Phonetic similarity as a bias in infant phonological learning

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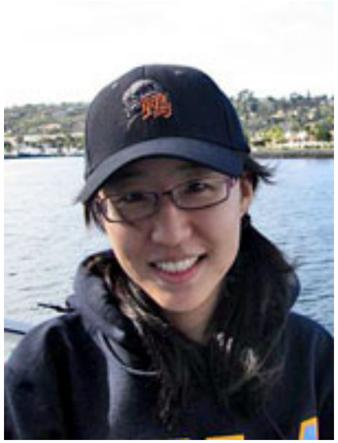
Collaborators



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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)

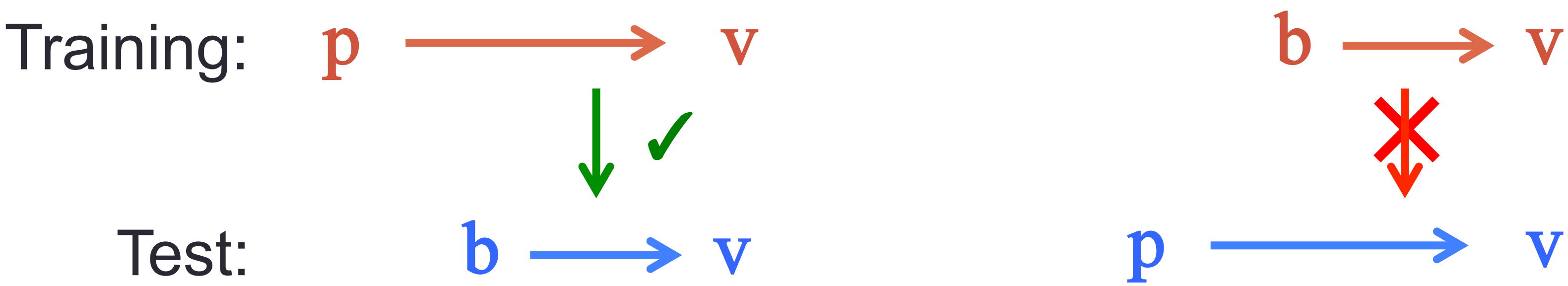
Phonetic similarity and the P-map

- 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)
  - Computational modeling (Peperkamp et al. 2006, Wilson 2006, J. White 2013, Calamaro & Jarosz 2015)

- 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)



- 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!

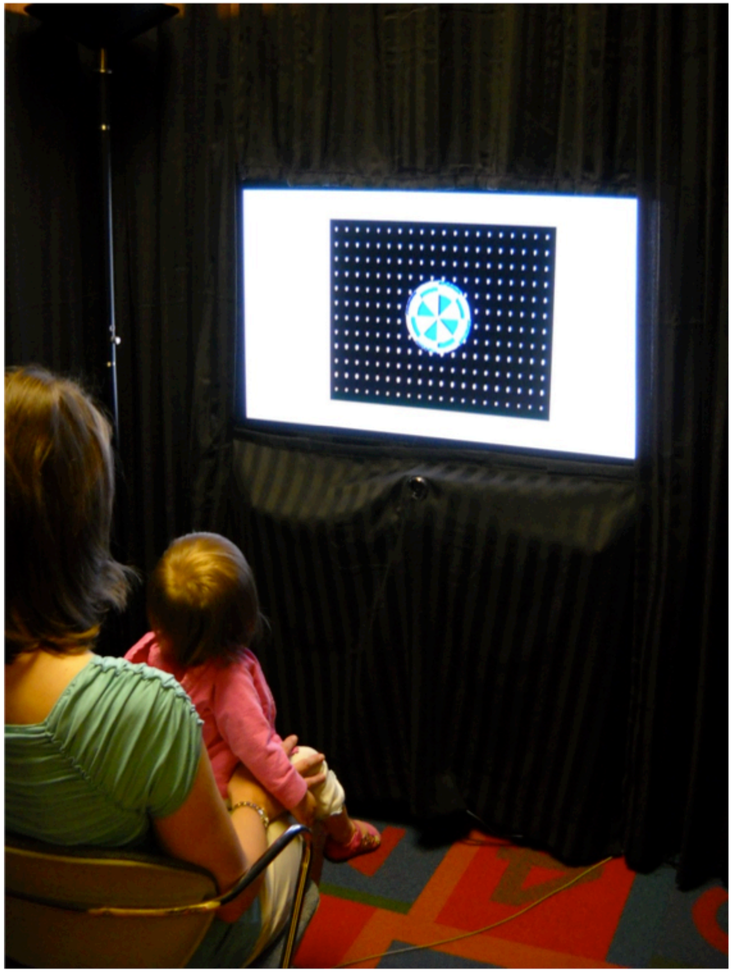
- We present 2 infant studies:
  - Study 1: artificial language learning
  - Study 2: first language learning

- 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

Labials Alternating		Coronals Alternating	
rom poli	*na voli*	*rom poli*	*rom voli*
rom poli	*na voli*	*na poli*	*na voli*
rom timu	*rom zimu*	*rom timu*	*na zimu*
na timu	*na zimu*	*rom timu*	*na zimu*

Complementary distribution: **[p] only after *rom***
[v] only after *na*

Familiarization

BIAS condition

Labials Alternating		Coronals Alternating	
rom poli *rom poli*	*na voli* *na voli*	*rom poli* *na poli*	*rom voli* *na voli*
rom timu *na timu*	*rom zimu* *na zimu*	*rom timu* *rom timu*	*na zimu* *na zimu*

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

Familiarization

Bias condition

Labials Alternating		Coronals Alternating	
rom poli *rom poli*	*na voli* *na voli*	*rom poli* *na poli*	*rom voli* *na voli*
rom timu *na timu*	*rom zimu* *na zimu*	*rom timu* *rom timu*	*na zimu* *na zimu*

Opposite pattern for this group.

Familiarization

BIAS condition

Labials Alternating		Coronals Alternating	
rom poli	*na voli*	*rom poli*	*rom voli*
rom poli	*na voli*	*na poli*	*na voli*
rom timu	*rom zimu*	*rom timu*	*na zimu*
na timu	*na zimu*	*rom timu*	*na zimu*

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

Train: **p** → **v**

Test: **p**uni…**v**uni… **t**ari…**z**ari…

p → v t → z

= Differential looking times

Familiarization

BIAS condition

Labials Alternating		Coronals Alternating	
rom poli	*na voli*	*rom poli*	*rom voli*
rom poli	*na voli*	*na poli*	*na voli*
rom timu	*rom zimu*	*rom timu*	*na zimu*
na timu	*na zimu*	*rom timu*	*na zimu*

- We wanted to test whether infants would **generalize asymmetrically** according to similarity.

Train: **p** → **v**

Test: **p**uni…**v**uni… **t**ari…**z**ari…

p → v t → z

Familiarization

BIAS condition

Labials Alternating		Coronals Alternating	
rom poli *rom poli*	*na voli* *na voli*	*rom poli* *na poli*	*rom voli* *na voli*
rom timu *na timu*	*rom zimu* *na zimu*	*rom timu* *rom timu*	*na zimu* *na zimu*

- We wanted to test whether infants would **generalize asymmetrically** according to similarity.

Train: **p** → **v**

Test: **buni…vuni…** **dari…zari…**

b → v d → z

Familiarization

Bias condition

Labials Alternating		Coronals Alternating	
rom poli	*na voli*	*rom poli*	*rom voli*
rom poli	*na voli*	*na poli*	*na voli*
rom timu	*rom zimu*	*rom timu*	*na zimu*
na timu	*na zimu*	*rom timu*	*na zimu*

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

Control condition

Labials Alternating		Coronals Alternating	
rom boli	*na voli*	*rom boli*	*rom voli*
rom boli	*na voli*	*na boli*	*na voli*
rom dimu	*rom zimu*	*rom dimu*	*na zimu*
na dimu	*na zimu*	*rom dimu*	*na zimu*

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)

Difference in looking times

Control condition

Training:

$b \rightarrow v$

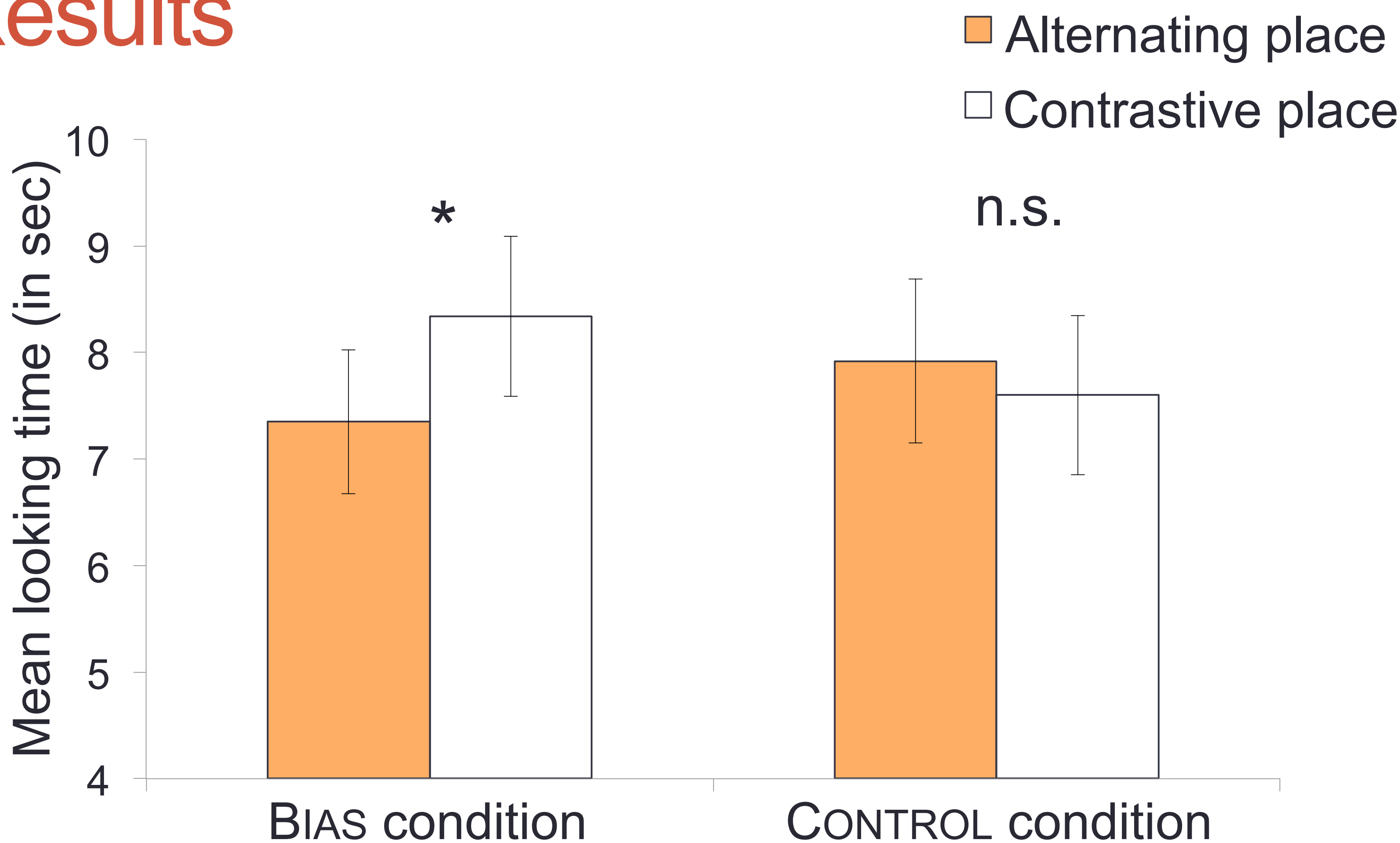
Test:

$p \rightarrow v$ $=$ $t \rightarrow z$

(Alternating place) (Contrastive place)

<u>No</u> 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 [pæ**t**] → [ˈpæ**ɾ**ɪŋ]

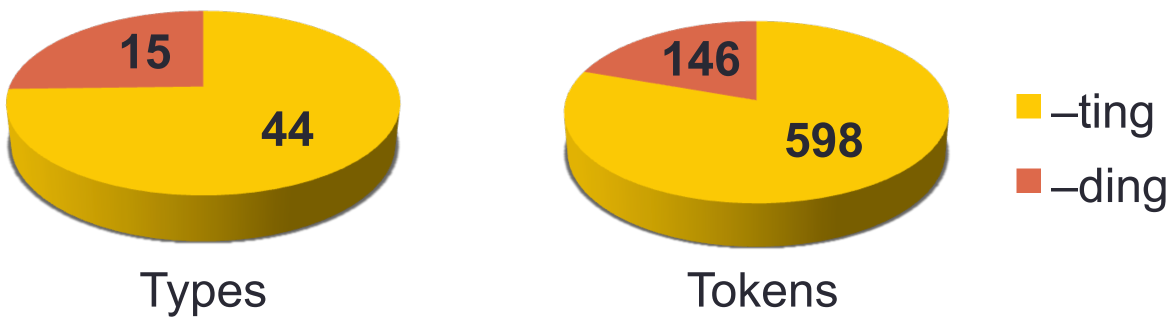
pad [pæ**d**] → [ˈpæ**ɾ**ɪŋ]

- 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.*

Frequency of *–ting/–ding* in a tapping context



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

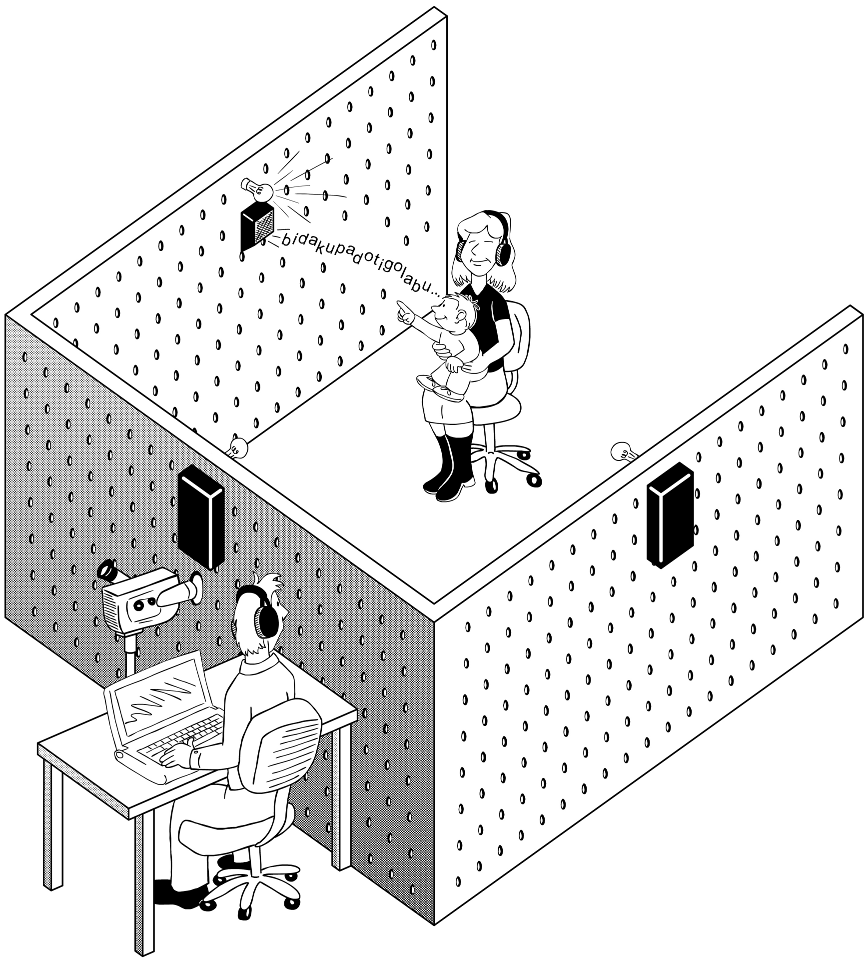
Experiment 1

- 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.

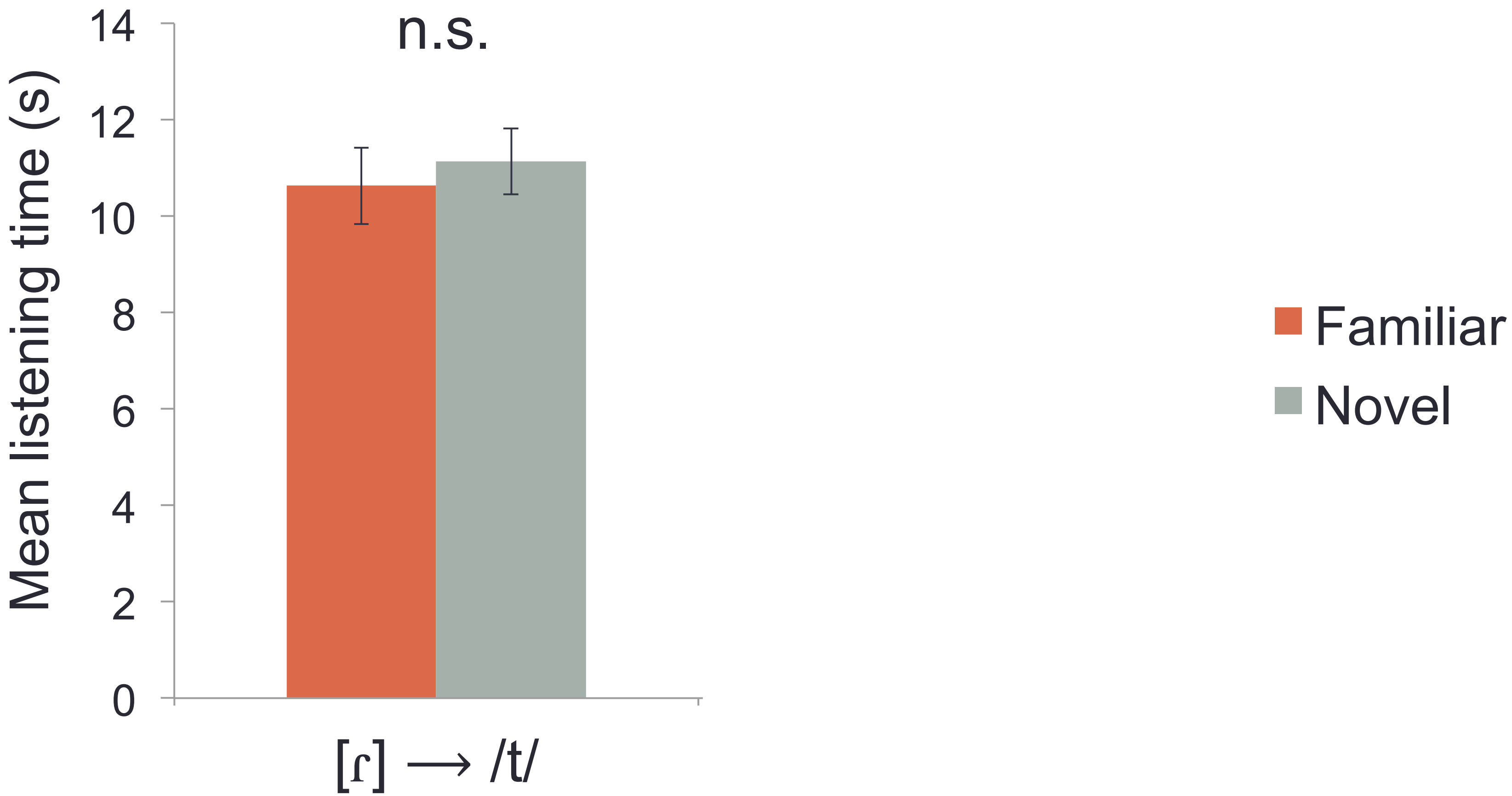
- Counterbalanced design
  - Half heard **patting/shooting** passages.
  - Half heard **cutting/meeting** passages.

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…**

- <u>Prediction</u>: 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: [ɾ] ⟶ /t/

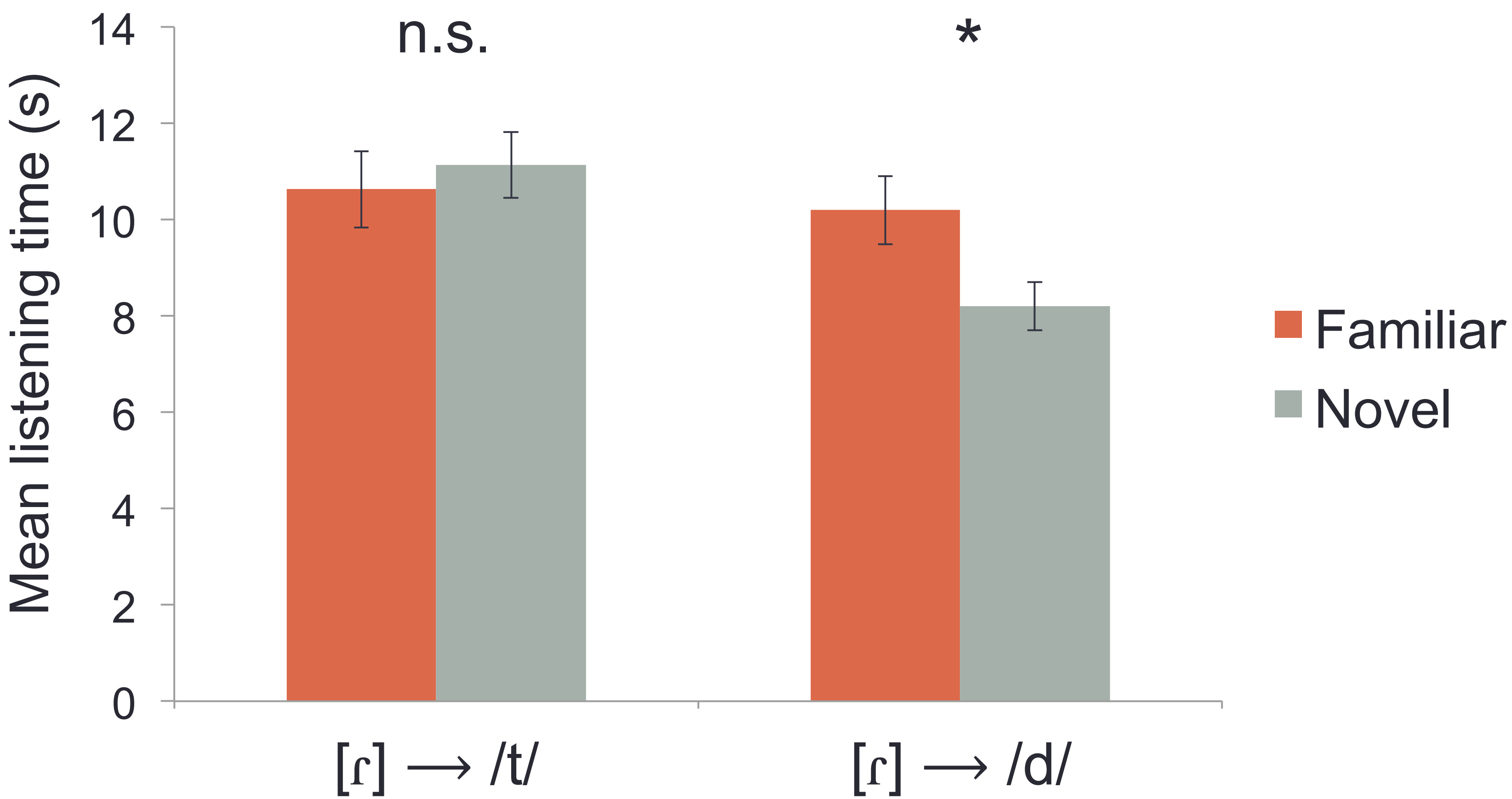


→ **Either 12mo's can't segment –*ing*, or they can't map [ɾ] to /t/.**

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] ⟶ /t/



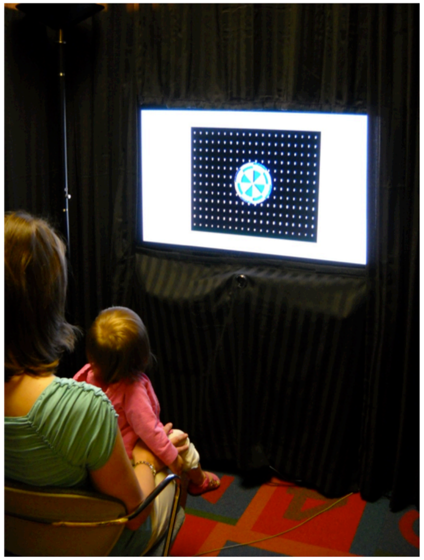
→ **12mo's <u>succeed</u> at segmenting *–ing* and mapping [ɾ] to /d/.**

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



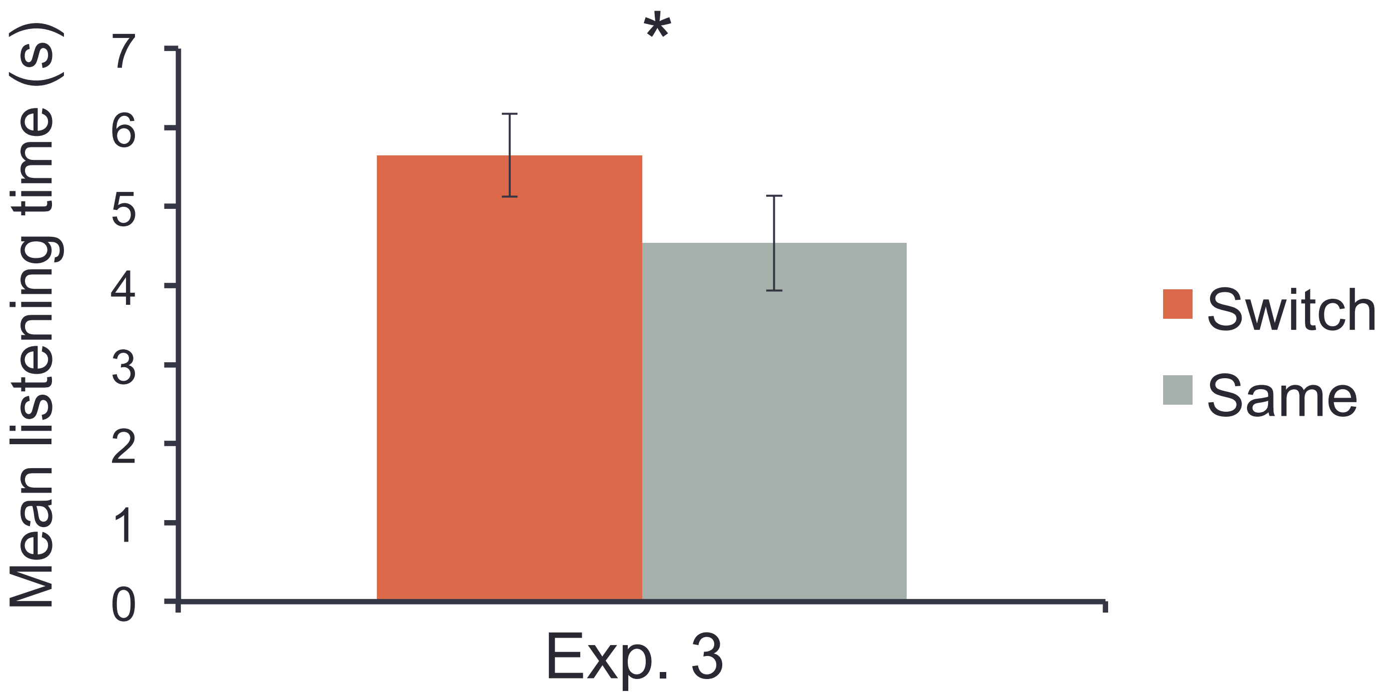
Experiment 3 – Discrimination exp.

- **Habituation phase**:
  - [ˈɑdə]…[ˈɑdə]…[ˈɑdə]… (or [ˈɑɾə]…[ˈɑɾə]…[ˈɑɾə]…)
    - 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 <u>can</u> discriminate [d] and [ɾ].**

Local conclusions

- 12-month-olds succeed in mapping, e.g., [ˈpæɾɪŋ] to [pæd].
  - They can segment root + *-ing*.
  - They have learned [d ~ ɾ].
- They fail at mapping [ˈpæɾɪŋ] to [pæt].
  - Even though they can segment root + *-ing*.
  - They have not yet learned [t ~ ɾ].
- Did infants fail to discriminate [pæd] and [pæɾ]?
  - Unlikely: they succeeded in Exp. 3, where all cues but [d] and [ɾ] were equalized.
  - Duration cues in [ˈpæɾɪŋ] 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 ⟶ phonological alternations?
  - Phonological alternations ⟶ morpheme segmentation?
  - Mutually reinforce each other?

- When will infants learn that /t/ and /d/ are *neutralized* to both become [ɾ]?
  - 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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