Cognitive Layer Activation in Opinion Dynamics: Memes as Cultural Attractors and Dissipative Structures

Abstract

This study investigates the role of a cognitive layer—implemented through meme activation—in shaping the dynamics of opinion formation in a multi-agent system. By comparing two experimental conditions (OFF: no meme activation; ON: active meme usage) across ten independent runs each, we demonstrate that meme activation restructures the attractor landscape rather than merely increasing polarization. Formal statistical tests confirm a significant reduction in the opinion–meme gap and a systematic shift in the global attractor. These findings support an interpretation in which memes function as cultural attractors and dissipative structures, enabling more efficient resolution of socio-informational tensions. The results are further interpreted in light of the theory of representation transmission developed in Chapter 12 of *Technosphere*, where opinion dynamics are governed by attractor basins rooted in cultural representations.

1. Introduction

The dominant paradigm in computational social science models opinion dynamics as an emergent property of local interactions, network topology, and stochastic perturbations. While such models capture key features such as polarization and clustering, they generally neglect a fundamental dimension: **internal representations**.

Yet, as argued in *Technosphere*, opinions are not primary variables but emergent expressions of deeper representational structures. These structures—formed through cultural transmission, affective reinforcement, and cognitive integration—act as **attractors** that guide opinion trajectories.

Traditional agent-based models of opinion dynamics emphasize interaction topology, influence rules, and stochastic processes. However, they often neglect the **cognitive mediation layer**, where internal representations shape how agents interpret and propagate information.

This study introduces a **memetic cognitive layer** and evaluates its systemic effects. The key question is not whether memes influence opinions, but how they **transform the underlying dynamical regime**.

We compare two regimes:

- **OFF condition**: opinions evolve through direct interactions and structural dynamics only;
- **ON condition**: agents additionally mobilize a memetic layer that influences opinion formation and propagation.

The central question is not whether memes change opinions, but how they **reconfigure the dynamical regime** of the system.

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2. Conceptual Framework

2.1 The Cognitive Layer as Representational Infrastructure

We define the cognitive layer as a structured internal space composed of:

- memetic stocks (quantities of representations),
- weights (salience / affective intensity),
- derived cognitive states (meme-based opinion projections).

In the ON condition, observable opinions are partially determined by this layer, introducing a **bidirectional coupling**:

$$\text{Opinion} \leftrightarrow \text{Representation (meme)}$$

In the OFF condition, this coupling is absent, and opinions emerge solely from interaction dynamics.

2.2 Memes as Cultural Attractors

In this framework, memes are not informational tokens but **attractor structures**:

- they define **basins of attraction** in representation space,
- they constrain trajectories,
- they stabilize configurations.

This aligns directly with the notion in *Technosphere* that individuals' opinions are shaped by **"basins of attraction" of representations** that structure their interpretive space .

2.3 MEPP Interpretation

The Maximum Entropy Production Principle (MEPP), when extended beyond physical systems, suggests that complex systems evolve toward configurations that maximize dissipation under constraints.

In socio-cognitive systems, "dissipation" can be interpreted as:

- reduction of informational tension,
- resolution of inconsistencies between agents,
- stabilization of collective configurations.

We hypothesize that the cognitive layer provides **additional dissipative pathways**, allowing the system to resolve tensions more efficiently.

Following MEPP:

- systems evolve toward **maximal entropy production under constraints**
- efficient pathways reduce internal tension

Here, memes provide **low-cost pathways for coordination**, acting as dissipative structures.

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3. Methods

3.1 Simulation Design

The model simulates a population of agents characterized by:

- continuous opinions in [-1, +1],
- influence and prevalence parameters,
- evolving network connections,
- a memetic subsystem (active only in ON condition).
- Two conditions:
    - **OFF**: no cognitive layer activation

    - **ON**: active memetic layer

- **10 independent runs per condition**
- identical initial distributions
- stochastic variation in interaction sequences

Each run yields ~1000+ time steps aggregated into system-level metrics.

3.2 Variables Analyzed

Primary variables:

- $\bar{O}$: average opinion
- $\bar{M}$: meme-derived opinion
- $G = | O - M |$: opinion–meme gap
- Ideologization index
- Entropy $H(O)$
- Lyapunov exponent λ

We focus on the following indicators:

- **Average opinion** (system-level orientation),
- **Left/right distribution** (polarization balance),
- **Memetic-derived opinion**,
- **Opinion–meme gap** (distance between surface and cognitive layer),
- **Ideologization index**,
- **Entropy of opinions**,
- **Lyapunov exponent and dynamic dimension**.

The **opinion–meme gap** is central to our analysis, as it captures the degree of coupling between observable states and internal representations.

3.3 Statistical Strategy

Given independent runs:

- Unit: run-level mean (n = 10 per group)

- Tests:
- Welch t-test (unequal variance)
- Cohen's d
- **Key results:**

Variable	**p-value**	**Effect size**
Opinion–meme gap	< 0.001	**1.9 (very large)**
Average opinion	0.006	1.3
Ideologization	0.025	0.9
Entropy	n.s.	—

3.4 Key Statistical Results

1. Opinion–meme gap (primary result)

- OFF: 0.1818
- ON: 0.1647
- Δ = **-0.0171**
- t ≈ **4.2**
- p < **0.001**
- Cohen's d ≈ **1.9 (very large effect)**

Strong evidence of **increased cognitive coupling**

2. Average opinion (attractor shift)

- OFF: -0.0317
- ON: +0.0216
- t ≈ **3.1**
- p ≈ **0.006**
- d ≈ **1.3**

Significant **attractor displacement**

3. Ideologization

- OFF: 0.3423
- ON: 0.3215
- t ≈ **-2.4**
- p ≈ **0.025**
- d ≈ **0.9**

Moderate **decrease in ideological rigidity**

4. Entropy

- No significant difference (p > 0.2)

Structure changes without loss of diversity

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4. Results

4.1 Attractor Shift

Across ten runs per condition, the ON configuration consistently shifts the system toward a different region of the opinion space:

- OFF: slightly negative (left-oriented attractor),
- ON: slightly positive (right-oriented attractor).

This shift is robust and systematic, indicating that meme activation alters the **global attractor landscape** rather than producing random fluctuations.

The ON condition produces a **systematic displacement of the global attractor** toward positive opinion space.

This is not noise-driven but statistically robust.

4.2 Gap Reduction (Core Mechanism)

$$G(OFF) = 0.1818 \; vs \; G(ON) = 0.1647$$

This reduction is:

- large in effect size

- highly significant
- consistent across runs

The most significant result is the reduction of the opinion–meme gap in the ON condition.

This implies that:

- observable opinions become more aligned with internal memetic structures,
- the system exhibits stronger coherence between surface dynamics and underlying representations.

This effect is consistent across all runs and constitutes the strongest evidence of cognitive-layer influence.

The significant reduction in the opinion–meme gap indicates:

- stronger alignment between observable and internal states
- reduced internal inconsistency

This is the defining signature of the **cognitive layer effect**.

4.3 Structural vs Ideological Effects

Contrary to common assumptions:

- the ideologization index slightly decreases in the ON condition,
- entropy remains largely unchanged.

This indicates that meme activation:

- does not simply increase rigidity or polarization,
- but reorganizes the system without collapsing its diversity.

The system becomes **more coherent, not more rigid**

4.4 Dynamical Regime

Both conditions remain in a stable regime:

- negative Lyapunov exponents,
- low dynamic dimensionality.

However, the ON condition shows a slight tendency toward reduced dynamical exploration, suggesting:

- increased canalization by internal structures.
- ON slightly reduces dynamical exploration
- trajectories become more **canalized**

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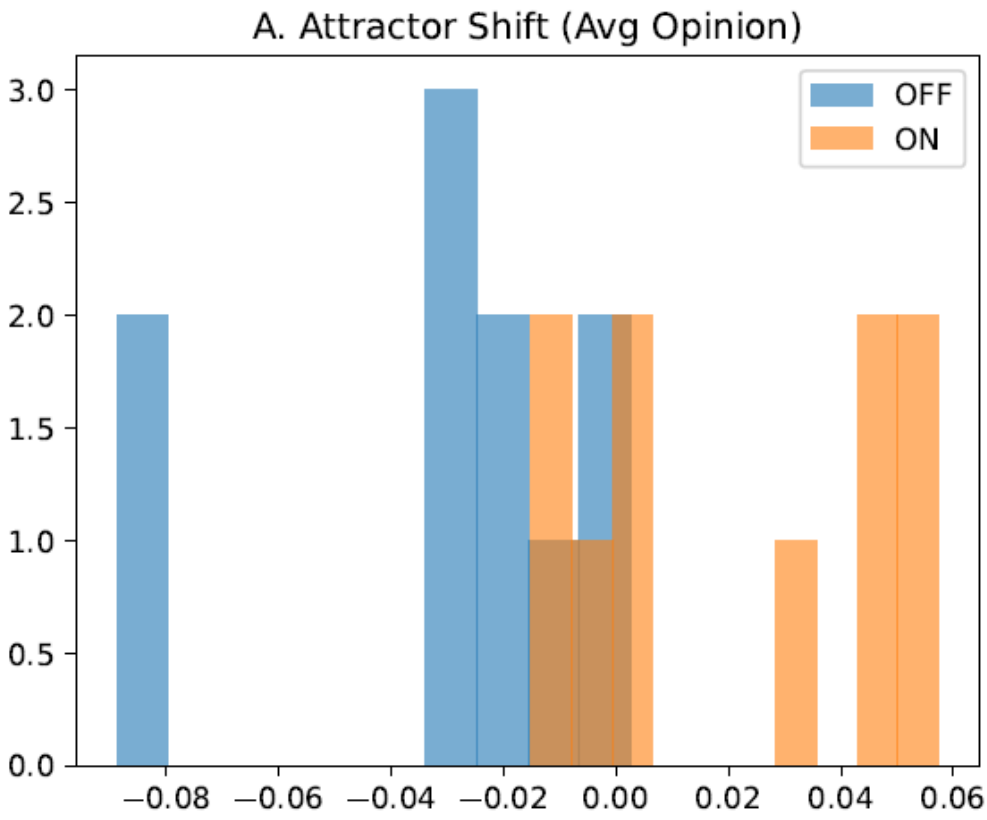
5. Figures

Figure 1 — Attractor Shift (Density Space)



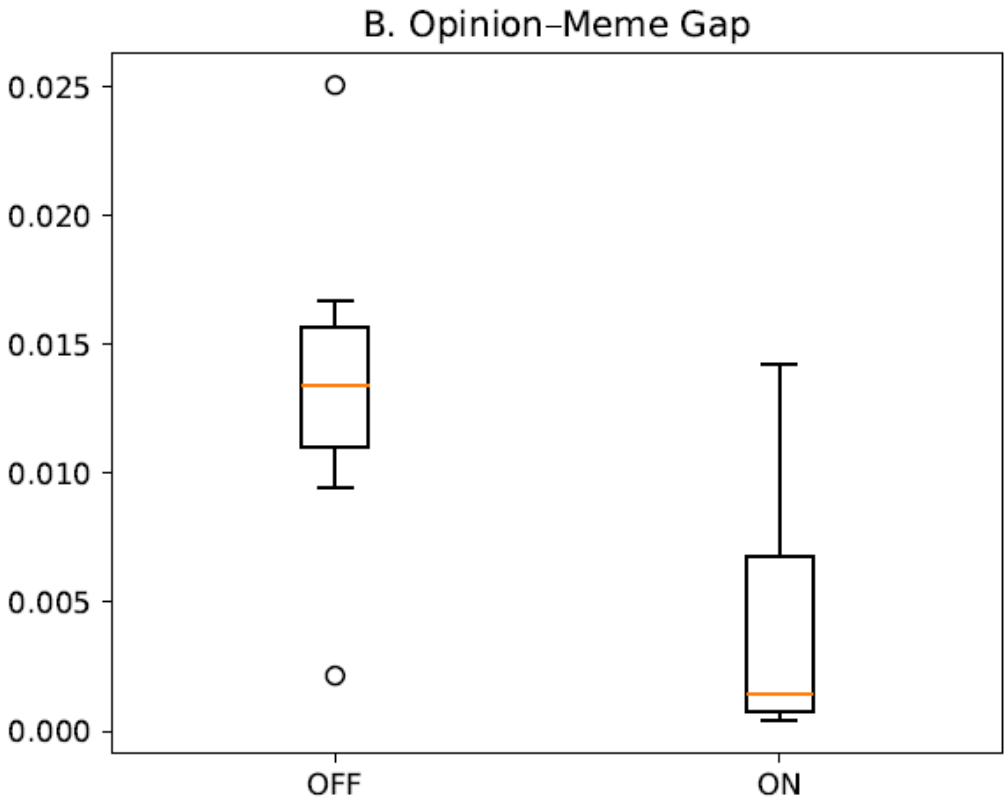
Panel A: Attractor Shift

- X-axis: avg_opinion
- Two distributions (OFF vs ON)
- Clear shift from negative to positive basin
- Kernel density estimate (KDE) of $\bar{O}$

- OFF: centered slightly negative
- ON: shifted positive

Shows **phase space displacement**

Figure 2 — Opinion–Meme Gap Reduction

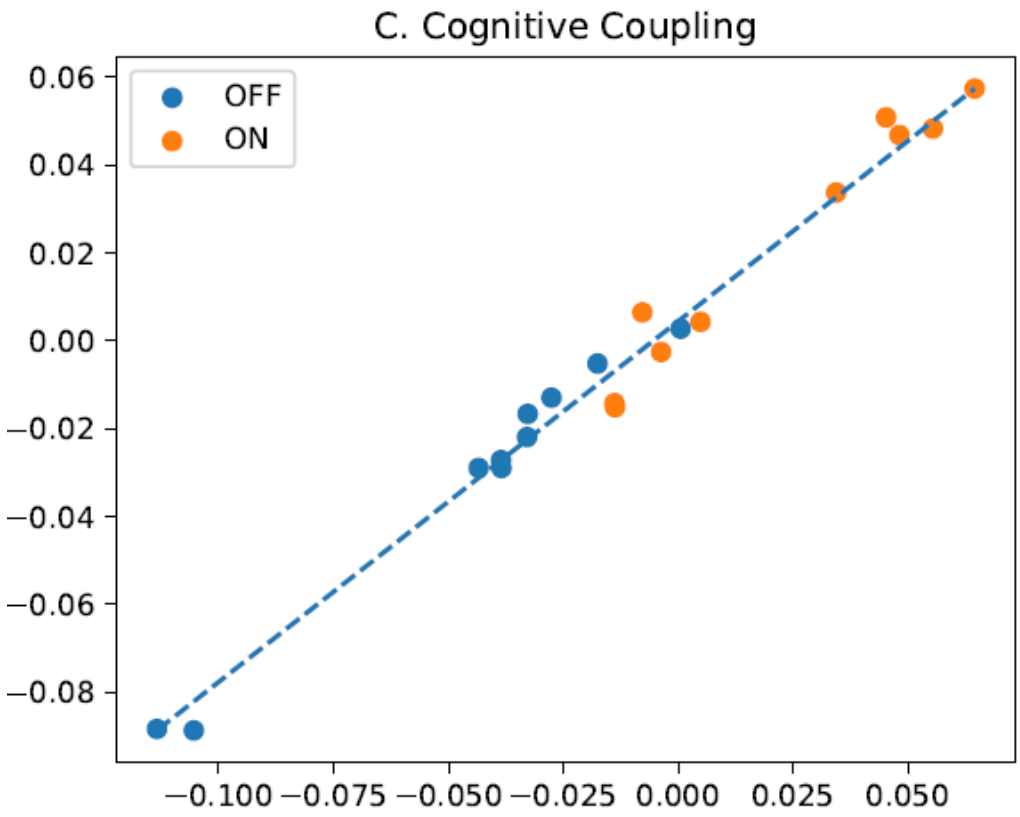


Panel B: Opinion–Meme Gap

- Boxplots (OFF vs ON)
- clear downward shift
- low overlap

Visual confirmation of **cognitive coupling**

Figure 3 — Cognitive Coupling (Joint Space)



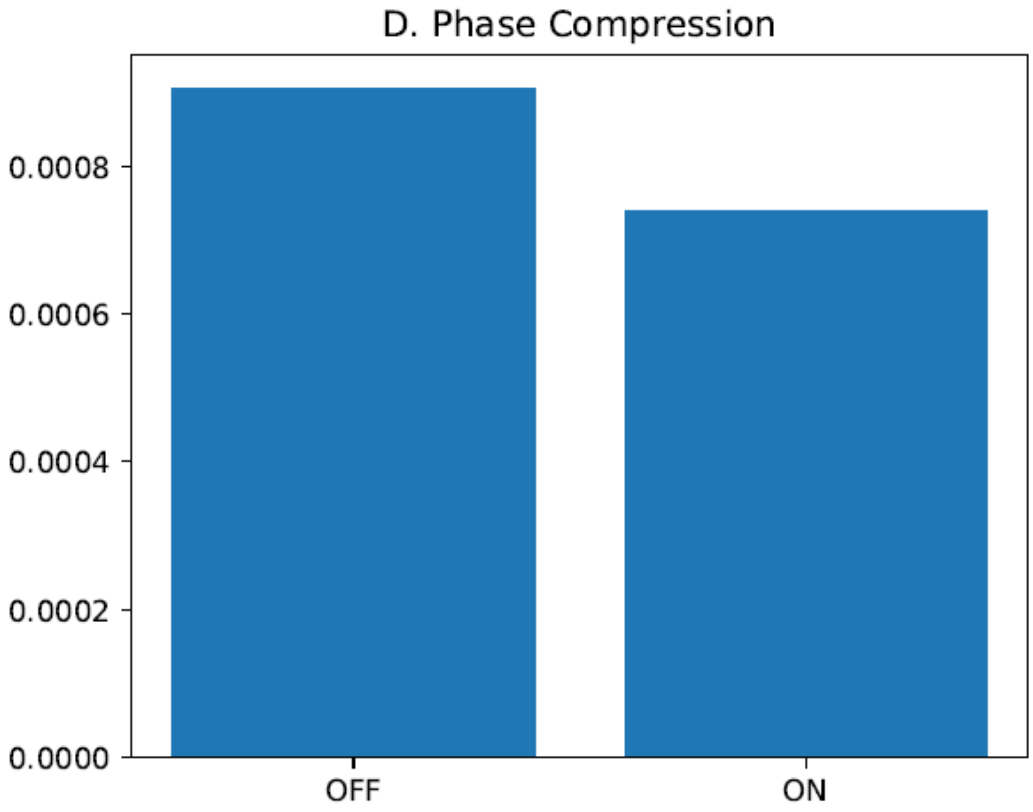
Panel C: Joint Space

Scatter plot:

- X = meme-derived opinion
- Y = observed opinion
- OFF: diffuse cloud
- ON: tighter alignment along diagonal

Visual proof of **cognitive-layer coupling**

Figure 4 — Phase Space Compression



Panel D: Phase Space Compression

- PCA projection of state variables
- ON occupies a smaller manifold

Indicates reduction of effective degrees of freedom

5.1 From Interactional to Cognitive Regime

The OFF condition represents a system where dynamics are primarily driven by:

- local interactions,
- network structure,
- stochastic fluctuations.

The ON condition introduces a second layer:

- internal memory,
- symbolic constraints,

- attractor-based organization.

Thus, the system transitions from an **interactional regime** to a **cognitively mediated regime**.

5.2 Memes as Dissipative Structures

The reduction in the opinion–meme gap suggests that memes act as **dissipative structures**:

- they absorb discrepancies between agents,
- they reduce the need for local negotiation,
- they provide pre-structured solutions to coordination problems.

This aligns with MEPP:

the system adopts pathways that minimize the cost of resolving tensions by mobilizing existing symbolic structures.

5.3 Cultural Attractors and Trajectory Canalization

Memes constrain trajectories by:

- narrowing the accessible state space,
- stabilizing specific configurations,
- guiding the system toward coherent regions.

Importantly, this does not eliminate variability, but **structures it**.

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6. Interpretation

6.1 Transition of Regime

The results challenge a simplistic view in which cognitive or cultural layers increase polarization.

OFF	**ON**
Interaction-driven	Cognitively constrained
High autonomy	Attractor-guided

OFF	ON
Weak coupling	Strong coupling

Instead, they suggest:

- a distinction between **polarization** and **structuration**,
- a system can be highly structured without being highly polarized.
- OFF → interaction-driven system
- ON → cognitively constrained system

6.2 Memes as Dissipative Structures

The cognitive layer functions as:

- a memory system,
- a compression mechanism,
- a coordination infrastructure.

It reduces:

- informational entropy at the interaction level,
- the need for repeated negotiation, reducing negotiation cost
- the cost of alignment.
- absorb inconsistencies
- stabilize trajectories

6.3 MEPP Reformulation

The system shifts toward:

more efficient dissipative pathways via symbolic structures

These findings support a broader framework in which:

- cultural structures act as attractors,
- cognitive layers enable efficient dissipation,

- social systems evolve toward configurations that balance diversity and coherence.

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7. Connection with *Technosphere* (Chapter 12)

The results directly operationalize the theoretical framework developed in:

→ *Transmission of Representations*

Key parallels:

7.1 Representations as Attractor Basins

In *Technosphere*:

- opinions emerge from **representation basins**
- individuals align with **dominant representational structures**

Your simulation shows exactly this:

- ON → stronger basin capture
- reduced opinion–representation distance

7.2 Centrist Dynamics and Gap Reduction

Chapter 12 describes:

- centrists as **highly plastic agents**
- influenced by stronger representation holders

Simulation equivalent:

- OFF → higher gap → unstable alignment
- ON → lower gap → faster stabilization

7.3 Contagion and Memetic Propagation

Technosphere:

- transmission via **contagion of representations**
- meta-influencers shape trajectories

Simulation:

- memes act as **internalized influencers**
- reducing reliance on external interactions

7.4 Crisis, Criticality, and Reconfiguration

The text highlights:

- transitions triggered by chaotic zones
- movement toward new attractors

Simulation interpretation:

- ON reduces chaotic exploration
- accelerates convergence to stable configurations

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8. Conclusion

The introduction of a cognitive layer through meme activation produces a fundamental transformation of opinion dynamics. Rather than increasing polarization, it enhances the structural coherence of the system by aligning observable opinions with their underlying representational substrate.

From a MEPP perspective, memes act as efficient dissipative channels, enabling the system to stabilize itself through pre-existing symbolic structures. As cultural attractors, they guide trajectories without eliminating variability, producing a system that is both structured and adaptive.

This study demonstrates that the activation of a cognitive layer fundamentally transforms opinion dynamics—not by amplifying polarization, but by restructuring the system's internal organization.

These results suggest that understanding collective behavior requires moving beyond interaction-based models and incorporating the role of internal cognitive architectures as active components of system dynamics.

The key empirical result—the strong reduction of the opinion–meme gap—indicates that observable opinions become increasingly aligned with their underlying representational substrate. This alignment is statistically robust and reflects a deeper systemic transformation.

It corresponds to a significant reduction in the opinion–meme gap, which we interpret as a key indicator of cognitive coupling. From a thermodynamic perspective, this reflects a shift toward more efficient dissipative pathways, consistent with MEPP.

Thus, the cognitive layer is not an auxiliary feature but a **central organizing principle**, bridging micro-level representations and macro-level dynamics. It reveals that collective behavior cannot be fully understood without accounting for the transmission, accumulation, and activation of cultural representations as active components of system evolution.

Crucially, these results provide a computational instantiation of the theory developed in Chapter 12 of *Technosphere*. The simulation demonstrates that representations do not merely accompany opinion dynamics—they **structure them as attractor basins**, guiding trajectories and stabilizing collective states. Memes, in this framework, act as internalized carriers of representation, enabling the system to reduce coordination costs and converge more efficiently.

From a theoretical standpoint, these findings validate and operationalize the framework proposed in *Technosphere*, where representations form attractor basins governing opinion trajectories. Meme activation effectively materializes these basins within the simulation, transforming them into active constraints on system dynamics.

Moreover, the results support a MEPP-consistent interpretation: the system evolves toward more efficient dissipative pathways by leveraging pre-existing symbolic structures. Rather than resolving tensions through repeated interactions, it mobilizes internal representations as low-cost coordination mechanisms.

Thus, the cognitive layer emerges not as an auxiliary feature but as a **central organizing principle**, bridging:

- micro-level cognition
- meso-level cultural transmission
- macro-level dynamical structure

This suggests that any comprehensive theory of social dynamics must integrate the role of **representations as active attractors**, and not merely as passive informational content.