

Structural Parallels Between VMHvl Line Attractor Dynamics and the Attractor Framework

Robert Galida

Independent Researcher

June 2026

fantasyattractor.com

Abstract

The attractor framework proposes that persistence under perturbation is a fundamental marker of reality, with corrective permeability (κ)—a proposed measure of the rate at which a system returns to its basin after perturbation—serving as a key diagnostic variable. Nair et al. (2023) discovered an approximate line attractor in the ventromedial hypothalamus (VMHvl) of mice that encodes an escalating aggressive state. The line attractor exhibits a single integration dimension with a long time constant that correlates with individual differences in aggressiveness. This paper identifies structural parallels between the VMHvl line attractor and the attractor framework. Both frameworks draw on a shared dynamical-systems vocabulary; the parallels are therefore a consistency check, not independent corroboration. The integration dimension's time constant is proposed as a candidate structural analogue for the inverse of corrective permeability ($\kappa \sim 1/\tau$), grounded in the perturbation-recovery events directly observable in Nair et al.'s data. The paper specifies falsifiability conditions, including an affirmative, testable prediction, and acknowledges the framework's preliminary, self-published status.

1. Introduction: Shared Vocabulary, Not Convergence

The attractor framework (Galida, 2026a, self-published May 2026 at fantasyattractor.com; no DOI) proposes that dissipative attractors—stable basins toward which systems converge and from which they resist displacement—are the fundamental units of persistent organization across physical, biological, cognitive, and social domains. Corrective permeability (κ) is a proposed measure of the rate at which a system returns to its basin after perturbation. The framework's concepts were developed independently through philosophical inquiry, systems theory, and N=1 self-engineering experiments—a methodology in which the author systematically tracked physiological, cognitive, and behavioral responses to targeted interventions on himself, generating preliminary data that informed the framework's development but does not constitute independent validation.

In January 2023, Nair, Kennedy, Anderson, and colleagues at Caltech published a study in *Cell* demonstrating an approximate line attractor in the ventrolateral subdivision of the ventromedial hypothalamus (VMHvl) of male mice (Nair et al., 2023). Using calcium imaging and dynamical systems modeling, they showed that neural population activity in VMHvl converges toward and progresses along a stable trough in neural state space, and that the position of activity along this trough correlates with the intensity of aggressive behavior.

Both the framework and the Nair et al. study use the vocabulary of dynamical systems—"attractor," "basin," "time constant." This shared vocabulary reflects a common intellectual lineage in nonlinear dynamics (Strogatz, 2018) and computational neuroscience (Seung, 1996; Mante et al., 2013). The parallels identified in this paper are therefore a

consistency check, not independent corroboration. The framework imported these concepts; it did not invent them. The relevant question is whether the framework's specific claims—about κ , basin depth, and cross-domain generalization—find structural analogues in the VMHv1 circuit that are non-tautological. This paper explores that question while acknowledging its limitations.

2. The VMHv1 Line Attractor

Nair et al. (2023) fit recurrent switching linear dynamical system (rSLDS) models to calcium imaging data from VMHv1Esrl neurons during social interactions. Their unsupervised analysis revealed a dominant integration dimension with a time constant exceeding 50 seconds—significantly longer than all other dimensions. This dimension accounted for approximately 20% of the total variance in neural activity.

The integration dimension exhibited slow ramping as aggression escalated, rising from low values during sniffing to intermediate values during dominance mounting to high values during attack. Once elevated, activity persisted for tens of seconds after the intruder was removed, decaying slowly along the attractor. When a new intruder was introduced, neural activity was transiently displaced from the attractor but rapidly returned to its previous position along the trough.

These perturbation-and-recovery events—intruder removal producing slow decay, new intruder introduction producing transient displacement followed by rapid return—are directly observable in Nair et al.'s Figure 3C–3D and Supplementary Videos 1 and 2. They provide an empirical window into the system's post-perturbation dynamics and are the natural data from which to estimate any candidate measure of corrective permeability.

Individual mice varied substantially in the time constant of their integration dimension. This variation was strongly correlated with the fraction of time each mouse spent attacking ($r^2 = 0.77$, $n = 14$ animals). Mice with longer time constants were more aggressive. It should be noted that alternative explanations for this correlation exist: testosterone and other androgens influence both VMHvl activity and aggressiveness, and individual differences in circuit excitability could produce both a longer time constant and more aggressive behavior. The time constant–aggression link is robust but not uniquely explained by attractor depth.

3. Structural Parallels with the Attractor Framework

3.1 The Line Attractor as a Basin. The line attractor is a stable region of neural state space toward which population activity converges and along which it progresses slowly. This is structurally analogous to the framework's concept of a basin—a configuration toward which the system gravitates and from which it resists displacement.

3.2 Integration Time Constant and Corrective Permeability (κ). The framework defines κ as a proposed measure of the rate at which a system dissipates perturbation and returns to its basin. As currently formulated, κ is qualitative and lacks a formal derivation from the framework's axioms. Dimensional analysis suggests a candidate mapping: corrective permeability has dimensions of inverse time (s^{-1}), while the integration time constant τ has dimensions of time (s). A natural structural analogue is $\kappa \sim 1/\tau$. Under this mapping, longer time constants (slower decay) correspond to lower κ (deeper persistence), and shorter time constants correspond to higher κ (faster recovery).

This dimensional argument is necessary but not sufficient. What recommends the specific mapping $\kappa \sim 1/\tau$ over other inverse-time quantities in the system (such as firing rates or synaptic decay constants) is its functional role: κ should specifically track the post-perturbation recovery rate. Nair et al.'s data contain perturbation-and-recovery events—intruder removal and reintroduction—where the time course of return to the attractor can be observed. The integration time constant τ directly governs the rate of this return. It is therefore the natural candidate for a functional, not merely dimensional, analogue. This mapping is a hypothesis, not a derivation. It is offered as a bridge for future formal work.

The observed correlation between the time constant and individual differences in aggressiveness is *consistent with* the framework's prediction that variation in κ may be associated with variation in persistent behavioral traits. It does not independently confirm that prediction.

3.3 Graded Position Along the Attractor as Intensity Encoding. The framework describes attractors as graded landscapes: a system can occupy different positions within a basin, each corresponding to a different state intensity. The VMHvl line attractor demonstrates this property: sniffing, dominance mounting, and attack occur at progressively higher values along the integration dimension.

3.4 Persistence and Resistance to Perturbation. When the intruder is removed, activity decays slowly rather than collapsing immediately. When a new intruder is introduced, activity is transiently displaced but returns to its prior position along the trough. This is a structural analogue of persistence under perturbation.

3.5 Leaky Integration Is Not Thermodynamic Dissipation. Nair et al. describe the VMHvl attractor as “leaky”—activity decays over tens of seconds rather than persisting indefinitely. The

attractor framework uses “dissipative” in a thermodynamic sense: a dissipative system exports entropy to its environment and is maintained by continuous energy flow. These are distinct concepts. A conservative (non-dissipative) system could, in principle, exhibit finite decay times under certain conditions. The framework’s “dissipative attractor” and the neurobiological “leaky integrator” share a structural property—finite persistence—but they are not identical in their underlying mechanisms. This distinction should be kept in view to avoid terminological conflation.

4. Rotational Dynamics as a Contrasting Geometry

Nair et al. also analyzed MPOA, a different hypothalamic nucleus controlling mating. They found no line attractor. Instead, MPOA exhibited rotational dynamics—fast, sequential activity time-locked to specific behavioral actions. This contrast demonstrates that not all neural circuits exhibit line attractor geometry.

The framework can accommodate this contrast as an instance of a broader principle: circuits encoding *scalable, persistent states* (such as the intensity of aggressive motivation) are predicted to exhibit line or point attractor geometries, while circuits encoding *sequential action programs* (such as the progression from sniffing to mounting to intromission) are predicted to exhibit rotational or heteroclinic dynamics. The VMHvl/MPOA contrast is consistent with this generalization. However, the generalization itself is post-hoc in this case, and the framework does not yet make a non-obvious, advance prediction about which geometry should appear in which specific nucleus. The contrast is therefore a productive organizing principle for future neural circuit taxonomy, not a confirmed prediction.

5. Limitations

This mapping is post-hoc. The parallels identified here are structural analogies, not independent evidence for the framework. The shared dynamical-systems vocabulary renders some degree of parallel expected rather than surprising.

The framework's κ remains qualitatively defined. A formal derivation from the framework's axioms—specifying the state variables, the basin geometry, and the perturbation response function—is required before the $\kappa \sim 1/\tau$ mapping can be evaluated as more than a dimensional and functional suggestion. Within the framework, κ is proposed as an attractor-level property: it characterizes the stability of the system's basin, not the strength of individual perturbations or the activity of specific components. It is derived from the persistence of a configuration under perturbation, measured as the rate of return to the attractor after displacement. A full formal derivation remains a task for future work.

The attractor framework is self-published and has not undergone independent peer review. The foundational paper (Galida, 2026a) was published on fantasyattractor.com in May 2026 and is not archived with a DOI, which limits the independent verifiability of the framework's claims and the timeline of its development.

6. Falsifiability Conditions

The following observations would weaken or invalidate the parallels drawn here:

- **Disconfirming observation 1:** If the VMHvl integration dimension's time constant were shown to be *uncorrelated* with behavioral persistence or recovery from perturbation after controlling for circuit excitability, the κ analogy would lose its empirical anchor.
- **Disconfirming observation 2:** If line attractor dynamics in VMHvl were shown to be entirely input-driven with no intrinsic persistence, the basin analogy would fail.
- **Disconfirming observation 3:** If alternative models of aggressiveness (e.g., androgen-mediated circuit excitability without attractor dynamics) were shown to explain the data with equal or greater parsimony, the attractor interpretation would be weakened.

Affirmative prediction: If $\kappa \sim 1/\tau$ is more than a dimensional coincidence, then pharmacological or optogenetic manipulations that prolong the integration time constant should produce corresponding increases in aggressive persistence—the tendency to maintain an escalated aggressive state *after the stimulus is removed*—without necessarily lowering the threshold for aggressive *initiation*. Conversely, manipulations that shorten the time constant should produce corresponding decreases in aggressive persistence. This dissociation between persistence and initiation is specifically predicted by the framework's claim that κ governs recovery from perturbation, not the threshold for entering the state, and distinguishes the attractor interpretation from alternative models in which circuit excitability uniformly modulates both initiation and persistence. Aggressive persistence should be operationalized as the latency to cease aggressive posturing or the duration of elevated VMHvl activity following intruder removal, rather than as the overall fraction of time spent attacking, which confounds initiation and persistence. It should be noted that experimentally dissociating these phases in the VMHvl circuit may be technically challenging, as the neurons involved are

active during both ramp-up and post-attack periods. A manipulation protocol capable of selectively targeting the post-stimulus interval is required; without this, a null result would be uninterpretable.

7. Conclusion

The VMHvl line attractor discovered by Nair et al. (2023) exhibits structural parallels with the attractor framework's description of a graded, persistent basin. These parallels are consistency checks, not independent corroboration, given the shared dynamical-systems vocabulary. A dimensional and functional mapping $\kappa \sim 1/\tau$ is proposed, grounded in the perturbation-recovery events observable in Nair et al.'s data. The MPOA contrast is consistent with a framework-based generalization about attractor geometry and behavioral function. The paper specifies both disconfirming and affirmative testable predictions. The framework remains a self-published, preliminary research program. This mapping is a contribution to its ongoing development.

References

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