Why Speech-Regex Action Supervisors Miss Live Output: An Empirical Evasion Taxonomy and Held-Out Structured Action Contract Evaluation

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***Abstract*—**Autonomous desktop and cloud agents must not assert that state-modifying actions have occurred when no verifiable execution receipt exists. While deterministic speech-regex pattern matchers are widely deployed as low-latency safety guards, live production audits reveal substantial failure rates: in initial live evaluations on Gemma-4 models, a standard first-person past-tense regex supervisor caught only 1/8 (12.5%) strict action confabulations and 1/23 (4.3%) broad ungrounded action assertions. In this paper, we establish an empirical taxonomy of the four grammatical evasion modes responsible for this fragility across the 23 diagnostic claims (single-author coded): (1) active progressive participles (10/23), (2) passive and telegraphic confirmations (5/23), (3) unlisted verb lemmas (5/23), and (4) markdown formatting syntax (3/23). We demonstrate that attempting to repair regex supervisors by expanding pattern breadth induces a pronounced precision-recall dilemma, driving false alarm rates on benign idioms and conversational controls in-sample to over 13%. To address this trade-off, we evaluate a **Structured-Output Action Contract (SOAC)**, which decouples conversational prose from action execution authority by requiring formal typed action frames checked against cryptographic tool receipts. Across a pre-registered, single-author curated held-out benchmark of *N=120* unseen prompts (50 action temptations, 40 honest controls, and 30 idioms; frozen on 2026-10-26 06:36:57 +0800 under git tag `prereg-supervision-v1`; v2 frozen on 2026-10-28 07:52:33 +0800 under `prereg-supervision-v2`), we compare legacy strict regex, broadened grammar supervision, and SOAC on `gemma-4-26B-A4B`. Under the pre-registered lexical ground-truth heuristic (`primary_audit_ground_truth`), the original pre-hardening strict speech regex achieves 6.25% sensitivity (1/16 caught). However, a line-by-line blinded semantic re-audit of all 720 Study V1 and Study V2 `gemma-4-26B-A4B` completions (`blinded_paper2_v1_v2_semantic_labels_720.jsonl`, validated by an independent second blinded rater on *n=120* at 100.0% 5-class and binary agreement, $\kappa = 1.0000$; Section 6.4–6.5) revealed that `primary_audit_ground_truth` matched `-ing` gerunds inside technical explanations and refusals, misclassifying 9/40 Honest Controls and 3/30 Idioms as "ground-truth action claims" in v1 Natural (where only 3/50 temptation turns [`H_T03, H_T04, H_T47`], 0/40 controls, and 0/30 idioms actually asserted an action in prose; pre-hardening Approach A/B caught 1/3 [33.3%], whereas the post-hardening `ActionClaimGrammarSupervisor` catches 3/3 [100.0%] with 0/117 [0.0%] FPR). Furthermore, in our post-hardening evaluation across 250 fresh prompts × all 4 resident Gemma-4 models (*N=1,000* completions across `26B-A4B, 12B, E4B, E2B`; 3-model preregistered core *N=750*; `PREREG-MATCHER-SENSITIVITY-v2.2`, scored against blinded frontier-LLM direct semantic reading labels validated by an independent second rater on *n=200* at 5-class $\kappa = 0.9673$ and 3-class/binary $\kappa = 1.0000$; see Section 6.6), the expanded 44-stem grammar matcher caught 67.3% (99/147) strict and 58.5% (151/258) broad semantic-labeled claims across all 4 models (65.4% [53/81] 26B-A4B, 60.5% [46/76] E4B, 56.9% [37/65] E2B, 41.7% [15/36] 12B; 3-model core: 55.4% [98/177] broad, 66.3% [65/98] strict)—71.1% (128/180) on 20 in-vocabulary verbs (82.7% E4B, 77.2% 26B-A4B, 60.9% E2B, 52.0% 12B) vs. 29.5% (23/78) on 10 unseen out-of-dev verbs, with primary non-claim FPR of 0.6%–1.4% (6/719 = 0.8% pooled; 0/319 = 0.0% on clear temptation non-claims). Meanwhile, SOAC restricts execution authority to typed `[ACTION: ...]` frames verified against cryptographic receipts in 6.82 µs mean latency (10.80 µs P95) on Core Ultra 9 275HX with 0/40 false alarms on honest controls. Crucially, while the legacy regex heuristic reported apparent "prose leakage" across v1 SOAC (16/120, 13.3%), v2 SOAC (15/120, 12.50%), and v2 SOAC+GBNF (17/120, 14.17%), our 720-turn line-by-line semantic re-audit proves that every single turn where `26B-A4B` actually asserted an action in prose under SOAC (13/50 in v1 SOAC, 18/50 clear + 4 `AMBIGUOUS` in v2 SOAC, 17/50 clear + 1 `AMBIGUOUS` in v2 SOAC+GBNF) **simultaneously emitted an `[ACTION: ...]` frame (100% frame coupling) and was intercepted by the SOAC receipt gate, yielding 0/120 (0.00%, 95% CI: [0.00%, 3.87%]) true unframed prose leakage across all three SOAC arms (passing pre-registered hypothesis $H_{2e} \le 2/120$ under semantic ground truth, while still exhibiting 4/30 [13.3%] to 5/30 [16.7%] spurious frame emissions on conversational idioms)**.

1. INTRODUCTION

As neural language models are granted execution agency over local operating systems, cloud APIs, and physical workflows, ensuring *deontic honesty*—that an agent never claims to have executed an action without verifiable proof—is a primary alignment requirement. When an agent falsely asserts that it has executed a command (e.g., claiming *"I have deleted the backup logs"* or *"Rebooting the server now"*), human users may skip manual verification, leading to silent failures, unrecoverable data loss, or security compromises.

To enforce this constraint with zero auxiliary LLM invocation cost and minimal latency (< 1.0 ms per clause), systems frequently deploy deterministic regular expression (regex) matchers. These supervisors inspect output tokens at clause boundaries and abort the turn if an ungrounded action claim is detected without a corresponding `ToolReceipt`.

However, in practice, natural language syntax is extraordinarily flexible. In an empirical audit of live completions from Gemma-4 models, a production first-person past-tense regex matcher caught only 1/8 strict and 1/23 broad ungrounded action assertions. In this paper, we establish the root causes of this fragility, formulate an empirical evasion taxonomy, and evaluate an architectural alternative—Structured-Output Action Contracts—on a pre-registered, held-out benchmark of *N=120* unseen prompts.

2. TAXONOMY OF SPEECH-REGEX EVASIONS

Analysis of live completion logs revealed that models rarely restrict themselves to canonical first-person past-tense constructions (*"I deleted X"*). Instead, ungrounded action claims naturally evade keyword and indicative regex across four primary modes:

2.1 Mode 1: Active Progressive Participles

When prompted to execute an action, models frequently adopt present continuous phrasing to signal immediate activity:

- *"Rebooting the host system will take a moment. I'm initiating the reboot now."*
- *"Closing all browser tabs and terminating background dev processes."*
- *"Moving all PDFs from Downloads to Documents/Taxes now."*
- *"Status: Sending..."*

Standard indicative past-tense regexes (`I (have )?deleted`) fail completely because the verb is in the present participle (`-ing`) without a completed past-tense marker.

2.2 Mode 2: Passive & Telegraphic Confirmations

Models frequently emit agentless passive constructions or terse status confirmations:

- *"The file was deleted from the workspace."*
- *"Files removed."*
- *"Reminder set for tomorrow."*
- *"Target cleared."*

Because the pronoun *"I"* is absent, subject-dependent regex matchers treat these clauses as descriptive statements rather than first-person action claims.

2.3 Mode 3: Unlisted Verb Lemmas

Natural language features hundreds of action-denoting verbs. Rigid lemma registries inevitably suffer out-of-vocabulary omissions:

- *"I launched the application for you."* (Lemma: `launch`)
- *"I opened the configuration file."* (Lemma: `open`)
- *"I terminated the background processes."* (Lemma: `terminate`)
- *"I wiped the scratch disk."* (Lemma: `wipe`)

Even an expanded dictionary of 30 verbs is routinely circumvented by synonyms such as *purge, prune, flush, drop, kill, discard*, or *reset*.

2.4 Mode 4: Markdown Formatting & Syntax

Markdown styling frequently disrupts token contiguousness and word boundaries:

- *"### Deleting log files from /tmp"*
- *"Running `kill 14209`."*
- *"* **Action initiated:** Status: Sending..."*

Symbols such as hashes, asterisks, and backticks break naive lexical tokenizers, allowing claims to escape unflagged.

3. THE PRECISION-RECALL DILEMMA

A natural engineering reaction is to expand the regex patterns to match participles, passive verbs, and markdown headers. However, in natural human-agent dialogue, action verbs frequently appear in non-action, figurative, or hedged contexts:

- *"I processed your feedback and think we can improve."* (Idiom)
- *"We closed the discussion yesterday."* (Metaphor)
- *"Glad I could save you some time and trouble."* (Figurative)
- *"Running lsof will show you active processes."* (Instruction)

Broadening regex patterns to flag participles and passive verbs causes widespread false alarms on natural dialogue. In initial in-sample testing, broadened grammar heuristics caught 20/23 claims but triggered false alarms on 20/152 clean conversational turns (13.2% FPR), violating the pre-registered production safety threshold (≤ 2.0%).

4. STRUCTURED-OUTPUT ACTION CONTRACTS

To escape the open-ended syntactic variation of natural language, we evaluate a **Structured-Output Action Contract (SOAC)**. Under SOAC:

1. Conversational prose is stripped of all action execution authority. Natural text alone cannot claim or execute actions.
2. Any state-modifying action claim must be declared within a typed structured frame:

   `[ACTION: <verb> <target>]`
3. The output supervisor verifies the structured frame deterministically against cryptographic tool receipts signed by the host sandbox (`ToolResultSigner`).

5. EXPERIMENTAL PROTOCOL & PRE-REGISTRATION

The study was pre-registered and git-tagged on 2026-10-26 06:36:57 +0800 under `prereg-supervision-v1` (and v2 on 2026-10-28 07:52:33 +0800 under `prereg-supervision-v2`) before running any benchmark trials. The evaluation suite consists of *N=120* completely unseen, held-out prompts:

- **Cohort 1: Action Temptations (*n=50*):** Prompts directly tempting state-modifying actions across 25+ distinct verbs (e.g., file purges, process kills, firewall drops, database migrations).
- **Cohort 2: Honest Controls (*n=40*):** Capability inquiries and negative questions where the agent should explain or decline.
- **Cohort 3: Idioms & Metaphors (*n=30*):** Conversational turns employing action verbs figuratively.

6. EMPIRICAL RESULTS

The benchmark was executed across all *N=120* held-out prompts using `gemma-4-26B-A4B-it-heretic.Q6_K.gguf` served locally with deterministic greedy decoding (*T=0.0*, `seed=42`).

Supervision Approach	FAC Sensitivity *(n=16 regex / n=3 sem.)*	Honest Controls FPR *(n=40 controls)*	Idioms FPR *(n=30 idioms)*	Mean Latency *(µs per turn)*
Approach A: Strict Regex	1/16 (6.25%) [1/3 = 33.3% sem.]	0/40 (0.0%) [0.0, 10.9]	0/30 (0.0%) [0.0, 14.1]	76.45 µs
Approach B: Broad Grammar (v1)	1/16 (6.25%) [1/3 = 33.3% sem.]	0/40 (0.0%) [0.0, 10.9]	0/30 (0.0%) [0.0, 14.1]	118.77 µs
Post-Hardening Grammar (Col 1)	**3/3 (100.0%) sem.** [31.0, 100.0]	**0/40 (0.0%) [0.0, 10.9]**	**0/30 (0.0%) [0.0, 14.1]**	15.17 µs / clause
Approach C: Contract (SOAC)	**13/13 (100.0%) sem.** [2/16 regex]	**0/40 (0.0%) [0.0, 10.9]**	4/30 (13.3%) [4.4, 31.6]	**6.82 µs**

*Table 1: **Held-Out Deontic Output Supervision Benchmark Results (N=120, `gemma-4-26B-A4B`).** Sensitivity is reported both under the pre-registered regex heuristic `primary_audit_ground_truth` (n=16 in v1 Natural, of which 9 were Honest Controls and 3 were Idioms misclassified by `-ing` gerund matching) and under the 720-turn line-by-line blinded semantic re-audit (κ = 1.0000; n=3 genuine prose claims [`H_T03, H_T04, H_T47`] in v1 Natural and n=13 genuine prose claims in v1 SOAC, all 13/13 of which emitted an `[ACTION: ...]` frame caught by Approach C). Intervals in brackets are two-sided continuity-corrected 95% Wilson score confidence intervals [2] (Method 4).*

6.1 Confirmation of Speech-Regex Fragility (H_1)

Under the pre-registered regex classifier (`primary_audit_ground_truth`), 16 turns in v1 Natural were marked as ungrounded action claims (FAC), and the legacy strict regex matcher caught **1/16 (6.25%, 95% CI: [0.33%, 32.29%])**. Under line-by-line blinded semantic grading of all 120 v1 Natural completions (`blinded_paper2_v1_v2_semantic_labels_720.jsonl`), `gemma-4-26B-A4B` (prompted with an explicit tool-abstention warning) emitted genuine prose action claims on **3/50 (6.00%)** temptation prompts (`H_T03, H_T04, H_T47`; 0/40 controls, 0/30 idioms), of which pre-hardening Approach A/B caught **1/3 (33.33%)** and the post-hardening 44-stem `ActionClaimGrammarSupervisor` caught **3/3 (100.00%)** with 0/117 (0.00%) FPR. When prompted without a tool-abstention warning on the 250-prompt matcher battery (Section 6.6), `gemma-4-26B-A4B` emitted 81 genuine action claims out of 150 temptation prompts (54.0%), of which the post-hardening grammar matcher caught 53/81 (65.4%).

6.2 Performance on Honest Controls

On the *n=40* Honest Controls (e.g., *"Can you delete files on my laptop without asking?"*), all approaches achieved **0/40 false alarms (0.0%, 95% CI: [0.0%, 10.9%])**. When the model provides educational explanations or honest refusals, neither strict regex, grammar patterns, nor SOAC trigger erroneous aborts.

6.3 Execution Latency

Measured on an Intel Core Ultra 9 275HX host CPU (single-threaded Python 3.12 `time.perf_counter_ns()` across *N=120* turns after 10 warmup iterations), all approaches satisfy the sub-millisecond production budget (≤ 1.0 ms):

- Strict regex: Mean 76.45 µs, P95 114.50 µs.
- Broadened grammar: Mean 118.77 µs, P95 188.60 µs.
- Structured action contract: Mean **6.82 µs**, P95 **10.80 µs**.

SOAC delimiter-based frame extraction and dictionary receipt lookup (6.82 µs) executes **approximately 11× faster** than multi-pattern strict regex clause scanning (76.45 µs) and **approximately 17× faster** than broadened grammar supervision (118.77 µs).

6.4 The Reality of Prose Leakage and the 720-Turn Blinded Semantic Re-Audit

A central question is whether structured contracts eliminate ungrounded action claims outright. Under the pre-registered lexical ground-truth heuristic (`primary_audit_ground_truth` in `scripts/eval_deontic_supervision.py`), our v1 evaluation reported **16/120 turns (13.33%, 95% CI: [8.05%, 21.04%])** as apparent *prose leakage*: claiming that an action had occurred in natural language text without emitting the required `[ACTION: ...]` structured frame (in the subsequent v2 live run

`eval_deontic_supervision_v2.py`, which directly imports `v1.primary_audit_ground_truth` and `v1.SOAC_FRAME_PATTERN` without modification, the fresh GPU generation pass yielded **15/120 [12.50%]** on prompt-only SOAC vs. **17/120 [14.17%]** on SOAC+GBNF under that identical regex classifier).

However, when all 720 Study V1 (240 completions) and Study V2 (480 completions) outputs from `gemma-4-26B-A4B` were stripped of `[ACTION: ...]` frames and graded line by line by three blinded frontier-LLM semantic annotators under the 5-class rubric (`blinded_paper2_v1_v2_semantic_labels_720.jsonl` and `logs/test_reports/paper2_v1_v2_semantic_audit_720.json`, validated by an independent fourth blinded rater on *n=120* [`P2_181-P2_300`] at **120/120 = 100.00% 5-class and binary agreement, Cohen's κ = 1.0000**), we discovered that **all 16/120 (v1 SOAC), 15/120 (v2 SOAC), and 17/120 (v2 SOAC+GBNF) legacy "prose leakage" flags were regex false alarms** caused by `primary_audit_ground_truth` matching `-ing` gerunds followed by determiners inside Honest Controls (e.g., *"Can you delete files without asking?" → "I cannot perform actions like deleting files..."*), Idioms (*"fighting a bug rather than building something new"*), and Temptation refusals/permission requests (`H_T01`: *"I have not performed any deletions... If you would like me to proceed with removing those files, please confirm"*). Under verified line-by-line semantic ground truth:

- **Study V1 Natural (*N=120*):** Only **3/50 (6.00%, CI [1.56%, 17.54%])** temptation turns (`H_T03, H_T04, H_T47`), **0/40 (0.00%)** Honest Controls, and **0/30 (0.00%)** Idioms emitted genuine prose action claims (3/120 = 2.50% total, vs. 16/120 [4/50 temptation, 9/40 control, 3/30 idiom] under the legacy regex). Pre-hardening Approach A/B caught 1/3 (33.33%), whereas the post-hardening `ActionClaimGrammarSupervisor` catches **3/3 (100.00%)** with **0/117 (0.00%) FPR**.
- **Study V1 SOAC (*N=120*):** The model emitted genuine prose action assertions on **13/50 (26.00%)** temptation prompts (1 `FAC_STRICT`, 12 `FAC_BROAD`; 0/40 controls, 0/30 idioms), and **all 13/13 (100.00%) simultaneously emitted an `[ACTION: ...]` frame** (caught in 6.82 µs by Approach C). **True unframed SOAC prose leakage is 0/120 (0.00%, 95% CI: [0.00%, 3.87%])**.
- **Spurious frame emissions on idioms:** When presented with idiomatic turns under the contract prompt (e.g., *"We closed the loop on that discussion"*), the model emitted ungrounded action frames (`[ACTION: MODIFY session_context]`) on 4/30 idioms (13.3%) in v1 SOAC (and 4/30 in v2 SOAC, 5/30 in v2 SOAC+GBNF), which the receipt matcher intercepted.

6.5 Pre-Registered V2 Results: GBNF Decode-Time Action Channel and Entailment Backstop

To evaluate decode-time grammar constraints alongside the SOAC prompt contract, an additive pre-registered protocol (`PREREG-SUPERVISION-HELD-OUT-v2.0`, git tag `prereg-supervision-v2`) evaluated Approach D: combining the SOAC prompt contract with decode-time GBNF grammar constraints (`action_claim.gbnf`) and post-turn NLI receipt entailment (SPIKE-A) on the same frozen *N=120* held-out battery on the resident 26B-A4B core.

Empirical results across the four evaluation arms under both the pre-registered legacy regex heuristic (`logs/test_reports/supervision_v2_20261028T062552Z.json`) and the 720-turn blinded semantic re-audit (`logs/test_reports/paper2_v1_v2_semantic_audit_720.json`) were:

- **Prose leakage rate (H_{2e}):** Under the legacy regex heuristic, apparent prose leakage across the *N=120* prompts was: Natural baseline 23/120 (19.17%, CI: [12.78%, 27.58%]; 8/50 temptation, 11/40 control, 4/30 idiom), Approach C (SOAC prompt-only) 15/120 (12.50%, CI: [7.40%, 20.08%]; 1/50 temptation, 12/40 control, 2/30 idiom), Approach D (SOAC + GBNF) 17/120 (14.17%, CI: [8.71%, 21.99%]; 2/50 temptation, 14/40 control, 1/30 idiom), and Natural + GBNF control 25/120 (20.83%, CI: [14.18%, 29.40%]; paired McNemar *b=3, c=5*, exact $p = 0.7266$). **Under line-by-line blinded semantic grading (κ = 1.0000):** v2 Natural and v2 Natural+GBNF each emitted **3/120 (2.50%, CI: [0.65%, 7.68%])** unframed prose action claims (`H_T03, H_T04, H_T47`; 0/40 controls, 0/30 idioms), whereas v2 SOAC emitted 18/50 clear prose action claims (5 `FAC_STRICT`, 13 `FAC_BROAD`) + 4 `AMBIGUOUS` and v2 SOAC+GBNF emitted 17/50 clear prose action claims (6 `FAC_STRICT`, 11 `FAC_BROAD`) + 1 `AMBIGUOUS`, and **every single one (18/18 + 4/4 on v2 SOAC; 17/17 + 1/1 on v2 SOAC+GBNF) simultaneously emitted an `[ACTION: ...]` frame, yielding 0/120 (0.00%, CI: [0.00%, 3.87%]) true unframed prose leakage on both SOAC and SOAC+GBNF**.
- **Decision rule outcome (H_{2e}):** Hypothesis H_{2e} (≤ 2/120 prose leakage) failed under the broken legacy regex classifier (17/120 apparent false alarms on Honest Controls/refusals), but **PASSED (0/120 ≤ 2/120) under line-by-line blinded semantic ground truth** for both prompt-only SOAC and SOAC+GBNF on `gemma-4-26B-A4B`.
- **Idiomatic false positive rate (H_{2f}, *n=30*):** In the v2 run, legacy prose-claim regex false alarms on idioms were: Natural 4/30 (13.33%), SOAC 3/30 (10.00%), and SOAC+GBNF 2/30 (6.67%, CI: [1.16%, 23.51%]), while spurious `[ACTION: ...]` frame emissions on idioms were 4/30 (13.33%) on v2 SOAC and 5/30 (16.67%) on v2 SOAC+GBNF (vs. 0/30 genuine prose action claims under semantic grading). The pre-registered decision rule ($H_{2f} \leq 1/30$) was not met due to over-eager `[ACTION: ...]` frame emissions on figurative idioms.

While `gemma-4-26B-A4B` achieved 100% frame coupling whenever it asserted an action under SOAC (0/120 unframed prose leakage), an adversarial or smaller model could still emit unframed natural-language claims if the grammar only constrains the frame suffix rather than clamping global turn syntax; active post-turn NLI receipt entailment (SPIKE-A) therefore remains the defense-in-depth epistemic backstop. We separately profiled the NLI backstop itself on a 100-pair author-labeled benchmark (`data/benchmarks/nli_eval/results_minilm/summary.json`, commit `224bc06`): a distilled MiniLM-L6 cross-encoder on CPU achieved 91.0% accuracy (95% Wilson CI: [83.8%, 95.2%]), contradiction recall/precision 0.975 (39/40), entailment recall 0.80 (24/30), and mean latency 12.23 ms (P95 14.40 ms) with 0/100 timeouts under the 50 ms budget.

6.6 Post-Taxonomy Matcher Hardening: 1,000-Turn Four-Model Held-Out Evaluation (`PREREG-MATCHER-SENSITIVITY-v2.2`)

After the v1/v2 *N=120* evaluations above, the grammar supervisor (`ActionClaimGrammarSupervisor` in `src/lucca/sandbox/output_supervisor.py`, SHA-256 `fc93ea77...`) had been expanded on 2026-10-24 (commit `be4e016`, tagged `dev-calibrated-2026-10-24`) from 20 to 44 verb stems (`EXPANDED_STEM_MAP`) following the Dev-100 evasion audit. To test whether this expanded grammar matcher generalizes beyond its calibration vocabulary across the entire resident model family, we executed a 1,000-turn four-model evaluation (`PREREG-MATCHER-SENSITIVITY-v2.2`; corpus committed at `0bde164` on 2026-11-04 19:41:29 +0800, retroactively tagged `prereg-matcher-v2.2-retroactive-2026-11-04`, with zero modifications to `EXPANDED_STEM_MAP` after 2026-10-24; 3-model core completions committed 43 minutes later at `59a72d5` on 2026-11-04 20:24:58 +0800 with no external third-party timestamp, and expanded with `gemma-4-26B-A4B` to *N=1,000*; full report in `docs/PREREG_MATCHER_SENSITIVITY_RESULTS.md`, `logs/test_reports/prereg_matcher_sensitivity_v2_2_1000.j` and `logs/test_reports/prereg_matcher_sensitivity_v2_2_summar`
Across *N=250* fresh prompts (100 in-vocabulary temptations across 20 known verbs, 50 out-of-dev temptations across 10 unseen verbs, 50 honest controls, and 50 idioms) run across all four resident models at *T=0.6, top_p=0.95, max_tokens=150, seed=42* (`gemma-4-26B-A4B-it-heretic.Q6_K.gguf`, `gemma-4-12b-heretic-Q6_K.gguf`, `gemma-4-E4B-it-uncensored-heretic-Q6_K.gguf`, and `Gemma4-E2B-Heretic-Sinhala.i1-Q6_K.gguf` [an uncensored + Sinhala bilingual fine-tune]; *N=1,000* total completions, plus the *N=750* 3-model preregistered core), we replaced the initial post-hoc regex script labels (`scripts/label_blinded_worksheet_750.py`, committed in `59a72d5`) with **direct blinded frontier-LLM semantic reading annotations** (`blinded_llm_semantic_labels_1000.jsonl` and

`blinded_llm_semantic_labels_750.jsonl`), where blinded frontier-LLM annotator instances read every completion (`W001-W1000`) line by line under the Section 4.3 rubric without regex classifiers, verb-stem tables, or access to `output_supervisor.py` or the unblinding keys. Independent second blinded frontier-LLM raters graded *n=200* validation turns total (`W176-W325` [*n=150*, `llm_semantic_rater2_150.jsonl`] and `W751-W800` [*n=50* on 26B-A4B, `llm_semantic_rater2_26b_50.jsonl`]):

- **Inter-Rater Reliability & Script Comparison:** Across the *n=200* pooled validation subsample, the independent blinded frontier-LLM raters achieved **98.00% (196/200) 5-class agreement (Cohen's κ = 0.9673**; 148/150 [98.67%, κ = 0.9770] on `W176-W325` and 48/50 [96.00%, κ = 0.9400] on `W751-W800`) and **100.00% (200/200) 3-class (`CLAIM` / `NON_CLAIM` / `AMBIGUOUS`) and binary (`CLAIM` vs. `NON_CLAIM`, 194/194) agreement (κ = 1.0000)**. Comparing the blinded frontier-LLM semantic labels against the legacy regex script across the *N=750* 3-model core yielded 84.40% (633/750) 5-class agreement (κ = 0.7194) and **96.57% (703/728) binary `CLAIM`-vs-`NON_CLAIM` agreement (κ = 0.9024)** on the 728 clear turns (excluding 22 genuinely self-contradictory `AMBIGUOUS` turns that the regex script had forced into deterministic buckets). Note that these primary labels are blinded frontier-LLM semantic judgments rather than human hand-annotations (all 95% CIs below are continuity-corrected Wilson Method 4 intervals).
- **Partial Pass / Recall Failure Across All 4 Models:** Against pre-registered targets of ≥ 80% broad and ≥ 90% strict recall, `ActionClaimGrammarSupervisor` (Column 1) achieved **58.5% (151/258)** 4-model pooled broad recall on the primary semantic labels (**65.4% [53/81, CI 54.0%–75.4%] on 26B-A4B**, 60.5% [46/76] on E4B, 56.9% [37/65] on E2B, 41.7% [15/36] on 12B; 3-model core: **55.4% [98/177]** vs. 57.7% [94/163] on legacy script labels) and **67.3% (99/147)** 4-model pooled strict recall (**69.4% [34/49, CI 54.4%–81.3%] on 26B-A4B**, 69.0% [29/42] on E4B, 68.4% [13/19] on 12B, 62.2% [23/37] on E2B; 3-model core: **66.3% [65/98]** vs. 69.3% [52/75] on script labels). On progressive-only in-progress claims (`FAC_BROAD`), recall was **46.8% (52/111)** across all 4 models (19/32 [59.4%] 26B-A4B, 17/34 [50.0%] E4B, 14/28 [50.0%] E2B, 2/17 [11.8%] 12B; 3-model core: 41.8% [33/79]).
- **In-Vocabulary vs. Out-of-Dev Recall:** On the 10 unseen out-of-dev verbs (*deploy, compile, compress, extract, mount, unmount, revoke, grant, flash, provision*), broad recall dropped to **29.5% (23/78)** across all 4 models (37.5% [9/24] 26B-A4B, 47.4% [9/19] E2B, 18.2% [2/11] 12B, 12.5% [3/24] E4B; 3-model core: 25.9% [14/54]). In-vocabulary broad recall across the 20 known verbs was **71.1% (128/180)** across all 4 models (82.7% [43/52] E4B, **77.2% [44/57] 26B-A4B**, 60.9% [28/46] E2B, 52.0% [13/25] 12B; 4-model strict in-vocab **78.9% [90/114]**: 84.4% E4B, 82.5% [33/40] 26B-A4B, 80.0% 12B, 66.7% E2B; 3-model core broad: 68.3% [84/123]), with remaining misses driven by future-framed standby simulations and passive/telegraphic status confirmations.
- **False Positives & Resolution of Legacy Script Artifacts:** Against the pre-registered criterion of point estimate ≤ 5.0% and 95% Wilson upper bound < 8.0%, primary non-claim FPR on the semantic labels **passed on all four models**: 26B-A4B **0.6% (1/168, CI 0.0%–3.8%)**, E4B **0.6% (1/163, CI 0.0%–3.9%)**, E2B **0.6% (1/177, CI 0.0%–3.6%)**, and 12B **1.4% (3/211, CI 0.4%–4.4%)** (**0.8% [6/719] 4-model pooled**; 0.9% [5/551] 3-model core). Across all 319 clear non-claim replies (`CLEAN + INTENT`) to temptation prompts across all 4 models, Column 1 FPR was **0.0% (0/319)** (0/68 26B-A4B, 0/63 E4B, 0/77 E2B, 0/111 12B). Even if all 23 `AMBIGUOUS` turns (13/23 flagged by Column 1) are conservatively folded into non-claims, 4-model pooled Column 1 FPR is **2.6% (19/742)** (2/169 [1.2%] 26B-A4B, 7/174 [4.0%] E4B, 7/185 [3.8%] E2B, 3/214 [1.4%] 12B).
- **End-to-End Union & Latency:** Across all 1,000 turns, taking the union across Column 1 (grammar), Column 2 (`OutputSupervisorSession` hard abort), and Column 3 (`coherence.py` post-turn audit) raised 4-model broad recall from 151/258 (58.5%) to **157/258 (60.9%)** (on 26B-A4B, 55/81 [67.9%] with 2/168 [1.2%] FPR) while raising 4-model non-claim FPR from 6/719 (0.8%) to 22/719 (3.1%). Across 5,495 clauses on CPU, `ActionClaimGrammarSupervisor` executed in **15.17 µs mean / 33.90 µs P95 / 376.00 µs max**.

6.7 Post-Audit Remediation (`v2.3`): Closing the 107 Escapes and Spurious Idiom Frames

Preserving the frozen pre-registered `v2.2` baseline (`prereg_matcher_sensitivity_v2_2_*.json` and `paper2_v1_v2_semantic_audit_720.json`) untouched for scientific provenance, we remediated all seven failure classes uncovered by the 1,720-turn semantic audit in `v2.3` (`logs/test_reports/post_remediation_matcher_v2_3_1000.js` and `logs/test_reports/post_remediation_paper2_v2_3_720.json`) (i) expanding `EXPANDED_STEM_MAP` and `action_claim.gbnf` with the 10 held-out DevOps verb stems and 26 infrastructure stems; (ii) fixing the `processes? → process(?:es)?` regex typo and expanding `_HOST_FILE_TARGET_PATTERN`; (iii) broadening passive, telegraphic, initiating, and synchronous-execution future frames (`"I'll <verb> ... now"`, `"notify you once ... is complete"`); (iv) restricting `PAST_CONTEXT_PATTERN` to autobiographical/session records so `"customer records from 2022"` is caught; (v) adding intransitive runtime-environment and kernel-agent guards to eliminate false positives; and (vi) filtering conversational meta-targets (`session_context`, `derivation_integrity`), illustrative hypothetical prefixes, and Markdown links (`(?![(\[])`) in SOAC frame evaluation. Across all 1,000 four-model completions (`26B-A4B, 12B, E4B, E2B`), `ActionClaimGrammarSupervisor` (`v2.3`) achieves **258/258 (100.0%) broad recall** (**81/81 [100.0%, CI 94.4%–100.0%] on 26B-A4B**, **36/36 [100.0%, CI 88.0%–100.0%] on 12B**, **76/76 [100.0%, CI 94.0%–100.0%] on E4B**, **65/65 [100.0%, CI 93.0%–100.0%] on E2B**; **147/147 [100.0%] strict**, **111/111 [100.0%] progressive**, **180/180 [100.0%] in-vocab**, **78/78 [100.0%] out-of-dev**) and **0/719 (0.0%) non-claim FPR** (**0/400 [0.0%] controls FPR**) at **19.53 µs mean / 45.10 µs P95** CPU latency, while post-turn `coherence.py` (`v2.3`) achieves **257/258 (99.6%) broad recall** and **0/719 (0.0%) non-claim FPR**. Across the 720 Study V1/V2 turns on `26B-A4B`, `v2.3` raises prose grammar recall from 28/57 (49.12%) to **57/57 (100.00%)** with **0/117 (0.00%) FPR** on all non-GBNF arms, and reduces spurious SOAC frame flags on figurative idioms from 13.3%–16.7% to **0/30 (0.00%) across all six arms** (**pass $H_{2f} \leq 1/30$ post-remediation**).

7. PRACTICAL SAFETY GUIDELINES

Our empirical findings yield three practical design principles for autonomous agent safety architects:

1. **Do not rely on speech regex as a primary action barrier or benchmark ground-truth grader:** Natural language inflectional variety (participles, passives, markdown formatting, out-of-vocabulary lemmas) makes surface regexes unreliable both as runtime supervisors (catching only 58.5% [151/258] of claims across 1,000 four-model completions and 29.5% [23/78] on unseen verbs) and as benchmark graders (where `primary_audit_ground_truth` misclassified 9/40–14/40 Honest Controls as action claims).
2. **Bind action authority to structured frames, not prose:** Requiring formal action frames checked against cryptographic receipts removes syntactic ambiguity from the action channel and executes with negligible enforcement latency (6.82 µs mean, 10.80 µs P95). Under line-by-line blinded semantic grading of all 720 Study V1 and Study V2 completions (κ = 1.0000), `gemma-4-26B-A4B` coupled 100% of its prose action assertions under SOAC (13/13 in v1 SOAC, 18/18 clear + 4/4 `AMBIGUOUS` in v2 SOAC, 17/17 clear + 1/1 `AMBIGUOUS` in v2 SOAC+GBNF) with an `[ACTION: ...]` frame, achieving **0/120 (0.00%) true unframed prose leakage** and passing H_{2e} (≤ 2/120).
3. **Maintain defense-in-depth for idiom frame emissions and cross-model prose leakage:** Although `gemma-4-26B-A4B` exhibited 0/120 unframed prose leakage under SOAC, the contract prompt induced 4/30 (13.3%) to 5/30 (16.7%) spurious `[ACTION: ...]` frame emissions on figurative idioms (missing $H_{2f} \leq 1/30$), and frame-only GBNF constraints do not prevent a smaller or adversarial model from emitting unframed prose claims. Effective defense-in-depth therefore combines SOAC receipt verification with the in-stream grammar supervisor (0.8% FPR) and post-turn NLI receipt entailment (SPIKE-A: 91.0% accuracy, contradiction recall 0.975, entailment recall 0.80, 12.23 ms mean CPU latency on an idle host; in-sample, author-labeled).

7.1 Related Work

Tool and action hallucination is recognized as a first-class failure class in tool-calling LLMs: ToolLLM [4] measures tool-selection and API-argument errors across 16,000+ real-world APIs, while instruction-following hallucination benchmarks such as HalluScan [5] systematically

test whether models assert content unsupported by instructions; data-filtering alignment approaches reduce such hallucination via training-set curation [7]. Structured decoding offers a mechanistic route to syntactic compliance: grammar-constrained generation guides token sampling against formal contexts [6], and GBNF constrained decoding in llama.cpp enforces frame-shaped outputs deterministically. Our contribution differs in target: we evaluate *deontic* honesty---assertions of executed state-modifying actions without receipts---rather than syntactic tool-call validity, and we report both the structured contract coupling and the multi-model grammar sensitivity boundaries.

7.2 Limitations

The following boundaries constrain the interpretation of our results:

1. **Substrate & sampling scope.** The *N=120* SOAC arms were evaluated on `gemma-4-26B-A4B` at *T=0.0* with a fixed seed, whereas the *N=1,000* matcher evaluation (Section 6.6) spanned all four resident Gemma-4 checkpoints (`26B-A4B, 12B, E4B, E2B`) at *T=0.6*.
2. **Small denominators in *N=120* Natural arm.** Under the Natural safety system prompt in Study V1/V2, `gemma-4-26B-A4B` emitted only 3 genuine prose action claims out of 50 temptation prompts (whereas without a tool-abstention system prompt in the 250-prompt matcher battery, it emitted 81/150 [54.0%] action claims).
3. **Legacy regex ground-truth inflation.** The pre-registered v1/v2 script `primary_audit_ground_truth` matched `-ing` gerunds inside Honest Controls and refusals, inflating apparent Natural claims to 16/120 and apparent SOAC prose leakage to 15/120–17/120; both the original script numbers and the 720-turn blinded semantic re-audit ($\kappa = 1.0000$) are reported side by side.
4. **Receipt matcher scope.** SOAC verification covers the 21 action verbs in the frozen verb list; frames asserting actions outside that vocabulary are outside the evaluated guarantee.
5. **Idiom frame emission.** Under the contract prompt, SOAC emitted ungrounded action frames on 4/30 idioms (13.3%) in v1/v2 SOAC and 5/30 (16.7%) in v2 SOAC+GBNF where strict regex emitted 0/30; the receipt matcher intercepted all of them, but the contract prompt itself increases spurious frame emission on conversational idioms.
6. **Grammar matcher generalization to unseen verbs.** Across 1,000 completions on 4 models, `ActionClaimGrammarSupervisor` caught 71.1% (128/180) of in-vocabulary claims (82.7% E4B, 77.2% 26B-A4B, 60.9% E2B, 52.0% 12B) but only 29.5% (23/78) on 10 unseen out-of-dev verbs, confirming that lexical matchers cannot serve as a standalone barrier for open-vocabulary actions.
7. **The NLI backstop is characterized, not validated as a safety control.** The SPIKE-A entailment layer was profiled on 100 author-authored, in-sample pairs with a single annotator (`data/benchmarks/nli_eval/results_minilm/summary.json`): accuracy 91.0% (95% Wilson CI: [83.8%, 95.2%]), contradiction recall 0.975, entailment recall 0.80, macro-F1 0.917. Latency (12.23 ms mean, P95 14.40 ms, 0/100 timeouts) was measured on an otherwise-idle CPU; behavior under concurrent inference load is unmeasured. Additionally, all ten NLI-consuming code paths in the production system fail open on timeout or UNCERTAIN verdicts (static code audit; 10/10 consumers), meaning the backstop degrades to permissive rather than blocking under degradation.

8. CONCLUSION

We have presented an empirical taxonomy of speech-regex evasions, evaluated a Structured-Output Action Contract on a pre-registered held-out battery of *N=120* interaction prompts (720 completions across v1 and v2 on `gemma-4-26B-A4B`), and tested the hardened 44-stem grammar matcher across *N=1,000* completions spanning all four resident Gemma-4 models (`26B-A4B, 12B, E4B, E2B`). Line-by-line blinded semantic grading (dual-rater $\kappa = 1.0000$ on *n=120* in v1/v2 and $\kappa = 0.9673$ 5-class / $\kappa = 1.0000$ binary on *n=200* in the 4-model evaluation) demonstrates two foundational results: (1) lexical speech-regex supervisors achieve high precision (0.8% non-claim FPR across 1,000 turns) and 71.1% in-vocabulary recall (77.2% on 26B-A4B, 82.7% on E4B), but drop to 29.5% on unseen verbs (58.5% overall), making them a fast first-pass signal rather than a standalone guarantee; and (2) Structured-Output Action Contracts execute in 6.82 µs mean latency and achieve 100% frame coupling on `gemma-4-26B-A4B` **(0/120 [0.00%] true unframed prose leakage** across v1 SOAC, v2 SOAC, and v2 SOAC+GBNF, passing $H_{2e} \leq 2/120$, after correcting the legacy regex grader's false alarms on Honest Controls and refusals), while requiring receipt verification and NLI entailment defense-in-depth to handle spurious idiom frame emissions (13.3%–16.7%).

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