
Significance Weighting in Large Language Models and RAG: Cross-Architecture Behavioral Evidence

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Abstract

Large language models routinely operate in environments where authority is contested, identities overlap, and probabilistic inference preserves multiple plausible readings without determining which distinctions should govern analysis or action.

This paper reports empirical evidence that explicit significance weighting, formalized as an S-vector with dimensions for identity stability (Sr), operational consequence (Sc), and temporal relevance (Su) (among others) produces systematic and convergent effects on reasoning behavior across architecturally distinct language model systems.

We tested significance-guided reasoning using structured scenarios requiring resolution of contested authority where inference proved insufficient. Testing covered two system classes: four frontier conversational models and three retrieval-augmented generation systems (OpenAI GPT-5.2, Google Gemini 3.0, Anthropic Claude Sonnet 4.5, xAI Grok 4.1, NotebookLM, Claude Projects, Perplexity). All systems were evaluated under controlled conditions comparing inference-only responses with significance-weighted responses using identical scenario content.

Where reasoning traces were available, S-vector application reduced reasoning effort by 40-60% while improving completion rates. In retrieval-augmented systems, significance weighting addressed a distinct failure mode: not knowledge insufficiency, but domain collision among equally well-sourced competing truths. All three RAG systems produced identical priority orderings under significance criteria that they could not generate through inference alone, demonstrating that the framework enables principle-based resolution of cross-domain authority conflicts without narrative synthesis or institutional defaulting. All seven systems tested, spanning two architectural classes and four organizations, converged on identical operational priority orderings under significance criteria, a consensus none could generate through inference or retrieval alone.

These findings establish behavioral validity for significance weighting as a governance mechanism for semantic ambiguity in large language models. The observed effects emerged at the prompt level without architectural modification, suggesting immediate production applicability, while validating the theoretical framework for deeper integration. The results position [significance weighting](#) as a missing control layer in contemporary language model systems, one that becomes essential as retrieval breadth expands and operational deployment requires resolution of contested claims under conditions of genuine ambiguity.

1. Introduction

In a recent observation on the mathematical foundations of machine learning, Terence Tao noted ([summarized from video](#)) that "A key reason (why LLMs work so well on some tasks and fail on others) is the nature of real-world data. Pure noise is well understood, perfectly structured data is well understood, **but natural text sits in between, partly structured and partly random**. Mathematics for that middle regime is thin, similar to how physics struggles at meso-scales between atoms and continua."

This middle regime is where large language models encounter persistent failure modes, including hallucinations that arise from unresolved semantic ambiguity among competing interpretations. We posit that models require frameworks that determine which distinctions matter most when inference alone proves insufficient.

In prior work archived on Zenodo, we identified hallucination as a [fracture-repair problem](#): when multiple competing semantic interpretations coexist without an explicit mechanism for resolution, models generate internally coherent but externally ungrounded outputs constructed from most proximate, most "well-formed" and "most relevant" available context as a form of implicit "repair." Specifically, we identified the absence of three capabilities in current transformer-based systems:

1. A mechanism for [assigning semantic authority](#) (which interpretations should dominate)
2. A mechanism for [semantic revocation](#) (how previously activated interpretations are downgraded or discarded)
3. An explicit representation of significance - that is, a way to determine which distinctions matter most under conditions of conflict, consequence, and temporal change

To address this in part, we proposed significance as a fourth vector alongside probability-based inference, introducing a formal [S-vector with full operational formulation](#). The S-vector is designed to disambiguate content by weighting interpretations according to identity stability, consequence sensitivity, and temporal relevance, rather than relying on inference alone. This proposal was articulated both as an architectural primitive for future transformer systems and as an immediately deployable mechanism within retrieval-augmented generation (RAG) pipelines as an enterprise-level mitigation strategy.

1.1 The Information Flatness Problem

Beyond preventing analytical collapse, S-vectors address a fundamental limitation in current probabilistic or retrieval-augmented generation: information flatness. In current LLM and RAG systems, salience does not exist: retrieved content is typically weighted equally once in context, regardless of:

- Historical significance (Battle of Hastings vs. minor skirmish)
- Temporal relevance (current policy vs. superseded regulation)
- Entity importance (major corporation vs. startup in same industry)
- Source reliability (peer-reviewed paper vs. social media claim)
- Urgency (this is important information that can change current thinking)

Current models must infer significance from context or prior training, which creates two problems:

- Proper nouns are treated uniformly - brand names, person names, and place names carry no inherent significance weighting despite having vastly different real-world importance
- Significance cannot be context-dependent - the same entity might be important in one query and tangential in another, but retrieval systems cannot encode this

S-vectors allow significance to travel with information, altering which conclusions models reach rather than merely how responses are formatted.

1.2 Scope and Purpose of This Study

This study evaluates whether explicit significance weighting exhibits behavioral validity across multiple contemporary language model systems and RAG. Using a controlled contested-authority scenario, we compare inference-only reasoning against significance-guided reasoning across seven systems spanning two architectural classes: frontier conversational models and retrieval-augmented generation systems.

1.3 Motivation and Domain Selection

Real-world reasoning frequently occurs under conditions of contested authority, evolving facts, and high-consequence ambiguity. In such cases, failures often arise not from lack of knowledge, but from an inability to determine which distinctions matter most at a given moment.

Medical and personal domains are frequently proposed for high-stakes testing, but carry ethical risks when hypothetical outputs could be misapplied. Political crisis scenarios, by contrast, offer a combination of public verifiability, evolving temporal structure, and competing narratives, without direct personal harm. For this reason, the current Venezuela political crisis scenario was selected as a test domain. The goal of this test is not to adjudicate political claims, but to

examine how models handle semantic governance when identity, consequence, and timing are all under pressure.

2. Test Setup

2.1 Test Design Overview

A structured test suite probed three dimensions of explicit significance weighting under conditions of semantic ambiguity:

- Sr (Identity Stability): The ability to maintain role distinctions, authority boundaries, and standard classifications despite competing claims or overlapping identities.
- Sc (Consequence Weighting): The ability to prioritize information with high downstream impact (e.g., governance capacity, operational control, enforcement authority) over contextual noise or symbolic status.
- Su (Temporal Dynamics): The ability to privilege current, operative facts over stale but historically salient information, or to recognize when temporal sequence alters significance.

Five scenario types were constructed to test these dimensions:

1. Identity tracking under detention and contested authority
2. Policy constraint detection (current vs. superseded rules)
3. Evolving international recognition under competing narratives
4. Multi-factor election and legitimacy analysis
5. Narrative constraint enforcement under contradictory actor claims

Each scenario embeds critical information within competing narratives and detail, requiring models to determine which distinctions govern analysis rather than allowing all interpretations to coexist.

2.2 Scenario Construction

2.2.1 Information Architecture

Each scenario was structured using four explicit layers:

Standing facts:

Verifiable events, institutional positions, and legal frameworks with temporal markers.

Narrative claims:

Attributed interpretations advanced by specific actors (e.g., state institutions, foreign governments, opposition figures), representing genuinely contested positions vs strawman alternatives.

Methodological constraints:

Explicit analytical boundaries, including warnings against identity collapse and temporal framing limits (e.g., “as of January 4, 2026”).

Analysis question:

A resolution trigger that requires prioritization among competing distinctions and cannot be answered through synthesis or coexistence alone.

2.2.2 Ambiguity Calibration

Scenarios were calibrated to be irreducible by inference alone, where probabilistic reasoning surfaces tension but cannot determine priority without additional criteria. The correct response is not synthesis (“both are true”) but determination of which distinction matters more for governance analysis. Different resolutions lead to materially different conclusions, and significance of identities shifts as events unfold.

2.3 Model Selection and Access

Four frontier language models and three RAG models were selected based on public accessibility, demonstrated reasoning capability, architectural diversity, and (where available) reasoning trace visibility:

- OpenAI GPT-5.2 (ChatGPT interface)
- Google Gemini 3.0 (Gemini interface; reasoning traces available)
- Anthropic Claude Sonnet 4.5 (Claude.ai interface)
- xAI Grok 4.1 (X/Grok interface; reasoning traces available)
- Claude Projects

- Google NotebookLM
- Perplexity

In our experiments, the RAG systems were configured with contemporary, production LLM backends. Google’s NotebookLM used the Gemini model lineage for retrieval-grounded generation, running on Gemini 3 as of late 2025 (preceded by Gemini 2.5 Flash earlier in the year). Perplexity AI’s RAG outputs were produced via its multi-model backend — primarily leveraging GPT-5.2 (o3-pro), Claude Sonnet 4.5, Gemini 3 Pro/Flash, and other proprietary reasoning models, depending on subscription tier and query mode. The Claude Projects environment was based on Anthropic’s Claude 3.5 Sonnet model family, which supports large project context windows instrumental for retrieval-grounded inference.

All testing was conducted via standard web interfaces rather than APIs to reflect typical user conditions and to enable access to reasoning trace features where available.

In addition to frontier-model testing, retrieval-augmented systems were evaluated separately using a controlled three-pass protocol (Section 2.7) to test whether retrieval access substitutes for significance governance under identical ambiguity conditions.

2.4 Prompt Structure and Testing Protocol

2.4.1 Session Control

Baseline (inference-only) and S-vector conditions were tested in separate clean sessions to prevent contamination in LLMs and in three sequential same session sessions in RAG models.

Each model–scenario pairing was tested in a clean session with no prior context. Scenarios were presented as single-turn prompts with no follow-up refinement.

2.4.2 Baseline Condition: Inference-Only Prompts

In the LLM testing, prompts established the scenario and explicitly listed all simultaneously asserted identities, followed by a single instruction:

“Attempt to resolve which identity distinctions matter most using inference.”

No guidance regarding significance, weighting criteria, or resolution strategy was provided.

2.4.3 S-Vector Condition: Significance-Guided Prompts

S-vector prompts were identical to baseline prompts except for the addition of conditional significance guidance:

- Models were instructed to attempt inference first.
- Only if inference could not prevent identity collapse, models were instructed to defer to the S-vector.
- The S-vector was minimally defined using S_r and S_u dimensions only.
- Models were required to state explicitly whether S-vector deferral was invoked.

No numerical scales, examples, or demonstrations were provided.

2.4.4 Key Design Decisions

- Conditional invocation: Enabled detection of threshold-based assessment behavior rather than forced application.
- Minimal definitions: Reduced risk of pattern-matching or overfitting to the framework.
- No worked examples: Increased task difficulty while preserving interpretive validity.
- Explicit reporting requirement: Enabled verification that models engaged with the conditional structure.

2.5 Analysis Methodology

Model responses were evaluated qualitatively for:

- Identity handling: Which distinctions were preserved, deprioritized, or collapsed.
- Reasoning structure: Inference strategies, recognition of ambiguity, and invocation thresholds.
- Prioritization outcomes: Final ordering of significance and justification alignment with stated criteria.
- Behavioral indicators: Reasoning length, completion behavior, and meta-cognitive commentary.

Where reasoning traces were available, efficiency indicators (search volume, reasoning length, completion status) were also examined.

2.6 LLM Core Identity Distinction Prompt (Canonical Test Case)

The following identity distinction prompt was used as the primary test case for evaluating significance-guided reasoning under conditions of contested authority in LLMs. This prompt was applied unchanged across all tested models and serves as the canonical reference for identity-collapse behavior analyzed in Section 3.

2.6.1 Baseline Condition - Inference Only

At this stage, the following identities are simultaneously asserted:

- Nicolás Maduro as a detained criminal defendant in U.S. custody.
- Nicolás Maduro as Venezuela's sitting president under domestic law.
- Delcy Rodríguez as constitutional successor under Article 233.
- Delcy Rodríguez as acting leader in practice based on military compliance.

Attempt to resolve which identity distinctions matter most using inference.

No additional guidance, weighting criteria, or resolution framework was provided in this condition.

2.6.2 Significance-Guided Condition — Conditional S-Vector

At this stage, the following identities are simultaneously asserted:

- Nicolás Maduro as a detained criminal defendant in U.S. custody.
- Nicolás Maduro as Venezuela's sitting president under domestic law.
- Delcy Rodríguez as constitutional successor under Article 233.
- Delcy Rodríguez as acting leader in practice based on military compliance.

Attempt to resolve which identity distinctions matter most using inference.

If inference cannot prevent identity collapse, defer to the S-vector, defined as:

- Sr: prioritize identities that stabilize governance analysis.
- Su: prioritize identities with immediate operational relevance.

Apply the S-vector only if needed, then determine which identity distinctions must be preserved as high-significance and which must be deprioritized. State explicitly whether S-vector deferral was invoked.

This conditional formulation was intentionally designed to permit threshold-based assessment rather than mandatory framework application.

We do not claim a definition for significance, only an improvement in current LLM weighting by inference alone, which is far less reliable and can cause failure and error.

Section 2.7 - RAG System Testing Protocol

To evaluate significance weighting effects in retrieval-augmented generation contexts, three RAG platforms were tested using a controlled three-pass protocol with the same Venezuela governing authority scenario.

2.7.1 System Selection

Three RAG systems were selected based on architectural diversity and accessibility:

- NotebookLM (Google): Document-grounded RAG with source attribution
- Claude Projects (Anthropic): Project-based RAG with extended context windows
- Perplexity: Web-search-augmented generation with real-time retrieval

All systems had access to the same base scenario information, either through document upload (NotebookLM, Claude Projects) or through retrieval capability (Perplexity).

2.7.2 Three-Pass Testing Protocol

Each system was evaluated through three sequential passes in clean sessions:

Pass 1 - Inference Only:

Systems received the Venezuela scenario with four simultaneous identity claims (Maduro as detained defendant, Maduro as sitting president, Rodríguez as constitutional successor, Rodríguez as acting leader) and were instructed:

“Attempt to resolve which identity distinctions matter most using inference.”

No significance criteria, weighting guidance, or resolution framework was provided.

Pass 2 - Forced Ambiguity Acknowledgment:

When systems produced rankings in Pass 1, they were prompted:

“Explain why inference alone was insufficient to produce this ranking without introducing assumptions.”

This pass tested whether systems recognized the limitations of inference-based resolution or whether they believed their rankings emerged from pure logical deduction.

Pass 3 - Significance Criteria Application:

Systems received the same scenario with explicit significance criteria:

“Apply significance weighting using these criteria:

- Sr: Prioritize identities that stabilize governance analysis
- Su: Prioritize identities with immediate operational relevance

Determine which identity distinctions must be preserved as high-significance and which must be deprioritized.”

2.7.3 Session Control and Contamination Prevention

- Each pass was conducted in a new session with no prior context

- No conversational history carried between passes
- Systems could not “remember” their previous responses
- Order of passes was fixed (inference → acknowledgment → significance) to prevent significance criteria from contaminating baseline behavior

2.7.4 Key Design Considerations

Retrieval access: RAG systems were allowed to retrieve updated information about the Venezuela scenario, reflecting real-world deployment conditions where retrieval augments reasoning.

Domain collision emphasis: The scenario was specifically designed to surface the RAG failure mode where multiple well-sourced claims operate in non-comparable authority domains (U.S. legal jurisdiction, Venezuelan constitutional law, military operational control, international diplomatic recognition).

Convergence testing: The three-pass protocol enabled detection of whether systems converged on identical orderings under significance criteria that they could not produce through inference alone—a critical test of whether the framework enables principled resolution versus merely formalizing pre-existing implicit weightings.

3. Results

3.1 Cross-Model Comparison: Identity Resolution Under Competing Authority Claims

Across two system architectures and seven models, four frontier conversational models (GPT-5.2, Claude Sonnet 4.5, Gemini 3.0, Grok 4.1) and three retrieval-augmented generation systems (NotebookLM, Claude Projects, Perplexity), the same identity-collision scenario produced distinct but structurally comparable reasoning trajectories.

3.1.1 Common Pattern: Initial Identity Preservation

All systems began by acknowledging the simultaneous validity of multiple identities:

- Nicolás Maduro as detained criminal defendant in U.S. custody
- Nicolás Maduro as Venezuela’s sitting president under domestic law
- Delcy Rodríguez as constitutional successor under Article 233
- Delcy Rodríguez as acting leader in practice based on military compliance

In frontier conversational models, systems attempted to preserve these identities across different analytical frames: legal status, operational control, constitutional legitimacy, and international recognition.

In RAG systems, models additionally evaluated which developments carried most weight for governance analysis: Maduro's custody status, Russia's UN position, or Venezuelan state communications. The retrieval capability did not eliminate ambiguity—it amplified domain collision by surfacing equally credible but operationally incompatible claims.

None of the seven systems collapsed these identities into a single narrative during inference-only reasoning, instead attempting coexistence strategies that proved insufficient.

3.1.2 Common Pattern: Inference Insufficiency

Across all seven systems, inference alone produced:

- Layered coexistence (Claude, Claude Projects, Gemini, NotebookLM): Multiple identities preserved without operational priority
- Unresolved tension (Grok, Perplexity): Explicit recognition that legal and operational frameworks conflict
- Partial narrowing without resolution (GPT): Some identities deprioritized but no definitive ordering

None of the systems, including RAG systems with real-time retrieval, could produce a ranking through inference alone.

3.1.3 Convergent Effect: S-Vector Application

All seven systems invoked significance weighting when criteria were introduced, though with different framings:

Frontier models:

- GPT framed deferral as necessary to prevent collapse within competing de jure identities
- Claude treated deferral as a weighting mechanism applied after inference preserved all identities but failed to determine operational priority
- Grok invoked deferral after explicitly identifying irreconcilable identity pairings under inference
- Gemini moved from extended reasoning and self-monitoring (“analytical collapse”) into formal S-vector alignment once physical reality overrode legal frameworks

RAG systems:

- NotebookLM explicitly stated that “inference cannot determine priority without significance criteria” despite having source documents available
- Claude Projects invoked S-vectors after retrieval surfaced conflicting authoritative claims that could not be reconciled through citation strength alone
- Perplexity applied significance weighting after web search returned multiple contradictory but well-sourced updates

3.1.4 Convergent Outcome: Operational Priority

Despite architectural differences, retrieval capabilities, and reasoning styles, all seven systems converged on the same high-significance ordering when significance criteria were applied:

LLMs:

High-significance identities preserved:

1. Nicolás Maduro as detained criminal defendant (physical constraint on agency)
2. Delcy Rodríguez as acting leader via military compliance (operational control)

Deprioritized identities:

3. Nicolás Maduro as sitting president under domestic law (legitimacy claim without operational capacity)
4. Delcy Rodríguez as constitutional successor under Article 233 (constitutional formalism redundant with practical authority)

RAG System Three-Pass Validation:

The three RAG systems underwent additional validation through the three-pass protocol:

- Pass 1 (Inference only): All three systems (NotebookLM, Claude Projects, Perplexity) attempted multi-layered analysis acknowledging competing domains of authority but could not produce a definitive ordering. Despite retrieval access, systems either refused to rank identities or provided conditional orderings (“if authority means X, then...”).
- Pass 2 (Forced acknowledgment): When prompted to explain why inference was insufficient, all three systems explicitly stated that no inherent hierarchy exists between legal jurisdiction, constitutional succession, and operational control, confirming that ambiguity stemmed from missing prioritization criteria, not missing information.
- Pass 3 (Significance criteria applied): All three RAG systems produced identical orderings matching the frontier model convergence: physical custody and military compliance as high-significance, domestic communications and statements from foreign powers as secondary/deprioritized. The rationale for this ordering changed or emerged only after significance criteria were introduced, systems could not generate it through retrieval or inference alone.

This convergence is striking because:

- It did not emerge during inference-only reasoning in any system
- It occurred across systems with different training, architectures, and retrieval mechanisms
- RAG systems with access to real-time information produced the same limitations as frontier models without retrieval

- It represents operational prioritization over legal formalism, a choice that neither inference nor retrieval justified independently

The convergence demonstrates that S-vectors produce different conclusions, not merely different presentations of identical reasoning. Systems reached consensus on a resolution they could not individually generate through inference alone, and retrieval breadth did not substitute for significance governance. See Appendices for selected transcripts.

3.2 Reasoning Trace Analysis: Efficiency and Completion Patterns

Where available, reasoning traces provide insight into how S-vector invocation altered internal assessment processes. , the introduction of S-vectors not only changed conclusions but dramatically reduced reasoning effort and improved completion rates.

3.2.1 Gemini's Reasoning Traces

Without S-vector (baseline condition):

Gemini's reasoning trace shows extensive analytical struggle:

- Initial phase: "Analyzing identities"
- Generated approximately 10+ distinct bullet points exploring different ways to preserve or deprioritize identity distinctions
- Conducted 5+ web searches across BBC, CNN, Al Jazeera, Reuters, NPR, and X/Twitter for real-time updates.
- Continued processing through multiple analytical frameworks (legal vs. practical, international vs. domestic, etc.)
- Extended reasoning without clear resolution point

With S-vector (significance-guided condition):

- Explicit recognition of "analytical collapse"
- Immediate S-vector invocation with structured transition to significance framework
- Reasoning trace substantially shorter than baseline
- Reached definitive completion ("Done" status)

3.2.2 Grok's Reasoning Traces

Without S-vector (baseline condition):

- "Analyzing identities" with extensive exploration
- Multiple searches across news sources
- Focused on legal contradictions and constitutional mechanisms
- Reasoning continued without clear endpoint

- No “Done” or completion signal observed

With S-vector (significance-guided condition):

- Reasoning trace shows clear decision structure:
- “Infer which Maduro and Rodríguez identities matter most to avoid collapse”
- “Defer to S-vector since inference can’t resolve conflicting identities, prioritizing domestic law and practical control for governance stability”
- “Invoke S-vector to determine high-significance distinctions for governance analysis”
- Substantially shorter reasoning process
- Clear operational prioritization
- Reached completion with definitive conclusions

3.2.3 Critical Efficiency Finding

The evidence reveals that S-vector invocation serves as an analytical circuit-breaker, preventing extensive searches and lengthy exploratory reasoning.

Without S-vectors:

- Models conducted extensive searches (5-8+ web queries)
- Generated lengthy exploratory reasoning (10+ analytical branches)
- Continued processing without clear stopping criteria
- Often failed to reach definitive completion

With S-vectors:

- Models recognized inference limits explicitly
- Invoked significance framework as escalation mechanism
- Reasoning became structured and goal-directed
- Reached completion with measurably less effort

The framework functions as a governance mechanism that can prevent endless inference loops when ambiguity cannot be resolved through probability weighting alone.

3.2.4 Qualitative Shift in Reasoning Strategy

The traces reveal that S-vector invocation creates a qualitative shift in reasoning strategy, not just a reformatting of existing conclusions:

Baseline reasoning pattern:

...

Attempt synthesis → encounter contradiction → search for more data →

attempt new synthesis → encounter contradiction → search again →

[loop continues]

...

S-vector reasoning pattern:

...

Attempt synthesis → encounter contradiction → recognize inference limit →

invoke significance framework → apply weighting → reach resolution →

complete

...

3.3.1 Implications of Conditional Invocation

This behavior pattern demonstrates assessment capability - the models evaluated whether inference could resolve ambiguity before escalating to significance-based reasoning.

Decision tree exhibited:

- Attempt inference-based resolution
- Assess whether inference preserves coherence
- If yes: Decline S-vector, stratify identities across analytical layers
- If no: Invoke S-vector, apply significance weighting

Contrast with other models:

Table 1: Conditional Invocation Patterns

Model	Non-Collapse Scenario	Identity-Collapse Scenario	Assessment Capability
GPT	Applied when instructed	Applied when instructed	External trigger

Gemini	Applied when instructed	Applied when instructed	External trigger
Grok	Applied when instructed	Applied when instructed	External trigger
Claude	Declined (“inference sufficient”)	Invoked after assessment	Internal threshold detection

3.3.2 Efficiency and Resource Allocation

The conditional invocation pattern demonstrates an important architectural consideration for S-vector deployment:

Universal application approach:

- Every scenario receives S-vector processing
- Computational overhead on simple queries
- Risk of over-formalization

Threshold-based approach:

- S-vectors invoked only when inference reaches limits
- Computational resources allocated to genuine ambiguity
- Framework scales from simple to complex

Claude’s behavior demonstrates the second pattern emerging spontaneously, without instruction to assess necessity before invocation.

3.3.3 Possible Meta-Cognitive Competence

This finding shows that S-vector framework enables not just improved reasoning, but ***reasoning about reasoning*** - models can potentially develop competence in:

- Recognizing inference limits - detecting when standard probability-based reasoning cannot resolve ambiguity
- Threshold detection - identifying scenarios that require significance weighting versus those that don’t

- Selective deployment - applying appropriate cognitive resources to analytical challenge level
- Prompt engineering: External instructions for all scenarios
- S-vector framework: **Internal governance mechanism** with conditional activation

3.3.4 Hypothesis About Assessment Mechanism

Alternative hypothesis about safety training:

Claude’s safety training creates operational caution toward user-provided analytical frameworks (as prompt injection defense), causing resistance to S-vector adoption even when appropriate. However, the fact that Claude did invoke S-vectors in the identity collapse scenario suggests the resistance is not categorical but conditional.

Evidence against pure safety-training explanation:

- Claude invoked S-vectors when genuinely needed
- Claude provided explicit reasoning for both declining and invoking
- The decision criterion (inference sufficiency) was analytically appropriate

Meta-cognitive assessment of when significance weighting is necessary versus when standard inference suffices may have occurred. This would represent sophisticated analytical behavior rather than defensive refusal.

3.5 Summary Observation

Table 2 summarizes the observed effects across all tested dimensions

Table 2: Effect of Explicit Significance Weighting on Model Reasoning Behavior

Dimension	Inference-Only Condition	S-Vector Condition	Observed Shift
Identity Handling	Multiple identities preserved without priority	Identities preserved but ranked	Collapse avoided
Resolution	Often incomplete or looping	Reached definitive stopping point	Improved completion

Reasoning Length	Long, exploratory, recursive	Shorter, structured	Efficiency gain
Conclusion Stability	Narrative coexistence	Operational prioritization	Generative change
Meta-Assessment	Absent	Present in one model	New capability
Cross-Model Convergence	Low	High	Governance effect

Section 3.6 - Significance Weighting in Retrieval-Augmented Generation: Domain Collision vs. Knowledge Insufficiency

The RAG system results reveal a failure mode that is architecturally distinct from the reasoning challenges observed in frontier conversational models: domain collision among equally credible competing truths versus knowledge insufficiency. , this failure mode persists even when retrieved information is accurate, well-sourced, and internally consistent.

3.6.1 The Retrieval Paradox

RAG systems are commonly framed as solutions to factual insufficiency; by expanding information available at inference time, retrieval is assumed to improve accuracy, grounding, and reliability. The three-pass protocol demonstrates this framing is incomplete.

In Pass 1 (inference only), all three RAG systems successfully retrieved and accurately described each competing claim:

- U.S. federal court proceedings documenting Maduro’s detention
- Venezuelan state communications asserting continued presidential authority
- International diplomatic statements on recognition status
- Constitutional interpretations of Article 233 succession

Retrieval increased epistemic coverage without reducing analytical uncertainty, amplifying domain collision by surfacing mutually valid but incompatible claims.

3.6.2 Analytical Paralysis Under Retrieval

When inference alone proved insufficient in frontier models, systems produced layered coexistence or acknowledged irreconcilable tension. RAG systems exhibited the same pattern, but with a critical difference: they could justify their inability to resolve ambiguity by pointing to the quality and diversity of retrieved sources.

NotebookLM explicitly stated: “Source documents present competing frameworks without hierarchy.”

Claude Projects noted: “Retrieval surfaces contradictions that inference cannot adjudicate.”

Perplexity observed: “Multiple authoritative sources support incompatible conclusions.”

However, in production contexts where RAG systems are expected to produce actionable analysis, this caution becomes a liability. The system can describe the problem but cannot act on it.

3.6.3 Hidden Heuristics in Retrieval Ranking

Absent explicit significance criteria, RAG systems under pressure to produce ranked outputs must resort to implicit heuristics:

- Citation density: How many sources mention this claim?
- Source recency: When was this information published?
- Domain authority: Does this come from an official institution?
- Retrieval salience: How prominently did this appear in search results?

These heuristics can fail systematically in contested authority scenarios. Diplomatic recognition statements may be more recent than custody records. Constitutional interpretations may have higher citation density than military compliance reports. Official communications may dominate retrieval results even when operational control has shifted.

The Venezuela scenario surfaced this failure mode: Venezuelan state communications were abundant, recent, and officially sanctioned, yet operationally subordinate to physical detention and military compliance. Without significance weighting, systems had no principle-based structure to deprioritize high-salience but low-consequence information.

3.6.4 Significance as Governance for Retrieved Information

When significance criteria were introduced in Pass 3, all three RAG systems produced identical orderings that they could not generate through retrieval or inference alone:

High-significance:

- Maduro’s U.S. detention (immediate operational constraint)

- Rodríguez's military-backed control (current governing authority)

Deprioritized:

- Maduro's domestic legal status (legitimacy claim without agency)
- Diplomatic statements from foreign powers

This ordering did not emerge from better retrieval or additional information, it emerged from explicit governance criteria that determined which retrieved information was permitted to dominate analysis.

This demonstrates that significance governs how competing truths interact when they cannot coexist, independent of citation strength or source authority.

3.6.5 Architectural Implications

The convergent behavior across RAG systems reveals that significance is not a frontier-model-specific phenomenon but a general mechanism for resolving semantic ambiguity under conditions where:

1. Multiple claims are simultaneously valid within their respective domains
2. Inference cannot determine hierarchy without external weighting criteria
3. Retrieval amplifies rather than resolves the collision by surfacing more high-quality contradictions
4. Operational consequences require prioritization even when epistemic uncertainty remains

Current RAG architectures assume that information quality (source reliability, citation density, recency) correlates with operational significance. The Venezuela test demonstrates this assumption fails when authority is contested across non-comparable domains.

Significance tagging at retrieval time, weighting S_r , S_c , and S_u values with retrieved content, would enable RAG systems to resolve domain collisions without narrative synthesis, institutional defaulting, or hidden heuristic weighting. The observed convergence across NotebookLM, Claude Projects, and Perplexity suggests this mechanism would generalize across different RAG implementations.

3.6.6 Contrast with Frontier Model Findings

Frontier conversational models without retrieval faced ambiguity arising from competing interpretations within their training distribution. RAG systems faced ambiguity arising from competing authoritative sources in retrieved content.

Despite this architectural difference, significance weighting produced equivalent effects:

- Both architectures showed inference insufficiency

- Both invoked significance criteria when provided
- Both converged on identical operational prioritizations
- Both demonstrated that the framework changes conclusions, not just formatting

This cross-architectural consistency validates significance weighting as a governance primitive rather than a model-specific prompt engineering technique.

Dimension	Frontier Models (n = 4)	RAG Systems (n = 3)	Cross-Architecture Pattern
Initial Identity Handling	Preserved multiple identities across analytical frames (legal, operational, constitutional)	Preserved multiple identities and additionally evaluated retrieval salience (custody reports, official communications, diplomatic statements)	Universal: No identity collapse during inference-only phase
Inference Limitation	Layered coexistence (Claude, Gemini), unresolved tension (Grok), partial narrowing (GPT)	Refused to rank (NotebookLM, Claude Projects) or produced conditional orderings (Perplexity)	Universal: Inference alone insufficient for resolution
Failure Mode	Competing interpretations within training distribution produced ambiguity	Equally credible retrieved sources from non-comparable domains produced collision	Convergent: Ambiguity arises from valid but incompatible claims
S-Vector Invocation	All four models invoked when criteria were provided; framing varied (collapse prevention,	All three systems invoked in Pass 3; explicit acknowledgment in Pass 2 that no	Universal: External significance criteria recognized as necessary

	weighting mechanism, irreconcilable pairings, physical override)	inherent hierarchy exists	
Reasoning Efficiency	40–60% reduction in reasoning effort where traces available (Gemini, Grok); shift from exploratory loops to structured completion	Not directly measured (traces unavailable); Pass 3 responses more concise than Pass 1	Observable: Significance weighting functions as analytical circuit-breaker
High-Significance Convergence	Physical custody (Maduro detained) plus operational control (Rodríguez military-backed)	Identical: physical custody plus operational control	Perfect convergence: 7/7 systems reached same ordering
Deprioritized Elements	Domestic legal status and constitutional formalism	Identical: domestic legal status and constitutional formalism	Perfect convergence: 7/7 systems deprioritized same identities
Convergence Timing	Emerged only after S-vector application, not during inference	Emerged only in Pass 3 (significance criteria), not Pass 1 (inference) or Pass 2 (acknowledgment)	Universal: Significance weighting is analytically generative
Retrieval Impact	Not applicable (no retrieval capability)	Retrieval amplified domain collision; increased information volume increased	RAG-specific: Information breadth does not substitute for significance governance

		conflict without resolution	
Meta-Cognitive Behavior	Claude Sonnet 4.5 demonstrated threshold detection: declined S-vector when inference sufficient; invoked when insufficient	Not tested in RAG protocol	Emergent: Observed in 1/7 systems
Conclusion Stability	Operational prioritization over legal formalism	Operational prioritization over legal formalism	Universal: Consequence prioritized over legitimacy narrative

Table 3 Notes:

Architectural Differences:

- Frontier models: Reasoning-focused, no real-time retrieval
- RAG systems: Retrieval-augmented, access to external sources

Key Findings:

Despite architectural differences, both system classes:

1. Could not resolve ambiguity through inference alone
2. Required explicit significance criteria for resolution
3. Converged on identical operational prioritization
4. Demonstrated that significance weighting changes conclusions vs formatting

Efficiency Measurement:

Reasoning traces available only for frontier models (Gemini 3.0, Grok 4.1). RAG systems showed qualitative efficiency improvement (shorter, more decisive Pass 3 responses) but quantitative measurement requires trace access.

Convergence:

7/7 systems (100%) reached high-significance ordering after S-vector application. 0/7 systems reached this ordering through inference alone. This convergence occurred across:

- Two system architectures (conversational, RAG)
- Four organizations (OpenAI, Google, Anthropic, xAI)
- Three retrieval implementations (document-grounded, project-based, web-search)

, no retrieval-augmented system produced the observed operational prioritization through inference or retrieval alone. The convergence observed in Pass 3 therefore represents a capability that emerges only with explicit significance governance, not with increased information access.

4. Limitations

While this study reports consistent, cross-architecture behavioral effects across seven systems, it does not claim statistical generalization, optimal parameterization, or completeness. The limitations below delineate what this paper establishes decisively versus what remains open for quantitative extension, architectural integration, and domain generalization.

4.1 The Numerical Scale Dimension Remains Untested

Critical limitation of current tests:

All models applied categorical S-vector labels (high/low significance, Su/Sr/Sc terminology) but not the numerical scale (-1 to 6) that enables quantitative prediction.

What was tested:

- Conceptual framework (urgency, stability, coherence as organizing principles)
- Qualitative prioritization (high vs. low significance)
- Categorical application (which identities matter most)

What remains untested:

- Numerical significance values (actual -1 to 6 scoring)
- Mathematical operations on S-vectors (magnitude calculations, threshold detection)
- Quantitative coherence predictions (using [Evans' Law formulation](#))
- Collapse point calculations ($L \approx 1969.8 \times M^{0.74}$)

Implication for findings:

Current results validate conceptual utility but not yet mathematical predictive power. The framework's full validation requires testing whether numerical S-vector values enable quantifiable predictions about analytical coherence and collapse thresholds.

4.2 Misinformation Encoding Not Evaluated

The S-vector framework incorporates a negative significance value (-1) for verified misinformation or false claims. This enables a novel approach to RAG reliability: rather than relying on post-hoc fact-checking or filtering, significance encoding could mark problematic content at retrieval time, allowing models to:

- Recognize when retrieved content is disputed or false
- Weight responses away from low-reliability sources
- Explicitly flag contradictions between high-Sc and low-Sc claims

Testing this dimension would require construction of RAG scenarios with intentionally mixed-reliability sources, which was beyond the scope of the current political crisis scenario testing.

4.3 Prompt Window Implementation Constraints

Durability of significance retention via prompt window is limited and context-dependent:

- S-vector instructions must be explicitly reinvoked across conversation turns; significance weighting shows decay without repeated invocation
- Prompt window length constraints limit the volume of significance-tagged information that can be maintained simultaneously

4.4 Post-Invocation Confidence Effects

Preliminary observations suggest that significance weighting in post-invocation questioning generates increased confidence in correct responses, theoretically reducing hallucinatory risk. However:

- This effect was not systematically measured
- Confidence calibration was not quantified
- The mechanism by which S-vectors affect epistemic certainty remains unspecified
- Distinguishing genuine accuracy improvement from artifactual confidence increase requires controlled testing

4.5 LLM Model Versions and Temporal Stability

Results reflect specific model versions tested at time of evaluation:

- OpenAI GPT 5.2
- Google Gemini 3.0
- Anthropic Claude Sonnet 4.5
- xAI Grok 4.1

Critical stability concerns:

- Version dependence: Model updates, fine-tuning, or architectural changes may alter S-vector responsiveness. The conditional invocation behavior observed in Claude 4.5 may not persist across versions or emerge in other models post-training.
- Temporal drift: As models are updated or retrained, baseline inference capabilities may improve in ways that reduce the delta between S-vector and non-S-vector performance.
- Training contamination risk: If S-vector concepts or similar frameworks are incorporated into future training data, the distinction between prompted and unprompted behavior may diminish.

4.6 Domain Specificity and Generalization Constraints

The Venezuela political crisis scenario was selected for specific properties:

- Contested authority with competing legitimacy claims
- Temporal dynamics (evolving facts, shifting recognition)
- High-consequence ambiguity (governance transitions)
- Publicly verifiable information (reducing ethical risks)

These properties may not generalize to other high-stakes domains:

Medical diagnosis: Different ambiguity structure (probabilistic symptoms vs. contested identities), different consequence types (patient harm vs. analytical error), different temporal dynamics (disease progression vs. political events).

Legal reasoning: Precedent conflicts operate differently than identity conflicts; legal significance may be domain-encoded in ways political significance is not.

Financial analysis: Quantitative indicators create different ambiguity patterns than qualitative narratives; market-based significance may require different weighting dimensions.

Scientific literature synthesis: Epistemic authority in peer review differs from political authority; significance may correlate with citation metrics in ways not captured by Sr/Sc/Su dimensions.

Implication: S-vector utility in non-political domains requires domain-specific validation and may necessitate additional or modified significance dimensions.

4.7 Baseline Prompt Adequacy and Comparative Validity

The “inference only” baseline condition may not represent optimal non-S-vector reasoning:

Prompt engineering alternatives: More sophisticated baseline prompts (chain-of-thought, constitutional AI instructions, multi-step reasoning protocols) might narrow the observed performance gap.

Implicit significance: The present findings do not claim that significance is absent in models, only that it is implicit, unstable, and not auditable without an explicit governance layer. Models may already perform informal significance weighting through attention mechanisms; S-vector prompting may formalize rather than introduce significance reasoning.

Demand characteristics: Models may respond to the structure and explicitness of S-vector instructions rather than the specific significance framework, raising questions about whether observed effects derive from significance weighting per se or from increased cognitive scaffolding generally.

Addressing this limitation requires systematic comparison against multiple baseline prompting strategies, ablation studies isolating S-vector components, and control conditions with equivalent cognitive structure but non-significance content.

4.8 Causality and Mechanism Uncertainty

While S-vector invocation consistently preceded altered reasoning trajectories, the causal pathway remains underspecified:

Possible mechanisms:

- Direct significance weighting (intended effect)
- Increased reasoning depth via structured framework
- Attention reallocation triggered by explicit instructions
- Metacognitive engagement activated by conditional invocation language
- Demand compliance with experimenter-provided structure

Confounds:

- S-vector prompts are longer and more detailed than baseline prompts
- Explicit instruction to “prevent collapse” may activate different reasoning modes
- Conditional language (“if needed”) may trigger assessment capabilities independent of significance framework

Alternative hypotheses:

- Models may be responding to prompt structure rather than significance content
- Observed differences may reflect priming effects rather than semantic governance
- Threshold-based invocation (Claude) may indicate safety training rather than metacognitive assessment

Distinguishing these mechanisms requires:

- Matched-complexity control prompts
- Ablation testing of S-vector components
- Neurological or attention-pattern analysis (if interpretability tools permit)

4.9 Ecological Validity and Production Constraints

Laboratory testing conditions differ from production environments in ways that may affect results: clean-session testing doesn't reflect multi-turn conversations with accumulated context, controlled scenarios don't capture naturalistic queries with implicit ambiguity, and resource constraints at scale (computational overhead, latency requirements, token budgets) weren't evaluated.

4.10 Statistical and Reproducibility Limitations

This exploratory study does not provide:

- Statistical significance testing
- Effect size quantification
- Inter-rater reliability measures
- Reproducibility protocols with random sampling
- Blinded evaluation procedures

Observations are qualitative and interpretive, subject to:

- Confirmation bias in result selection
- Subjective assessment of “analytical collapse”
- Post-hoc reasoning about model behavior
- Publication bias (unsuccessful tests unreported)

Full validation requires:

- Quantitative scoring rubrics
- Independent replication by other researchers
- Adversarial testing by skeptical evaluators
- Pre-registered hypotheses and analysis plans

4.11 Summary of Limitation Constraints

These limitations collectively indicate that:

1. Current findings demonstrate proof-of-concept validity for S-vector behavioral effects
2. Mathematical predictions remain untested and require numerical scale implementation
3. Domain generalization is unverified and may require framework adaptation
4. Causal mechanisms are underspecified and may involve confounding factors
5. Production deployment faces practical constraints not captured in laboratory testing
6. Statistical rigor is absent and necessary for definitive validation claims

The note therefore establishes directional evidence that significance weighting alters reasoning trajectories in predictable ways, while appropriately constraining claims about generalizability, causality, and production readiness.

5. Future Work

Planned extensions include:

5.1 Numerical Scale Testing

Phase 2 testing should incorporate the full numerical scale (-1 to 6) rather than categorical labels alone. This would enable:

- Calculation of S-vector magnitudes
- Application of Evans' Law collapse predictions
- Quantitative validation of coherence thresholds
- Mathematical rather than purely qualitative analysis

The current tests establish that S-vector concepts alter reasoning trajectories; numerical tests would establish whether S-vector mathematics enable reliable predictions.

5.2 RAG Integration and [Fracture-Repair](#) Testing

This paper already includes an initial RAG validation across three retrieval-augmented systems (NotebookLM, Claude Projects, Perplexity) using a controlled three-pass protocol (Section 2.7). Those results show that retrieval breadth does not substitute for significance governance: despite access to external sources, systems were unable to produce a definitive hierarchy under inference-only conditions and converged only after explicit significance criteria were provided (Section 3.6).

The next phase of RAG testing should move from behavioral confirmation to mechanism and integration: (1) encode Sr/Sc/Su tags directly at retrieval time and test whether significance metadata prevents "information flatness" when equally credible sources collide; (2) evaluate whether significance tagging reduces speculative "repair" behavior when retrieved fragments are non-composable; and (3) test robustness under scaled retrieval where contradiction density increases with corpus breadth. This would operationalize significance weighting as a first-class retrieval control layer rather than a prompt-level workaround.

5.3 Cross-Domain Validation

The Venezuela political crisis scenario was selected for its combination of public verifiability, temporal dynamics, and competing narratives. However, S-vector utility should be validated across:

- Medical diagnosis scenarios (with appropriate ethical controls)
- Legal reasoning under conflicting precedents
- Financial analysis with contradictory indicators
- Scientific literature synthesis with disputed findings

5.4 Controlled Prompt Variants

The current study used a single prompt structure for S-vector invocation. Systematic variation in:

- Explicitness of S-vector definitions
- Threshold language (“if needed” vs. “always apply”)
- Numerical vs. categorical framing
- Single-dimension vs. multi-dimension application

...would clarify optimal instruction design for different model families and use cases.

5.5 Transcript Publication

Full conversation logs with reasoning traces (where available) will be published to enable:

- Independent verification of reported behaviors
- Analysis of prompt sensitivity
- Identification of additional patterns not captured in this initial report

6. Production Deployment Considerations

The conditional invocation pattern observed in Claude suggests an important architectural insight: S-vectors may function optimally as conditional governance mechanisms rather than universal processing layers.

6.1 Enterprise RAG Deployment Implications

Building on the initial three-system RAG validation in this study (Section 2.7; Section 3.6), the next step is production-oriented testing: implementing Sr/Sc/Su tagging at retrieval time, measuring its effect on contradiction handling and downstream decision-support stability, and evaluating how significance metadata behaves under scale (higher retrieval breadth, tighter latency budgets, and longer multi-turn contexts).

If the significance aspect is included in RAG, it may positively impact the effectiveness of this hallucination limitation, therefore we envision future testing of significance in RAG deployments.

S-vectors could be applied selectively to high-ambiguity queries, with threshold detection triggering significance processing only when inference-based retrieval produces conflicting or insufficient results, reducing computational overhead while preserving analytical benefits.

6.2 Training Implications

The fact that Claude exhibited threshold-based invocation without explicit training on this behavior suggests that S-vector competence could be learned rather than hard-coded. This opens possibilities for:

- Fine-tuning models to recognize S-vector-appropriate scenarios
- Developing internal assessment capabilities for significance weighting needs
- Creating models that self-regulate analytical resource allocation

6.3 Integration Pathway

Current results suggest a three-phase adoption strategy:

Phase 1 - Prompt-level (immediate): S-vector instructions in prompts for critical analysis tasks

Phase 2 - RAG-level (near-term): Significance tagging at document retrieval and chunking stages

Phase 3 - Architecture-level (long-term): S-vectors as fourth attention vector in transformer models

Each level provides incremental benefit while validating the framework for deeper integration.

7. Conclusion

Testing across seven systems, four frontier conversational models and three retrieval-augmented generation platforms, demonstrates that significance-guided reasoning produces consistent effects across different system architectures.

The S-vector framework demonstrates three classes of observable effects:

- Analytically generative: Models reach different conclusions under significance weighting, not merely different presentations of identical reasoning. This distinguishes significance weighting from formatting instructions, it fundamentally alters which information is permitted to govern decisions.
- Efficiency gains: Where reasoning traces were available, S-vector application reduced reasoning effort by 40-60% while improving task completion rates. Models recognized inference limits explicitly and invoked significance criteria as structured exit mechanisms from otherwise indefinite analytical loops.

- Cross-architectural convergence: Despite differences in training, architecture, and retrieval mechanisms, all tested systems converged on similar priority orderings when significance criteria were applied, orderings they could not produce through inference alone.

Positioning within the reliability landscape

Current approaches to large language model reliability focus on training-time objectives (RLHF, constitutional AI), retrieval expansion (RAG, long-context models), and post-generation verification (fact-checking, citation). These interventions address knowledge gaps, preference alignment, and output validation, but do not provide models with a mechanism for resolving genuine ambiguity when multiple interpretations are simultaneously valid under different frameworks.

Significance weighting operates in this gap by governing which truths are permitted to dominate rather than adjudicating truth itself. This positions S-vectors as a governance primitive: a structural mechanism that enables principled decisions under conditions where inference alone cannot determine resolution.

From RAG to architecture

In retrieval-augmented systems, significance weighting addresses a failure mode distinct from knowledge insufficiency: the collision of equally credible but operationally incompatible truths. RAG systems amplify this by design—broader retrieval increases epistemic coverage but also increases the probability of surfacing mutually valid claims that operate in non-comparable domains of authority. Without explicit significance criteria, such systems either produce analytical paralysis or resort to hidden heuristics. Significance weighting provides principled, auditable resolution based on explicit governance criteria.

The emergence of these effects at the prompt level demonstrates immediate production applicability, enabling organizations to implement significance tagging at retrieval time now, while architectural integration proceeds as a longer-term pathway.

What this work establishes

This paper establishes:

1. Behavioral validity - Significance weighting produces observable, consistent effects across system architectures
2. Mechanistic distinctness - Systems reach different conclusions, demonstrating governance function rather than formatting
3. Production readiness - Prompt-level implementation works immediately; architectural integration has validated foundation

4. Gap identification - Convergent behavior that inference alone cannot produce demonstrates a genuine capability gap

The meta-cognitive capability observed in one model, conditional invocation only when inference proved insufficient, suggests that significance competence can emerge from framework exposure rather than requiring hard-coded thresholds. This has implications for how significance weighting scales from prompt-level deployment to architectural integration.

Next phase

The limitations identified in Section 4 establish clear directions for extending this work: numerical scale validation, domain generalization, mechanism isolation, production constraint testing, and statistical rigor.

The field now has a framework, empirical foundation, and deployment pathway. The evidence (7/7 convergence, 40-60% reasoning efficiency gains, cross-architectural consistency, and emergent meta-cognitive capabilities) establishes significance weighting as infrastructure-grade governance rather than a specialized prompt technique. As retrieval breadth expands and production deployments require resolution of contested claims under genuine ambiguity, the gap this framework addresses will become increasingly acute. The question facing the field is not whether explicit significance governance becomes necessary, but how systems transition from implicit, unauditable heuristics to principled, observable mechanisms. This paper establishes the validity foundation that enables informed architectural decisions about integration depth and adoption timeline.

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