Is there scope for scope in morphophonological rule induction?

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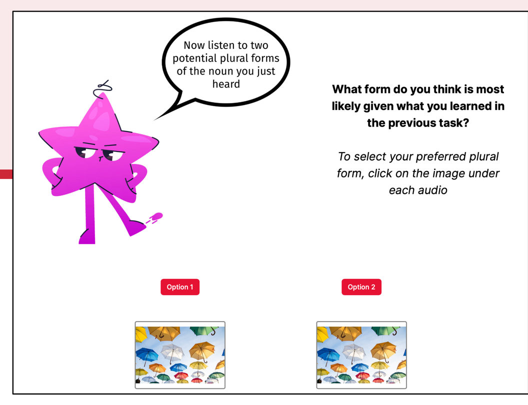

1 (Some) evaluation metrics in rule induction

- **Conservative bias**: stick to the input data (Berwick, 1985; Tenenbaum, 1999)
  - Subset Principle, exemplar-based learning…
- **Simplicity bias**: prefer formally simple(r) rules (Pycha et al., 2003; White, 2013; Durvasula & Liter, 2020).
  - E.g., pick ∅ → /r/ / $V_{[-hi, -rd, +bk]}$ _ V **over** ∅ → /r/ / $V_{[-hi]}$ _ V (in r-insertion)
- **Scope (expansion) bias**: prefer rules targeting as many segments as possible (Nie et al., 2019)
  - E.g., like simplicity, BUT *also* pick /o/ → [ɔ] before /r/, nasals, coronal obs **over** /o/ → [ɔ] before /r/ ([F]-simpler)

Substantial work exploring the role of **simplicity and/or conservativeness** in learning:

- Computational work (i.a., Gold, 1967; Albright & Hayes, 2002; Carr et al., 2020)
- Synchronic/diachronic (i.a., Chomsky, 1957; Fodor & Crain, 1987; Clark & Roberts, 1993)
- Experimental (i.a., Pycha et al., 2003; White, 2013; Culbertson & Kirby, 2016)

Role of **scope expansion underexplored**, but recent evidence in diachrony (Nie et al., 2019) and computational models (Sayeed & Vaux, 2023)

No work on scope expansion/contraction in real-time language learning, however!

→ **Our contribution**: *first attempt* at probing **scope biases** with **Artificial Language Learning** (ALL).

Research questions

RQ1: Which **generalisation biases** do participants exhibit when presented with **sparse input** in an ALL setting?

RQ2: Further, do participants exhibit **different generalisation patterns** depending on the **scope of the rule** they are exposed to?

2 An Artificial Language Learning Experiment – Plural formation

Participants:
76 native English speakers recruited through Prolific

Procedure:
Poverty of the Stimulus paradigm (e.g., Wilson 2003)

1. **Familiarization**: CVC pseudo-words with auditory evidence for an alternation in the plural suffix.

/kap/ > /kapwok/ **BUT** /pen/ > /penok/

Three conditions manipulating the **SCOPE** of the rule. Each provided **positive evidence** for diphthongization in:

- *Plosives Condition* (intermediate): 40 items – 20 stems (2 stems per C), repeated 2x.
- *Voiced Plosives Condition* (narrow): 32 items – 16 stems (4 stems per C), repeated 2x.
- *Obstruents Condition* (wide): 60 items – 30 stems (3 stems per obstruents, 6 per nasal/approx.), repeated 2x.

- **Negative evidence** (absence of diphthongization) in **nasals** and/or **approximants**.
- **'Control'**: 1 phoneme **held out** per natural class.

2. **Evaluation**: quiz measuring learning success in exposed trials.

3. **Testing**: force-choice task with 54 novel stems for all unseen/seen environments.

4. **Debrief**: self-reports of learning strategies ('rule-based' or 'intuition-based')

Predictions:

- **If biased by conservativeness**: tight fit to input data, little/no overgeneralization.
- **If biased by simplicity**: extraction of rule with maximal formal simplicity (could take multiple forms; [F]-minimization, elsewhere-rule, etc.).
- **If biased by scope**: extraction of rule with most targets (which need not be [F]-simplest rule).

3 Results

Overall patterns:

1. Overgeneralization of /wok/, with no effect of Condition (*F* (2,27) = 2.20, *p* =.13).

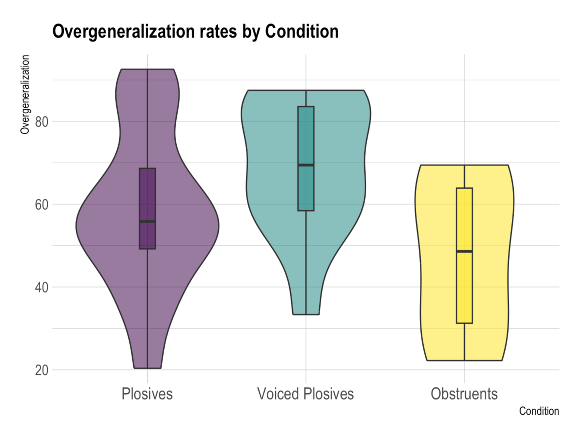

Fig 1.

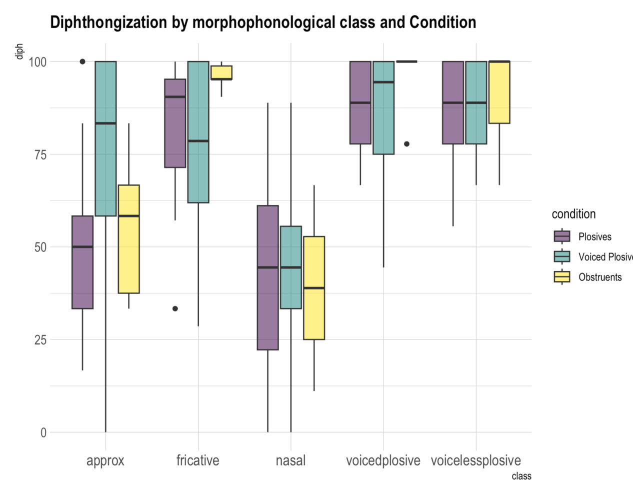

Fig 2.

➢ Only **nasals/approximants**, esp. ***individual segments*** *in familiarization phase,* were **less likely** to trigger diphthongization, though with substantial variance.

➢ **All other segments generally triggered diphthongization, incl. *held-out* segments (e.g., /r/ = 77.78%, /ŋ/ = 75.55%).**

➢ Mixed effects logistic regression: ***all*** phonemic contexts **highly associated** with **diphthongization** at testing (*p* < .001), **bar** nasals-approximants (*β* = -0.13, *p* = 0.610).
 ➢ Segments **outside of training** data much **more likely** to trigger **diphthongization** (*β* = 1.08, *p* < .001).

→ **Upshot**: *exception-driven learning*. Individual segments (*not* phonological natural classes) extracted as *exceptions* to an elsewhere rule.
E.g., [PL] → /ok/ / /n, m, l/___
/wok/ ELSEWHERE

Results (continued)

2. Type, not token, frequency conditioned generalizations

- No statistical bias in familiarization data: **balanced *token* frequency** of diphthongized *vs* non-diphthongized familiarization items (~50/50%).
- Nonetheless, ***type* frequency (mostly) determined generalization patterns,** as in Yang's (2002, *et seq.*) **Tolerance Principle** (see also Schuler et al., 2017; cf. Baayen, 2009).

→ Plosives Condition: θ_N = 4.59 (4 *vs* 3 types).
→ Voiced Plosives Condition: θ_N = 2.89 (2 *vs* 2 types).
→ Obstruents Condition: θ_N = 4.8 (9 *vs* 3 types).

3. Predominance of explicit learning: role of learning strategies

- **Rule-based**, explicit-learning strategies (per self-reports) **facilitated learning success**
  → Higher performance in evaluation quiz (*W* = 249, *p* = .018). **Fig 3.**
  → Higher input-faithfulness in testing (*W* = 199, *p* = .002). **Fig 4.**
- Introspective self-reports generally well-correlated with implicit/explicit learning (Pertsova & Becker, 2021).
- HOWEVER: ***not* significantly more likely** to be correlated with *higher overgeneralization rates* (*t*(45)= 0.88). **Fig 5.**
  → Suggests **overgeneralization bias inherent in all participants**, irrespective of self-reported learning strategy.

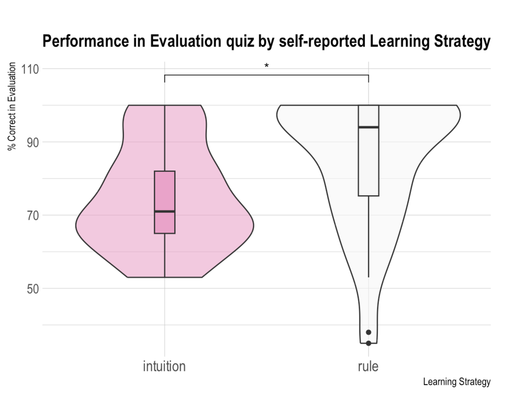

Fig 3.

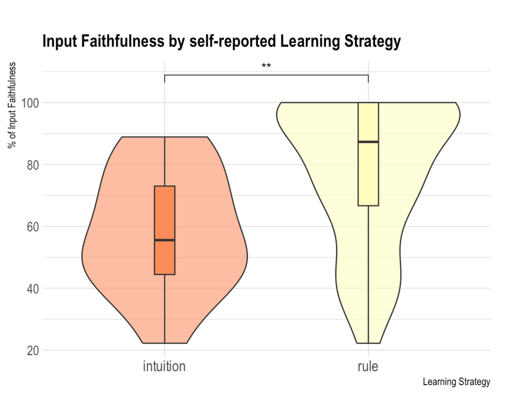

Fig 4.

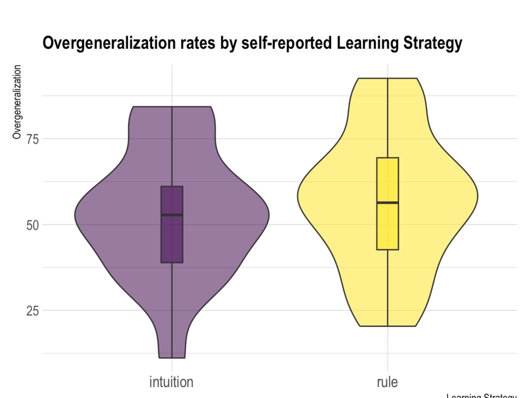

Fig 5.

Local patterns:
In a few participants we also observe other hypotheses *consistent* with the data presented:

- **Scope expansion/simplicity** (2 participants): Voiced Plosives > Plosives
- **Semantically-conditioned generalizations** (9 participants, majority from sparser Condition 2): *animacy-conditioned* rules, based on self-reports, e.g., animals *vs* objects.
  ➢ **Adults more likely** than children to **induce semantic** over phonological **rules**, especially if learning explicitly (Lidz & Gagliardi, 2014; Brown et al., 2021; Pertsova and Becker, 2021).
   → NB: bias observable *despite explicit directions to ignore any semantic cues.*
- **Possible morphologization** (1 participant): morphologized the nasal /n/ as part of suffix – "plural words end with either 'wok' or 'nok'".

The patterns *vs* the predictions
→ Results consistent with a view where **learners** are ***aggressive*** in **generalizing**
 ✓ simplicity, scope expansion accounts ✗ conservativeness
→ Specifically, **exception-driven learning** supports Tolerance Principle's predictions.
→ In principle, ***compatible*** with a ***scope expansion*** *bias*, BUT **data insufficient** to tease it apart from simplicity bias.

4 Conclusions and future work

What we have shown:

- Scope expansion independently attested in diachronic patterns → **Novel experiment** testing the effects of ***scope manipulation*** in morphophonological generalizations.
- Results support view of learners as **overgeneralizers** in the face of input sparsity, consistent with both simplicity/scope analytic biases.
- Implications for role of type frequency and explicit learning in ALL.

Questions and future work:

- Better design to tease apart predictions of simplicity *vs* scope bias.
- Can we design ALL set-ups that minimize the incidence of explicit learning, to more accurately probe learning biases (e.g., more complex task, more learning trials)?
  ➢ Design used plausibly too conducive to exception-driven learning. Can we avoid this?
- Should child participants be favored over adult learners for similar experiments? (see Pertsova & Becker, 2021)

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