Phonetic similarity as a bias in infant phonological learning

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Adam Chong (UCLA)
Megha Sundara (UCLA)

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Collaborators

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Statistical learning

- Infants are excellent distributional learners.
  - Discrimination of speech sounds (Anderson et al. 2003, Maye et al. 2002)
  - Phonotactics (Chamber et al. 2003)
  - Word segmentation (Saffran et al. 1996)

- Also plays a role in learning phonological alternations (e.g. complementary distribution).
  - Experimental work with infants (K. White et al. 2008)
  - Computational modeling (Peperkamp et al. 2006, Calamaro & Jarosz 2015)
Phonetic similarity and the P-map

- Learners are biased by **phonetic similarity** – they prefer alternations between phonetically similar sounds.
  - **Typology** (Steriade 2001; Hayes & J. White, in press)
  - **Adult artificial language studies** (Skoruppa et al. 2011, J. White 2014)

- Theoretical account: Steriade’s **P-map.** (Steriade 2001)
  - *A priori* ranking of **FAITH** constraints. (Steriade 2001, Zuraw 2007)
  - Prior (soft bias) implemented in MaxEnt models. (Wilson 2006, J. White 2013)
Adults have a P-map bias

- Adults learning novel alternations in an artificial language generalize in a biased way. (J. White 2014)

Training: \( p \rightarrow v \) \( b \rightarrow v \)

Test: \( b \rightarrow v \) \( p \rightarrow v \)

- This asymmetry holds even when participants are explicitly trained that /p/ changes, but /b/ does not.

- Results consistent with a P-map prior, which makes alternations between similar sounds preferred. (J. White 2013)
Infant acquisition?

▸ Few infant studies looking at this question!

▸ We present 2 infant studies:
  • Study 1: artificial language learning
  • Study 2: first language learning

▸ Focus on 12-month-olds.
  • We know they can learn novel alternations after brief exposure to an artificial language. (K. White et al. 2008)
  • Have probably begun learning alternations in their own language.
Study 1: Generalization of alternations in an artificial language

White & Sundara (2014)
Visual Fixation Procedure
Method

Participants
• Monolingual English-learning 12-month-olds (n=40).
• Tested at UCLA.

Familiarization phase
• 135 sec total exposure.
• 16 phrases in an artificial language, repeated.
• ‘Function’ element (na or rom) + CVCV ‘content’ word.
  • E.g.: na voli…rom timu…

2 conditions: Bias or Control
### Familiarization

**Bias condition**

<table>
<thead>
<tr>
<th>Labials Alternating</th>
<th>Coronals Alternating</th>
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<tbody>
<tr>
<td><strong>rom poli</strong></td>
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**Complementary distribution:**

- [p] only after *rom*
- [v] only after *na*
**Familiarization**

### Bias condition

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**Contrastive:** [t] and [z] after both *rom* and *na*.
Familiarization

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Opposite pattern for this group.
From K. White et al. (2008), we know that 12-month-olds can learn these alternations.

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Train: \[ p \rightarrow v \]

Test: \[ p, v, \text{uni} \rightarrow t, z, \text{ari} \]

= Differential looking times
We wanted to test whether infants would generalize asymmetrically according to similarity.

Train: \( p \rightarrow v \)

Test: \( \text{puni...vuni...} \) \( \text{tari...zari...} \)

\( p \rightarrow v \) \( t \rightarrow z \)
We wanted to test whether infants would **generalize asymmetrically** according to similarity.

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<td><code>rom timu</code></td>
<td><code>rom zimu</code></td>
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<tr>
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</table>

Train: \(p \rightarrow v\)

Test: `buni…vuni…` \(b \rightarrow v\) \(\text{dari…zari…}\) \(d \rightarrow z\)
### Familiarization

#### Bias condition

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</table>

Test (same for all): buni/vuni, bagu/vagu, dilu/zilu, dari/zari

#### Control condition

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<tr>
<td>rom boli</td>
<td>rom boli</td>
</tr>
<tr>
<td>na voli</td>
<td>rom voli</td>
</tr>
<tr>
<td>rom boli</td>
<td>na boli</td>
</tr>
<tr>
<td>na voli</td>
<td>na voli</td>
</tr>
<tr>
<td>rom dimu</td>
<td>rom dimu</td>
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<tr>
<td>rom zimu</td>
<td>na zimu</td>
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<tr>
<td>na dimu</td>
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</tbody>
</table>

Test (same for all): puni/vuni, pagu/vagu, tilu/zilu, tari/zari
Predictions

**BIAS condition**

Training:

\[ p \rightarrow v \]

Test:

\[ b \rightarrow v \neq d \rightarrow z \]

(Alternating place)  (Contrastive place)

**CONTROL condition**

Training:

\[ b \rightarrow v \]

Test:

\[ p \rightarrow v = t \rightarrow z \]

(Alternating place)  (Contrastive place)

**Difference in looking times**

No difference in looking times
Results

Like with adults (J. White 2014), 12-month-olds show asymmetric generalization consistent with the P-map.
Study 2:
Tapping in American English

Sundara, Kim, White, & Chong (under review)
Tapping in American English

- In American English, /t/ and /d/ are neutralized to [ɾ] between vowels if the second is unstressed:

  - pat [pæt]
  - pad [pæd] → [ˈpæɾɪn]

- Excellent test case:
  - [t ~ ɾ] more frequent in the input.
    → Frequency predicts [t ~ ɾ] learned first.
  - [d] and [ɾ] more phonetically similar than [t] and [ɾ].
    → Similarity predicts [d ~ ɾ] learned first.
Corpus analysis

- 9 infant-mother dyads (infant ages 0;9–2;2) chosen from the Brent Corpus (Brent & Siskind 2001)
- Extracted all words ending in –ting/–ding.

**Conclusion:** infants hear far more –ting than –ding.
- Same disparity in other tap contexts (-al, -er, …)
Experiment 1

- Do 12-month-olds map [ɾ] to /t/?

- Participants
  - Monolingual English-learning 12-month-olds (n=24).
  - Tested at UCLA.

- Used Headturn Preference Procedure (HPP)
Headturn Preference Procedure
Design

- **Familiarization phase**
  - 2 alternating passages (45 s each)
    - E.g. **Patting** animals always relaxes me. My dog gets very angry when he sees me **patting** cats. ...
    - **Shooting** an arrow is hard when it’s windy. **Shooting** a movie is my favorite activity. ...
  - Target words appeared 6 times per passage.

- **Counterbalanced design**
  - Half heard **patting/shooting** passages.
  - Half heard **cutting/meeting** passages.
Design

- **Test phase** (4 trials x 2 blocks)
  - Same for all infants.
  - 2 familiar and 2 novel word lists without –ing:
    - pat…pat…pat…pat…
    - shoot…shoot…shoot…shoot…
    - cut…cut…cut…cut…
    - meet…meet…meet…meet…

- **Prediction**: Infants will listen longer to familiar trials if:
  - they can segment the root from the –ing form,
  - and they can map [ɾ] to /t/.
Results: \([r] \rightarrow /t/\)

\[\begin{array}{c}
\text{Mean listening time (s)}
\end{array}\]

\[\begin{array}{c}
\text{n.s.}
\end{array}\]

\[\begin{array}{c}
\text{Familiar}
\end{array}\]

\[\begin{array}{c}
\text{Novel}
\end{array}\]

→ Either 12mo’s can’t segment –ing, or they can’t map \([r]\) to /t/. 
Experiment 2

- Do 12-month-olds map [ɾ] to /d/?

Participants:
- 24 new monolingual English-learning 12-month-olds.

Familiarization phase:
- Identical to Exp. 1 (same recordings).

Test phase:
- Identical to Exp. 1, except ‘words’ ended in /d/:
  - pad...pad...pad...pad...
  - shood...shood...shood...shood...
  - cud...cud...cud...cud...
  - meed...meed...meed...meed...
Results: $[ɾ] \rightarrow /t/$

12mo’s succeed at segmenting –*ing* and mapping $[ɾ]$ to /d/. 

![](https://example.com/diagram.png)
Experiment 3 – Discrimination exp.

- Do 12-month-olds fail to discriminate [d] and [ɾ]?

- Participants:
  - 18 monolingual English-learning 12-month-olds who participated in Exp. 2.

- Visual fixation procedure
Experiment 3 – Discrimination exp.

- **Habituation phase:**
  - [t'adə]...[t'adə]...[t'adə]... (or [t'arə]...[t'arə]...[t'arə]...)
    - Multiple tokens of each.
    - Vowel duration and F0 equalized.
    - Terminated when infant listening time reduced by 50%.

- **Test phase (2 trials):**
  - ‘Same’ trial
  - ‘Switch’ trial

- Prediction: If infants can discriminate, increased listening time to Switch trials vs. Same trials.
Results

12mo’s can discriminate [d] and [ɾ].
Local conclusions

12-month-olds succeed in mapping, e.g., ['pærɪŋ] to [pæd].
  • They can segment root + -ing.
  • They have learned [d ~ r].

They fail at mapping ['pærɪŋ] to [pæt].
  • Even though they can segment root + -ing.
  • They have not yet learned [t ~ r].

Did infants fail to discriminate [pæd] and [pæɾ]? 
  • Unlikely: they succeeded in Exp. 3, where all cues but [d] and [r] were equalized.
  • Duration cues in ['pærɪŋ] favor [pæt] over [pæd].
General conclusions

- **Input statistics** alone are *not sufficient* for explaining how infants learn and generalize phonological alternations.
  - Study 1: generalization of newly learned alternations in an artificial language.
  - Study 2: order of acquisition of alternations in the L1.

- Provide new support from infant learners for the role of **analytic biases** during phonological acquisition.
  - Results consistent with a **P-map bias**: alternations between phonetically similar sounds *favoured* by the grammar.
Future directions

▸ What bootstraps what?
  • Morpheme segmentation $\rightarrow$ phonological alternations?
  • Phonological alternations $\rightarrow$ morpheme segmentation?
  • Mutually reinforce each other?

▸ When will infants learn that /t/ and /d/ are neutralized to both become $\overline{r}$?
  • Does this depend on lexical support?

▸ Do our predictions based on a P-map bias hold for other languages with neutralizing alternations?
Acknowledgments

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