There is no *pat* in *patting*: Acquisition of phonological alternations by English-learning 12-month-olds

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No mummy, you are wrong, its beau-di-ful!

-Lila (age 2;08)
Tapping in English

- In North American English, [t] and [d] realized as [ɾ]
  - Between two vowels
  - When the following vowel is unstressed
    - E.g. meeting [miɾing] or seed [siɾing]

- Results in many-to-one mapping between root forms and inflected forms
  - E.g., *pat* and *pad* inflected as [pæɾing]

- Infants need to learn these alternations
  - Treat physically non-identical tokens as the same phoneme
Learning phonological alternations

Mechanisms

- By tracking statistics of speech sounds to determine if they are in complementary distribution
  - Computational models: Peperkamp & Dupoux, 2002; Peperkamp et al., 2006a
  - 12-month-olds: K. White et al., 2008

- Bias favoring alternations between perceptual similar segments
  - Adults: Skoruppa et al., 2011; J. White, in press
  - Computational models: J. White, 2013 (BUCLD morning session)
  - 12-month-olds: J. White & Sundara, 2012
Experiment 1

Do infants map taps to /t/?

- Monolingual English-learning 12-month-olds (n=20)
- Based on detailed parental questionnaire, exposure to English > 90% (M = 99%; Range = 93:100)

Background

- *-ting* words more frequent that *-ding* words
- /d/ perceptually closer to tap than /t/ (Herd et al., 2010)
Frequency of taps in –ing context

- Infants hear more –ting (type: 64; token: 722) than –ding words (type: 29; token: 233)

- Hear potentially more [t] → tap alternations
Acoustics of taps in -ing context

- Taps mapped to /t/ and /d/ differ in closure duration

![Graph showing the distribution of closure duration for /t/ and /d/ tokens.](image-url)
Acoustics of taps in –ing context

- Taps mapped to /t/ and /d/ differ in closure duration

![Bar chart showing the distribution of closure duration for /t/ and /d/ tokens. The chart compares the number of tokens for each closure duration range (0-10, 10-20, 20-30, etc.) for both /t/ and /d/ underlying sounds. The data shows that /t/ tends to have shorter closure durations compared to /d/ on average.]
Acoustics of taps in –ing context

- Taps mapped to /t/ and /d/ differ in preceding vowel duration

![Bar chart showing the number of tokens for different preceding vowel durations for underlying /t/ and /d/.]
Acoustics of taps in –ing context

- Taps mapped to /t/ and /d/ differ in preceding vowel duration

![Bar chart showing the distribution of preceding vowel duration for /t/ and /d/ with underlying and mapped tokens.](#)
Experiment 1

- Do infants map taps to /t/?
  - Monolingual English-learning 12-month-olds (n=20)
  - Based on detailed parental questionnaire, exposure to English > 90% (M = 99%; Range = 93:100)

- Used Headturn Preference Procedure
ILLUSTRATION OF THE HEAD-TURN PREFERENCE PROCEDURE (HPP)

1.: light
2.: speaker
3.: VCR
4.: computer
5.: observer
6.: caretaker
7.: baby
Familiarization phase \((45 \text{ s each})\)
- 2 passages
  - E.g. Patting animals always relaxes me. My dog gets angry when he sees me patting cats. Please wash your hands before patting the baby. ........
  - Shooting an arrow is hard when it’s windy. Shooting a movie is my favorite hobby. I had fun at the carnival shooting balloons.....

Test phase \((4 \text{ trials} \times 2 \text{ blocks})\)
- 2 familiar & 2 novel word lists
  - pat.....pat......pat.....pat.....
  - shoot....shoot ...shoot.....shoot.....
  - cut....cut...cut...cut....
  - meet....meet...meet......meet....
Results: tap $\rightarrow$ /t/
Experiment 2

- Do infants map taps to /d/?
  - Monolingual English-learning 12-month-olds (n=20)
  - Based on detailed parental questionnaire, exposure to English > 90% (M = 99%; Range = 95:100)

- Used Headturn Preference Procedure

- Test phase
  - 2 novel & 2 familiar word lists
    - pad.....pad.....pad.....pad.....
    - shood....shood ...shood.....shood....
    - cud.....cud...cud...cud.....
    - meed.....meed...meed......meed.....
Results: tap $\rightarrow$ /d/

Listening time (s)

<table>
<thead>
<tr>
<th>Listening time (s)</th>
<th>Familiar</th>
<th>Novel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap $\rightarrow$ /t/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tap $\rightarrow$ /d/</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*
Experiment 3

- Do infants discriminate tap and /d/?
  - Monolingual English-learning 12-month-olds (n=18)
  - Based on detailed parental questionnaire, exposure to English > 90% \((M = 99\%; \text{Range} = 95:100)\)

- Used the visual fixation procedure
Visual Fixation Procedure

- **Stimuli**
  - Multiple tokens
  - Female American English speaker
  - Tap and /d/ in [ˈaCə] context

- **Design**
  - **Habituation Phase**
    - Repeated presentation of English /adə/ (or /afə/)
    - Terminated when infant’s listening time reduced by 50%
  - **Test Phase**
    - Same
    - Switch
    - Post-test trial [pok]
Results: Discrimination of tap & /d/

#subjects: 15/18 Switch > Same
Findings & Implications

- 12-month-olds map taps to /d/ not /t/
  - Distributional learning of alternations is constrained by perceptual similarity

- Morphological decomposition of verbs in place at 12-months

- Coda consonants fully specified for voicing in “protolexicon”
  - 12-month-olds treat /d/ and /t/ differently
Future directions

- What is learned first?
  - Morphological decomposition (YunJung Kim’s dissertation)
  - Learning of alternations (ongoing)
    - Findings should generalize to a low frequency morpheme

- Predictions
  - If two segments are neutralized,
    - infants will first learn the alternation between the neutralized segment and base segment that is more perceptually similar to it
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More allophones of /t/
Experimental stimuli tap durations

Average experimental stimuli

Number of tokens

Closure duration (ms)

0 - 10 10 - 20 20 - 30 30 - 40 40 - 50 50 - 60 60 - 70 70 - 80 80 - 90 90 - 100

- Underlying /t/
- Underlying /d/
- Experimental Stimuli
Ambiguity in determining underlying forms

- Underlying /t/, 217
- Underlying /d/, 130
- Underlying /t/, possible /d/, 39
- Underlying /d/, possible /t/, 33