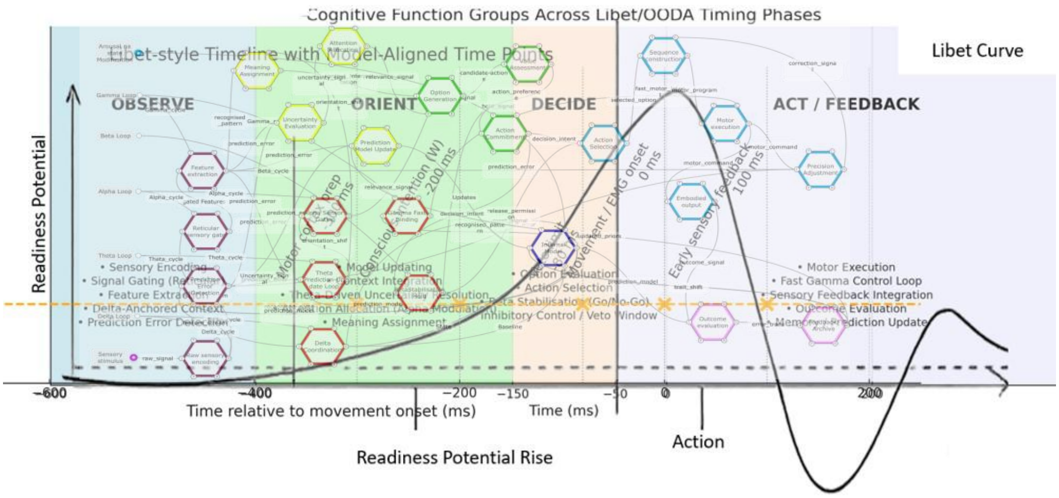

The Temporal Dynamics of Intention: Integrating Libet, OODA, and FRAM

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Abstract

This work proposes a new functional model of volition that integrates empirical timing data from Libet's experiments, the operational logic of the OODA decision cycle, and the systemic architecture of the Functional Resonance Analysis Method (FRAM). Rather than treating the brain as a collection of isolated centres responsible for discrete cognitive or emotional roles, the model conceptualises intention and action as emergent properties of dynamically synchronised neural assemblies distributed across the cortex and subcortex. These assemblies interact through rhythmic oscillatory mechanisms, forming transient system-wide avalanches that activate learned and innate behavioural pathways. The resulting framework offers a mechanistic explanation for the temporal evolution of conscious intention, veto control, action execution, and feedback learning. By grounding cognition in dynamic coupling rather than localisation, the model provides a basis for simulation, clinical insight, and the design of aligned human–AI interaction systems. By using the FRAM built system model, the natural variability of the functions can be examined systematically to determine the effects of system behaviour and performance. For example, what difference would variability in the reticular gating function have on the overall cognition process, etc. A real prospect of exploring neurodiversity scientifically?

Keywords; Volition; neural synchronisation; OODA loop; Functional Resonance Analysis Method (FRAM); predictive processing; agency; decision-making; Neurodynamics.

Introduction

Human decision-making is often experienced as instantaneous: a thought, an intention, a movement. Yet, beneath this surface impression lies a finely timed cascade of processes distributed across neural networks, cognitive systems, and embodied responses. Historically, the *phenomenology* of choosing—what it feels like to decide—has been allowed to dominate our understanding of volition. However, advances in cognitive neuroscience, cybernetic control theory, and systems modelling increasingly demonstrate that volitional action is not a moment, but a *trajectory*.

The pioneering work of Benjamin Libet in the early 1980s made this temporal structure visible. Through EEG measurements, Libet identified the **readiness potential (RP)**: a slow-rising neural signal that begins **hundreds of milliseconds before a person reports consciously deciding to act**. Subsequent research refined this finding—distinguishing movement preparation, conscious awareness, inhibitory control, and execution phases. Yet, what remained missing was a **framework capable of integrating these timings with a structured, mechanistic model of cognitive function.**

This work proposes such a framework by integrating three previously separate perspectives:

- **Neuroscientific timing data** (Libet, Kornhuber & Deecke, Haggard)
- **The OODA cycle** (Observe–Orient–Decide–Act), a control-theoretic model of adaptive behaviour
- **The Functional Resonance Analysis Method (FRAM)**, a systems-modelling approach developed for complex socio-technical systems

Together, these perspectives allow us to reconstruct volition as a multistage system: a set of interacting functions operating under dynamic oscillatory regulation, evolving in time rather than occurring in discrete linear steps.

The Model

The first stage of the process involved establishing a precise reference timeline grounded in Libet's empirical research and its subsequent replications. This provided anchoring points including readiness-potential onset (between −800 and −550 ms), pre-motor cortical commitment, the moment of conscious awareness of intention (Libet's W at approximately −200 ms), the narrowing veto window, and the execution point of physical action. This scaffold forms the temporal spine on which subsequent modelling rests.

Once the temporal baseline was established, the OODA decision cycle was mapped directly onto it. Rather than treating OODA as a conceptual overlay, each phase was aligned with specific temporal dynamics: the Observe phase corresponds to the slow, unconscious physiological buildup reflected in early readiness-potential activation; Orient aligns with the period during which prediction updating and uncertainty reconciliation occur; Decide corresponds to the narrowed corridor in which alternative actions may still be vetoed; and Act includes both the moment of execution and the subsequent early sensory return. This mapping allowed the decision structure to be temporally grounded rather than purely declarative.

Having established temporal and behavioural structure, the work then turned to identifying plausible cognitive mechanisms associated with each stage. Functions such as sensory encoding, signal gating, feature extraction, model updating, attentional selection, inhibition, execution, and feedback comparison were assigned to their respective phases.

A key turning point in the work was the development of Table 1, which aligned these functions to major oscillatory mechanisms in the brain.

Table 1 — Oscillatory Control Loops and Functional Roles

Oscillation Band	Approx. Frequency	Primary Role in System	Functional Domain	Timing Relative to Libet Window
Delta (δ)	0.5–4 Hz	Global physiological/affective grounding; energetic baseline regulation	Brainstem–thalamic loop, interoception, autonomic input	Continuous; active throughout −800 → +400 ms
Theta (θ)	4–8 Hz	Prediction error computation, uncertainty resolution, contextual integration	Hippocampus–ACC–PFC loop	Peaks during −400 → −150 ms (Orient phase)
Alpha (α)	8–12 Hz	Sensory gating, inhibition of irrelevant information, attentional weighting	Parietal and fronto-thalamic gating systems	Fast rise during −350 → −100 ms; overlaps Orient → Decide
Beta (β)	13–30 Hz	Motor control stability, action selection, "veto window" inhibitory function	Basal ganglia–SMA–motor cortex loop	Dominant in −150 → −50 ms; defines the decision corridor
Gamma (γ)	30–100 Hz	Precision execution, rapid motor output, feedforward sensory–motor binding	Cortical microcircuit fast loop	Onsets at ~−50 ms, peaks at 0 ms, continues into early feedback
Late Consolidation (no single band — mixed slow-wave + spindle influence)	—	Memory update, prediction strengthening, priors revision	Cortical–striatal–hippocampal consolidation pathway	Begins +100 ms; strongest +200 → +600 ms (Feedback cycle)

Delta was identified as a system-wide grounding rhythm operating throughout the entire sequence, whereas theta activity appears concentrated during uncertainty resolution and contextual integration. Alpha oscillations play a decisive role in gating and selective processing, while beta oscillations underpin action stabilisation and the veto window. Finally, gamma oscillations correlate with precision execution and motor behaviour. This mapping allowed the timing architecture to be understood not merely in terms of abstract processing sequences but as the emergent effect of interacting electrophysiological control systems.

To operationalise this temporal architecture, the process was expressed as a full FRAM model. Each hexagon represented a functional component (e.g., **Prediction Error Detection**, **Attention Allocation**, **Action Selection**, **Outcome Evaluation**, **Feedback Archive**), and each function was linked through its Inputs, Outputs, Preconditions, Controls, Resources, and time-dependencies.

Unlike linear cognitive models, FRAM depicts behaviour as an evolving landscape of couplings—where variability, uncertainty, and resonance shape which pathways propagate and which are suppressed. In this context:

- The **reticular sensory gate** regulates entry conditions.
- The **internal model** provides context-dependent priors.
- **Theta and beta loops** determine whether updating continues or stabilises.
- **The veto window** marks a final inflection point between potential and commitment.
- **Gamma feedback loops** support execution precision and adaptive correction.

This FRAM system model (Figure 1) captures not only *how* volition emerges, but also *how it fails*, adapts, or deviates. It provides a tangible simulation framework capable of exploring neurodiversity, fatigue, training, disorder, or artificial augmentation.

The full list of the functions modelled is given in Table 2 (Appendix)

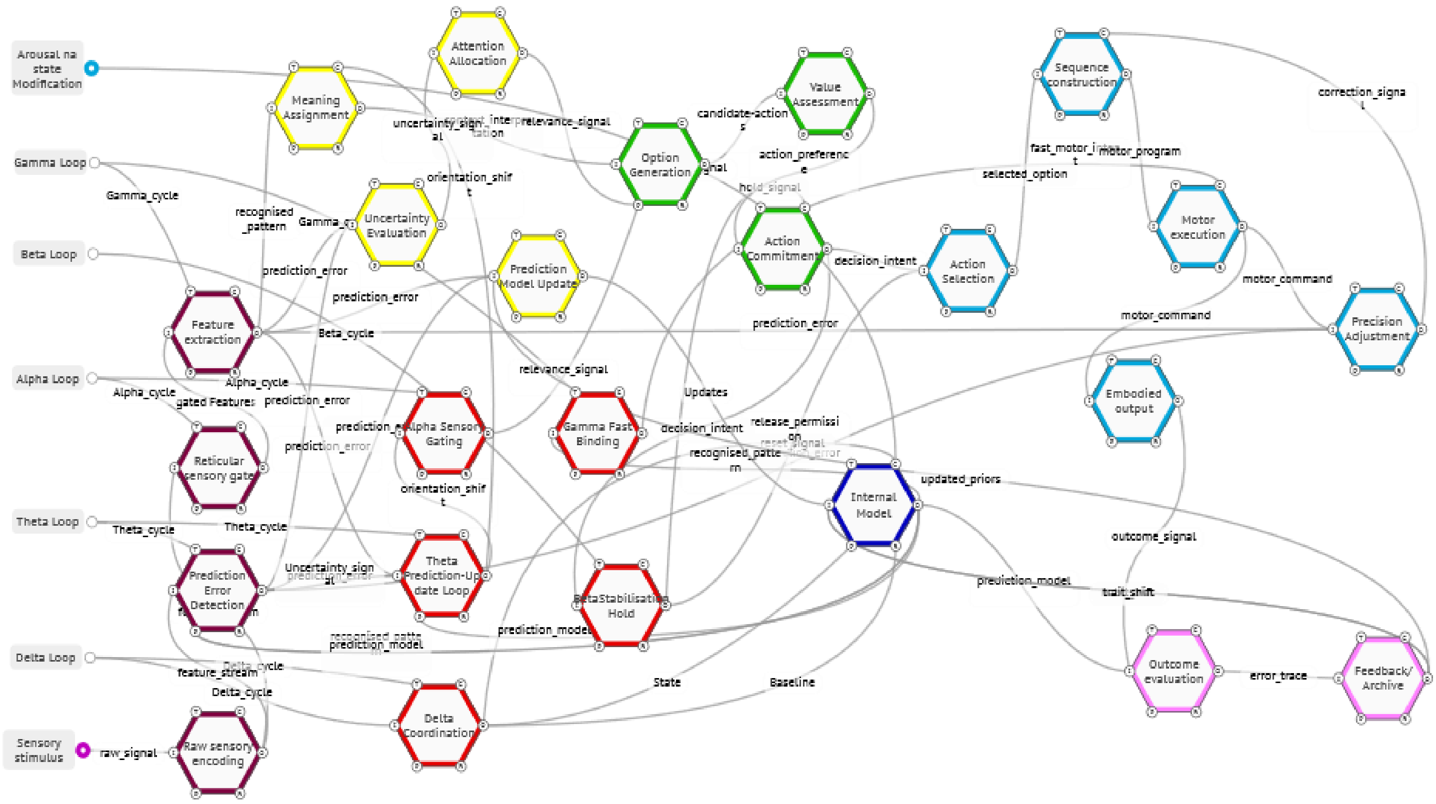

Figure 1.

Functional architecture of volitional cognition expressed as a FRAM model.

Each node represents a cognitive function with associated input, output, control, resource and temporal aspects. The model illustrates the distributed and non-linear nature of volitional processing.

In this representation, cognitive functions are shown not as steps in a sequence but as interconnected nodes whose activation depends on conditions, resources, controls, and temporal coupling. The model highlights the distributed nature of the system: sensory encoding, prediction mechanisms, attentional regulation, action selection, execution and feedback integration all exist as functional units whose relationships vary according to internal context and external demands. This perspective reframes decision-making as an emergent activity arising from heterogeneous interactive subsystems rather than a linear deliberative chain.

The next step was to situate this functional system within a temporal frame grounded in neurophysiological evidence. Figure 2 provides this scaffold.

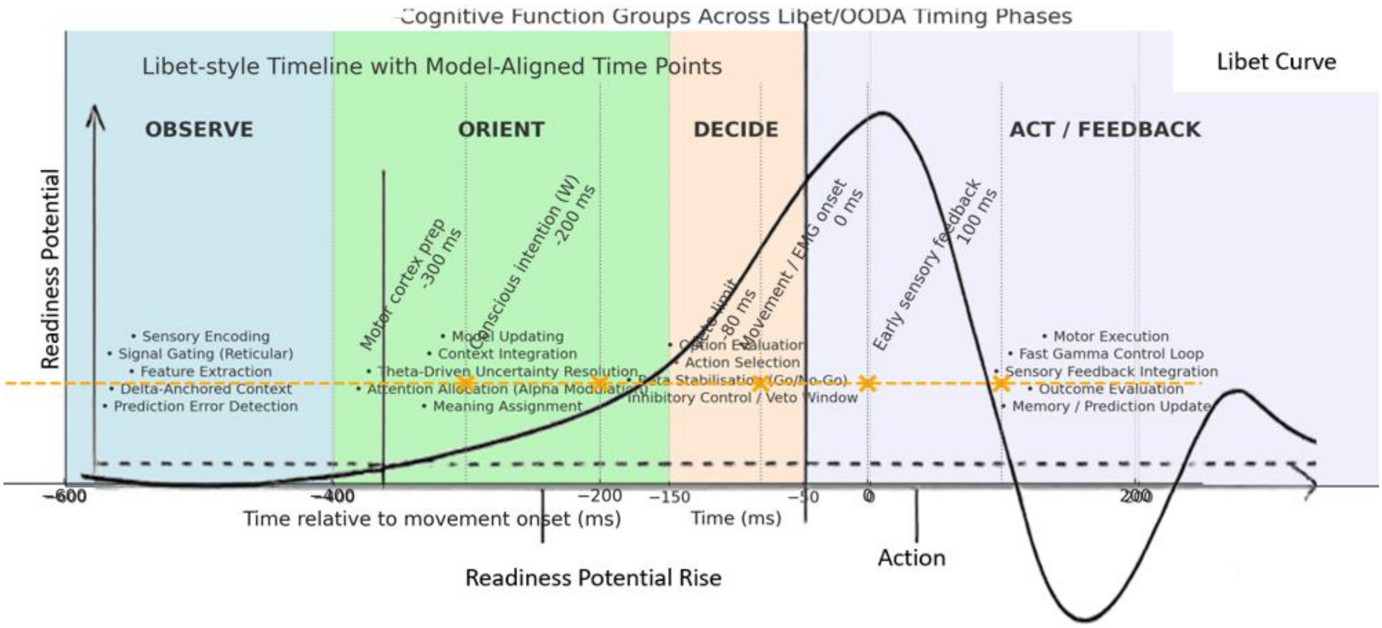

Figure 2.
Libet-style temporal model aligned with OODA phases and cognitive function groupings.

The readiness potential curve and key timing events (RP onset, conscious intention, veto window and movement onset) are aligned with operational cognitive phases.

Based on Libet's experimental findings, the figure depicts the readiness-potential (RP) buildup beginning several hundred milliseconds before movement onset, the emergence of conscious intention (Libet's "W"), the final selection corridor in which actions may still be aborted, and the execution point. Superimposed on this are the OODA phases, revealing that the familiar operational cycle of Observe, Orient, Decide and Act is not metaphorical but corresponds closely to the unfolding time course of volitional processing. The Observe phase aligns with unconscious sensory and preparatory neural activity, the Orient phase emerges alongside prediction updating and meaning-assignment mechanisms, the Decide phase maps onto the inhibition–selection corridor, and the Act phase includes both motor execution and early sensory feedback.

Table 3 subsequently integrated the three frameworks — Libet's timing markers, the OODA stages, and the FRAM functions — into a single alignment matrix. This table highlights the interdependence of neural dynamics, functional behaviour, and systems-theoretic decision modelling.

For example, the emergence of conscious intention at approximately −200 ms coincides with the alpha-to-theta crossover in dominance, suggesting a threshold between relevance gating and contextual recomputation. Likewise, the veto corridor aligns with a period of beta-mediated stabilisation, indicating that the decision is neither instantaneous nor deterministic but mediated through oscillatory regulatory processes. The post-action rebound, often overlooked in Libet discussions, appears to play a functional role in updating priors and calibrating future predictions

Table 3 — Temporal Alignment Between Libet Findings, OODA Phases, and FRAM Activity

Libet Timing Landmark	Approx. Time (ms)	OODA Phase	Dominant FRAM Function(s)	Interpretation
Readiness Potential Onset	~−550 to −800	Observe	F1, F2, early F3	System begins preparing before awareness; unconscious ramp
Pre-motor cortex activation	~−300	Orient	F3 → F4 → F5	Meaning and relevance are being shaped; prediction updating engaged
Conscious Intention ("W")	~−200	Orient → Decide transition	Peak F4 and strong F5	Awareness emerges as threshold crossing of integrated prediction
Libet Veto Corridor	−150 to −50	Decide	F6 dominant	Action may still be stopped or revised; inhibition is possible
Action Execution	0	Act	F7 → F8	The motor command is triggered; system commits
Sensory Feedback	+50 to +150	Feedback	F9	Outcome evaluation begins; mismatch detection
Memory Update / Future Biasing	+200 to +600	Feedback → Reset	F10	Priors strengthened; next cycle influenced

The tables therefore serve as more than summaries: they demonstrate convergence between three distinct disciplinary models — one experimental (Libet), one operational (OODA), and one systemic (FRAM). What was originally a theoretical juxtaposition has now evolved into a temporally aligned cognitive architecture with explicit functional and oscillatory correlates. In this form, the system becomes suitable not only for conceptual reasoning but for simulation, FRAM-HAZOP analysis, metadata assignment, and eventually for digital-twin implementations where variability, delay, and functional resonance can be quantified.

Taken together, the results show that volitional behaviour is neither instantaneous nor purely conscious. Instead, it emerges from a temporally layered interaction between unconscious build-up, predictive updating, attentional gating, executive stabilisation, embodied execution, and post-hoc reflection. Each of these processes can now be represented functionally, temporally, and electrophysiologically — and has been embedded within a FRAM model that reflects these dependencies explicitly.

Conclusion: Toward a Science of Applied Volition

What emerges from this work is a shift in how volition and cognition can be understood—not as the product of isolated neural centres, but as the coordinated activity of distributed functional assemblies capable of synchronising into transient, system-wide cascades. The FRAM-based approach developed here highlights that intention, decision, and action are not driven by individual modules such as the thalamus, hippocampus, amygdala, or cortex acting alone. Instead, they arise from dynamically coupled ensembles, where multiple regions resonate through shared oscillatory rhythms, forming temporary coalitions that shape behaviour.

This perspective aligns with contemporary evidence of neuronal avalanches and large-scale network synchronisation, where the brain transitions between states through brief but coherent surges of activity. In this framing, learned and innate behavioural patterns are not rigidly encoded "programs" but emergent pathways that become accessible when the system enters the right resonance conditions. The timing architecture described in this study—grounded in Libet physiology, structured through the OODA loop, and operationalised via a FRAM model—illustrates how these resonances both constrain and enable action selection, veto, execution, and learning.

The implications are substantial. By replacing the doctrine of localisation with a model of distributed synchronisation, we gain a more accurate foundation for interpreting intentional behaviour, agency, and adaptive control. Disorders of volition can now be conceptualised not as damage to discrete centres but as disruptions in coupling, rhythm, and functional coordination. Likewise, interfaces between biological cognition and artificial systems—whether clinical, assistive, or augmentative—can be designed to align with the brain's temporal orchestration rather than impose linear procedural logic on a system that is anything but linear.

In this sense, the contribution of this work is not merely descriptive but generative: it offers a framework capable of simulation, interrogation, and refinement. It suggests that the brain's capacity for will, inhibition, choice, and change is inseparable from the dynamic organisation of distributed functional networks acting in synchrony across time. If earlier models asked *where in the brain decisions happen*, this framework asks a deeper and more fruitful question: *under what conditions does the system organise itself into a state capable of deciding*?

This does not end the inquiry—it marks the point where the model becomes an instrument for future investigation. Through iterative refinement, empirical testing, and digital-twin simulation, the approach outlined here may help transform the study of volition from a philosophical problem into an operational science of adaptive human agency.

Future work will expand this into a computational model capable of iterative refinement and real-time simulation. The potential is substantial: by understanding how volition unfolds, we may learn not only how humans act—but how they *could* act better.

This is not the end of the investigation. It is the point at which the model becomes usable.

Appendix : Table 2 – The FRAM Functions Used.

#	Function Name	System Role	Functional Domain	Notes
1	Raw Sensory Encoding	Entry / Source	Sensory	Converts external input to neural representation
2	Reticular Sensory Gate	Filter / Control	Arousal & Attention	Modulates input based on salience
3	Feature Extraction	Transform	Perception	Extracts patterns and primitives
4	Prediction Error Detection	Comparator	Predictive Coding	Compares sensory input with predicted state
5	Delta Coordination Loop	State Regulation	Oscillatory / Regulatory	Anchors context and bodily baseline

#	Function Name	System Role	Functional Domain	Notes
6	Delta-Anchored Context	Stabiliser	Internal Model Priming	Provides slow contextual prior
7	Theta Prediction Update Loop	Updating Process	Predictive Coding	Adjusts priors when mismatch detected
8	Alpha Sensory Gating	Noise Suppression	Attention / Perception	Filters irrelevant or low-value signals
9	Attention Allocation	Resource Assignment	Executive Control	Directs limited cognitive bandwidth
10	Meaning Assignment	Interpretation	Semantic / Cognitive	Converts patterns to interpreted significance
11	Uncertainty Evaluation	Monitoring	Metacognition	Estimates ambiguity / confidence
12	Prediction Model Update	Model Revision	Internal Model	Refines predictive schema
13	Option Generation	Planning	Decision Architecture	Produces candidate actions
14	Value Assessment	Evaluation	Expected Utility	Cost/benefit evaluation of options
15	Action Commitment	Thresholding	Executive Control	Signals pending action
16	Action Selection	Switch / Output Gate	Decision Resolution	Locks selected behaviour
17	Beta Stabilisation / Hold	Motor Inhibition	Motor Control	Maintains suppression until release
18	Gamma Fast Binding	Action Binding	Motor Integration	Rapid temporal coupling before execution
19	Sequence Construction	Motor Planning	Procedural Motor	Builds movement program structure
20	Motor Execution	Output Function	Motor System	Executes selected action
21	Precision Adjustment	Control Refinement	Closed-Loop Control	Corrective feedback during action
22	Embodied Output	Physical Output	Body Interface	Observable movement
23	Sensory Feedback Integration	Feedback	Interoception & Exteroception	Converts outcome into evaluative data
24	Outcome Evaluation	Comparator / Learning	Adaptive Control	Judges correctness, success, and error
25	Feedback Archive	Learning / Memory	Plasticity & Consolidation	Stores adaptive traces and experience