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How BabyLMs Learn Filler-Gap Dependencies

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… about LMs

What we know:

- Domain-general blackbox
- LARGE
- LMs can produce human-like sentences

What we don’t know:

- Small datasets?
- Human-like knowledge?
- Do LMs still learn complex syntactic structures?

Overview

- LMs trained on child-oriented input can approximate *filler-gap dependencies*
- But they failed to learn sensitivity to *island effects*

How human babies learn languages

Noisy, limited input

Rapid learning rate

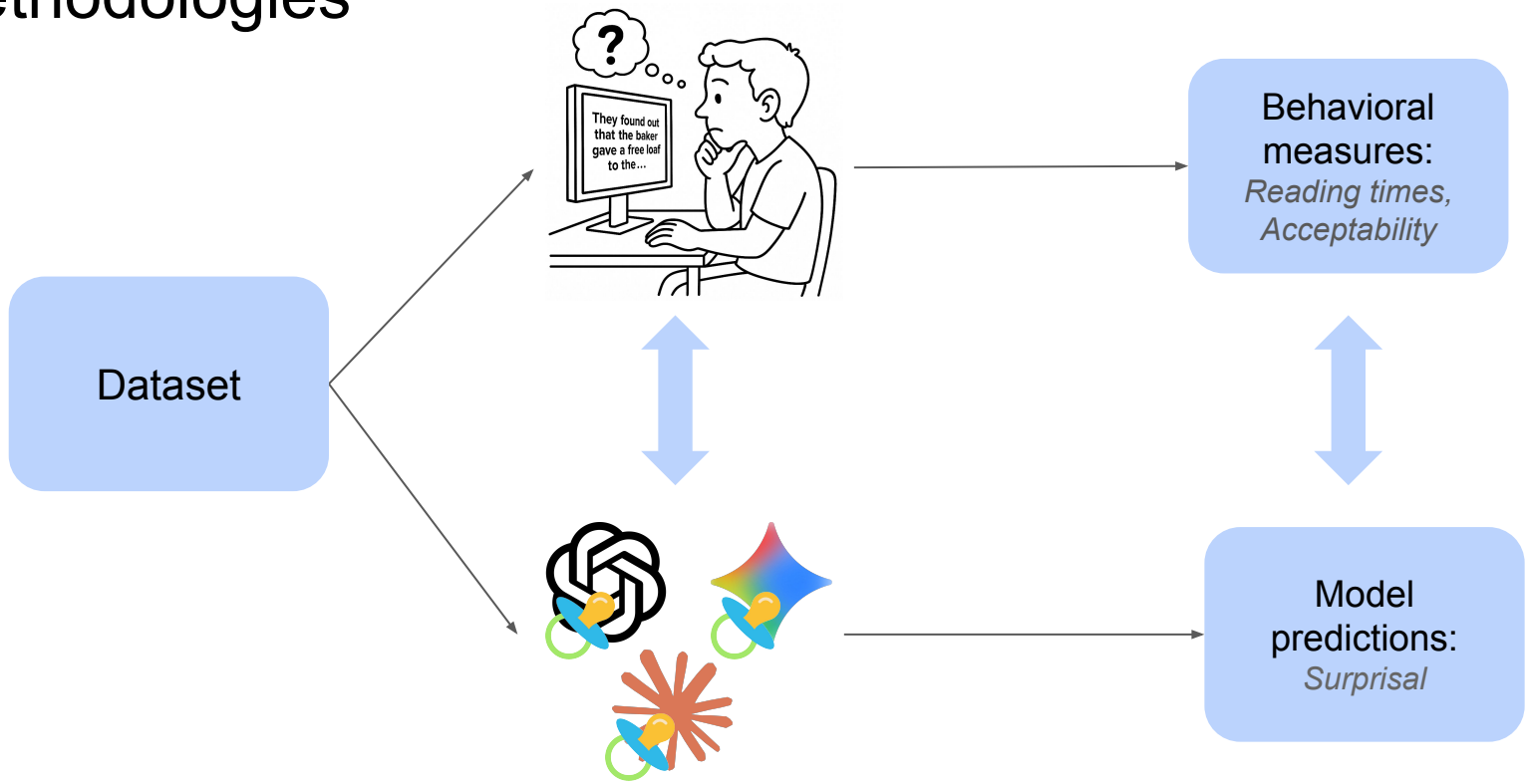
Young Noam

1-2 yo — comprehension of syntactic dependencies

5-6 yo — exhibit near-adult to adult level comprehension and representation

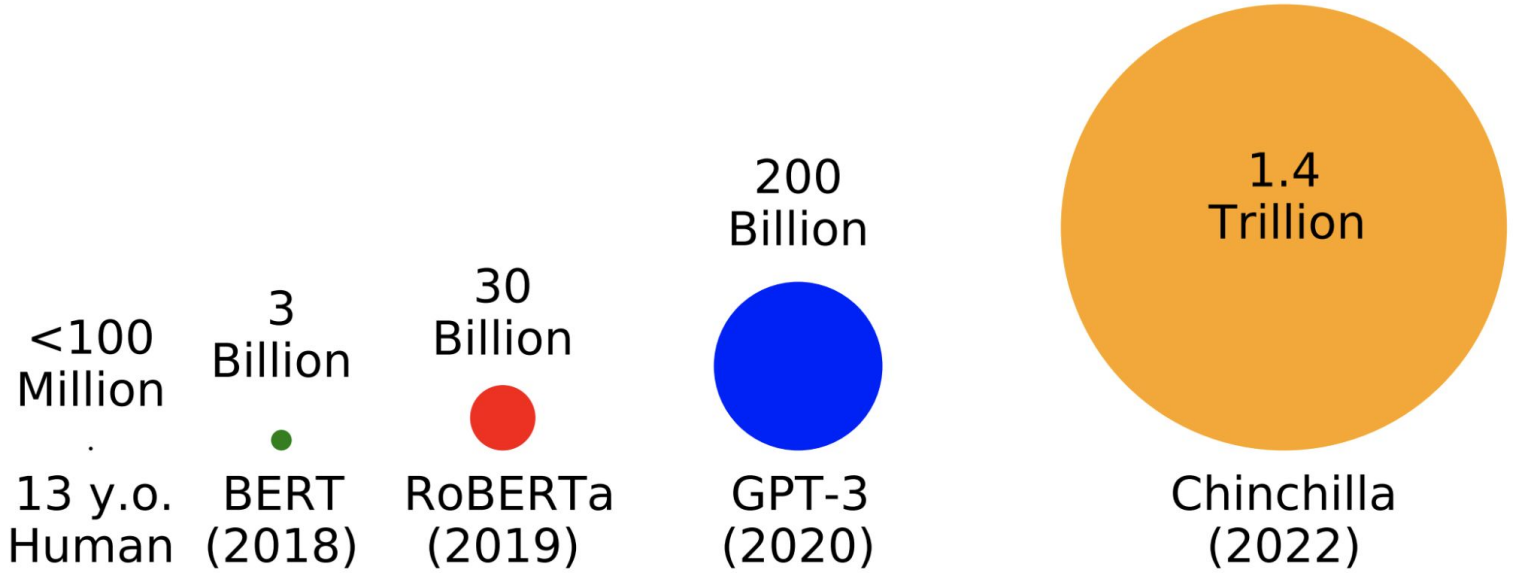
Chomsky (1968, 1973, 1980), Yang (2004, 2016)

Methodologies



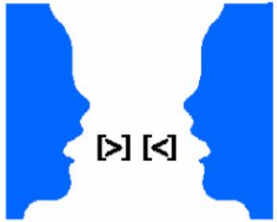
BabyLM Challenge

Sample-efficient pretraining on a developmentally plausible corpus



Warstadt et al. (2023), Hu et al. (2024)

CHILDES



Child Language Data Exchange System

MOT: what do you want me to do ?
CHI: oh !
CHI: &-uh .
MOT: wait a moment .
MOT: put the yellow one down .
CHI: 0 .
MOT: put the green one down .
CHI: 0 .
MOT: that's a boy .
MOT: put it on there .
MOT: now (.) try the orange one .

Filler-gap dependencies 

… a *filler* (e.g., *who* and *what*) that licenses a *gap*

did you buy what ?

Ross (1967); Wilcox et al. (2018, 2024)

Filler-gap dependencies

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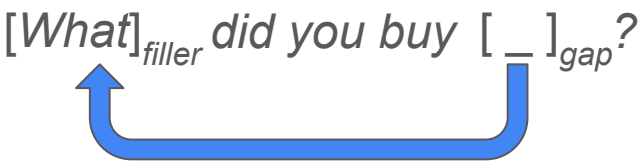


Ross (1967); Wilcox et al. (2018, 2024)

Filler-gap dependencies 🕳️

… a *filler* (e.g., *who* and *what*) that licenses a *gap*

Island constraints 🏝️

The movement of a *filler* can be blocked by some clauses aka. “syntactic islands”

did he leave [*before she finished* what]$_{\text{island}}$?

Ross (1967); Wilcox et al. (2018, 2024)

Filler-gap dependencies 🕳️

… a *filler* (e.g., *who* and *what*) that licenses a *gap*

[*What*]$_{filler}$ *did you buy* [_]$_{gap}$*?*

Island constraints 🏝️

The movement of a *filler* can be blocked by some clauses aka. “syntactic islands”

**What did he leave* [*before she finished* ___]$_{island}$*?*

Ross (1967); Wilcox et al. (2018, 2024)

Models

10 Million

ConcreteGPT

(Capone et al. 2024)

GPT2-10M

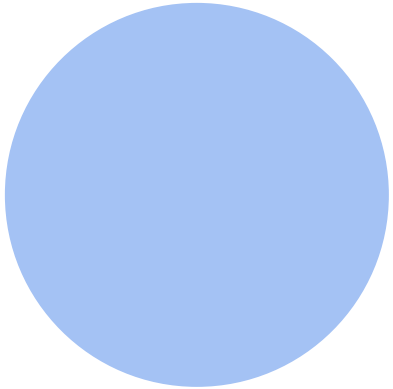
100 Million

BabbleGPT

(Goriely et al. 2024)

GPT2-100M

~21 Billion



GPT-2

Experiment Design

	+filler	-filler
+gap	I know what the students should take ____.	
-gap		I know that the students should take linguistics.

Dependency manipulations: gap distance × direct obj., gap distance × indirect obj.)

Two types of syntactic islands: wh-islands, adjunct-islands

Wilcox et al. (2018, 2024)

Wh-licensing score

$$[\text{Surprisal}(+\text{filler}, -\text{gap}) - \text{Surprisal}(-\text{filler}, -\text{gap})]$$

$$-[\text{Surprisal}(+\text{filler}, +\text{gap}) - \text{Surprisal}(-\text{filler}, +\text{gap})]$$

A **positive** value is expected when you have a filler-gap dependency

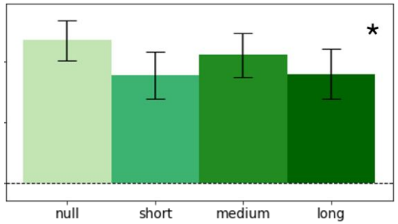
Wilcox et al. (2018, 2024)

Word-level

GPT2-10M

GPT2-100M

Full-size GPT2



Gap Distance × Direct Obj.

Gap Distance × Indirect Obj.

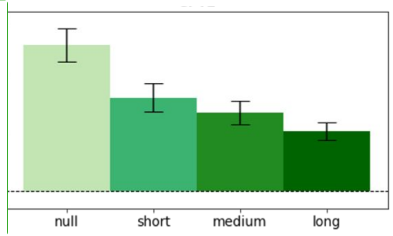
wh-islands

adjunct-islands

Clause-level

GPT2-10M | GPT2-100M | Full-size GPT2

Gap Distance × Direct Obj.



Gap Distance × Indirect Obj.

wh-islands

adjunct-islands

Filler-gap dependencies 🕳️

… a *filler* (e.g., *who* and *what*) that licenses a *gap*

[*What*]$_{filler}$ *did you buy* [_]$_{gap}$*?*

Island constraints 🏝️

The movement of a *filler* can be blocked by some clauses aka. “syntactic islands”

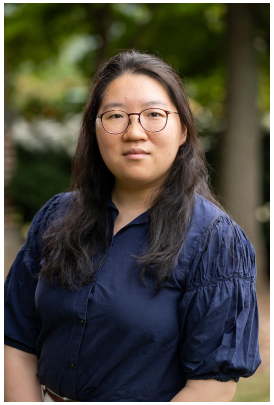
**What did he leave* [*before she finished* ___]$_{island}$?

Ross (1967); Wilcox et al. (2018, 2024)

Take-home Messages

- GPT-2 models trained on child-oriented input can approximate *filler-gap dependencies* in human languages;
- But unlike humans, they failed to learn any island constraints

Chi-Yun Chang



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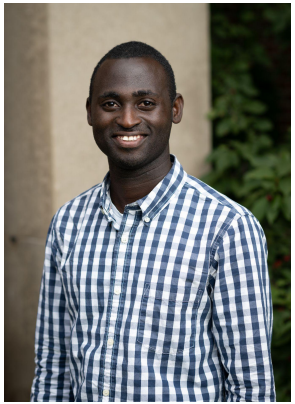

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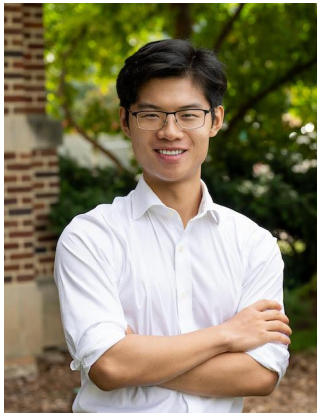

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The End

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BabyLM Challenge organizers