scale is the threshold-crossing (tracking-loss) time set by $\kappa = h_{KS} - C_{\text{eff}} \ln 2 > 0$,

$$\tau_{\text{SK}} = \frac{1}{2\kappa} \ln\frac{\sigma_{\text{tol}}^2}{\sigma_0^2} \approx 60\text{–}80 \text{ ms,} \tag{5}$$

i.e. the amplitude e-folding time $1/\kappa \approx 23$ ms inflated by the threshold log factor (consistent with the κ-route estimate above).

Biological observers would not be expected to track their own basis faster than this within the assumptions of this model, due to:

- semantic filtering (umwelt constraints),
- metabolic constraints,
- internal signal competition.

This aligns with the $\tau_{\text{SK}} \approx 68$ ms scale used in the main IOF narrative.

Important alignment note (IOF vs OR): The threshold-crossing time t_{break}—the operational t_* of the corpus's canonical clock table, a threshold variant of $\tau_\kappa = 1/\kappa$ rather than the bare e-folding clock—is only meaningful in the chaos-wins regime ($\kappa > 0$). It is an *observer-relative* tracking timescale: the time over which the visibility of the observer's *unconditioned* records degrades as its internal reference frame θ drifts beyond the tracking budget. This is reference-frame physics within standard quantum mechanics, not a measurable departure from it—the lost contrast is recoverable in principle once the missing reference information is supplied, so t_{break} marks where the unconditioned record loses contrast, not a breakdown of QM. With the biological-scale parameters above the layer sits firmly in chaos-wins ($\kappa \approx 43$ nats/s, far from threshold); the observed ∼68 ms scale is the threshold-crossing time $t_{\text{break}} = (1/2\kappa)\ln(\sigma_{\text{tol}}^2/\sigma_0^2)$—the e-folding time $1/\kappa \approx 23$ ms inflated by the logarithmic tolerance factor—not a near-threshold artifact. This is the layer where comparisons to objective-reduction timescales are discussed.

4.3 Layer 2—Multi-Level Observer Integration (cognitive ignition)

The brain is not a single observer; it is a hierarchy:

- neurons,
- microcircuits,
- cortical columns,
- regional networks,
- fronto-parietal "global access" system.

Each level must resolve its own basis uncertainty before the next can integrate it.

With a per-level convergence time ∼ 60–80 ms and 3–4 necessary cortical stages:

$$\tau_{\text{hier}} \;\approx\; N_{\text{layers}} \times \tau_{\text{SK}} \;\approx\; 200\text{–}300 \text{ ms}. \tag{6}$$

This aligns with:

- N200 / P300 components in event-related potentials,
- recurrent cortical "ignition" (Dehaene's global neuronal workspace),
- minimal time for a percept to become reportable.

4.4 Layer 3—Full Libet Lag (motor integration)

Adding final motor-plan convergence and response preparation:

$$\tau_{\text{Libet}} \;\approx\; \tau_{\text{hier}} + \tau_{\text{motor}} \;\approx\; 300\text{–}380 \text{ ms}, \tag{7}$$

giving an order-of-magnitude match to delays discussed in Libet-style experiments between readiness potential and reported conscious intention.

4.5 Summary Table

Layer	**IOF Estimate**	**Neuroscience**	**Mechanism**
Layer 0	$\tau_{\text{raw}} \approx 23$ ms	N/A	Raw Shannon limit
Layer 1	$\tau_{\text{SK}} \approx 68$ ms	60–80 ms	Semantic filtering ($C_{\text{eff}} < C$)
Layer 2	$\tau_{\text{hier}} \approx 200$–300 ms	N200/P300	Hierarchical convergence
Layer 3	$\tau_{\text{Libet}} \approx 350$ ms	∼350 ms	Motor integration

4.6 Two Finite-Capacity Subsystems: Basis Stabilisation and Record Formation

The layered lag above invites a structural reading of *what* the finite capacity is spent on. A finite observer factors into two capacity-limited functions that a laboratory apparatus separates explicitly and an organism merely hides in the same tissue:

- **Basis stabilisation**—the loop that orients and holds the measurement reference θ. In the laboratory this is control hardware (phase-locked loops, field coils, timing gates); in the organism it is the non-conscious machinery that orients attention, fixes gaze, and prepares action. This is the subsystem whose finite C_{eff} and instability burden h_{KS} set σ_θ^2 and the timescales tabulated above.
- **Record formation**—the coarse-graining channel that registers *which* outcome occurred. In the laboratory this is the detector, digitiser, and memory; in the organism it is whatever renders a percept or decision reportable as "this happened" / "I chose this."

The companion Born derivation[5] separates exactly these roles. Basis stabilisation fixes the *predictive weight* a finite observer must assign to the available records—the binary Born form $p(\theta) = \cos^2(\theta/2)$ on a calibrated context. Record formation is the distinct, downstream step that registers one finite outcome through the coarse-graining channel; the realized record is fixed by the particular history, not drawn by the world—in that paper's phrase, "the world does not sample; the observer does." The weight is a credence over records; the registered record is the one this observer ends up holding.

Read against the Libet lag (Layer 3) as analogy, not mechanism, the division of labour is suggestive. The readiness potential is the basis-stabilisation subsystem at work—the orientation and motor preparation that fix the effective θ—while the reportable "I chose this" is the registered record, arriving *after* the basis-fixing chain is already underway, because tracking one's own basis is precisely the capacity-limited task that the layered timescales bound. On this reading the sense of authorship is the record's content, not the cause of the outcome—consistent with the framework's account of causal self-opacity, and asserting nothing about consciousness beyond the registration of a finite outcome. The correspondence is structural and interpretative, in keeping with the status of this supplement.

5 Biological Observers as Hierarchical Ignorant Observers

IOF defines an observer as a system that:

1. must track itself while
2. remaining partially ignorant of its own state
3. due to finite capacity
4. while embedded in a dynamical world.

The cortex can be modeled in this way at multiple nested scales.

This suggests a possible stacked observer-of-observers picture:

[5] A. Dekker, *The Born Rule from Finite Observation: A Conditional Derivation of the Binary Born Form*, OSF Preprints (2026). DOI: 10.17605/OSF.IO/U5RDE.

- Each level has its own σ_θ^2 (basis uncertainty)
- Each level has its own C_{eff} (umwelt-filtered capacity)
- Each level must converge before higher levels can integrate

5.1 Serial Umwelt Filtering

Each cortical level defines its own umwelt at a different abstraction scale:

- **V1**: oriented edges, spatial frequencies, local contrast
- **V4**: colors, shapes, texture boundaries
- **IT**: objects, faces, complex patterns
- **PFC**: abstract goals, plans, task representations

This serial filtering supports the scaling:

$$\tau_{\text{hier}} \approx N_{\text{layers}} \times \tau_{\text{SK}}. \tag{8}$$

5.2 Recurrent Processing and Predictive Coding

Modern neuroscience emphasizes recurrent processing: higher areas send predictions down while lower areas send prediction errors up.

This is compatible with IOF:

- **Top-down predictions**: higher levels use their current basis estimate to predict lower-level signals
- **Bottom-up errors**: lower levels report deviations from predictions
- **Convergence**: occurs when prediction error drops below a threshold (equivalently, when σ_θ^2 stabilizes)

Even with recurrent loops, convergence remains bottlenecked by finite C_{eff} at each stage.

6 The ∼68 ms Scale and Objective Reduction (interpretative)

The appearance of a ∼60–80 ms characteristic scale in biological observers arises here at Layer 1, where semantic filtering constrains capacity.

In IOF language, this layer sits firmly in the chaos-wins regime,

$$\kappa = h_{KS} - C_{\text{eff}} \ln 2 \approx 43 \text{ nats/s} > 0,$$

so the ∼60–80 ms scale is the threshold-crossing time t_{break}—the e-folding time $1/\kappa \approx 23$ ms inflated by the logarithmic tolerance factor—rather than a near-threshold coincidence. Comparisons to objective-reduction timescales (e.g., Penrose OR) are therefore made at this semantic-filtered layer, and remain suggestive rather than explanatory.

7 Comparative Biology and Scaling Laws

IOF suggests that tracking delay τ need not be a universal biological constant, but may depend on the ratio between instability burden h_{KS} and effective capacity C_{eff}.

7.1 The Paradox of Complexity

Evolution can increase both processing capacity and internal complexity. If effective complexity grows faster than effective throughput, higher organisms can experience a greater "epistemic lag" than simpler ones.

- **Low-h_{KS} observer (e.g., Diptera/flies):** high critical flicker fusion frequencies ($>$200 Hz) suggest very short integration windows. With minimal internal narrative, effective h_{KS} may be low.
- **High-h_{KS} observer (humans):** the Default Mode Network (DMN) sustains a high-load self-referential prediction stream. This raises effective tracking burden, increasing integration windows toward the $\sim$300–500 ms range.

Conclusion (interpretative): "Higher" cognition can be characterized by a deeper buffering of the "Now" required to stabilize higher internal instability burden.

7.2 Variable Latency in Humans (the "Quiet Mind" hypothesis)

If the delay is driven by internal burden h_{KS}, then transient reductions in that burden should reduce the lag. This aligns with reports of flow states and meditative absorption:

- **High burden (anxiety/analysis):** controller saturation; reaction times increase.
- **Low burden (flow/mushin):** reduced internal noise improves the ratio C_{eff}/h_{KS}; hesitation shrinks and immediacy increases.

In this framing, "presence" may be modeled as improved efficiency of the observer's tracking loop. This remains a hypothesis, not a clinical or contemplative claim.

8 Limitations and Scope

This supplement is interpretative.

IOF is a physical framework; biology and neuroscience are external domains to which it can be applied, but they do not constrain the core theory.

Accordingly:

- None of the empirical values here validate IOF
- They illustrate compatibility with known biology
- The supplement remains separate from the main derivations

Further testing is required to determine whether biological implementations of IOF principles actually operate via the mechanisms described here.

9 Conclusion

IOF predicts a limitation on self-knowledge due to finite capacity and internal instability burden. When applied to biological systems, these principles can reproduce the approximate layered temporal structure of human awareness—from ∼60–80 ms semantic-filtered tracking windows to ∼300–400 ms reportability delays.

On this view, biological cognition can be interpreted as a hierarchical analogue of IOF-style tracking. Characteristic timescales emerge from:

- semantic filtering reducing effective capacity ($C_{\text{eff}} < C$),
- hierarchical architecture requiring serial convergence,
- umwelt partitioning across nested observer levels.