REFORM 2/26: Grokking

Charlotte Peale, Silvia Casacuberta

What is “grokking”?

https://towardsdatascience.com/i-used-to-hate-overfitting-but-now-im-grokking-it-e6e1dcfbdfd8/

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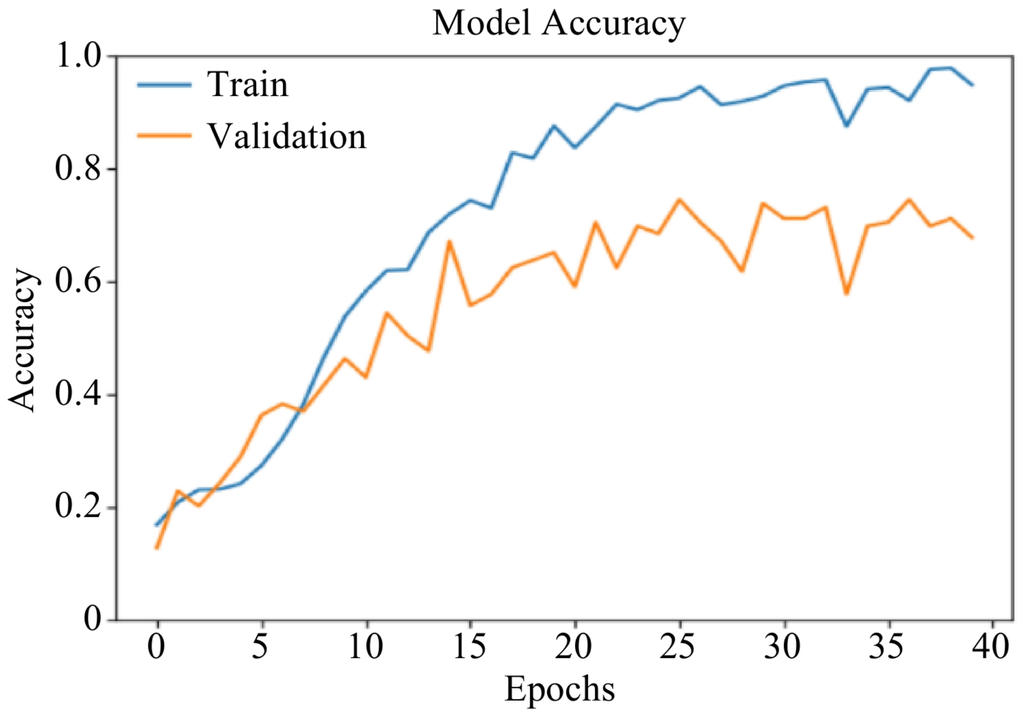

Typical Training Dynamics

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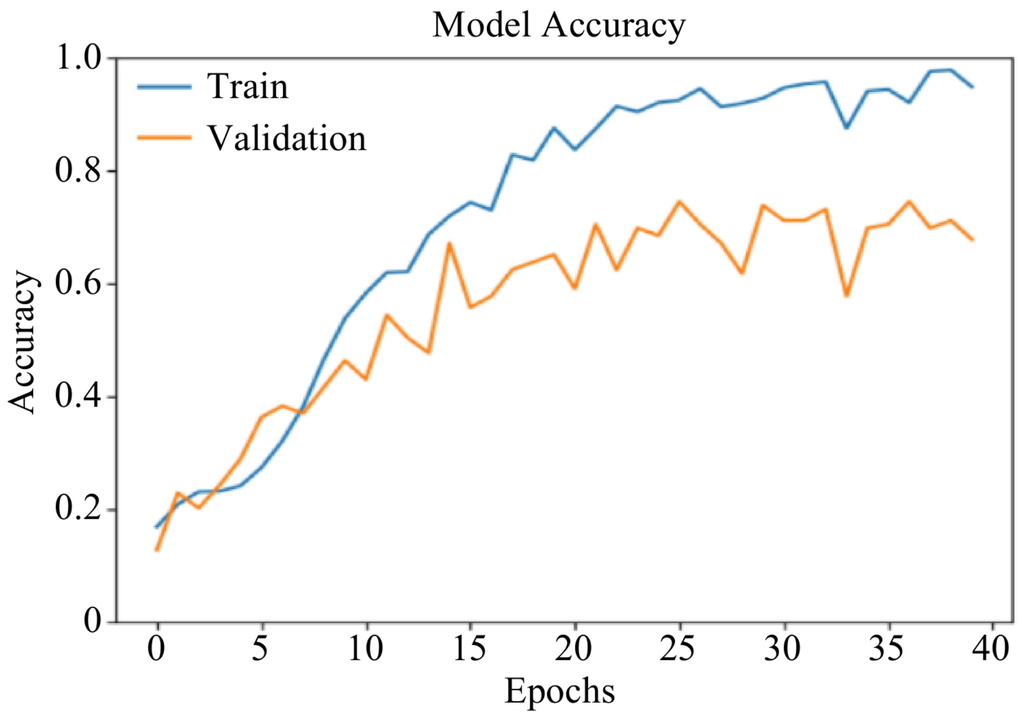

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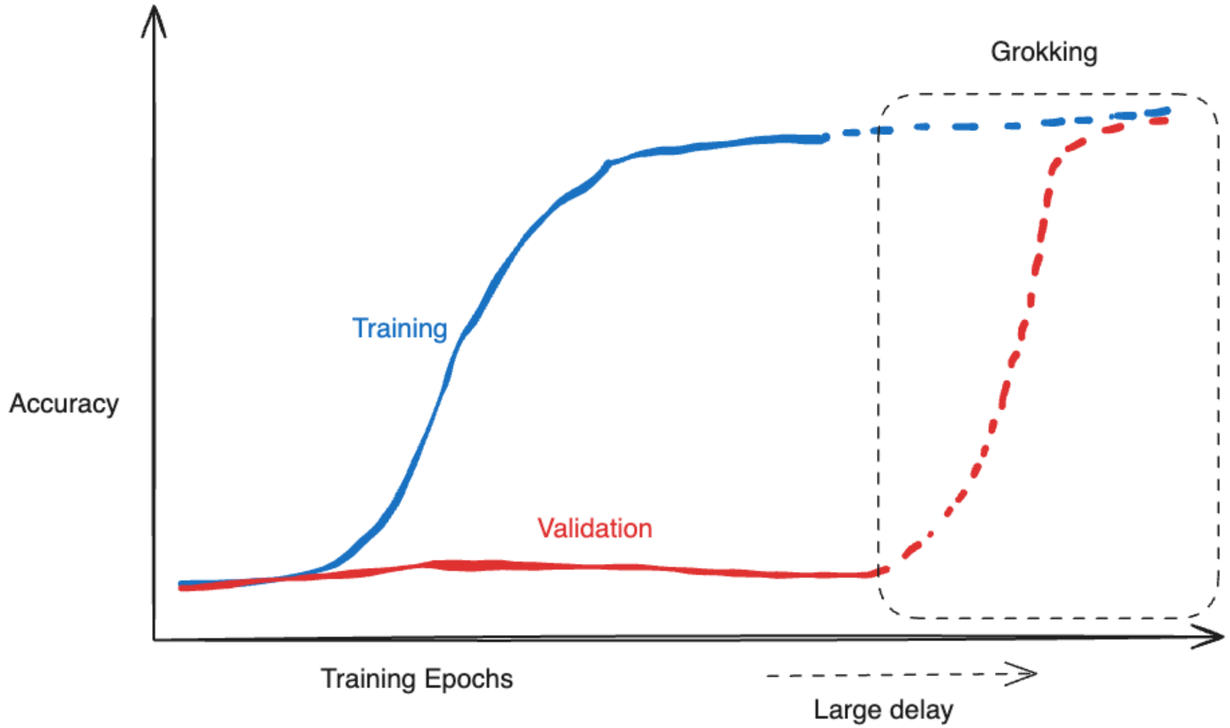

Grokking

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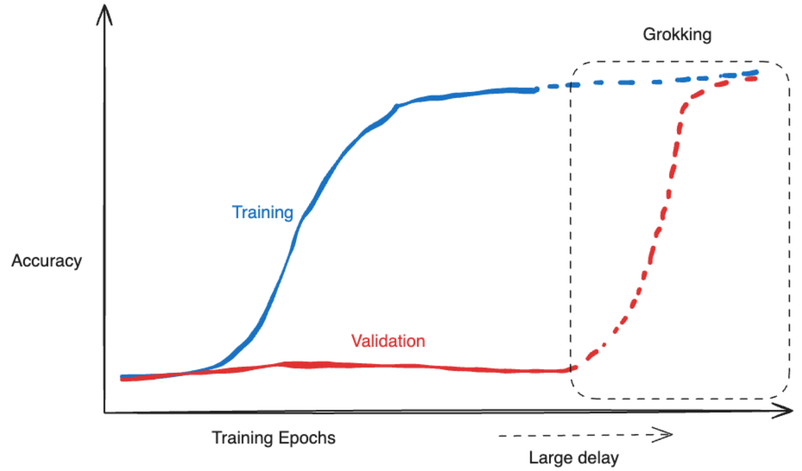
What is “grokking”?

- Observed in transformers
- Structured/algorithmic learning tasks



Task-of-interest for today: **modular addition**

$$a, b \in \{0,1,...,P-1\} \longrightarrow (a+b) \mod P$$

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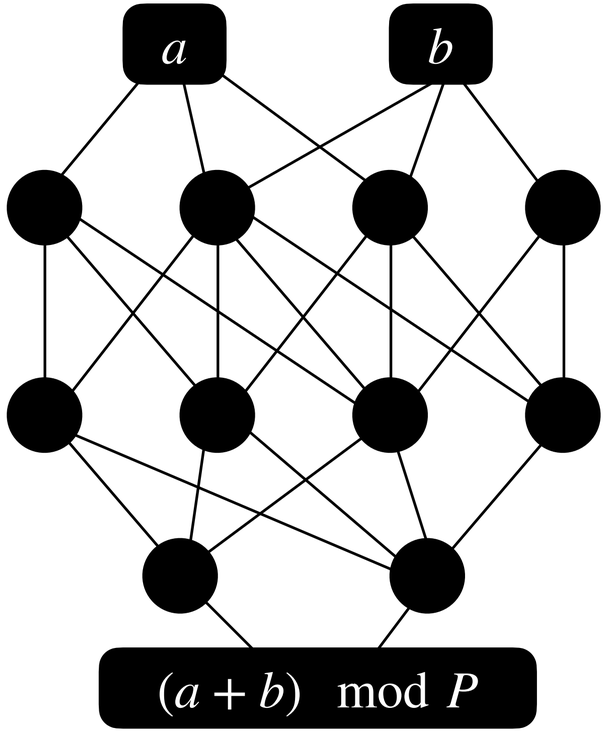
Why does grokking happen?

- **Current hypothesis:** competition between memorization and generalization.
  Explaining grokking through circuit efficiency, Varma et al. 2023

a, b	f(a,b)
1, 2	3
45, 34	79
23, 6	29
17, 21	38
51, 10	61

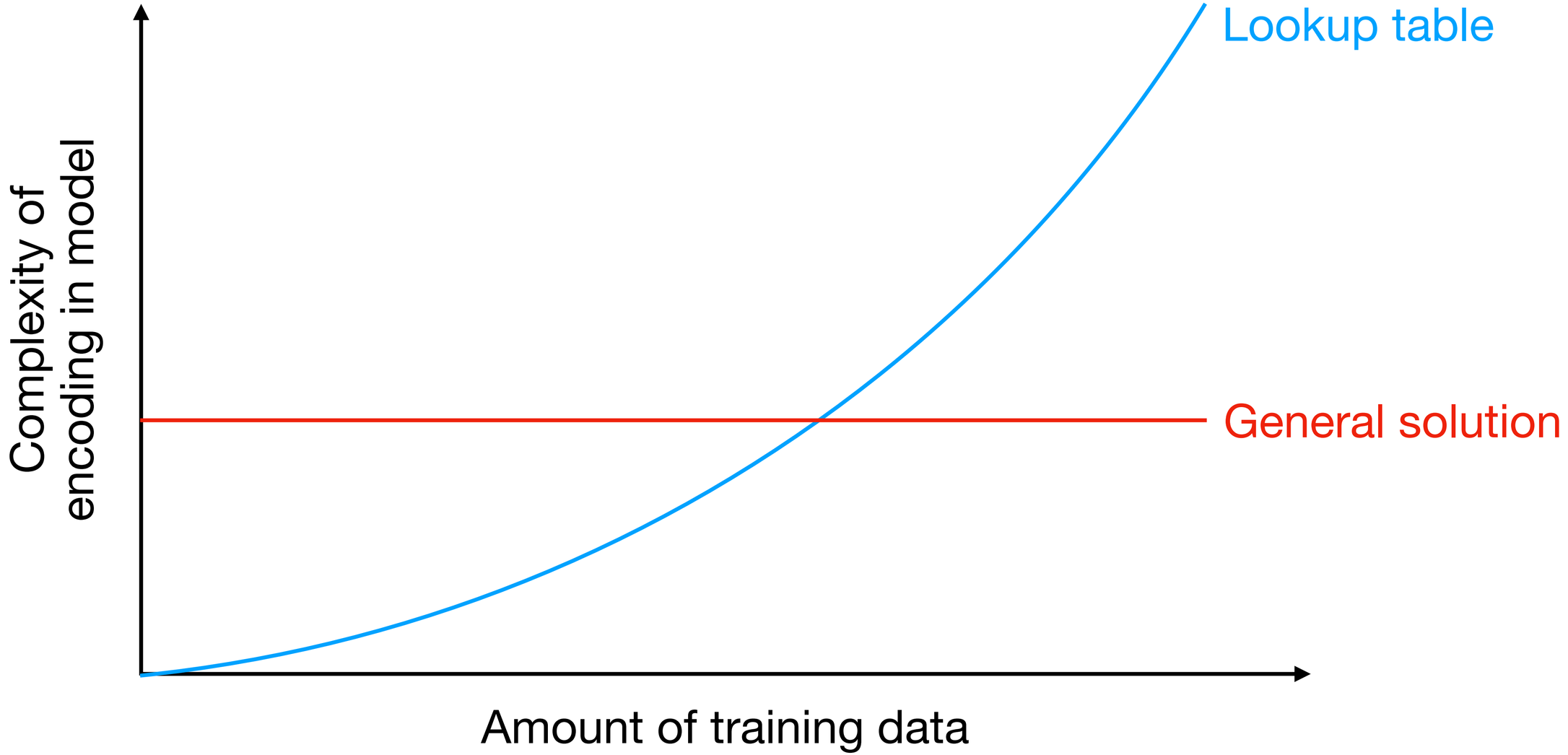
lookup table for training data

vs

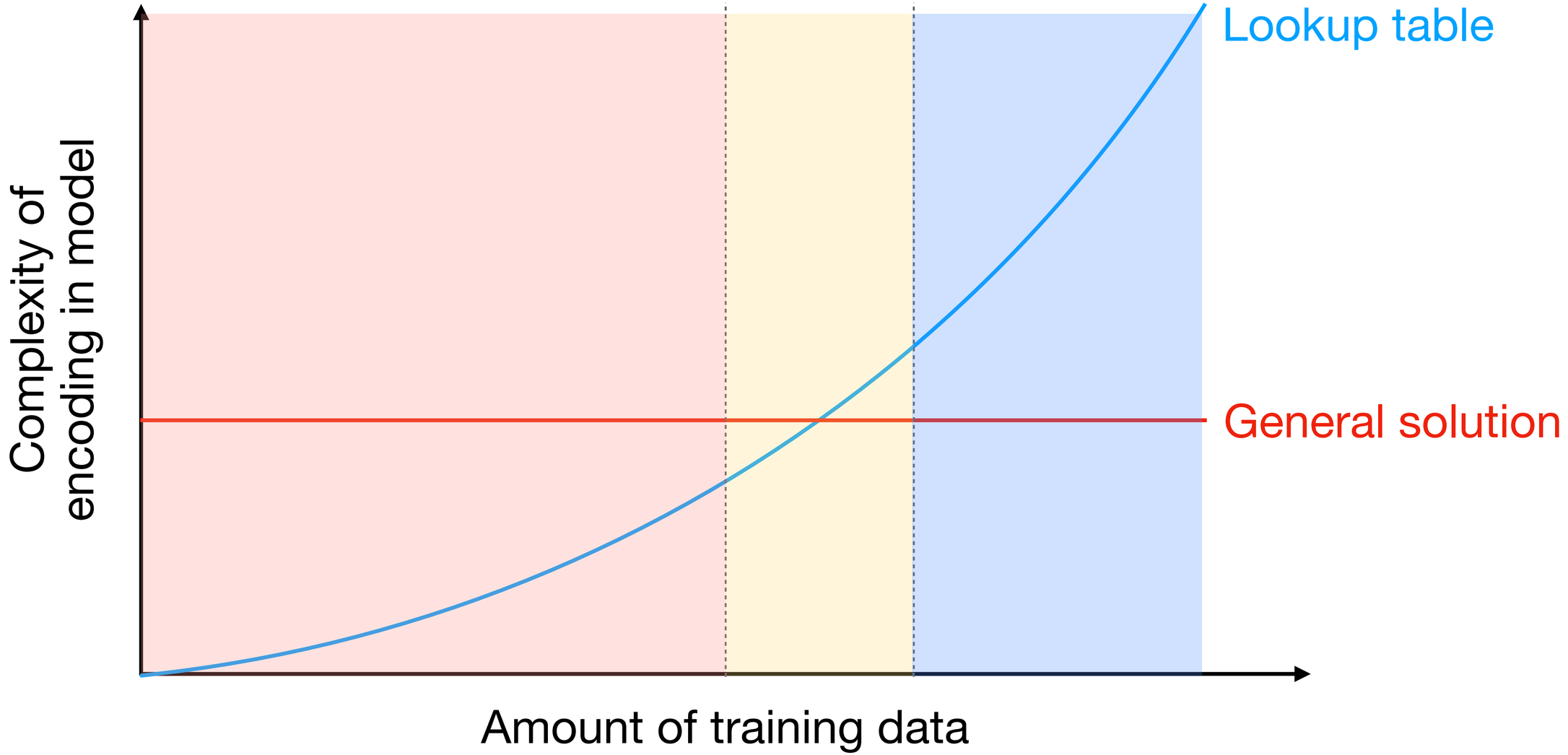


General circuit for addition

Memorization vs Generation Complexity



Memorization vs Generation Complexity



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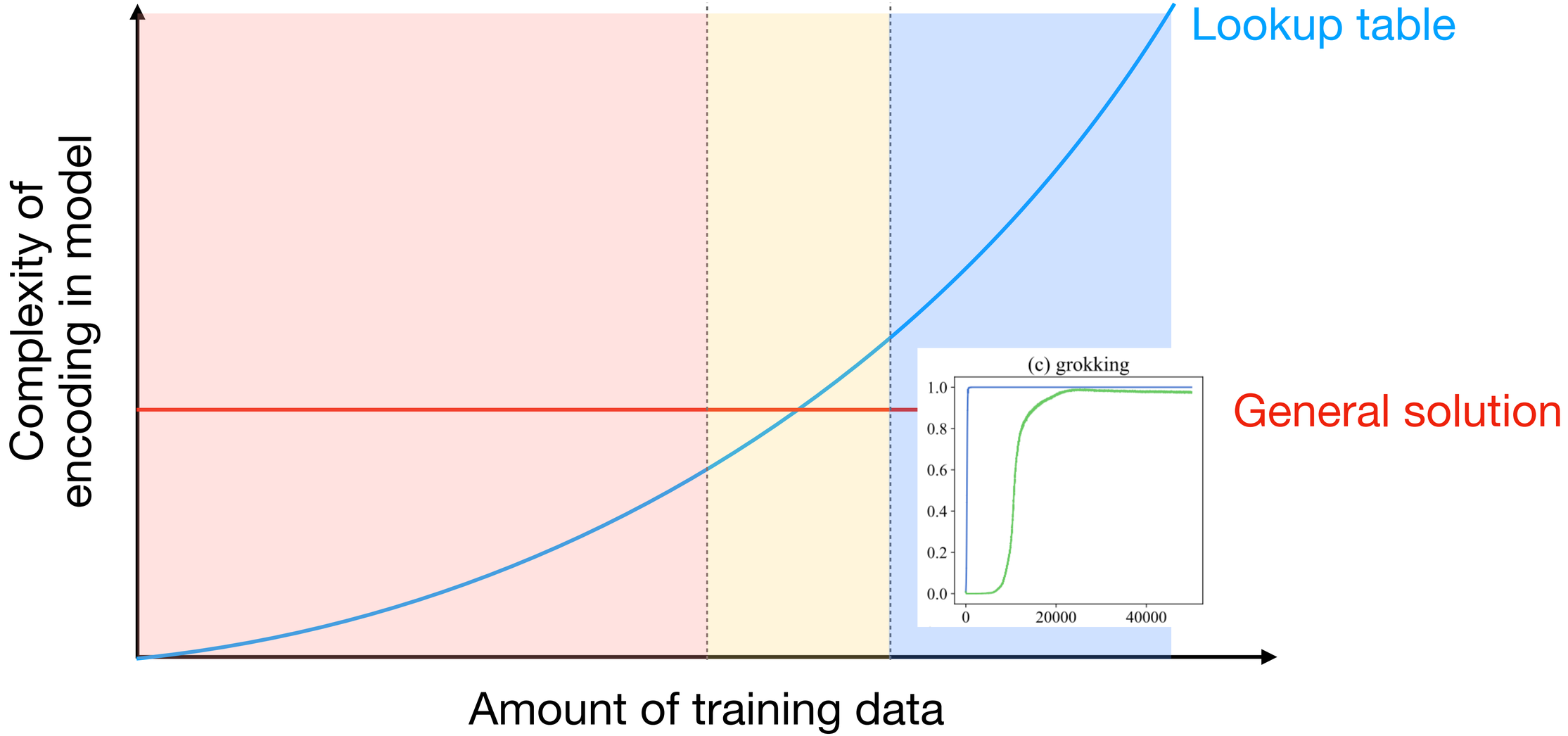

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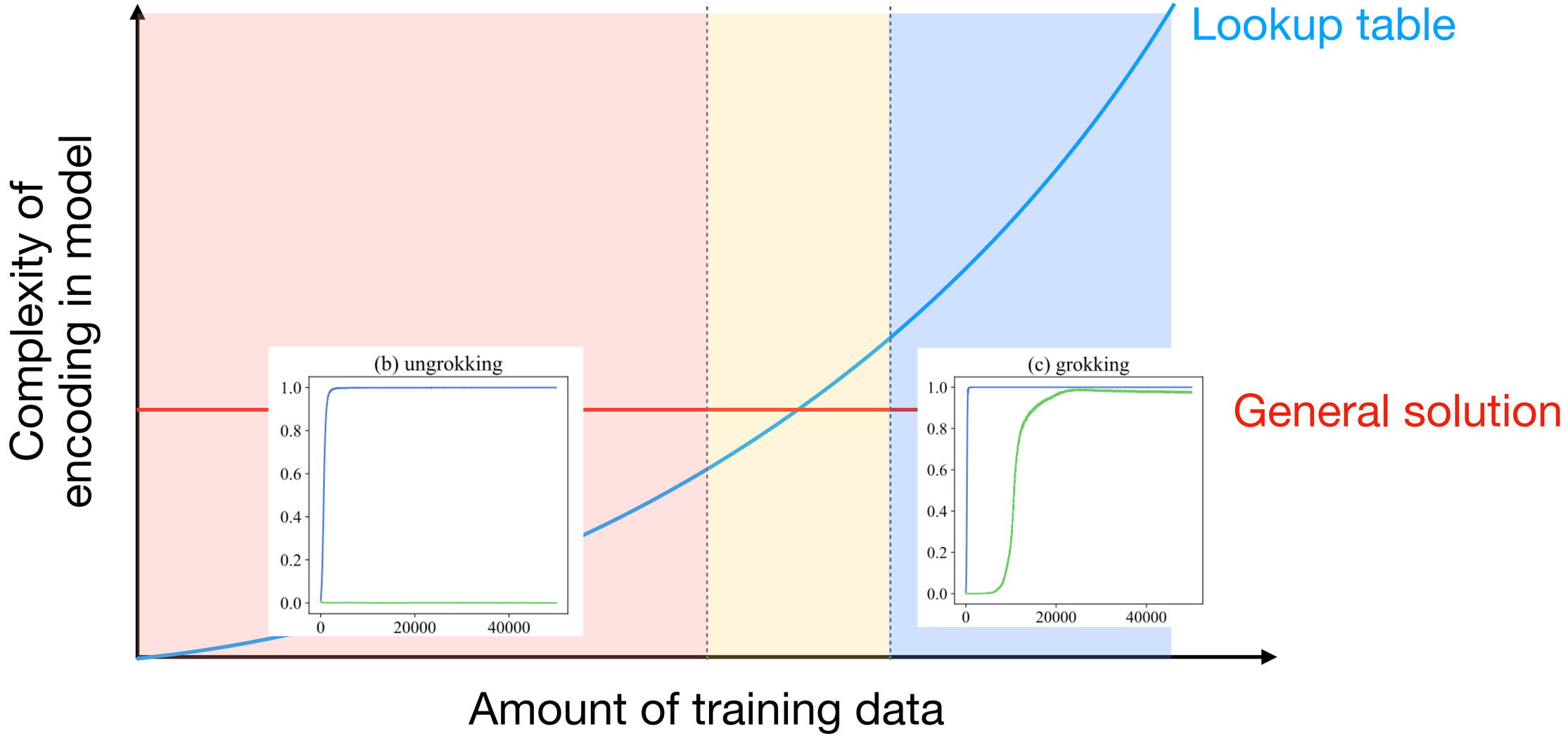

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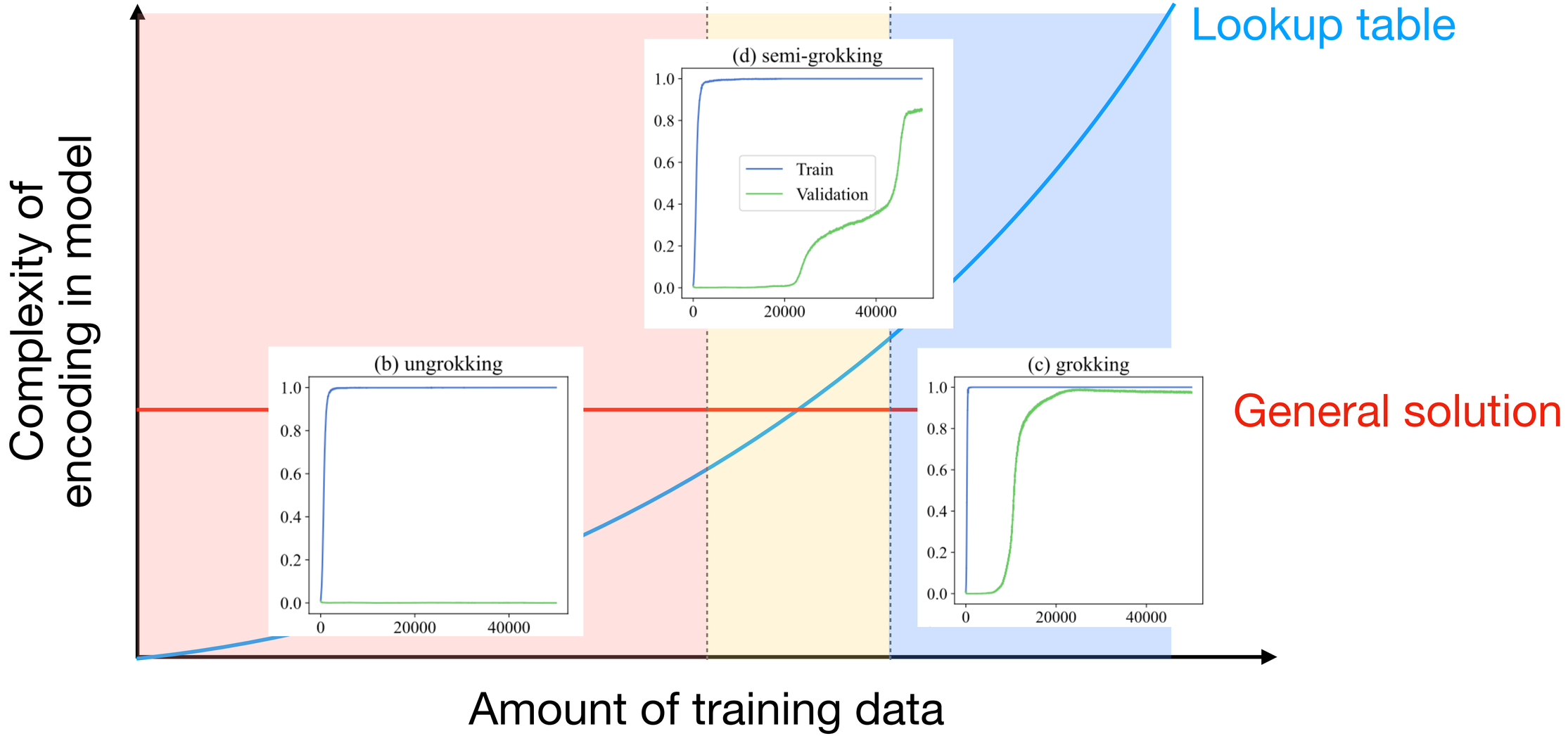


Unified View of Grokking, Double Descent and Emergent Abilities: A Perspective from Circuits Competition

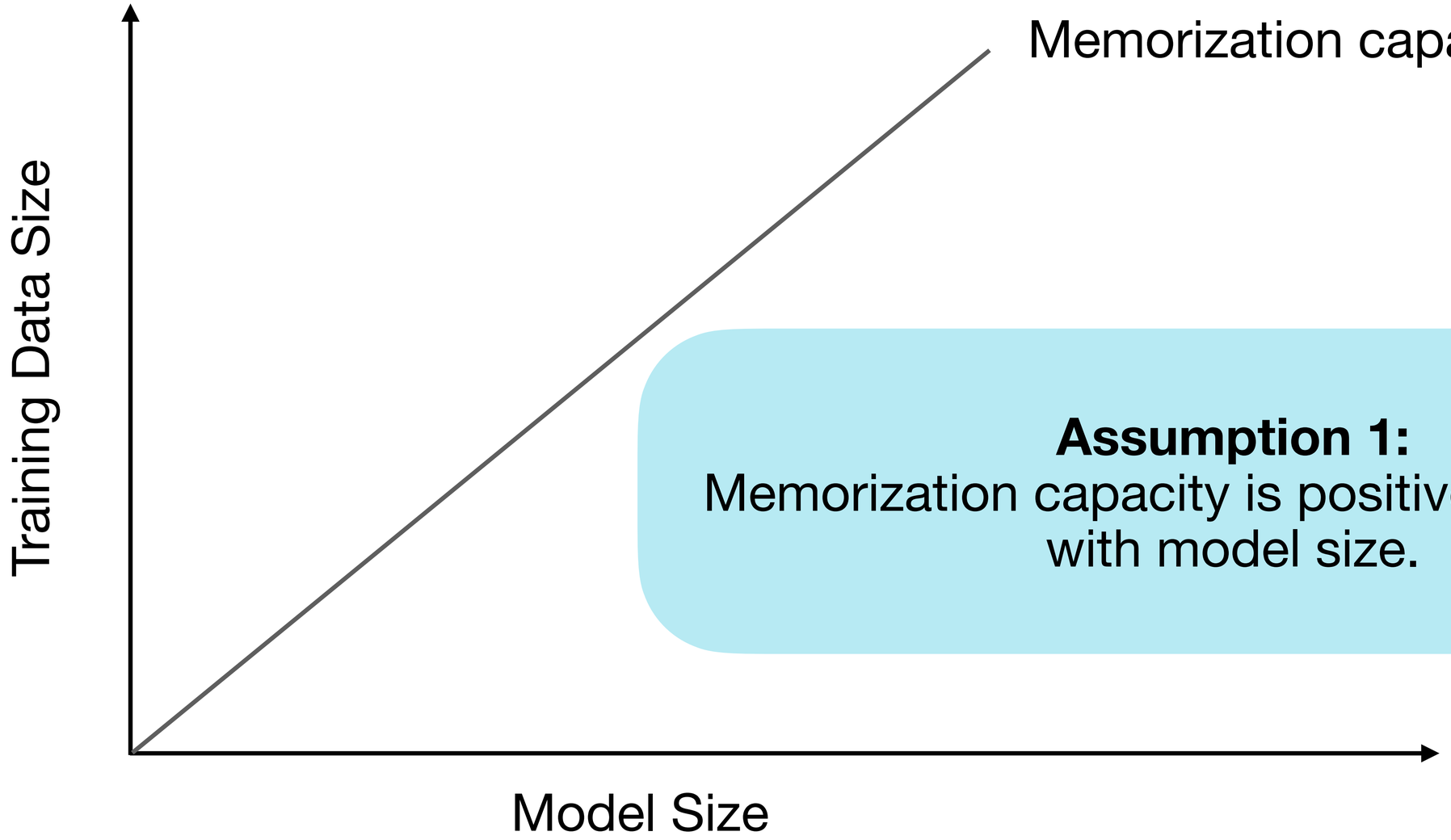
Yufei Huang [1] **Shengding Hu** [1] **Xu Han** [1] **Zhiyuan Liu** [1] **Maosong Sun**[† 1]

1. Map out landscape of training dynamics varying train set size *and* model size.

2. Use landscape to give an explanation for double descent.

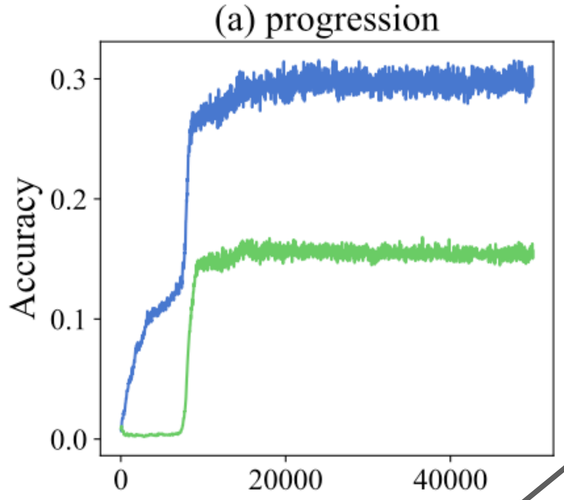
3. [Look at how emergent abilities relate to grokking]

Memorization and Model Size



Assumption 1:
Memorization capacity is positively correlated with model size.

Memorization and Model Size



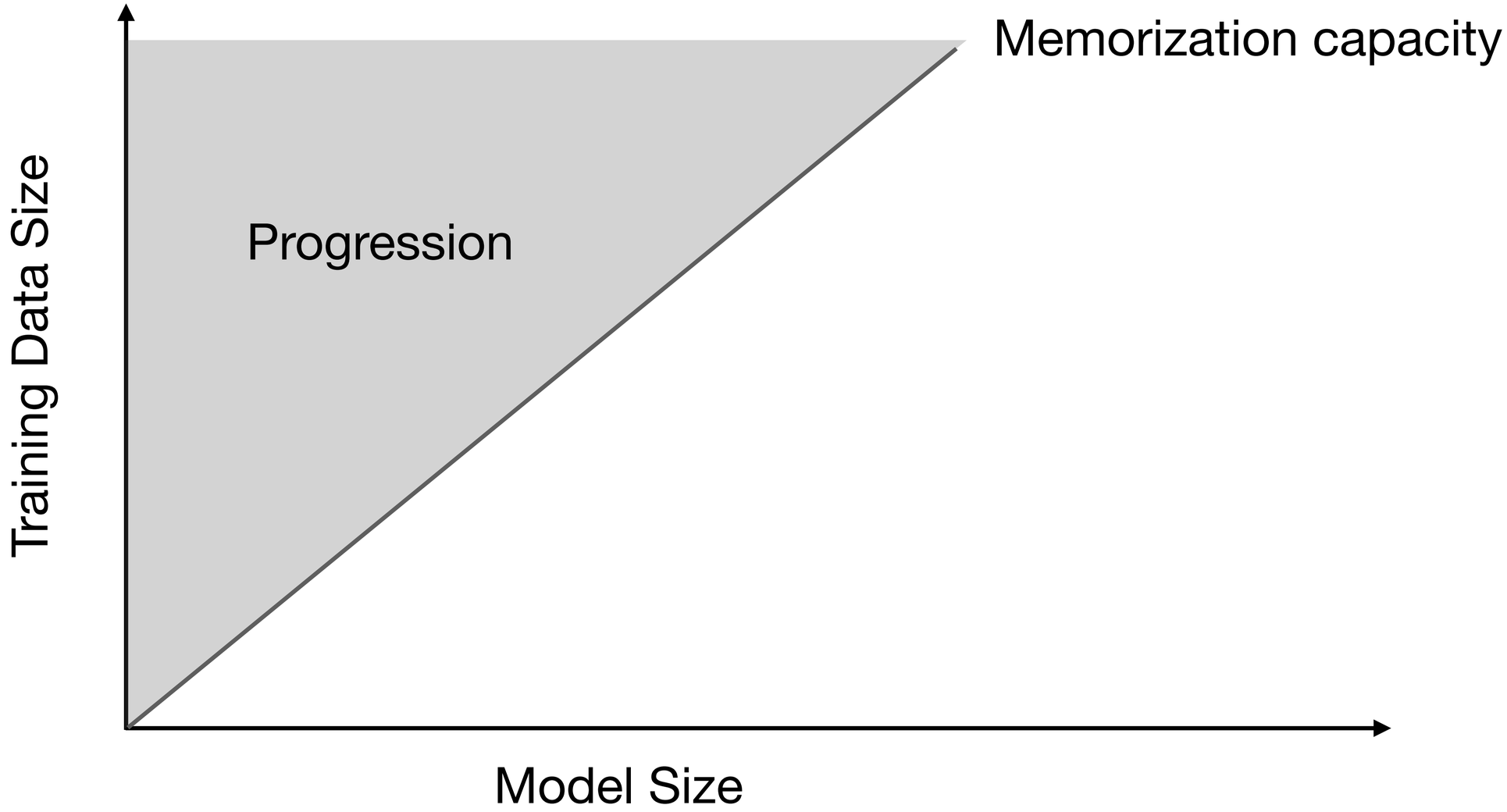
Memorization capacity

Training Data Size

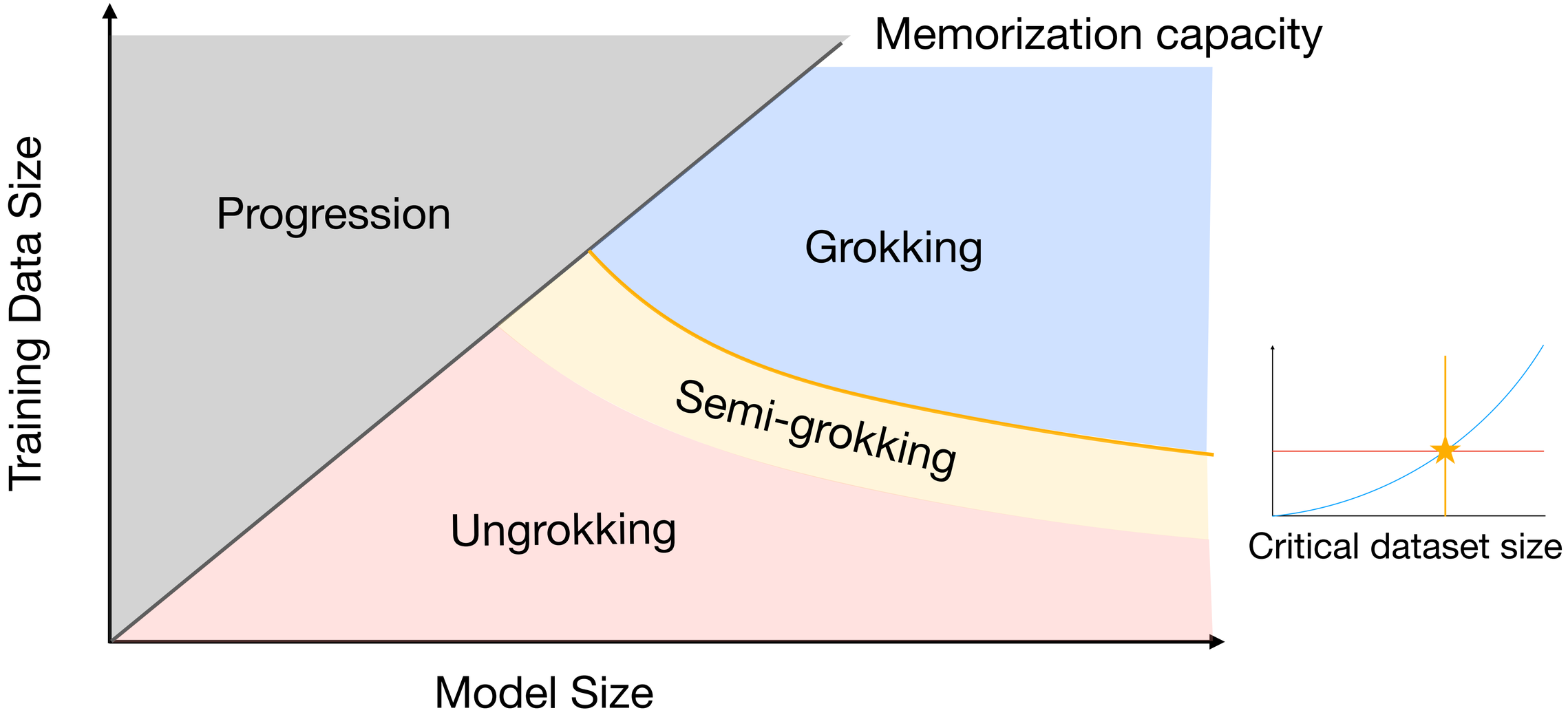
Model Size

Assumption 1:
Memorization capacity is positively correlated with model size.

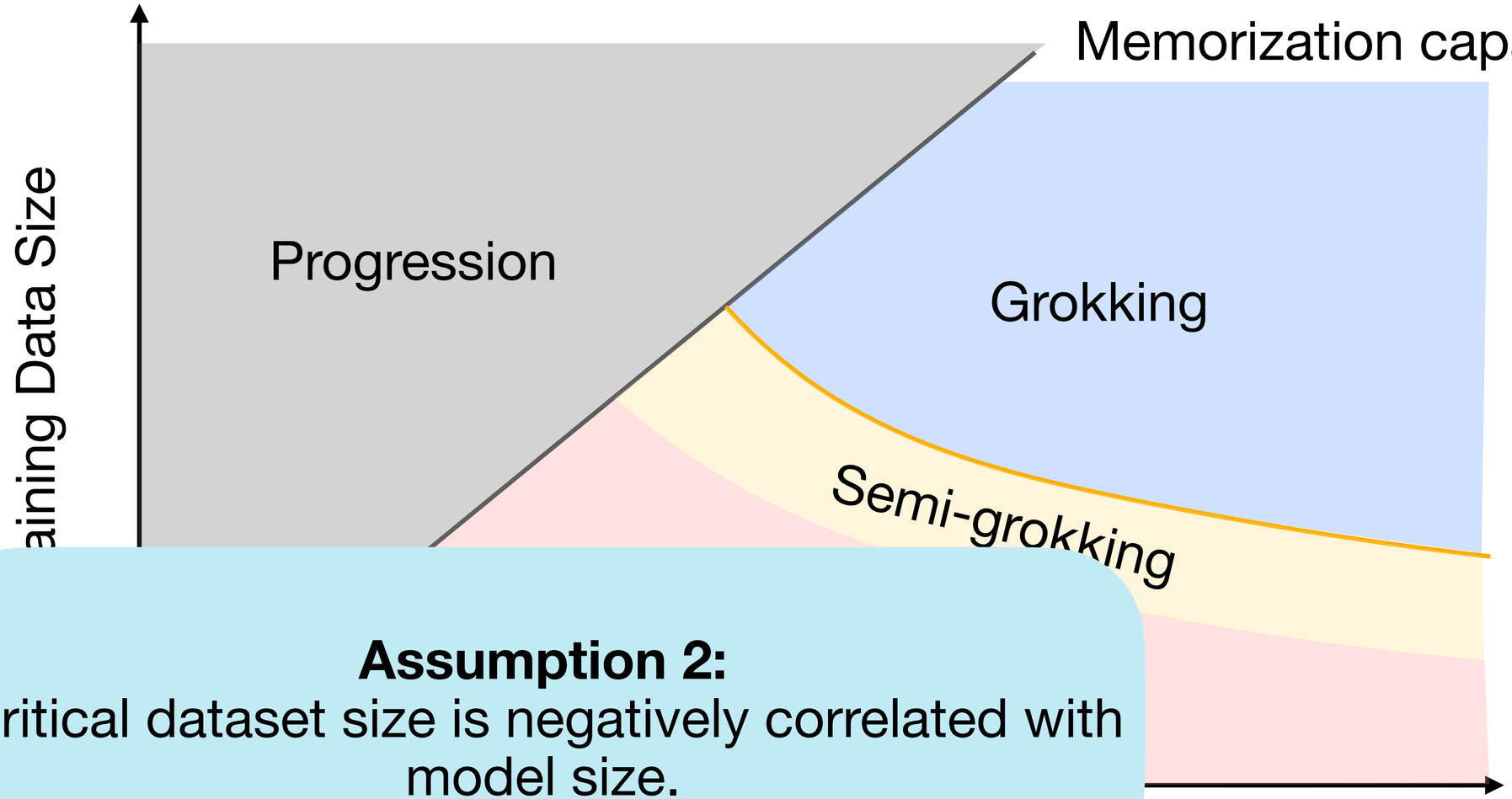
Grokking and Critical Dataset Size

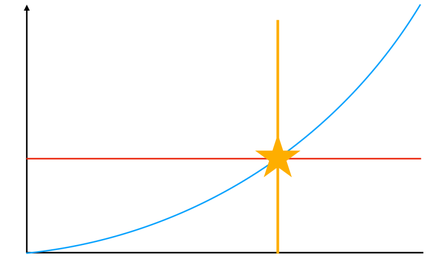


Grokking and Critical Dataset Size



Grokking and Critical Dataset Size

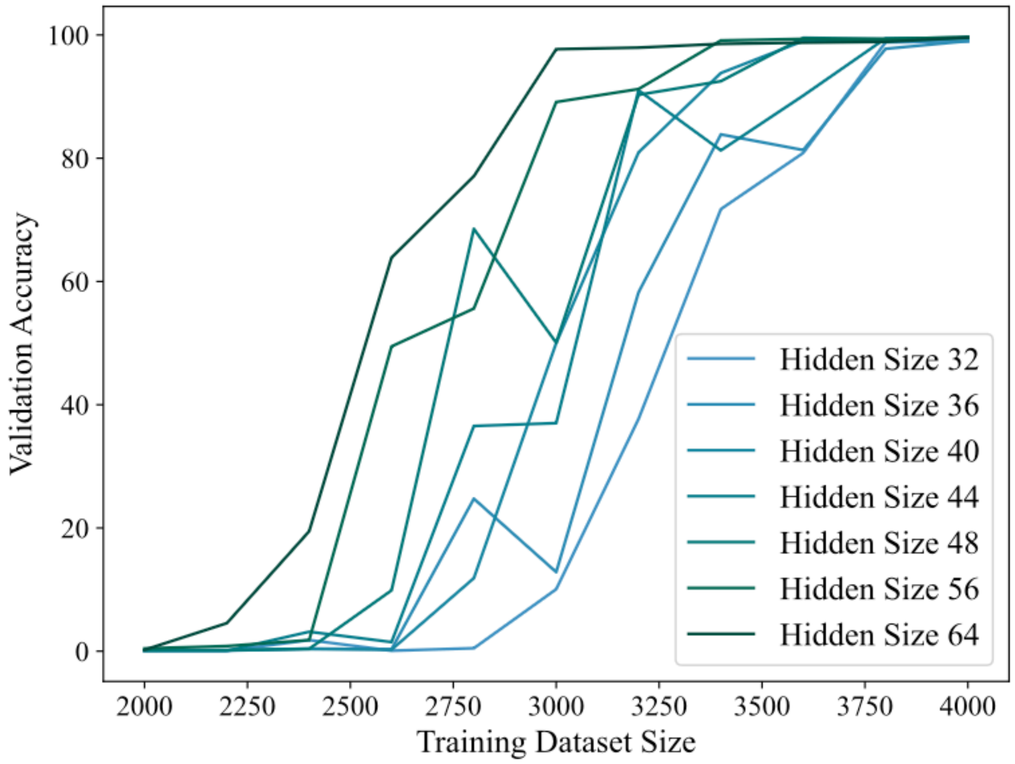




Critical dataset size

Assumption 2:
Critical dataset size is negatively correlated with model size.

Critical Dataset Size and Model Size



Assumption 2:
Critical dataset size is negatively correlated with model size.

Empirical Justification: Larger models achieve perfect validation accuracy with smaller train datasets.

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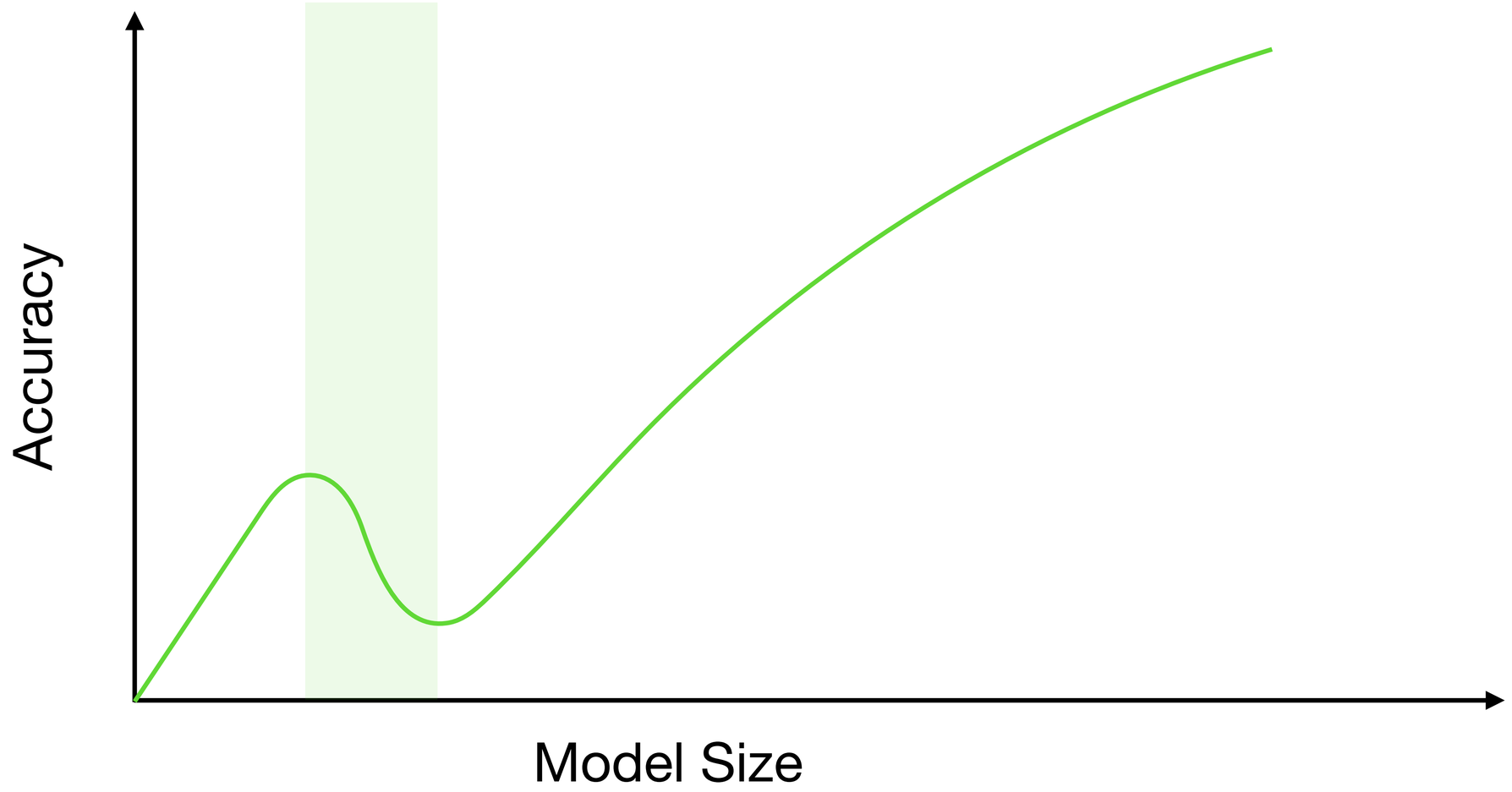
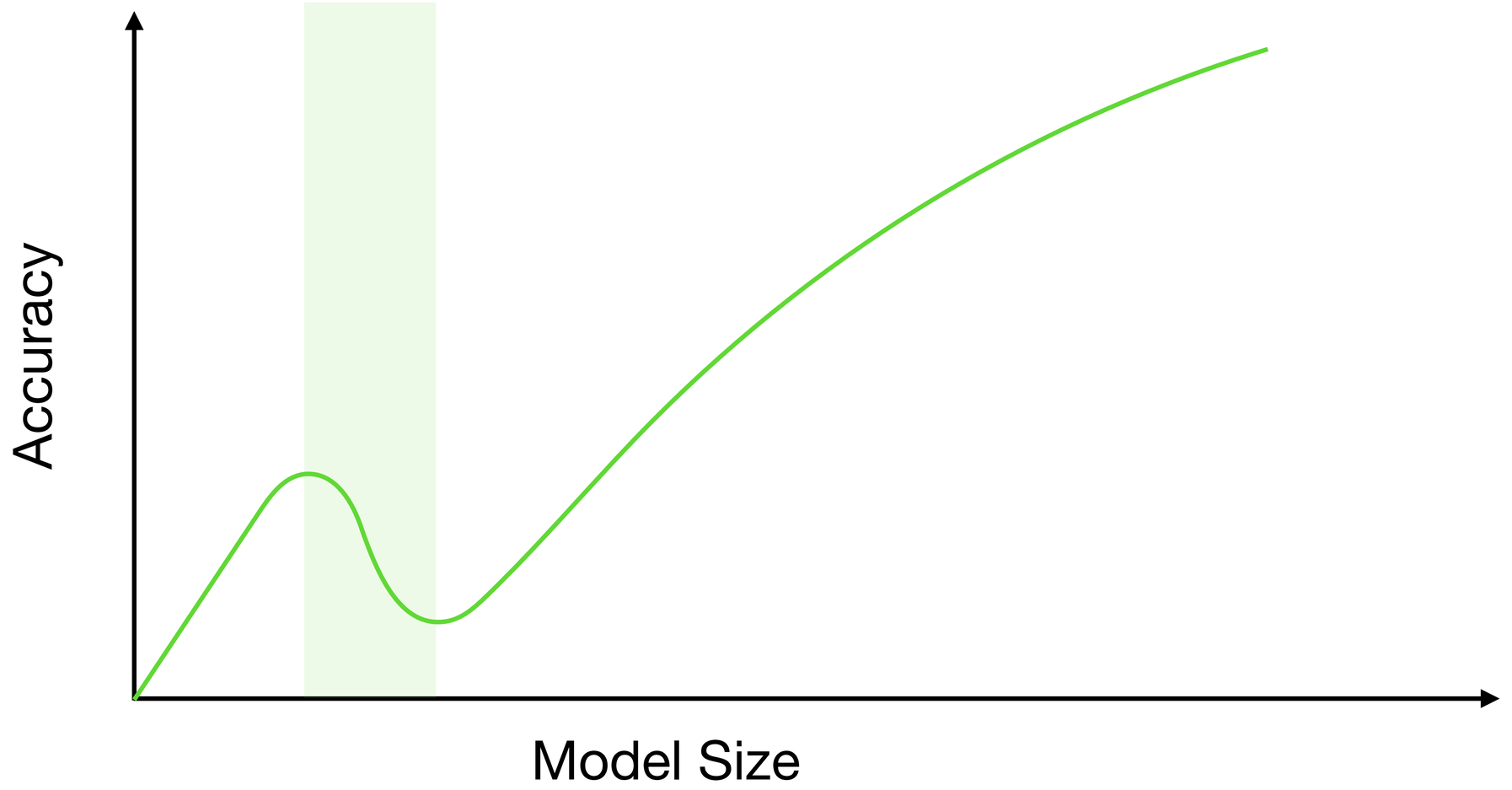
Refresher: Double Descent

- Temporary drop in accuracy as model size increases.



Double Descent and Grokking Landscape

- Double descent plots a fixed train set size while varying model size.



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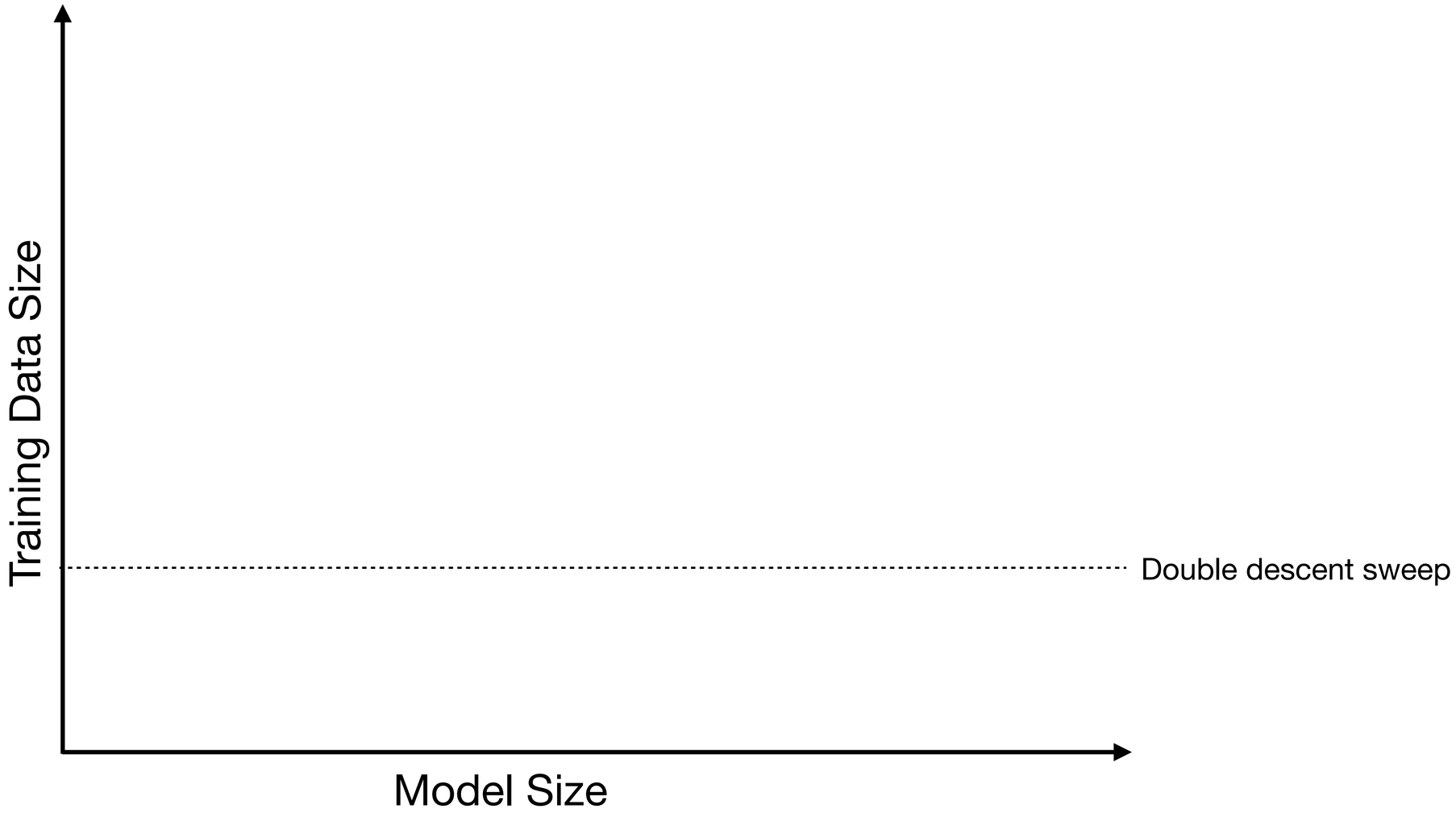
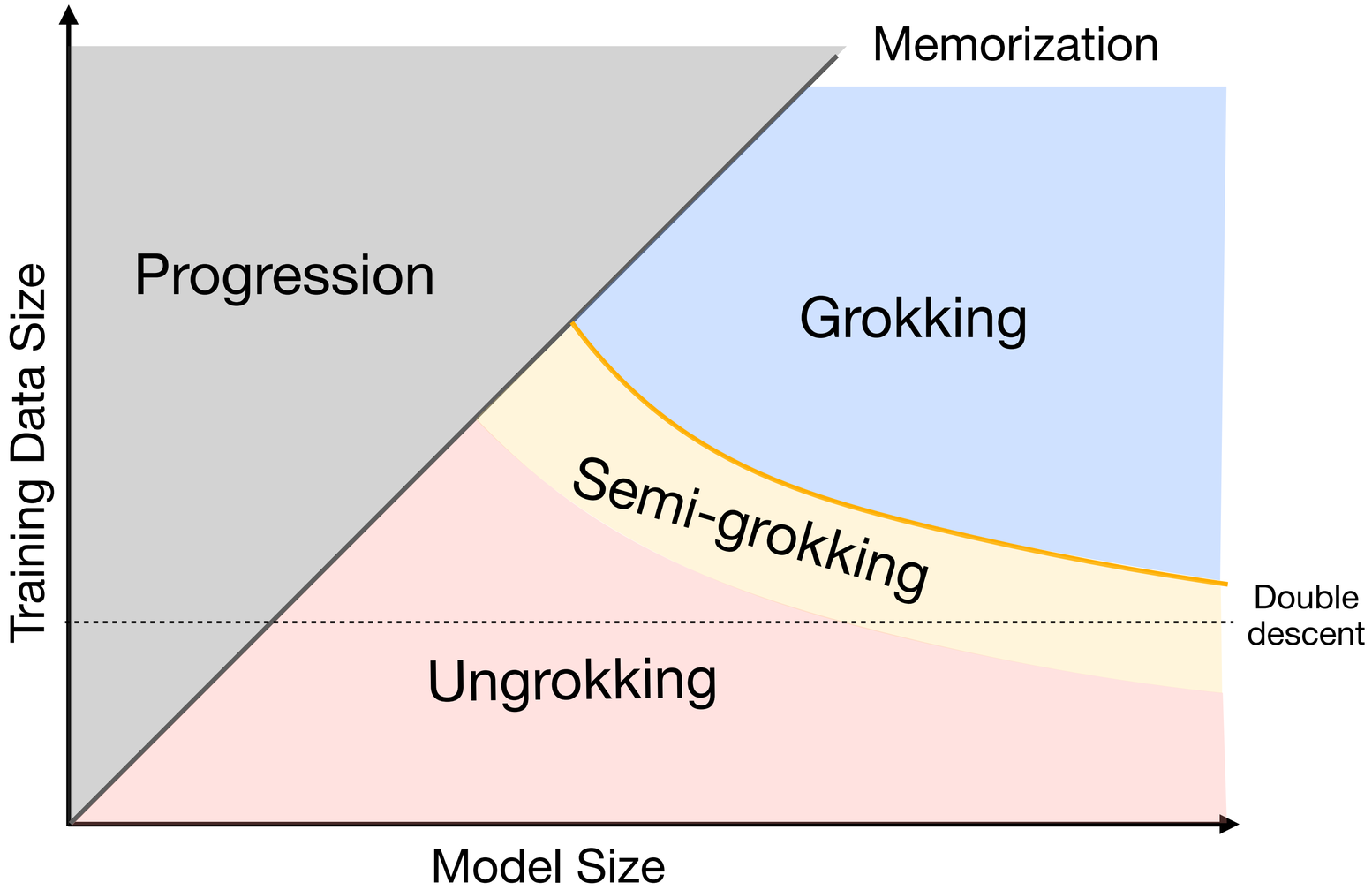


Double Descent and Grokking Landscape

- Observation: Model size sweeps pass through multiple regions.



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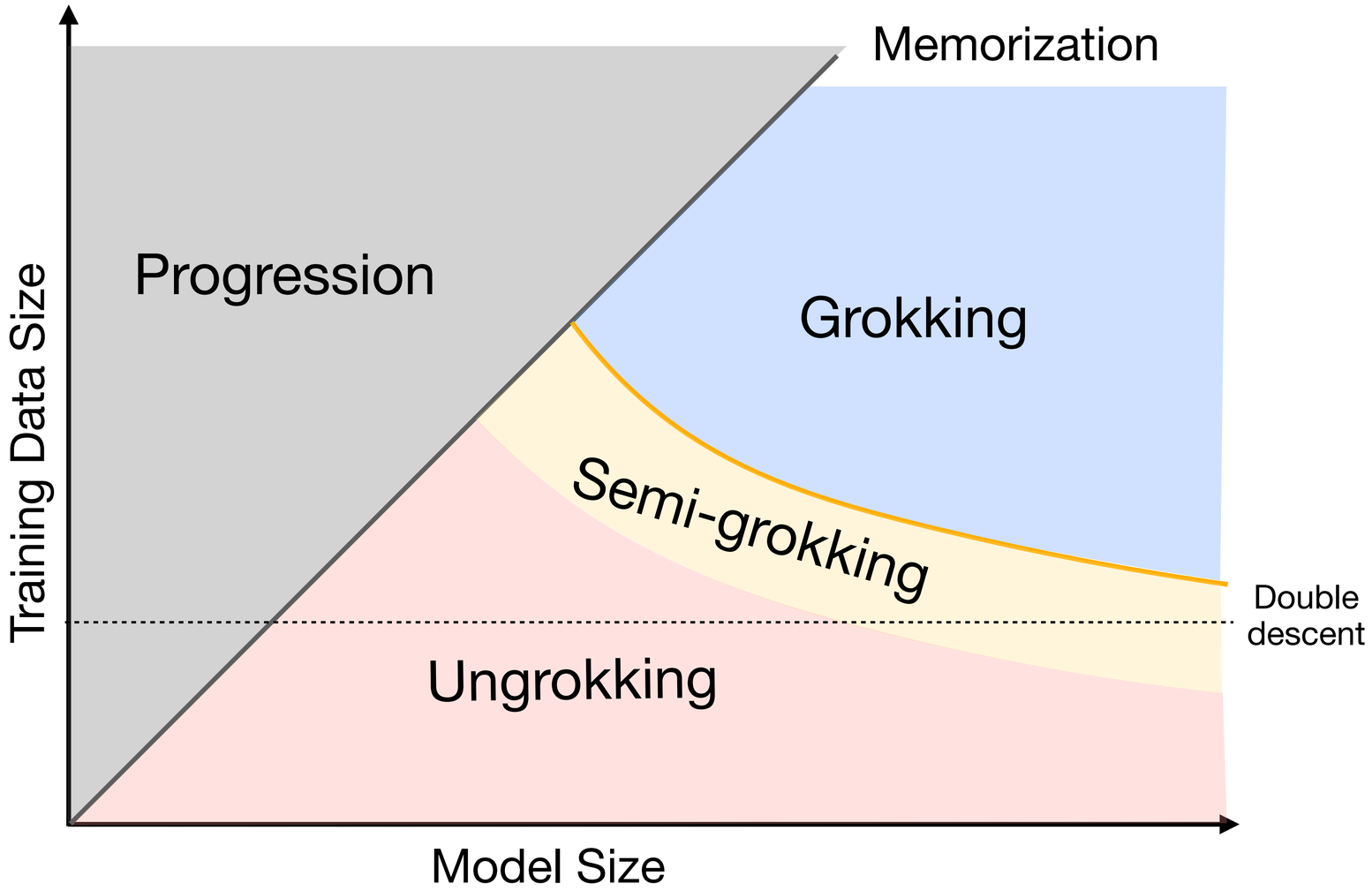
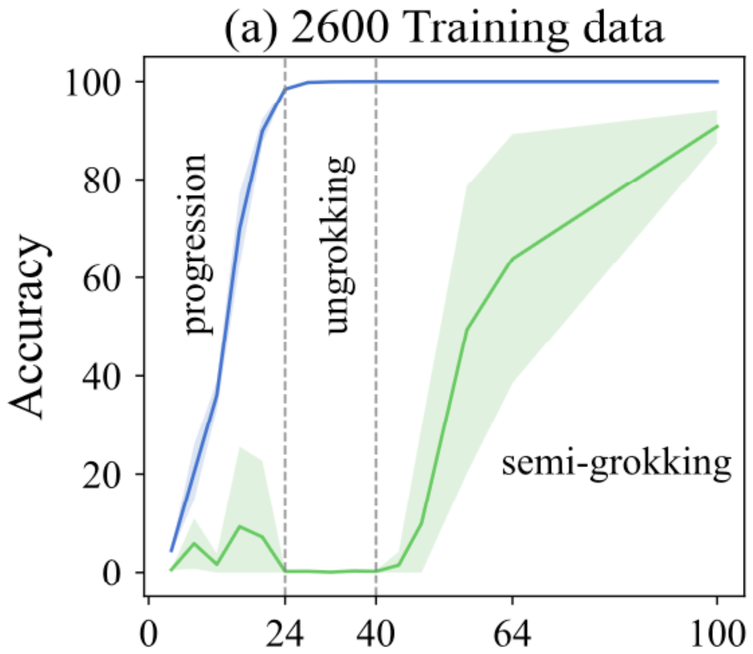
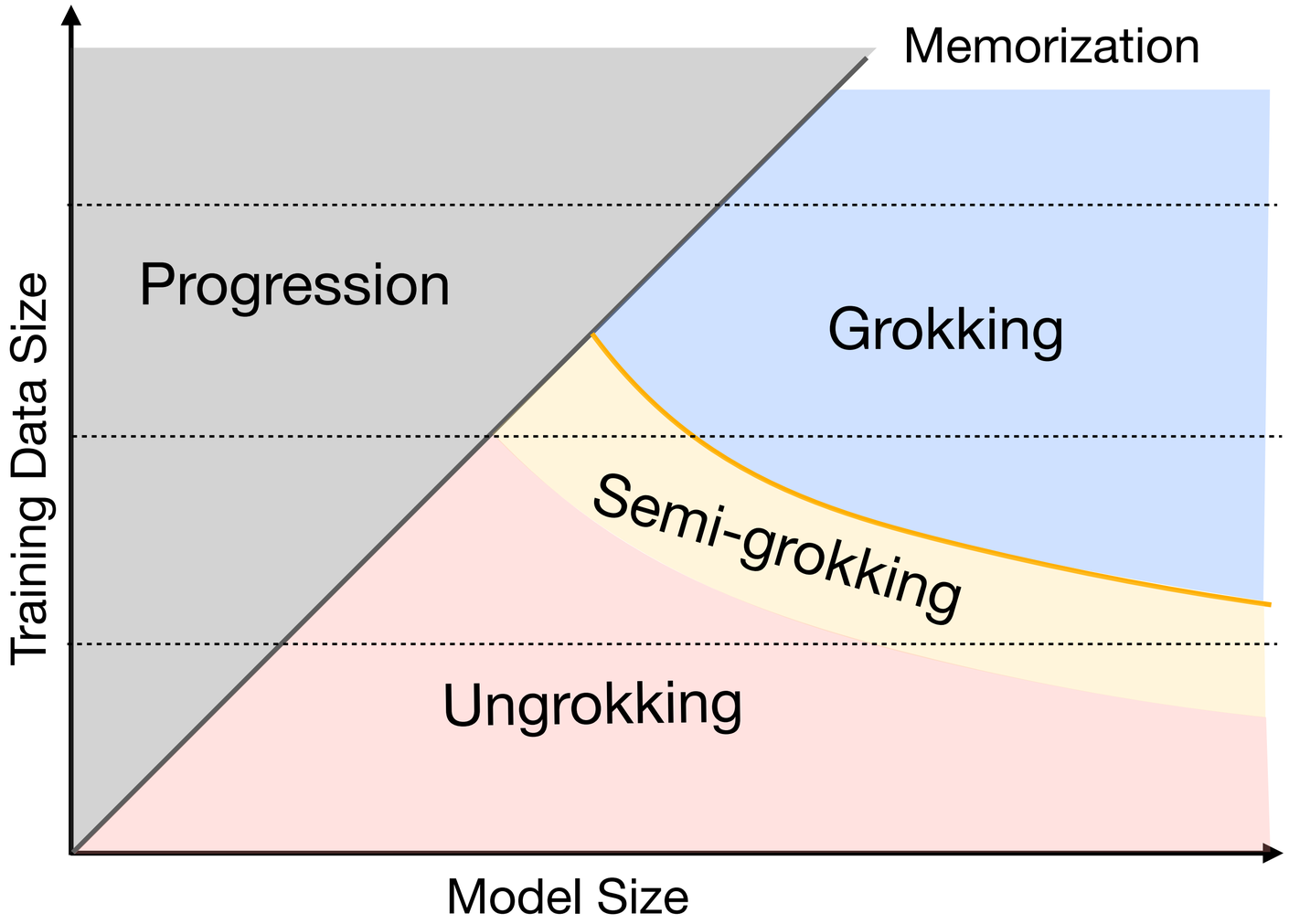
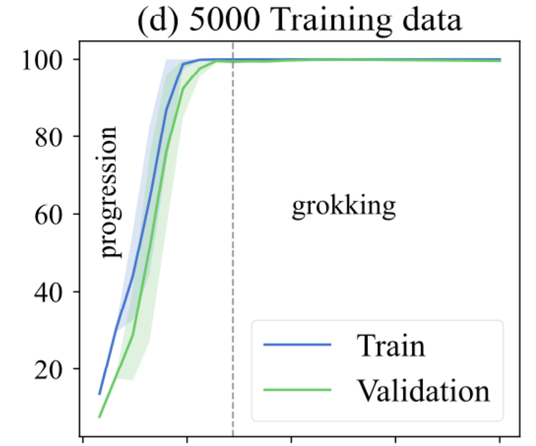


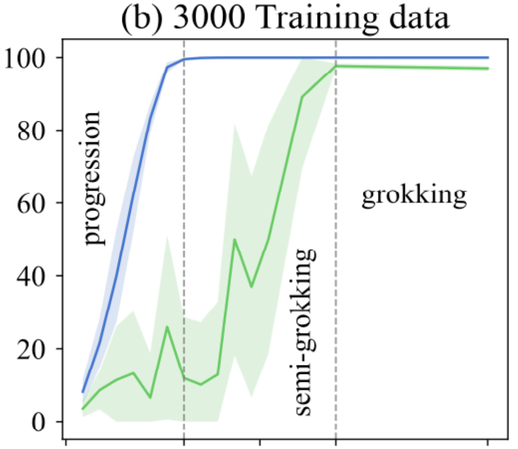


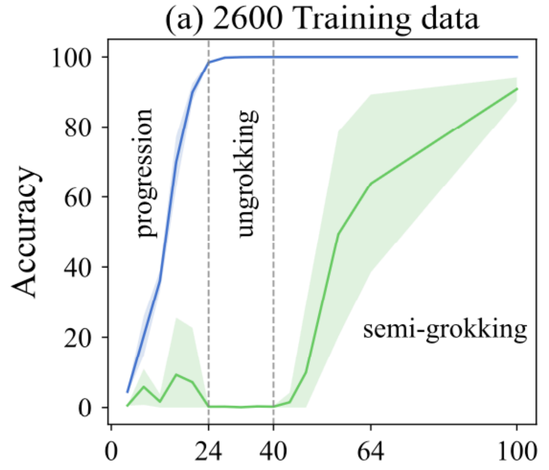
Sweeping Training Data



Double descent







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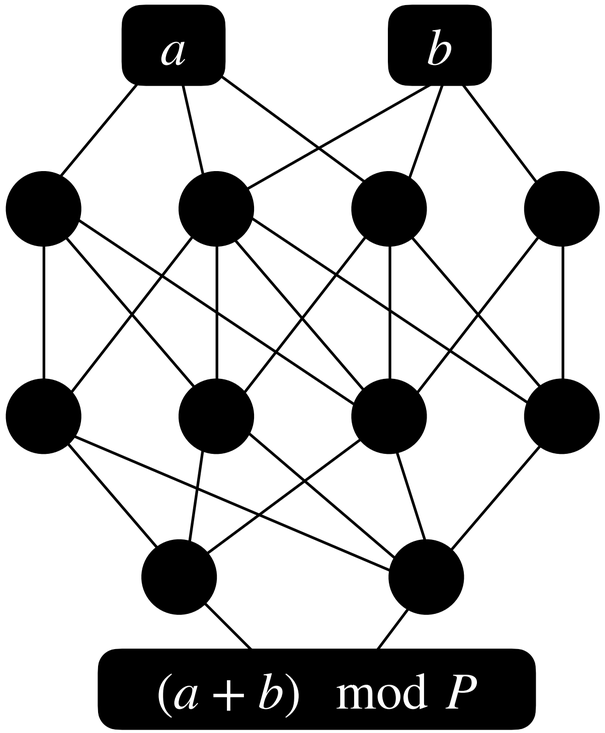
3. [Look at how emergent abilities relate to grokking]

Up next from Silvia

What does this general circuit actually look like?



General circuit for addition

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3. How emergent abilities relate to grokking.

Multi-Task Learning

- Data is a mixture of different tasks (e.g. LLM pretraining)
- Emergent task abilities — smoothly decreasing overall loss, but sudden increases in individual task success.

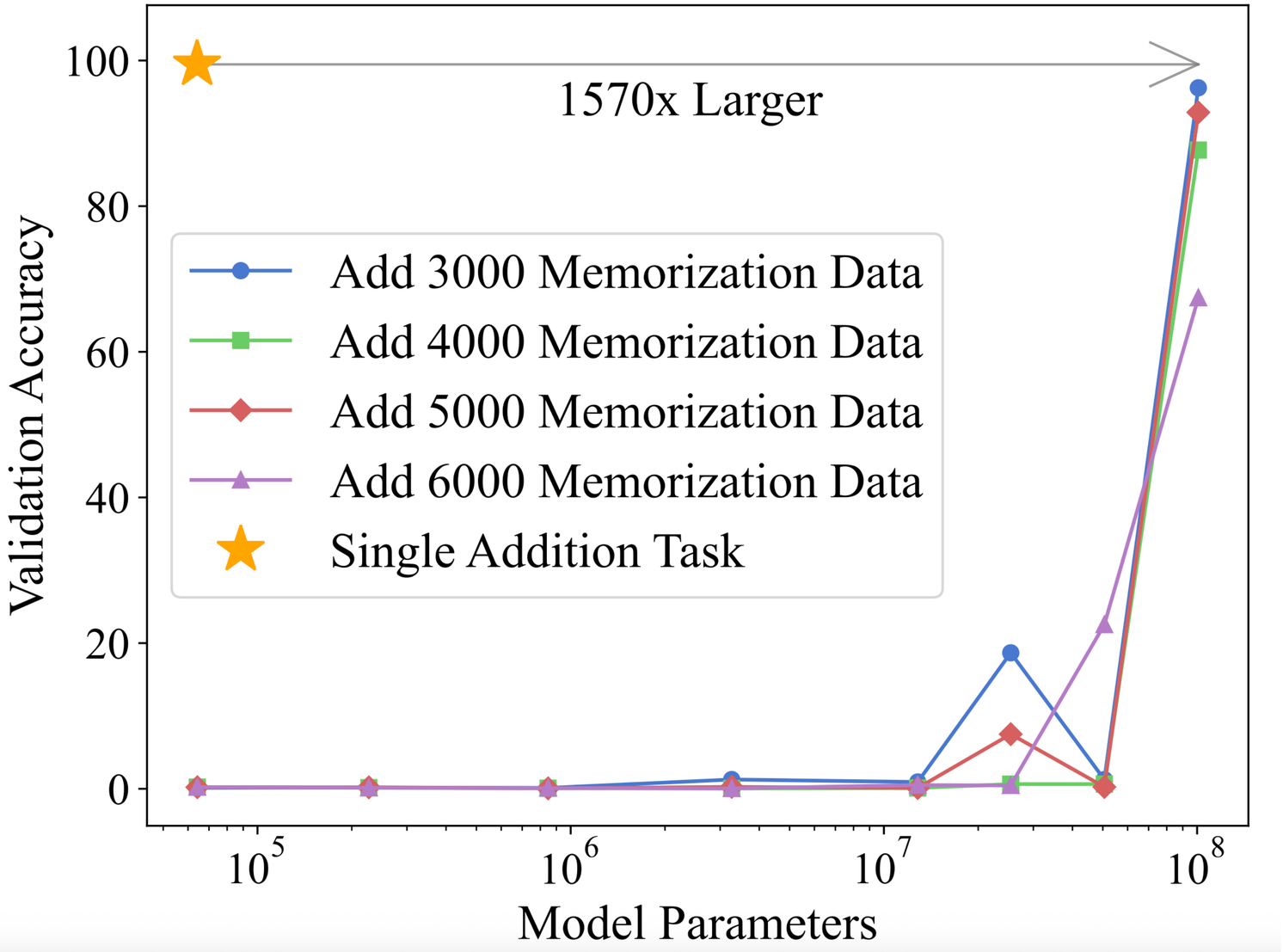
How does learning multiple tasks affect grokking behavior?

Multi-Task Learning

- Data is a mixture of different tasks (e.g. LLM pretraining)
- Emergent task abilities — smoothly decreasing overall loss, but sudden increases in individual task success.
- Setup:
  - Same modular addition task (can generalize)
  - Additional task with random labels (memorization only)
  - Train on various ratios of data, varying model size.

Multi-Task Learning

- Addition task + memorization task.
- Memorization data hinders addition task success
  - but amount of data doesn't seem to matter much
- *plot best of 3 runs



Multi-Task Learning

- Addition task + memorization task.
- Memorization data hinders addition task success
- Purposefully **separating** how the model treats addition vs memorization data helps somewhat.