Searching for Morphological Productivity

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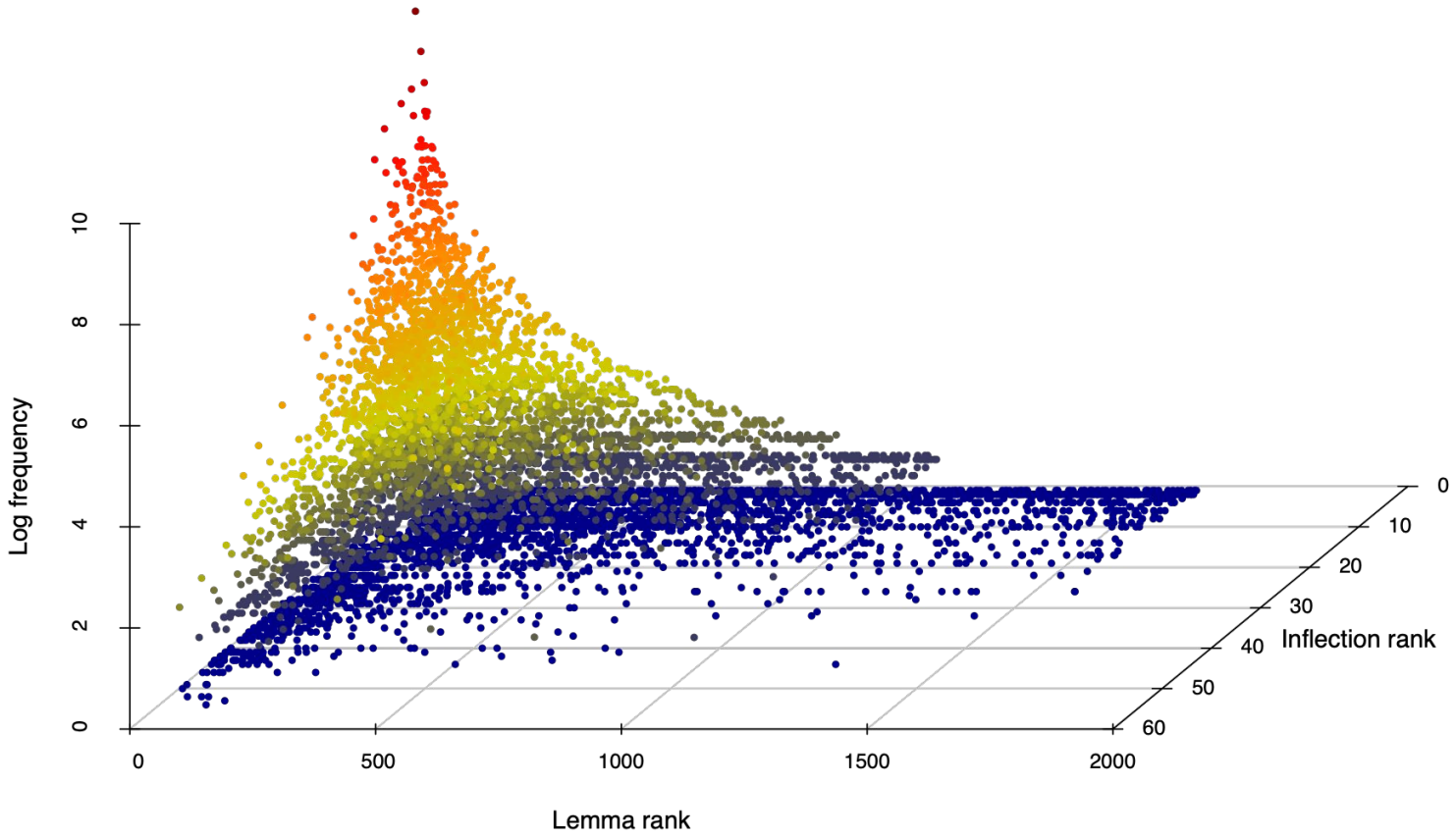
Searching for Productivity

How do children discover productive generalizations?

- Overcoming sparsity
- Despite exceptions
- When multilayered

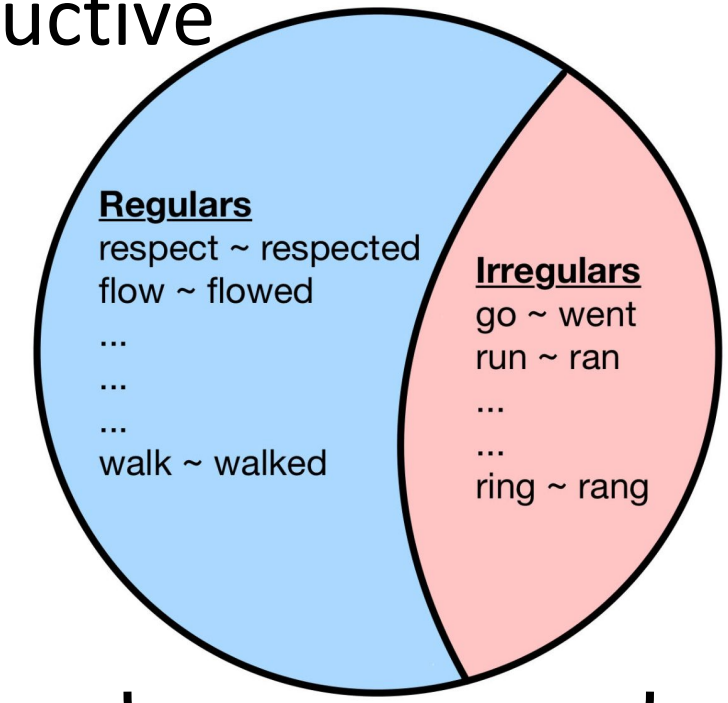
Background: Sparsity



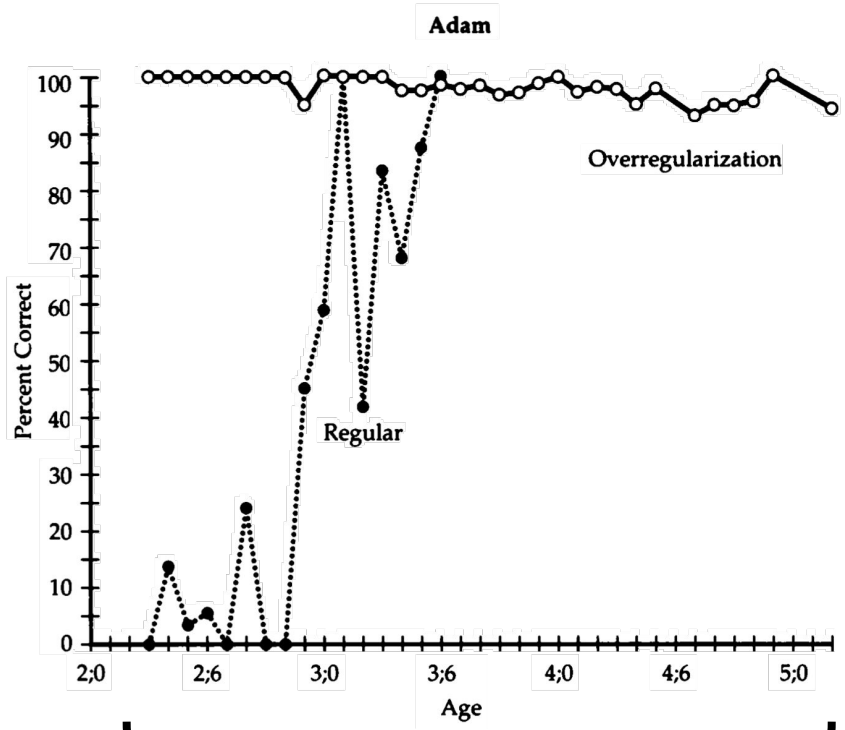
Courtesy of Erwin Chan & Constantine

Background: Productivity

English Past Tense: Statistically dominant rule = productive



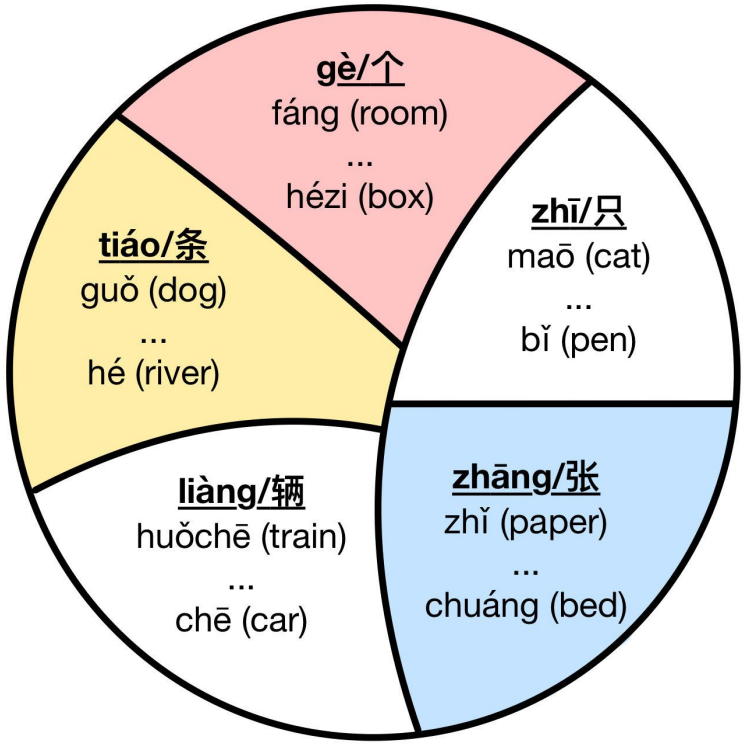
Productivity Despite Exceptions



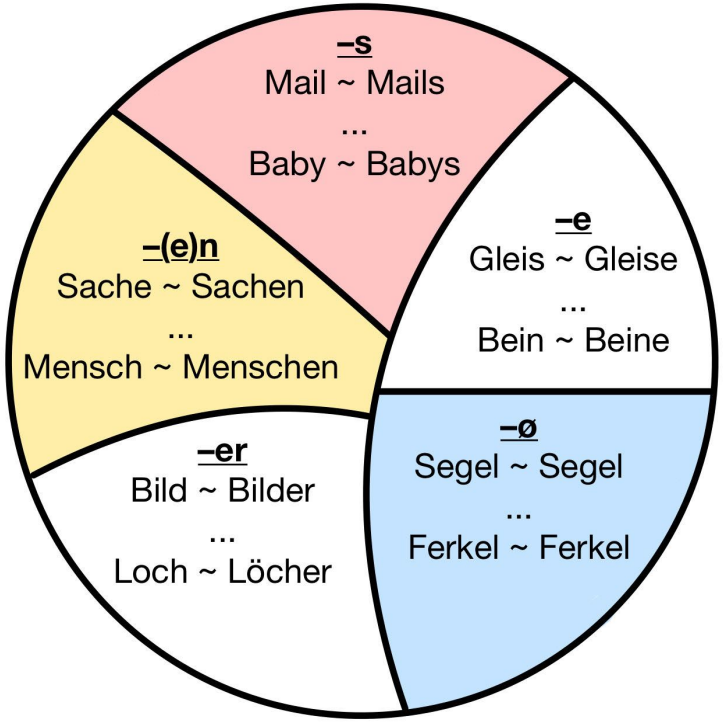
"U-shaped" learning

Background: Productivity

German Plurals & Mandarin Classifiers: Restricted to subgroups



Semantics



Gender & Phonology

Contributions

We present a model of morphological learning capable of extracting *linguistically interpretable rules* from developmentally plausible vocabularies

Data

Input: (lemma, inflected, feature)

English: (walk, walked, {3, SINGULAR, PAST})

German: (Sache, Sachen, {FEMININE})

Chinese: (rén, gè rén, {+ANIM, +CONC, -FLAT, +HUM, +NAT, -SLEN, -VEH})

	English Past Tense	German Plurals	Mandarin Classifiers
Max Training Size	600 words	360 words	100 words

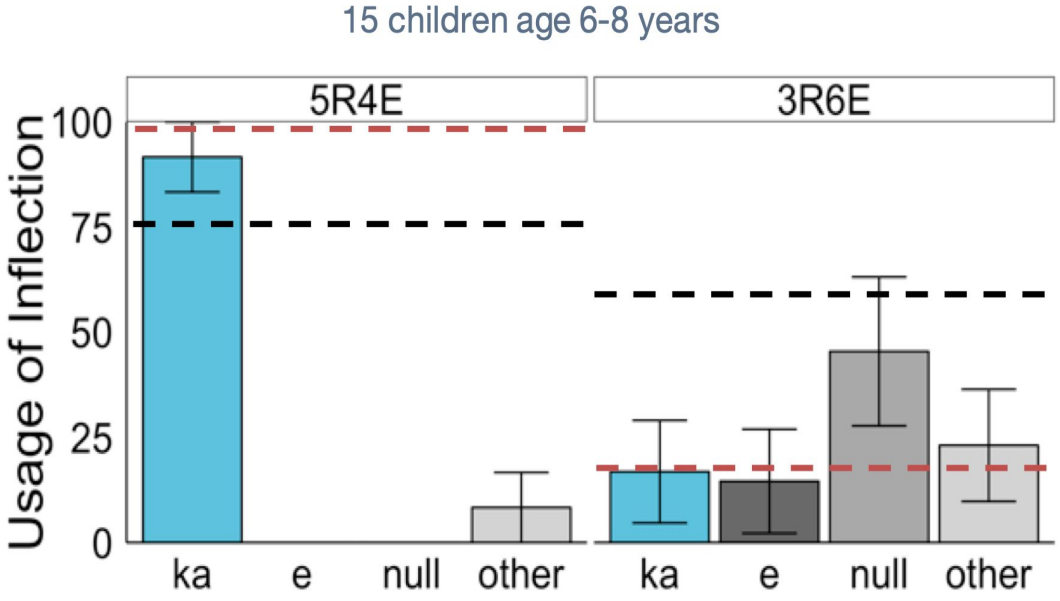
Model: The Tolerance Principle

- **Intuition:** given a set of items:
  - If *many* do X, then all do X (generalization)
  - If *few* do X, then remember the few that do (lexicalization)
- Threshold defined by efficiency:

$$\underbrace{e}_{\text{exceptions}} \leq \underbrace{\theta_N = \frac{N}{\ln N}}_{\text{threshold}}$$

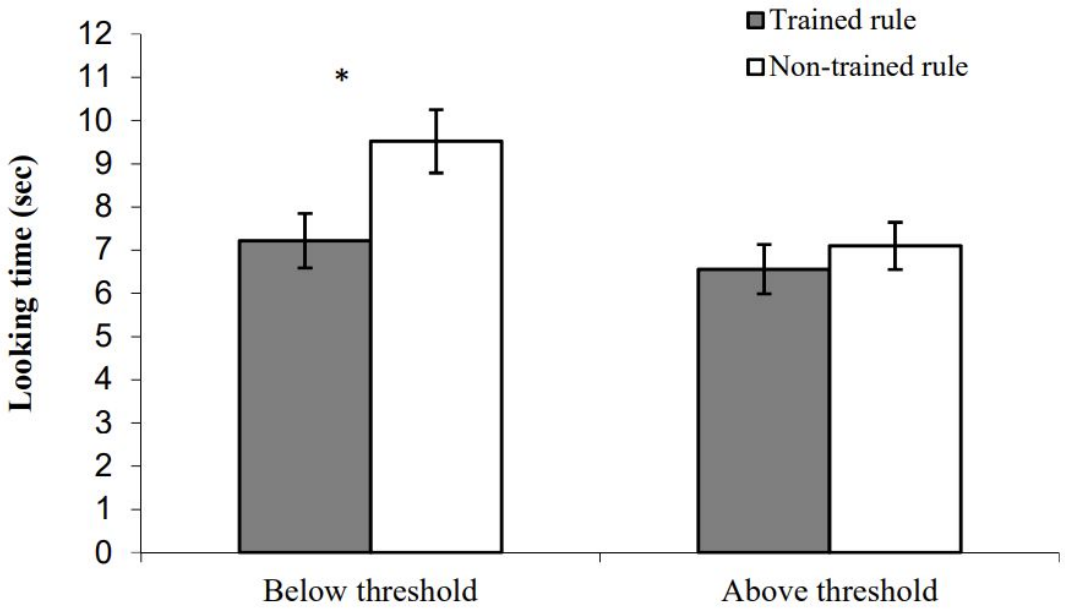
Model: The Tolerance Principle

Empirical evidence from artificial language studies



Schuler, Yang & Newport (2016, Submitted)

$$\theta_9 = 4.2$$



Emond & Shi (2021)

$$\theta_{16} = 5.7$$

Model: Abductive Search

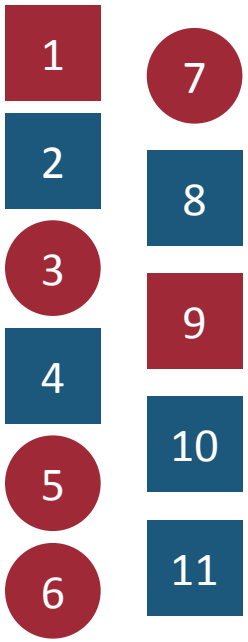
TP applied recursively:

- Try forming **rule** over **set** of **N** items
- If **rule** not productive, subdivide **set** into disjoint subsets
- Repeat within each subset

Terminates when

- Productive rule found (generalization)
- Or, no more subdivisions possible (lexicalization)

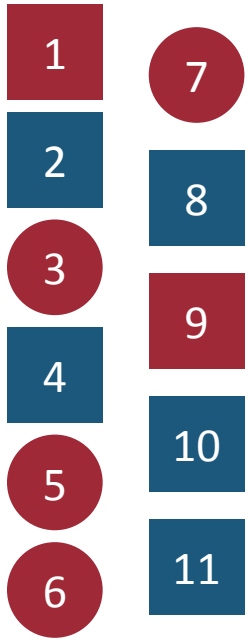
Model: Abductive Search



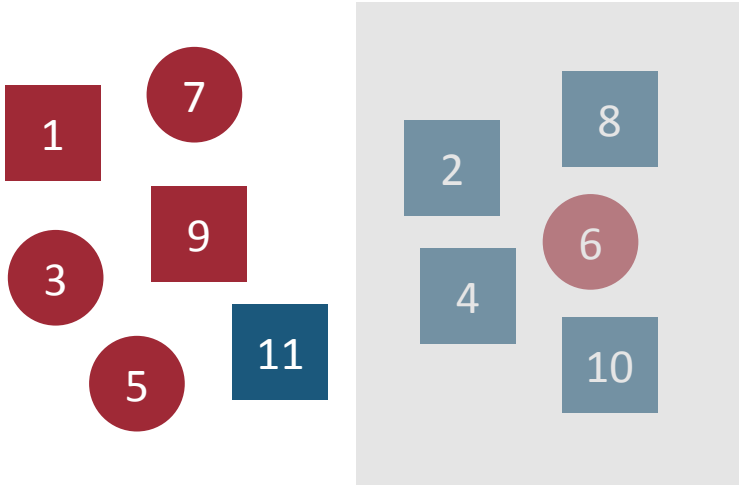
- Find the most frequent color (6 vs. 5 ■)
- **Hypothesize** a rule {Features} ? ■
  - Odd→ ■
- **Test** the rule "Odd→ ■ "
  - *TP check (N=6, e=1)*: 1, 3, 5, 7, 9, 11
- R1 productive: Odd→ ■ Exceptions 11
- Recurse over remaining items
- R2 productive: Even → ■ Exceptions 6

Model: Selecting a Feature

Multiple ways to subdivide **N** items

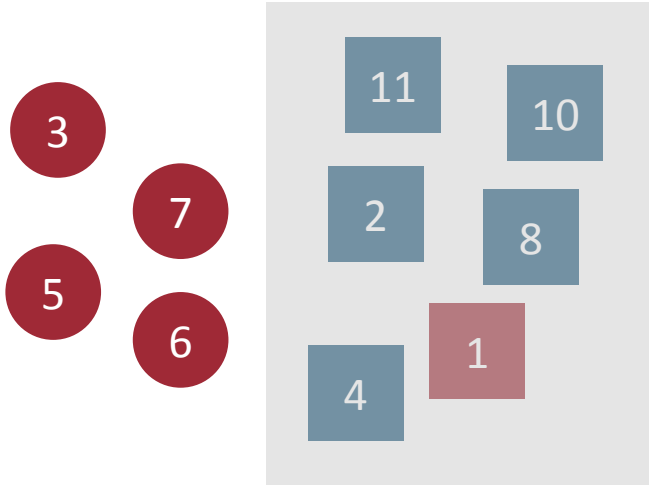


11 Items



Most **Frequent** [1]

Odd ? Red



Most **Consistent** [2,3]

◯ ? Red

[1] Carla L Hudson Kam and Elissa L. Newport. 2005. Regularizing unpredictable variation: The roles of adult and child learners in language formation and change. *Language Learning and Development*, 1(2):151–195.

[2] LouAnn Gerken. 2006. Decisions, decisions: Infant language learning when multiple generalizations are possible. *Cognition*, 98(3):B67–B74.

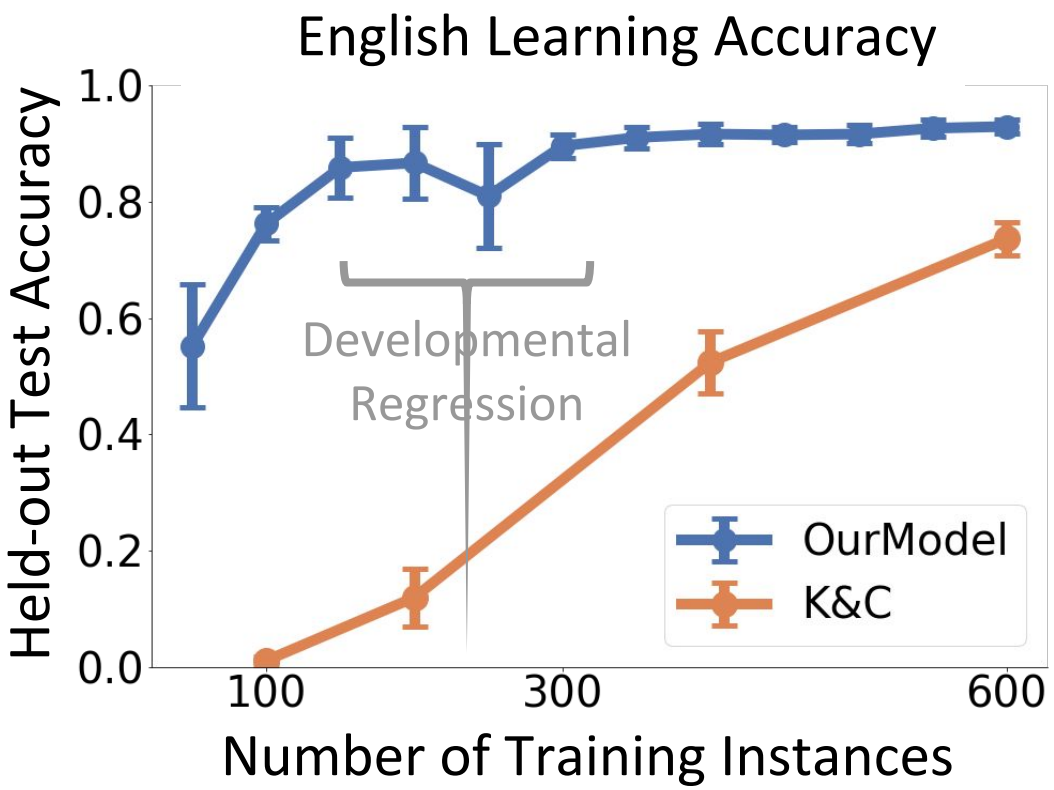
[3] Patricia A Reeder, Elissa L Newport, and Richard N Aslin. 2013. From shared contexts to syntactic categories: The role of distributional information in learning linguistic form-classes. *Cognitive psychology*, 66(1):30–54.

Results

- Q1: How accurately does our model learn morphology?
  - English past tense
  - German plurals
  - Comparison: Kirov and Cotterell (2018)'s Neural Network model (K&C)
- Q2: Are the results developmentally plausible?
  - English past tense learning trajectory
  - Linguistic interpretability of rules
  - Attends to relevant features

Results: English Past Tense

Child-like developmental trajectory

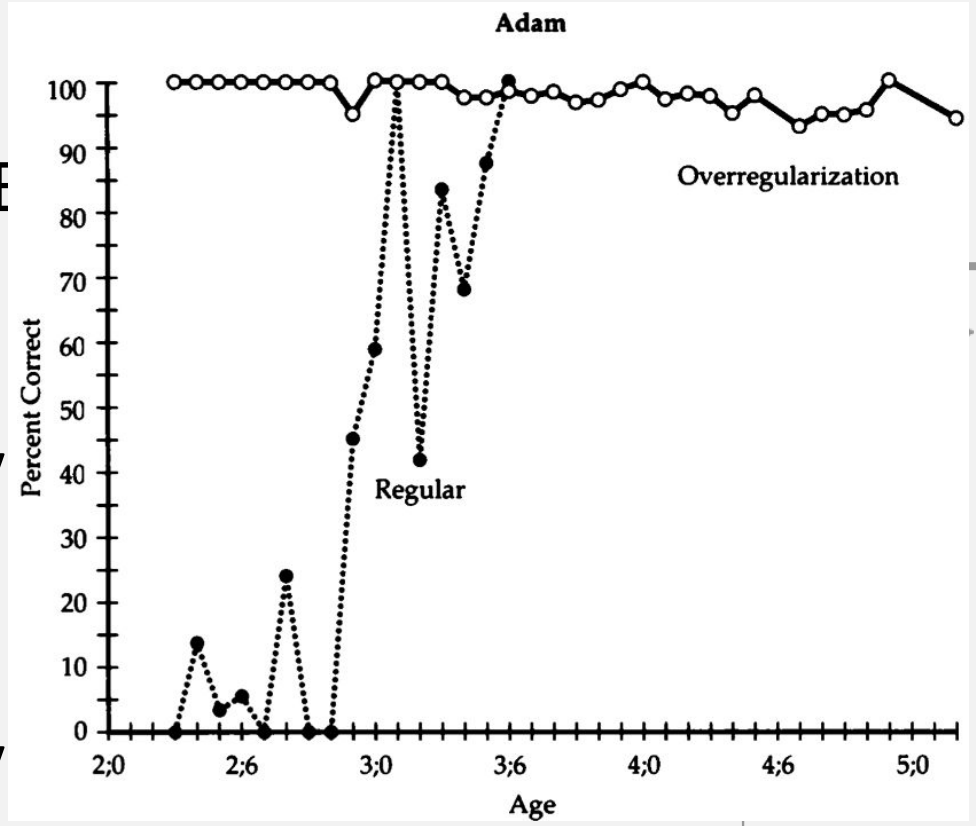


Linguistically interpretable rules

[+VE ...]#

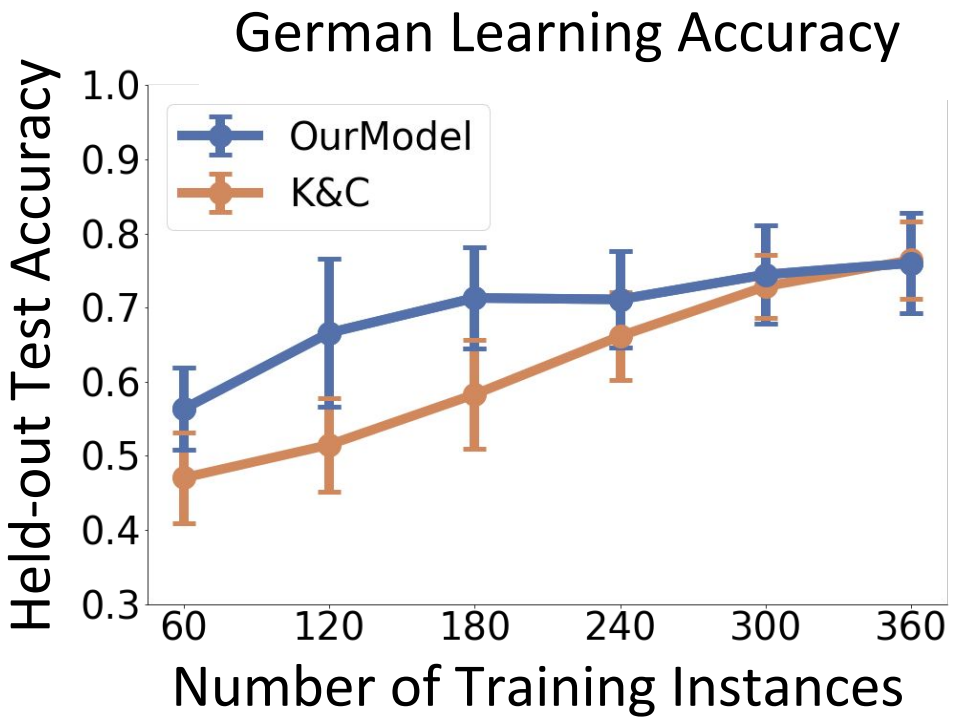
[+V

[+V



Results: German Plurals

Child-like developmental trajectory



Linguistically interpretable rules

Gender

Phonology

[M] → -e / [d, b, f, g, h, z, s, k, m, …]#

[F] → -en / [r, t, n, g, z, hl]#

[F] → -n

(e)n

…

[N] → -e / [r, l, m, t, n, z]#

…

[4] Wiese 1996. *The phonology of German.* Cambridge.

[5] McCurdy, K., Goldwater, S., & Lopez, A. (2020). Inflecting when there's no majority: Limitations of encoder-decoder neural networks as cognitive models for german plurals. In Proceedings of the 58th annual meeting of the association for computational linguistics, ACL (pp. 1745–1756).

Results: Mandarin Classifiers

[-Veh, -Slen, -Flat, -Hum, -Anim, +Conc, -Nat] → gè (個/个)

[-Veh, -Slen, -Flat, -Hum, -Anim, +Conc, +Nat] → gè (個/个)

[-Veh, -Slen, -Flat, -Hum, -Anim, -Conc, -Nat] → gè (個/个)

…

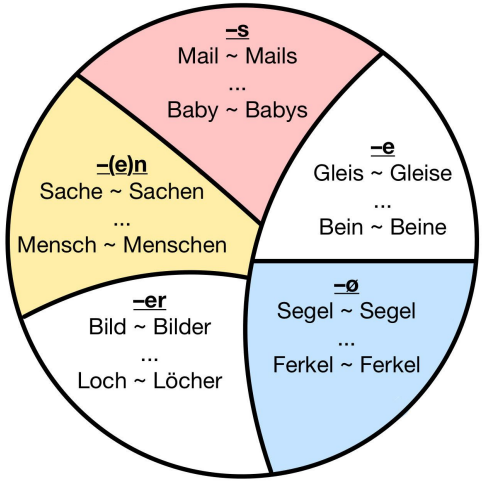
[-Anim, -Hum, -Nat, +Conc, -Slen, -Flat, +Veh] → liàng (輛/辆)

- Semantic conditions learned ✓
- Irrelevant phonological properties ignored [5] ✓

[5] Hu 1993. The acquisition of Chinese classifiers by young Mandarin-speaking children. BU dissertation.

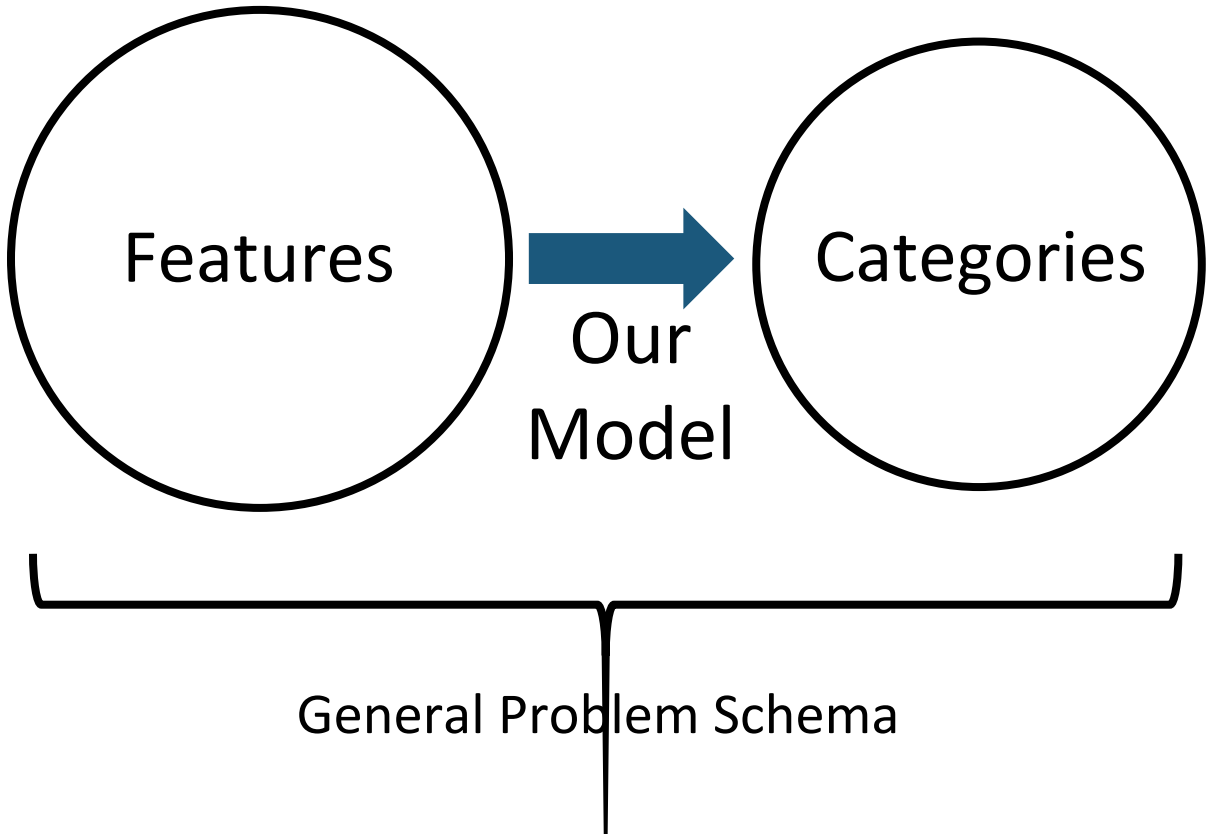
Conclusion

- Abductive, recursive search + TP provides plausible account of morphological acquisition
- Lexicon partitioned into categories
  - The rules yielding these categories are a ‘good enough’ grammar
  - That is, they regularize learning
- Preserves explicit distinction between
  - generalization and lexicalization [6, 7]
  - walk → walked vs. run → ran



[6] Berko, J. (1958). The child’s learning of english morphology. Word, 14(2-3), 150–177.
[7] Lignos, C., & Yang, C. (2016). Morphology and language acquisition. In G. Hippisley Andrew R. abd Stump (Ed.), The Cambridge handbook of Morphology (p. 765-791). Cambridge: Cambridge University Press.

Conclusion

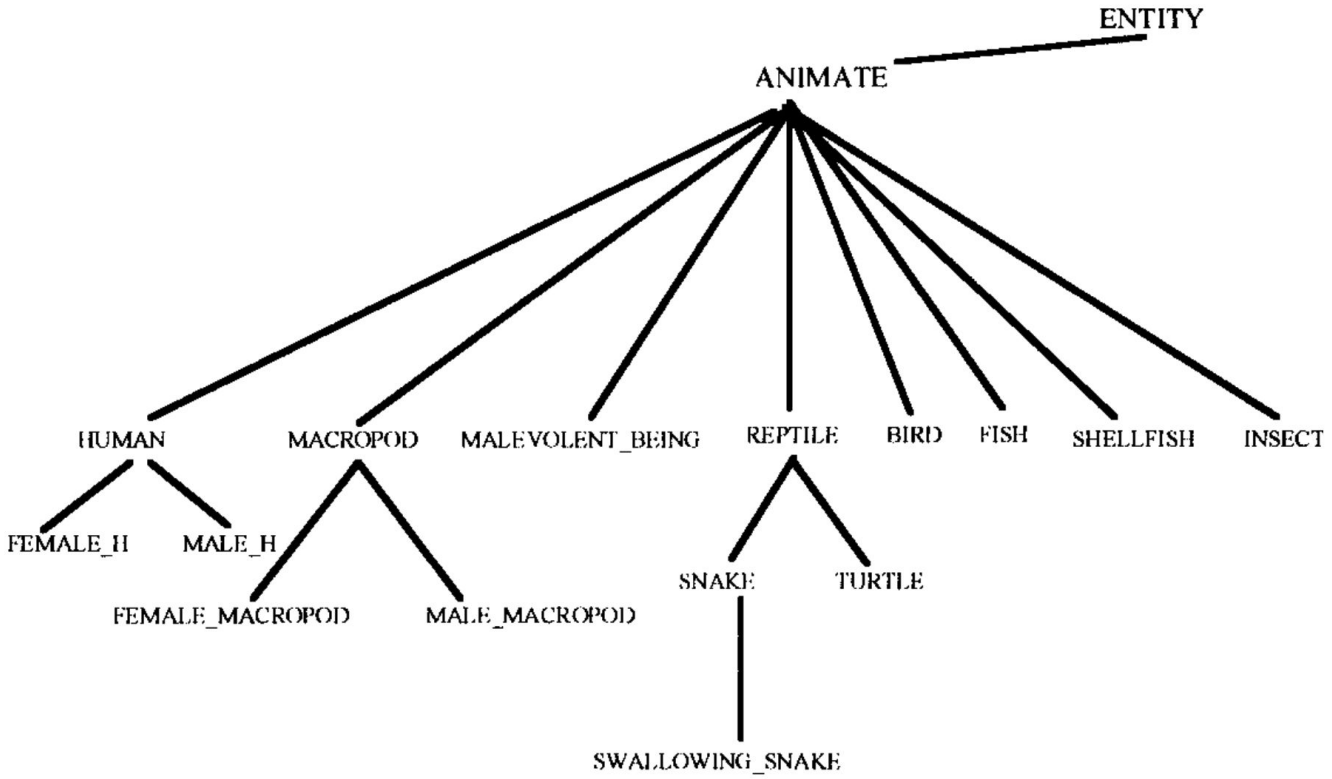


Applicable to linguistic mappings beyond morphology e.g.,

- {Phonology, Semantics} → Gender
- {Distributional Properties} → Phonological Natural Classes

…

Conclusion

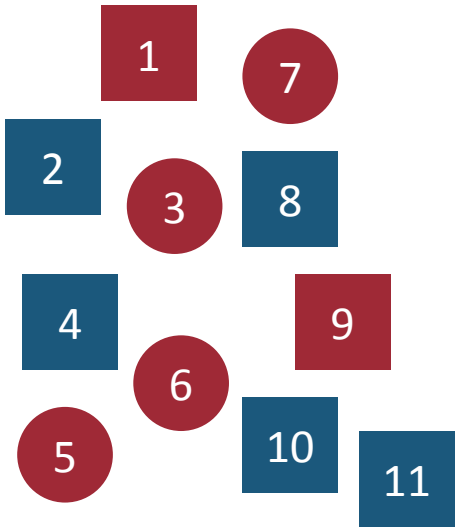


Animate Semantic Hierarchy Mayali

Evans, Brown & Corbett (2002/2019:132)

Maybe general category formation process?

- Object Properties Categories



Thank you!!!

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