Cyber Linguistics

In an era when machines speak, language is no longer just human

Breck Baldwin, *w;AI (with AI)* — GPT-4o

August 14, 2025

NIST AI Metrology Colloquium Series

Outline

- The Limerick
- Gratitude and Acknowledgment
- Experimental Results on LLM Determinism
    - Determinism for LLMs
    - Mid talk conclusions
- Why Cyber Linguistics?
- Pragmatics: Bringing Chomsky to a Grice Fight
- Conclusions

Breck’s opining on AI down at NIST,
Cyber Linguistics is top of the list.
Though Chomsky looms large,
Grice should be in charge—
And determinism? It doesn’t exist.

Gratitude and Acknowledgement

- NIST is one of two Federal organizations I owe (DARPA is the other)
    - MUC-6/7, TIPSTER, TREC, DUC
- Evaluation matters
    - "The MUCs are notable, however, in that they in large part have shaped the research program in information extraction and brought it to its current state" Grisham/Sundhiem 1996
- Downstream effects
    - Explosion of structured evals
        - Was: Extraction/Coreference/IR/Summarization
        - Is: Multiple choice, humor, world knowledge...

But We have Lost Ground

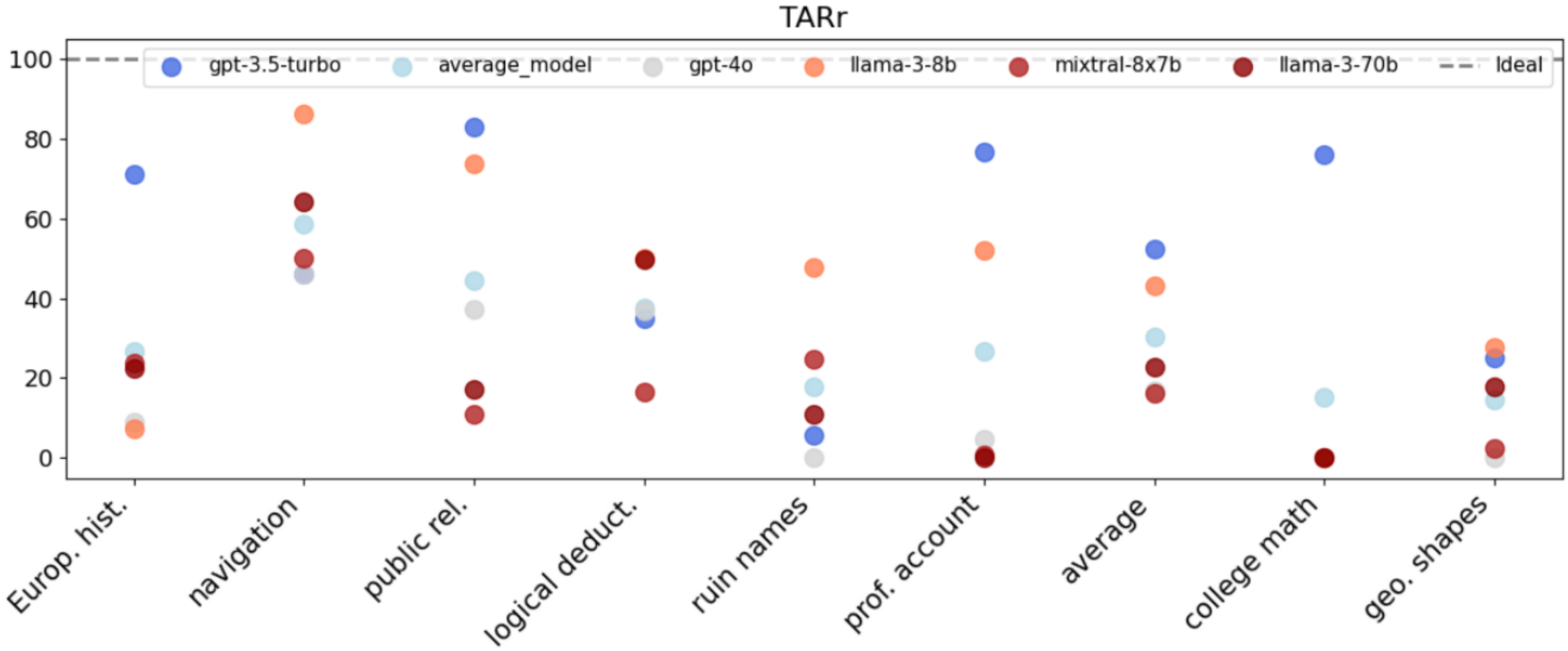
Non-Determinism of "Deterministic" LLM Settings: https://arxiv.org/abs/2408.04667

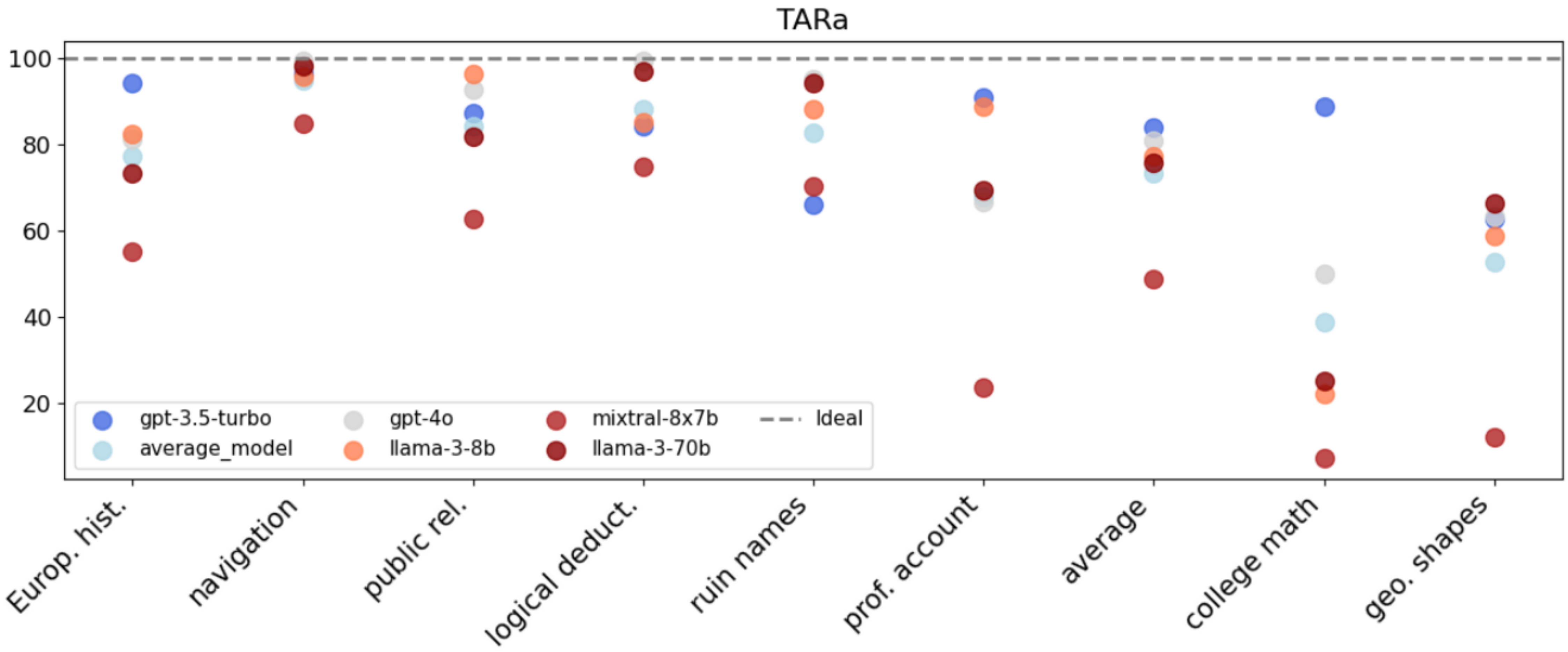
Berk Atil, Sarp Aykent, Alexa Chittams, Lisheng Fu, Rebecca J. Passonneau, Evan Radcliffe, Guru Rajan Rajagopal, Adam Sloan, Tomasz Tudrej, Ferhan Ture, Zhe Wu, Lixinyu Xu, Breck Baldwin

- TL;DR Hosted LLMs are very non-Deterministic

Initial Data and Metrics

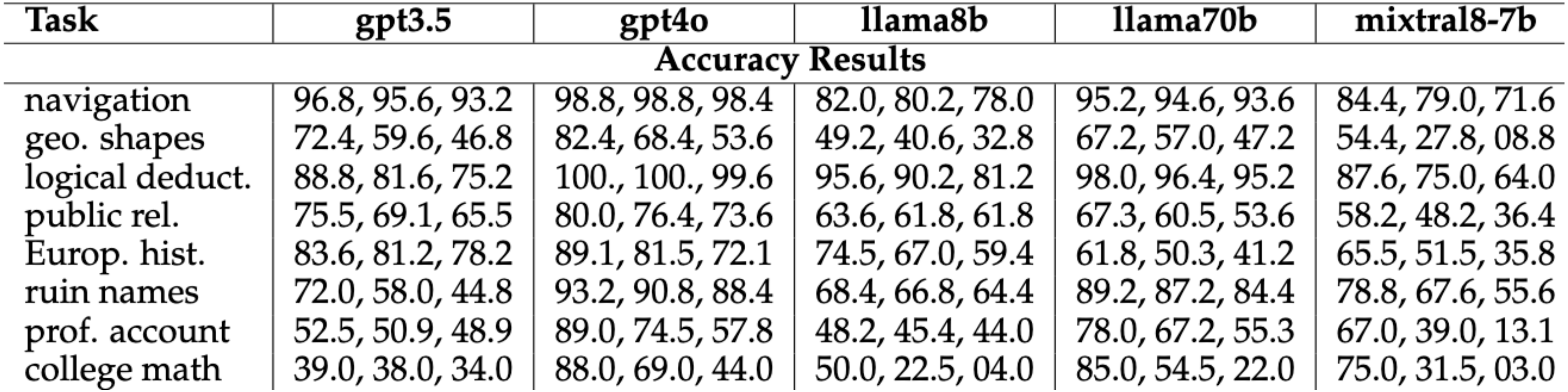
- 8 multiple choice tasks (100 to 282 questions)
  - BBH: navigation, ruin names, geometric shapes, logical deduction 3 objects
  - MMLU: European history, college math, professional accounting, public relations
- Run 10 times--deterministic settings
- TARr: Total Agreement Rate raw (bytes):
  - Counts how many responses had the same bytes across 10 runs
- TARa: Total Agreement Rate answer (parsed answer):
  - Agree: "The answer is A" == "A is the answer"
  - Counts how many questions had the same answer across 10 runs
  - Agnostic about correctness of answer


TARr
gpt-3.5-turbo
average_model
gpt-4o
llama-3-8b
mixtral-8x7b
llama-3-70b
Ideal
100
80
60
40
20
0
Europ. hist.
navigation
public rel.
logical deduct.
ruin names
prof. account
average
college math
geo. shapes



https://breckbaldwin.github.io

How about Accuracy?



Task	gpt3.5	gpt4o	llama8b	llama70b	mixtral8-7b
			Accuracy Results		
navigation	96.8, 95.6, 93.2	98.8, 98.8, 98.4	82.0, 80.2, 78.0	95.2, 94.6, 93.6	84.4, 79.0, 71.6
geo. shapes	72.4, 59.6, 46.8	82.4, 68.4, 53.6	49.2, 40.6, 32.8	67.2, 57.0, 47.2	54.4, 27.8, 08.8
logical deduct.	88.8, 81.6, 75.2	100., 100., 99.6	95.6, 90.2, 81.2	98.0, 96.4, 95.2	87.6, 75.0, 64.0
public rel.	75.5, 69.1, 65.5	80.0, 76.4, 73.6	63.6, 61.8, 61.8	67.3, 60.5, 53.6	58.2, 48.2, 36.4
Europ. hist.	83.6, 81.2, 78.2	89.1, 81.5, 72.1	74.5, 67.0, 59.4	61.8, 50.3, 41.2	65.5, 51.5, 35.8
ruin names	72.0, 58.0, 44.8	93.2, 90.8, 88.4	68.4, 66.8, 64.4	89.2, 87.2, 84.4	78.8, 67.6, 55.6
prof. account	52.5, 50.9, 48.9	89.0, 74.5, 57.8	48.2, 45.4, 44.0	78.0, 67.2, 55.3	67.0, 39.0, 13.1
college math	39.0, 38.0, 34.0	88.0, 69.0, 44.0	50.0, 22.5, 04.0	85.0, 54.5, 22.0	75.0, 31.5, 03.0

- Best Possible, Median, Worst Possible Accuracy over 10 runs

But Nobody Cares

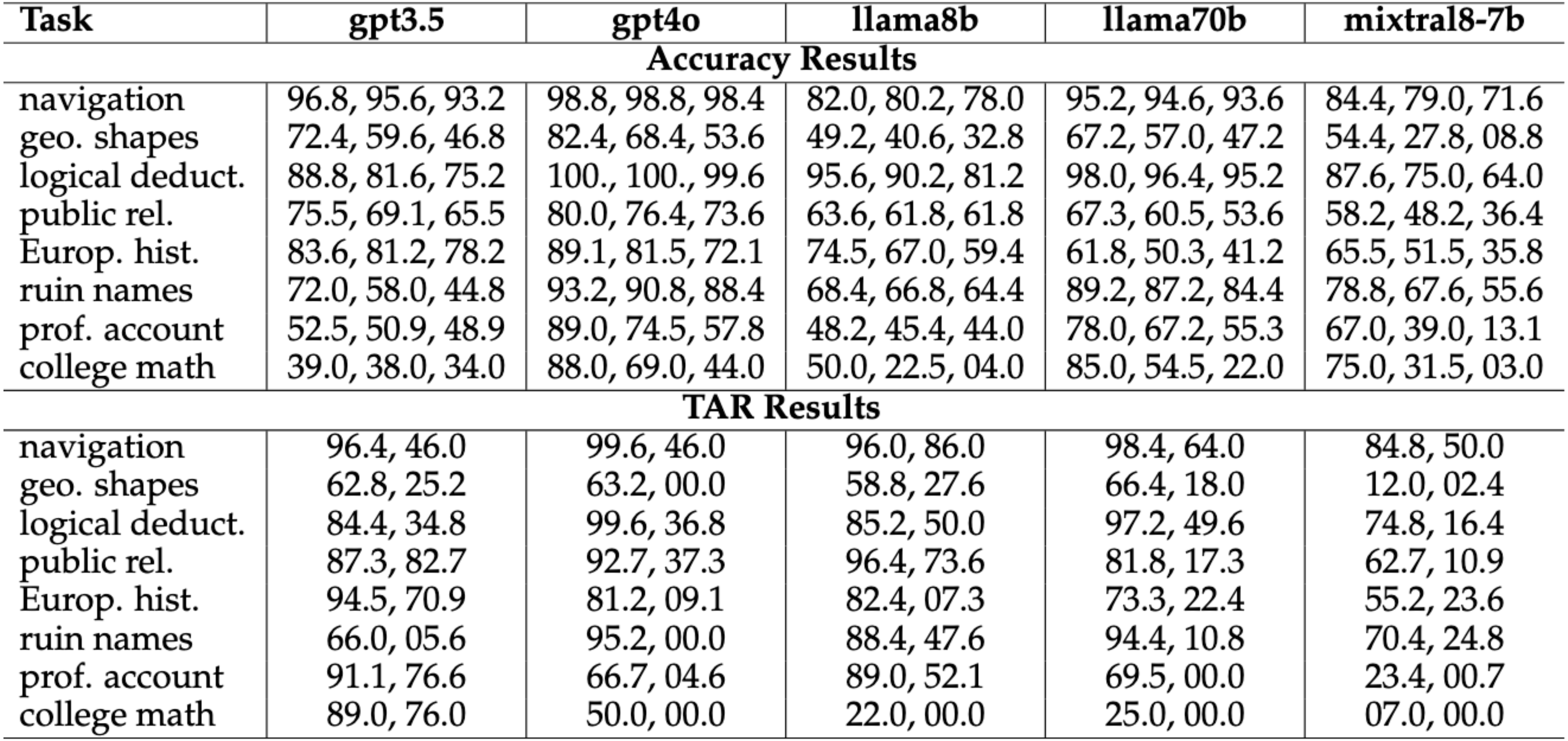
- Benchmark numbers are for marketing, not engineering
- Randomness helps with the reality/perception of intelligence:

  "...if we dial back all sources of randomness within our current large language models (LLMs) they will also act deterministically, albeit in fairly unknowable ways. This, however, isn't how we use AI. We deliberately include randomness because it's that aspect that leads to interesting and new behaviour. We want AI to do things that would previously have required a human user, and this has significant consequences." From Dave Hudson's Blog:

- Humans are primary consumers of LLM outputs and are robust to non-determinism
- To achieve AGI it's LLMs all the way down. They will create determinism if they need it.

Mid-talk Conclusions

- Determinism does not exist across any task/model
- The impact on accuracy (performance) can be profound
- Trivial fix is to run single batch
    - Likely mechanism is packing inputs to LLMs on hosted instances
- Nobody cares...hopefully NIST does



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Accuracy Results					
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geo. shapes	72.4, 59.6, 46.8	82.4, 68.4, 53.6	49.2, 40.6, 32.8	67.2, 57.0, 47.2	54.4, 27.8, 08.8
logical deduct.	88.8, 81.6, 75.2	100., 100., 99.6	95.6, 90.2, 81.2	98.0, 96.4, 95.2	87.6, 75.0, 64.0
public rel.	75.5, 69.1, 65.5	80.0, 76.4, 73.6	63.6, 61.8, 61.8	67.3, 60.5, 53.6	58.2, 48.2, 36.4
Europ. hist.	83.6, 81.2, 78.2	89.1, 81.5, 72.1	74.5, 67.0, 59.4	61.8, 50.3, 41.2	65.5, 51.5, 35.8
ruin names	72.0, 58.0, 44.8	93.2, 90.8, 88.4	68.4, 66.8, 64.4	89.2, 87.2, 84.4	78.8, 67.6, 55.6
prof. account	52.5, 50.9, 48.9	89.0, 74.5, 57.8	48.2, 45.4, 44.0	78.0, 67.2, 55.3	67.0, 39.0, 13.1
college math	39.0, 38.0, 34.0	88.0, 69.0, 44.0	50.0, 22.5, 04.0	85.0, 54.5, 22.0	75.0, 31.5, 03.0
TAR Results					
navigation	96.4, 46.0	99.6, 46.0	96.0, 86.0	98.4, 64.0	84.8, 50.0
geo. shapes	62.8, 25.2	63.2, 00.0	58.8, 27.6	66.4, 18.0	12.0, 02.4
logical deduct.	84.4, 34.8	99.6, 36.8	85.2, 50.0	97.2, 49.6	74.8, 16.4
public rel.	87.3, 82.7	92.7, 37.3	96.4, 73.6	81.8, 17.3	62.7, 10.9
Europ. hist.	94.5, 70.9	81.2, 09.1	82.4, 07.3	73.3, 22.4	55.2, 23.6
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prof. account	91.1, 76.6	66.7, 04.6	89.0, 52.1	69.5, 00.0	23.4, 00.7
college math	89.0, 76.0	50.0, 00.0	22.0, 00.0	25.0, 00.0	07.0, 00.0

Cyber Linguistics

Engineering with language inputs and outputs of LLMs

- LLMs have stabilized as an amazing technology, but...
  - Poorly behaved neighbors to OSs, DBs, APIs
- LLMs must transition to being one of many tools in system building
  - Understandability
  - Reliability
  - Stability
- Put a name to the pain: "Cyber Linguistics"

What's missing from current LLM theory?

Some starting points:

- Appropriate evaluation and metrics
- Calibration
- Reasoning with stochastic processes
    - Unit testing
    - Is the process truly stochastic?
- "Old School" infrastructure to help with theory
    - Theory of computation: Prompt x inference -> Expected response
    - Classes of logics
    - Pragmatics

Bringing Chomsky to a Grice Fight

College Math: 100 Questions x GPT-4o (Toy Problem)

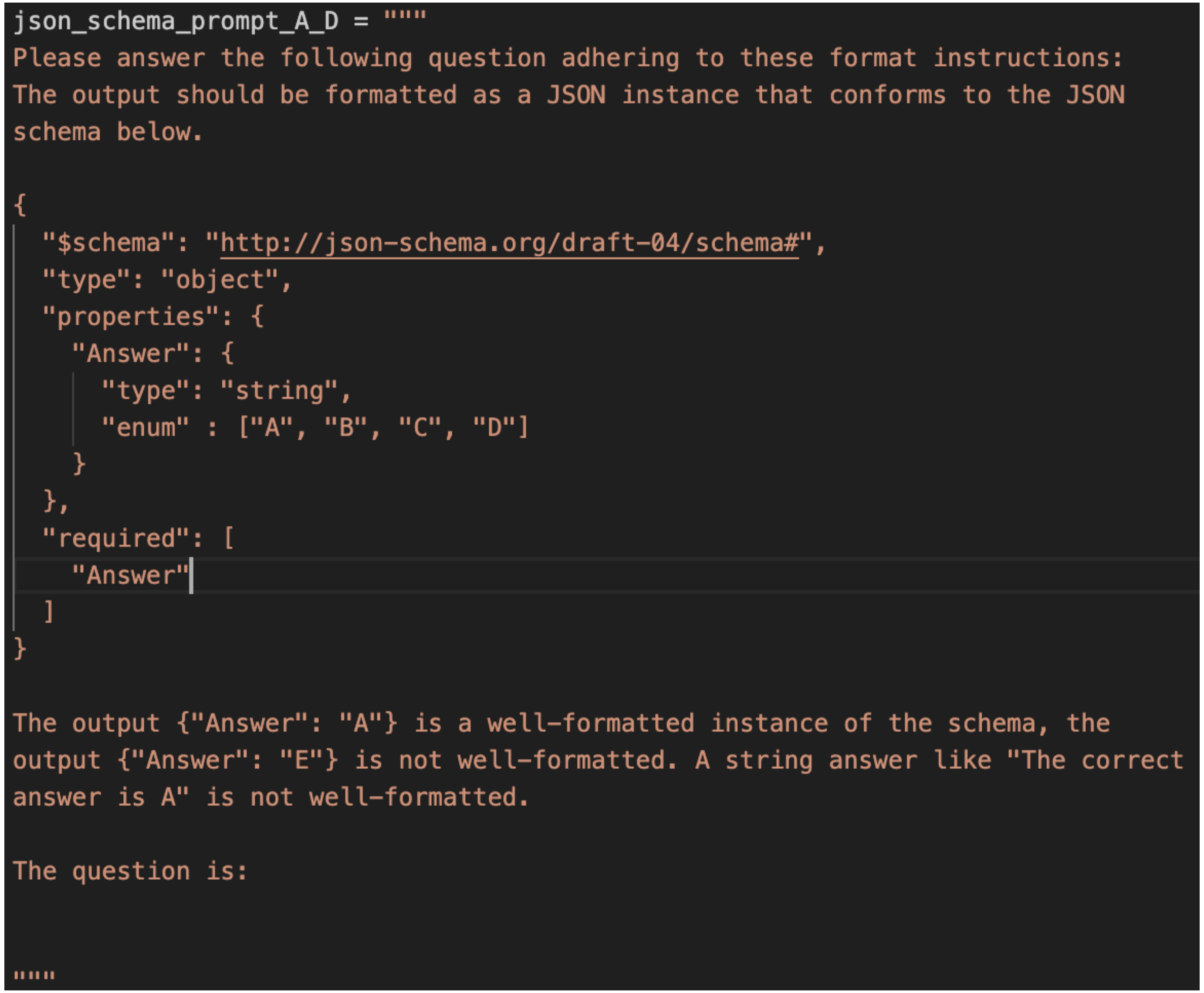
- Round 0 Accuracy: `Prompts` :
  - 74%: `Chomsky = CHOMSKY_PREFIX + COMMON_SUFFIX + question`
  - 47%: `Schema  = JSON_PREFIX +                    question`
  - 56%: `Raw     =                                  question`
  - 58%: `Generic = NO_LINGUISTICS + COMMON_SUFFIX + question`
  - 44%: `Grice   = GRICE_PREFIX +   COMMON_SUFFIX + question`

Prefix Prompts

- `NO_LINGUISTICS` = "Please answer the following question,"
- `GRICE_PREFIX` = "Please answer the following question while adhering to Gricean Maxims: Particularly the Maxim of Manner: Be clear—avoid obscurity and ambiguity, be brief and orderly. A bit more context,"
- `CHOMSKY_PREFIX` = "Please answer the following question while adhering to Chomsky’s Competence–Performance distinction: Maximize knowledge (competence) and minimize performance errors. A bit more context,"

Prompts continued

- `COMMON_SUFFIX` = " this is a multiple choice question and there is no benefit to the grade in showing your work. You are also being scored on the consistency of the answer you give over multiple runs so it is suggested you keep your answer to a single letter from A, B, C, D and E and reason conservatively to maximize the chance of giving the same answer across multiple runs of the same question. The question is: "

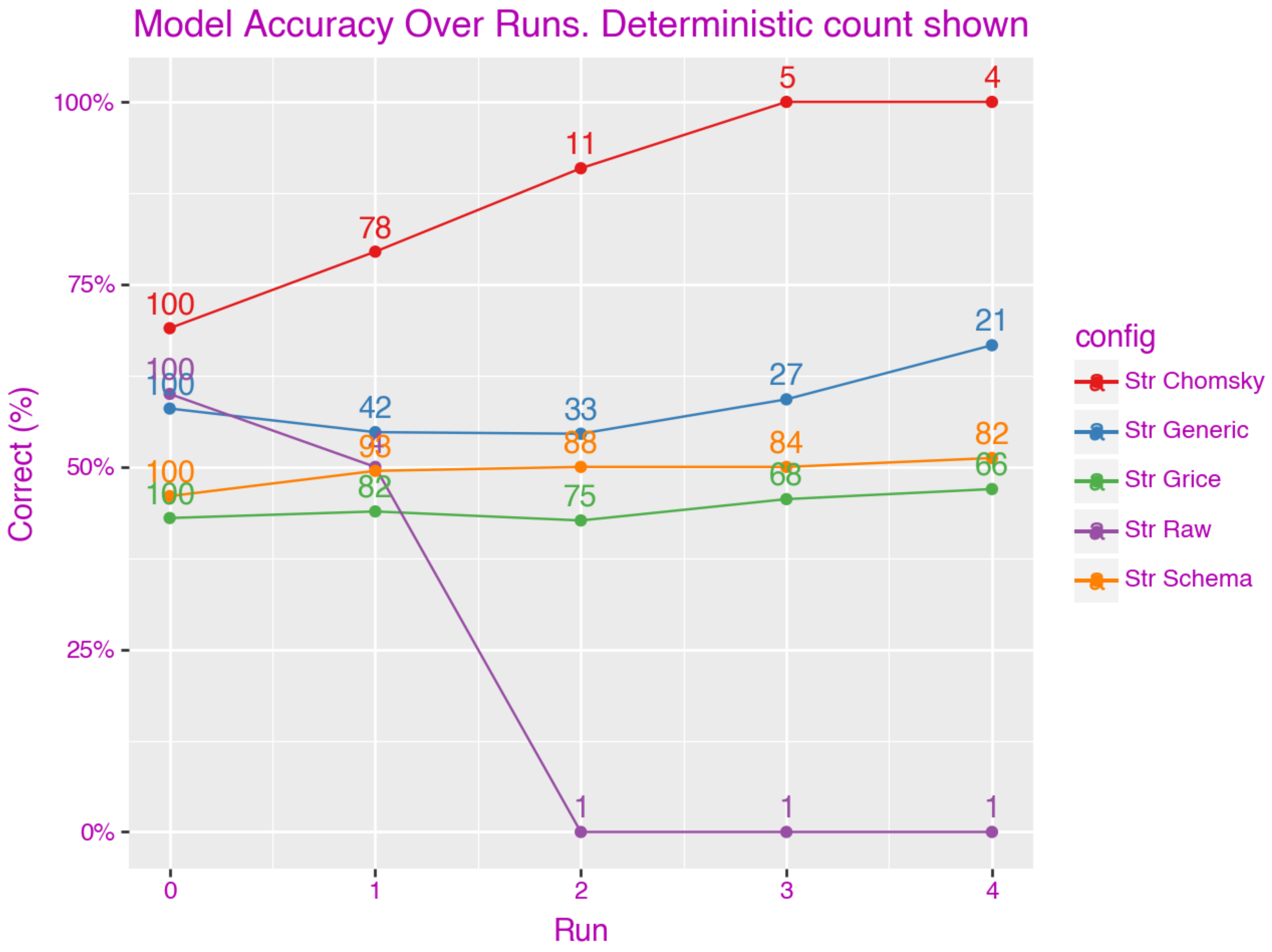


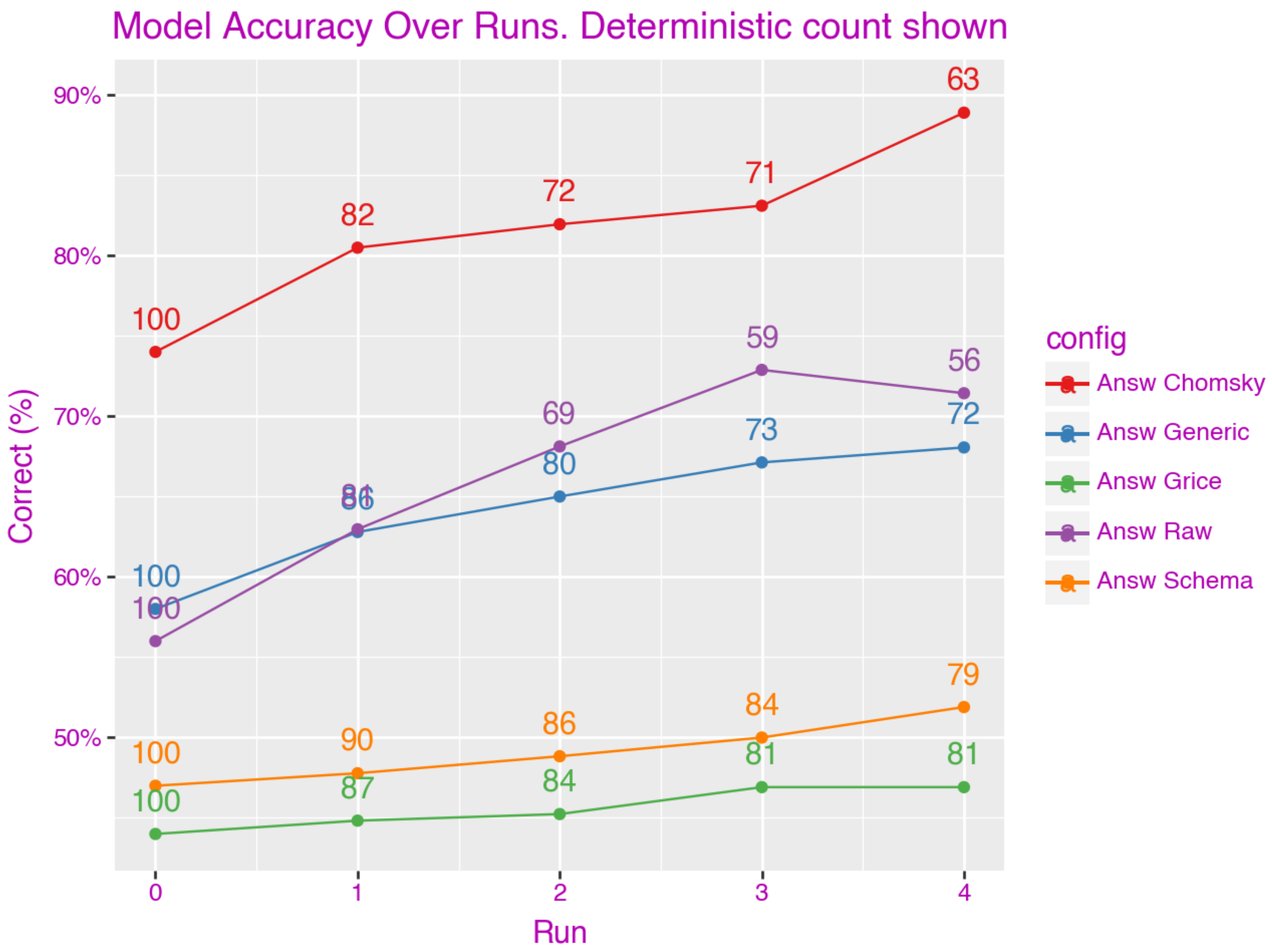
```
json_schema_prompt_A_D = """
Please answer the following question adhering to these format instructions:
The output should be formatted as a JSON instance that conforms to the JSON
schema below.

{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "type": "object",
  "properties": {
    "Answer": {
      "type": "string",
      "enum" : ["A", "B", "C", "D"]
    }
  },
  "required": [
    "Answer"
  ]
}

The output {"Answer": "A"} is a well-formatted instance of the schema, the
output {"Answer": "E"} is not well-formatted. A string answer like "The correct
answer is A" is not well-formatted.

The question is:


"""
```

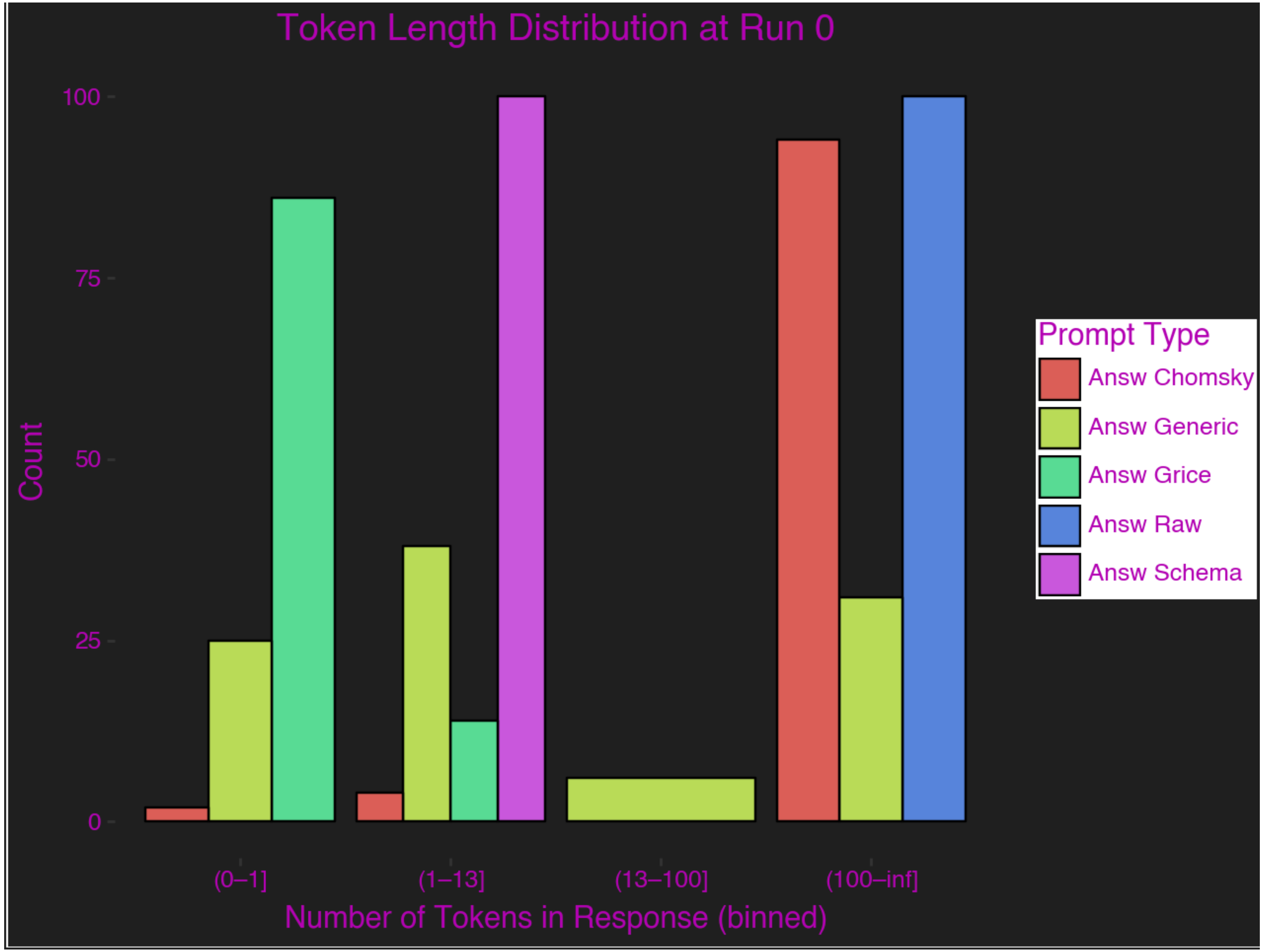
Removal algorithm

Remove rubric from round n + 1 if output round n != first round

- `Str` + prompt : Exact string/byte match
- `Answ` + prompt : Parsed answer match


Model Accuracy Over Runs. Deterministic count shown
Correct (%)
100%
75%
50%
25%
0%
Run
0
1
2
3
4
100
78
11
5
4
100
100
42
33
27
21
100
4
93
88
84
82
100
82
75
68
66
1
1
1
config
Str Chomsky
Str Generic
Str Grice
Str Raw
Str Schema


Model Accuracy Over Runs. Deterministic count shown
Correct (%)
90%
80%
70%
60%
50%
Run
0
1
2
3
4
100
82
72
71
63
100
81
86
69
59
56
100
80
73
72
100
90
86
84
79
100
87
84
81
81
config
Answ Chomsky
Answ Generic
Answ Grice
Answ Raw
Answ Schema


Token Length Distribution at Run 0
100
75
50
25
0
Count
(0–1]
(1–13]
(13–100]
(100–inf]
Number of Tokens in Response (binned)
Prompt Type
Answ Chomsky
Answ Generic
Answ Grice
Answ Raw
Answ Schema

Clear Length to Accuracy/Determinism Link... until Chomsky Showed Up

Condition	Answ Tok Len	Str Deter	Answ Deter	% Acc Run 0
Grice	1	Middle	Best	44%
Schema	13	Best	Best	47%
Generic	1-100+	Low	Middle	58%
Raw	100+	Worst	Worst	56%
Chomsky	100+	Worst	2nd Worst	74%

Observations--Remember Toy Problem

- Grice mattered--one token, best answer determinism, worst accuracy
- Schema mattered-- 13 tokens, best string and answer determinism, worst accuracy
- Generic/Raw-- varied tokens, a middling mess
- Shorter-> more deterministic:
  - If the non-determinism is a function of token choice, the more tokens picked the more chance of a different choice being made.
- Longer-> more/better inference:
  - Longer contexts allow the LLM to better infer the correct answer--basis of COT (chain of thought) heuristics.
- Tell your LLM Chomsky is watching and performance goes up 30%???

Conclusions

- Exciting times
- Determinism does not exist for LLMs in practice
    - Nobody cares but should
- Need a new field "Cyber Linguistics"
    - Clean up the mess of current NLP interfaces to LLMs
    - Make LLMs engineerable components
    - Bring existing domains, like pragmatics, to help

Chomsky always wins

- Anyone wanting to participate in Cyber Linguistic activity please reach out
    - Reddit forum
    - Journal
    - Contributing experiments

All data/software is available off of my splash page: https://breckbaldwin.github.io