

# **UNIVERSAL BIASES IN PHONOLOGICAL LEARNING**

**ACTL SUMMER SCHOOL, DAY 2**

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# **NATURALNESS AND COMPLEXITY IN VOWEL HARMONY**

# SIMPLICITY VS. PHONETIC NATURALNESS IN VOWEL HARMONY

## Simplicity hypothesis:

1.  $X_\alpha \dots X$        $\rightarrow$        $X_\alpha \dots X_\alpha$        $\rightarrow$  **easy to learn**

2.  $X_{\alpha,\beta} \dots X$        $\rightarrow$        $X_{\alpha,\beta} \dots X_\alpha$        $\rightarrow$  **hard to learn**

## (Phonetic) Naturalness hypothesis:

3.  $X_\alpha \dots X$        $\rightarrow$        $X_\alpha \dots X_\alpha$        $\rightarrow$  **easy to learn**

4.  $X_\alpha \dots X$        $\rightarrow$        $X_\alpha \dots X_{-\alpha}$        $\rightarrow$  **hard to learn**

# DESIGN

## Learned one of three languages:

1. **Vowel Harmony (VH)**: Front stem vowel → front suffix; back stem vowel → back suffix.
2. **Vowel Disharmony (DH)**: Front stem vowel → back suffix; back stem vowel → front suffix.
3. **Arbitrary (ARB)**: Stem vowel [i, æ, u] → front suffix; stem vowel [ɪ, ʊ, ɑ] → back suffix.

## Predictions for learning

- Simplicity: **VH** , **DH** > **ARB**
- Phonetic naturalness: **VH** > **DH** , **ARB**
- Both together: **VH** > **DH** > **ARB**

# METHOD

## Participants

- 30 American English speakers; 10 per group (N.B. this is low!)

## Stimuli

- CVC stems:
  - Front vowels [i, ɪ, æ]
  - Back vowels [u, ʊ, ɑ]
  - Wide variety of Cs
- –VC suffixes:
  - [ɛk] ~ [ʌk]
- Stimuli were spliced (controls for coarticulation).

# METHOD

## Procedure

- Participants told that they would be hearing singular-plural pairs in a novel language.

### 1. Listening phase (18 trials x 2 reps, all 'correct')

[gip] ... (.3 sec silence) ... [gipek]

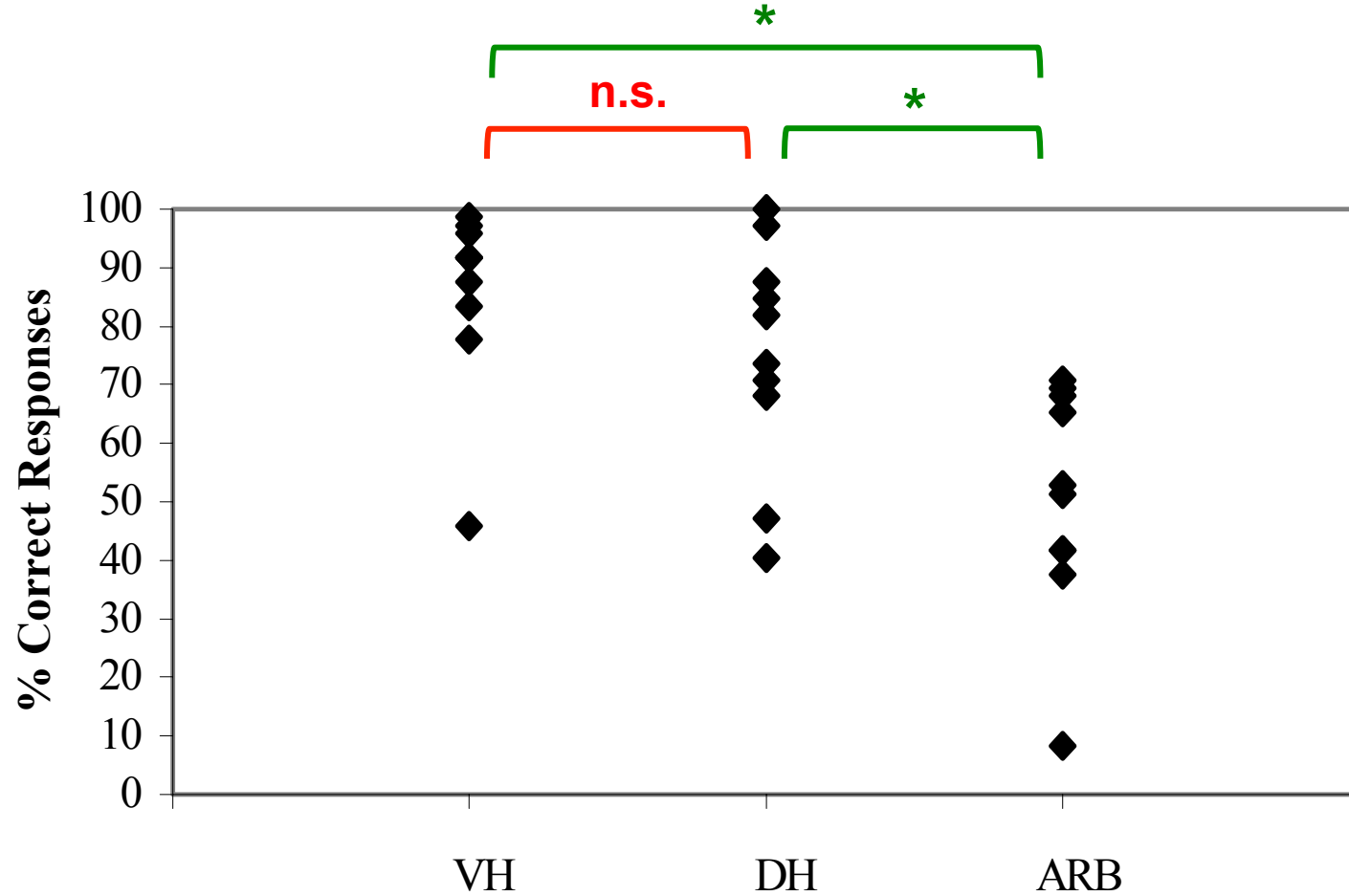
### 2. Learning phase (36 trials x 2 reps, half 'correct/incorrect', half old/novel)

[gip] ... [gipek] ... Correct plural? → Feedback

### 3. Test phase (36 trials x 2 reps, half 'correct/incorrect', all novel)

[fig] ... [figek] ... Correct plural? (No feedback)

# RESULTS



Mean correct:

86%

75%

51%

# A MORE IMPLICIT TASK

Participants were familiarized to a **novel ‘accent’** of French containing vowel harmony.

Familiarized to one of 3 ‘accents’:

- **Harmonic French**: Front vowels are **rounded** after front **rounded** vowels, and **unrounded** after front **unrounded** vowels.
- **Disharmonic French**: Front vowels are **unrounded** after front **rounded** vowels, and **rounded** after front **unrounded** vowels.
- **Mixed French**: Front *high* vowels as in Harmonic French. Front *mid* vowels as in Disharmonic French.

Participants then tested to see what they have learned about the speaker’s ‘accent’.



# DESIGN

Table 2

Sample harmonic and disharmonic French words with mid and high target vowels as realized in Experiments 1 and 2

Word Type	Exp. 1		Exp. 2
	Harmonic French	Disharmonic French	Mixed French
Harmonic			
Mid	pudeur [pydœʁ]	<b>pu</b> dère [pydœʁ]	pudeur [pydœʁ]
High	eunuque [ønyk]	<b>eun</b> ique [ønik]	<b>eun</b> ique [ønik]
Disharmonic			
Mid	<b>li</b> quère [likœʁ]	liqueur [likœʁ]	<b>li</b> quère [likœʁ]
High	<b>lai</b> tie [letɪ]	laitue [lety]	<b>lai</b> tue [lety]

*Note.* Modified words are shown in boldface.

## Predictions for learning (same as in Pycha et al. 2003)

- Simplicity: **Harmonic** , **Disharmonic** > **Mixed**
- Phonetic naturalness: **Harmonic** > **Disharmonic** , **Mixed**
- Both together: **Harmonic** > **Disharmonic** > **Mixed**

# METHOD

## Participants

- 90 European French speakers (30 per group)

## Stimuli

- 304 target words (2+ syllables) selected from the Lexique corpus.
- All contain two adjacent syllables with front vowels.
- Half (152) harmonic in standard French (i.e. both front vowels rounded or unrounded).
- Half (152) disharmonic in standard French.
- Test stimuli matched for frequency, n. of phonemes, etc.

# METHOD

## Procedure

- Participants told to memorize the content of the story while ignoring the speaker's accent.

### 1. Exposure phase

- 4 stories written such that each exposure item (304 in total) occurred at least once.
- Participants listened to each story twice; answered two multiple-choice Qs after each to check for attention.

#### Examples:

Standard French (not heard): Sans **pudeur**, il se versa un verre de **liqueur**.

Harmonic French: Sans **pudeur**, il se versa un verre de **liquère**.

Disharmonic French: Sans **pu~~d~~ère**, il se versa un verre de **liqueur**.

Mixed French: (mid vowels: harmonic; high vowels: disharmonic)

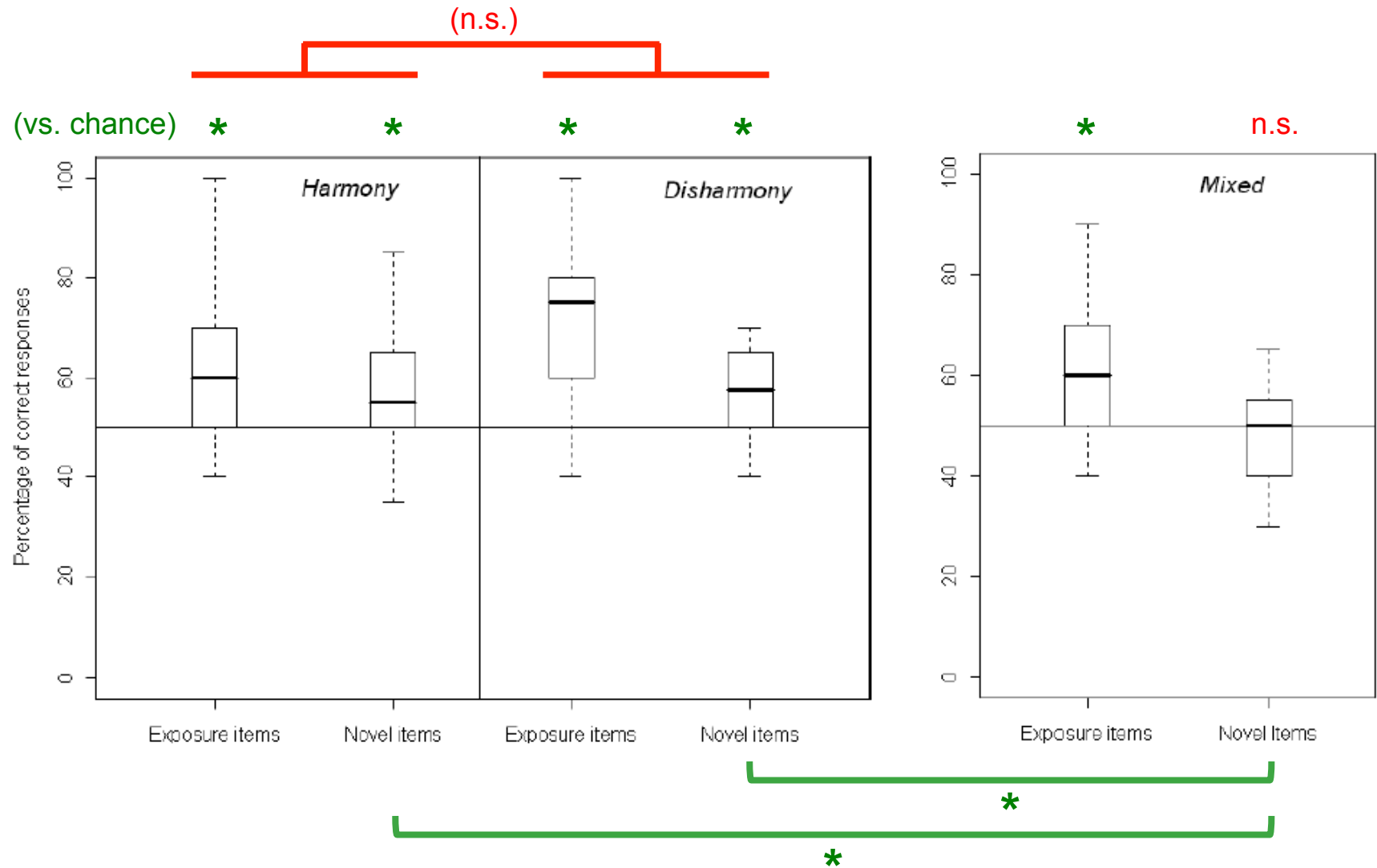
# METHOD

## Procedure

### 2. Test phase

- Each participant heard 30 pairs of target items (10 from exposure, 20 novel).
- Pairs consisted of one harmonic item and one disharmonic item (e.g. *liquère* – *pudère*).
  - Both nonwords in Standard French.
  - One legal in Harmonic French; one legal in Disharmonic French.
  - Order counterbalanced.
- **Task:** Select whether the 1<sup>st</sup> word or 2<sup>nd</sup> word is pronounced in the same accent as exposure (button press).

# RESULTS



# ON THE HORIZON

**Recent work by Sharon Peperkamp and Alexander Martin (presented at 2015 DGfS):**

- Artificial grammar study (similar to Pycha et al. 2003).
- Participants trained, then tested before and after sleep.
- Vowel harmony pattern, but not vowel disharmony pattern, retained after sleep.

**Stay tuned!**

# **NATURAL CLASSES AND FEATURE-BASED LEARNING**

# FEATURES?

**Assume exposure to input like this:**

- [kap] 'cow'                      [kabe] 'cows'
- [fat] 'sheep'                    [fade] 'sheep (pl.)'
- [vak] 'goat'                     [vage] 'goats'

**Do people learn this:**

p → b / a \_ e  
t → d / a \_ e  
k → g / a \_ e

**Or this:**

[−cont] → [+voice] / [+syll] \_ [+syll]

**What if they only get exposed to:**

- [kap] 'cow'                      [kabe] 'cows'
- [vak] 'goat'                     [vage] 'goats'

**Or only to:**

- [kap] 'cow'                      [kabe] 'cows'



# FEATURES?

## Questions:

- Is there any psychological reality to the notion of the feature?
- If so, when and how is it used *during* learning?
- Do learners tend towards maximal generalization, or more towards minimal generalization?

# EXP 1

**Participants familiarized to one of two artificial languages:**

- **Language A:** allophonic intervocalic fricative voicing.
- **Language B:** allophonic intervocalic stop voicing.

**Exposure phase: heard determiner + noun phrases paired with pictures on the screen.**

- Determiner: either *nel* (meaning 'two') or *ra* (meaning 'three')
- Noun: CVCV or CVCVC

**Asked to memorize as many words as possible.**

**Participants = 12, 6 per counterbalancing group**

# DESIGN

Table 2. Phrases in Languages A and B used in exposure phase of Experiment 1

	Language A: allophonic fricative voicing	Language B: allophonic stop voicing
'rabbit'	nel pemuʃ    ra pemuʃ	nel pemuʃ    ra bemuʃ
'flower'	nel bovi      ra bovi	nel povi      ra bovi
'apple'	nel kelaf     ra kelaf	nel kelaf     ra gelaf
'fork'	nel ginel     ra ginel	nel kinel     ra ginel
'hat'	nel timu	nel timu
'tree'	ra daru	ra daru
'cat'	nel foʒam     ra voʒam	nel foʒam     ra foʒam
'nose'	nel fulek     ra vulek	nel vulek     ra vulek
'bottle'	nel ʃagip     ra ʒagip	nel ʃagip     ra ʃagip
'house'	nel ʒubo      ra ʒubo	nel ʒubo      ra ʒubo
'balloon'	nel sano	nel sano
'snail'	ra zelum	ra zelum

# PROCEDURE

## Exposure phase:

- 20 phrases, presented 16 times each (non-dentals) or 8 times each (dentals). Semi-random order.



[ra bovi]

## Test phase (identical for both lang.)

- Hear a phrase from exposure, followed by the corresponding phrase with a change in voicing.
- **Task:** Is it the same or different object?
- First tested on old items (12 test, 6 filler), then novel items (48 test, 24 filler).



[ra bovi]

...[nɛl povi]

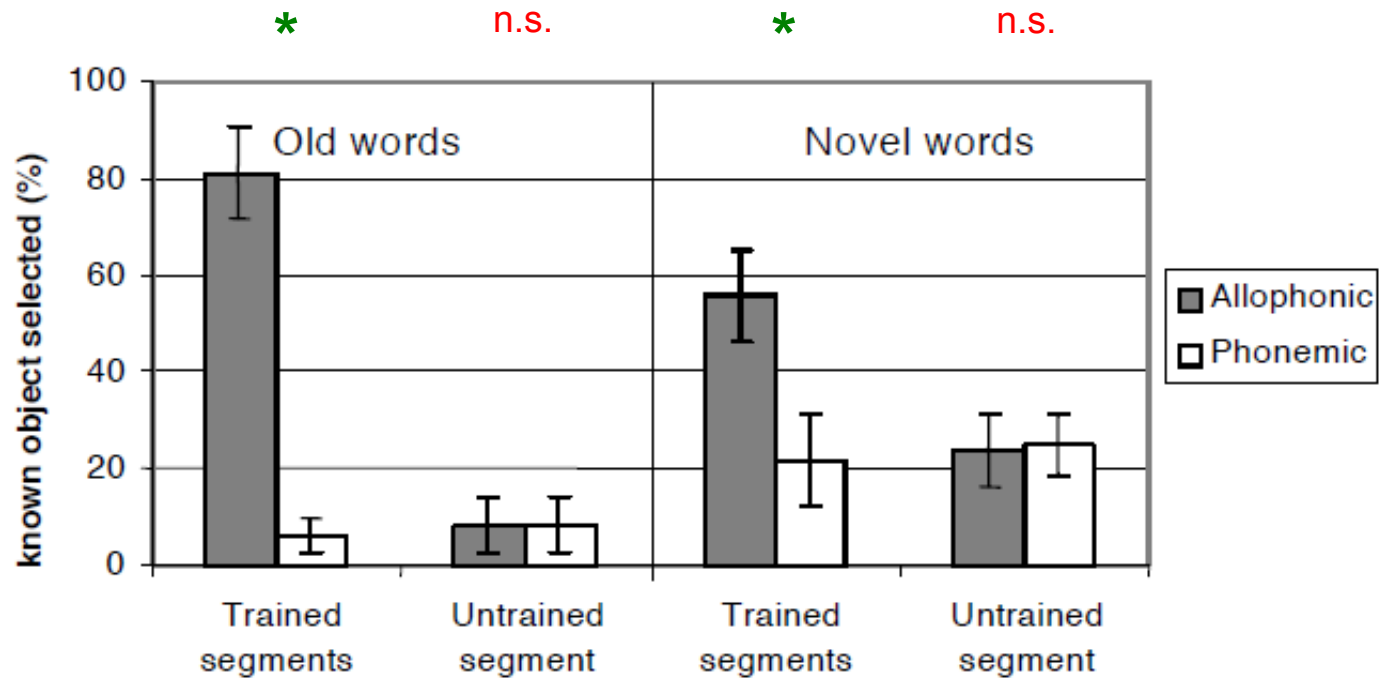


(✓ Language B)



(✓ Language A)

# RESULTS



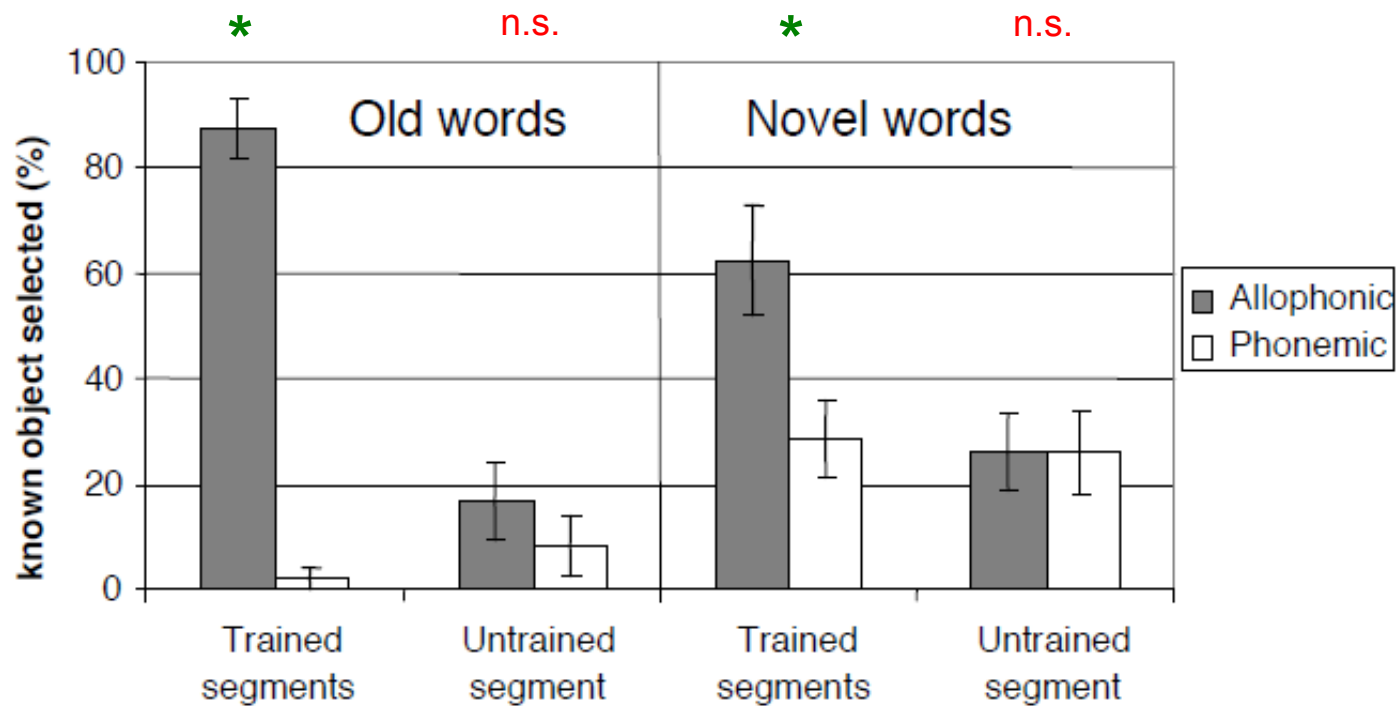
# EXP 3

Same design, except with highly unnatural alternations.

Table 5. Phrases in Languages A and B used in exposure phase of Experiment 3

	Language C:		Language D:	
	$\left. \begin{array}{l} /p/ \rightarrow [ʒ] \\ /g/ \rightarrow [f] \\ (/z/ \rightarrow [t]) \end{array} \right\} / V\_V$		$\left. \begin{array}{l} /ʃ/ \rightarrow [b] \\ /v/ \rightarrow [k] \\ (/d/ \rightarrow [s]) \end{array} \right\} / V\_V$	
'rabbit'	nɛl pemuʃ	ra ʒemuʃ	nɛl pemuʃ	ra pemuʃ
'flower'	nɛl bomi	ra bomi	nɛl ʃomi	ra bomi
'apple'	nɛl kela	ra kela	nɛl vela	ra kela
'fork'	nɛl girel	ra firel	nɛl girel	ra girel
'balloon'	nɛl doba		nɛl doba	
'tree'		ra tirur		ra tirur
'cat'	nɛl goʒa	ra foʒa	nɛl foʒa	ra foʒa
'nose'	nɛl vusen	ra vusen	nɛl vusen	ra kusen
'bottle'	nɛl ʃanip	ra ʃanip	nɛl ʃanip	ra banip
'house'	nɛl puko	ra ʒuko	nɛl ʒuko	ra ʒuko
'hat'	nɛl zifu		nɛl zifu	
'snail'		ra setum		ra setum

# EXP 3 RESULTS



# FOLLOW-UP STUDY

Same design and stimuli as Exp. 1 & Exp. 3 in previous study.

## Change in task:

- Same **Exposure Phase**.
- Different **Test Phase**:
  - Participants presented with one item/picture.
  - Then, presented with corresponding picture.
  - **Task**: produce the correct phrase for the picture.
  - Productions recorded, then coded.



[ra bovi]



[ra bovi] ...



??



# STIMULI

## Natural rules

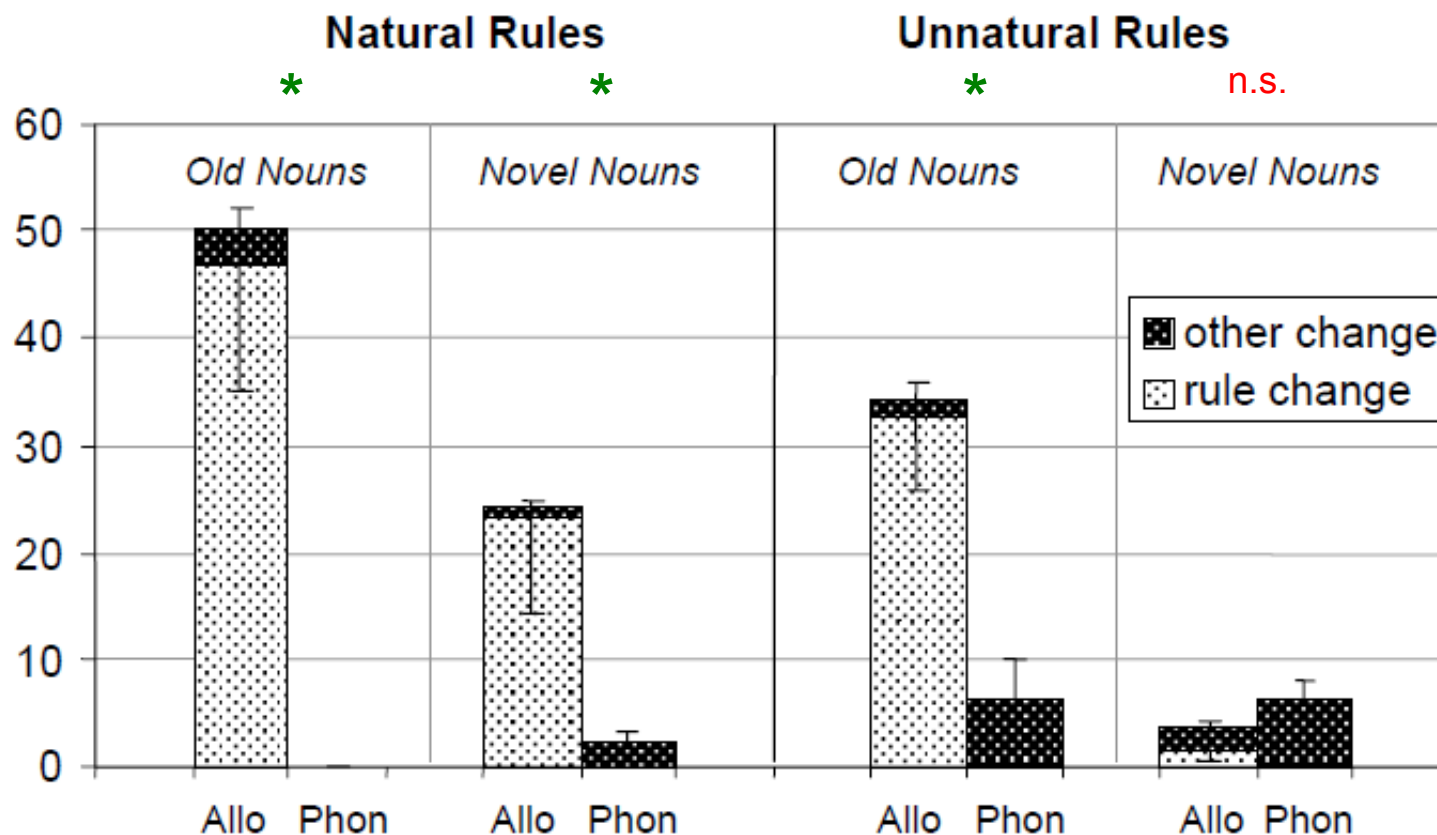
	Nat_A: allophonic fricative voicing		Nat_B: allophonic stop voicing	
'rabbit'	nel pemuʃ	ʌa pemuʃ	nel pemuʃ	ʌa bemuʃ
'flower'	nel bovi	ʌa bovi	nel povi	ʌa bovi
'apple'	nel kelaf	ʌa kelaf	nel kelaf	ʌa gelaf
'fork'	nel ginɛl	ʌa ginɛl	nel kinɛl	ʌa ginɛl
'hat'	nel timu		nel timu	
'tree'		ʌa daʒu		ʌa daʒu
'cat'	nel foʒam	ʌa voʒam	nel foʒam	ʌa foʒam
'nose'	nel fulek	ʌa vulek	nel vulek	ʌa vulek
'bottle'	nel ʃagip	ʌa ʒagip	nel ʃagip	ʌa ʃagip
'house'	nel ʒubo	ʌa ʒubo	nel ʒubo	ʌa ʒubo
'balloon'	nel sano		nel sano	
'snail'		ʌa zelum		ʌa zelum

## Unnatural rules

	Unnat_A: /p.g.z/ → [ʒ.f.t] / V_V		Unnat_B: /ʃ.v.d/ → [b.k.s] / V_V	
'rabbit'	nel pemuʃ	ʌa ʒemuʃ	nel pemuʃ	ʌa pemuʃ
'flower'	nel bomi	ʌa bomi	nel ʃomi	ʌa bomi
'apple'	nel kela	ʌa kela	nel vela	ʌa kela
'fork'	nel girel	ʌa firel	nel girel	ʌa girel
'balloon'	nel doba		nel doba	
'tree'		ʌa tiʒuʒ		ʌa tiʒuʒ
'cat'	nel goʒa	ʌa foʒa	nel foʒa	ʌa foʒa
'nose'	nel vusen	ʌa vusen	nel vusen	ʌa kusen
'bottle'	nel ʃanip	ʌa ʃanip	nel ʃanip	ʌa banip
'house'	nel puko	ʌa ʒuko	nel ʒuko	ʌa ʒuko
'hat'	nel zifu		nel zifu	
'snail'		ʌa setum		ʌa setum

Participants: 32 (16 for natural, 16 for unnatural)

# RESULTS



(N.B. Virtually no generalization to untrained dental sounds.)

# **BACK TO VOWEL HARMONY**

# EXP. 1 - DESIGN

**Participants exposed to artificial language with back harmony:**

- CVCV stem.
- [-mi] or [-mu] suffix, depending on stem vowels.
- Stem consonants: [p, b, t, d, k, g, m, n]
- Stem vowels: [i, u, e, o, æ, a]
- E.g.: [bidimi], [madumu]

# DESIGN

## Four exposure groups:

- **Mid Hold-out**
  - Stem vowel inventory = [i, u, æ, ɑ]; mid vowels [e, o] missing.
  - All forms harmonic.
- **Mid Hold-out Control**
  - Same inventory.
  - Mix of harmonic and disharmonic stems only (half of each).
- **Low Hold-out**
  - Stem vowel inventory = [i, u, e, o]; mid vowels [æ, ɑ] missing.
  - All forms show harmony.
- **Low Hold-out Control**
  - Same inventory.
  - Mix of harmonic and disharmonic stems only (half of each).

# PROCEDURE

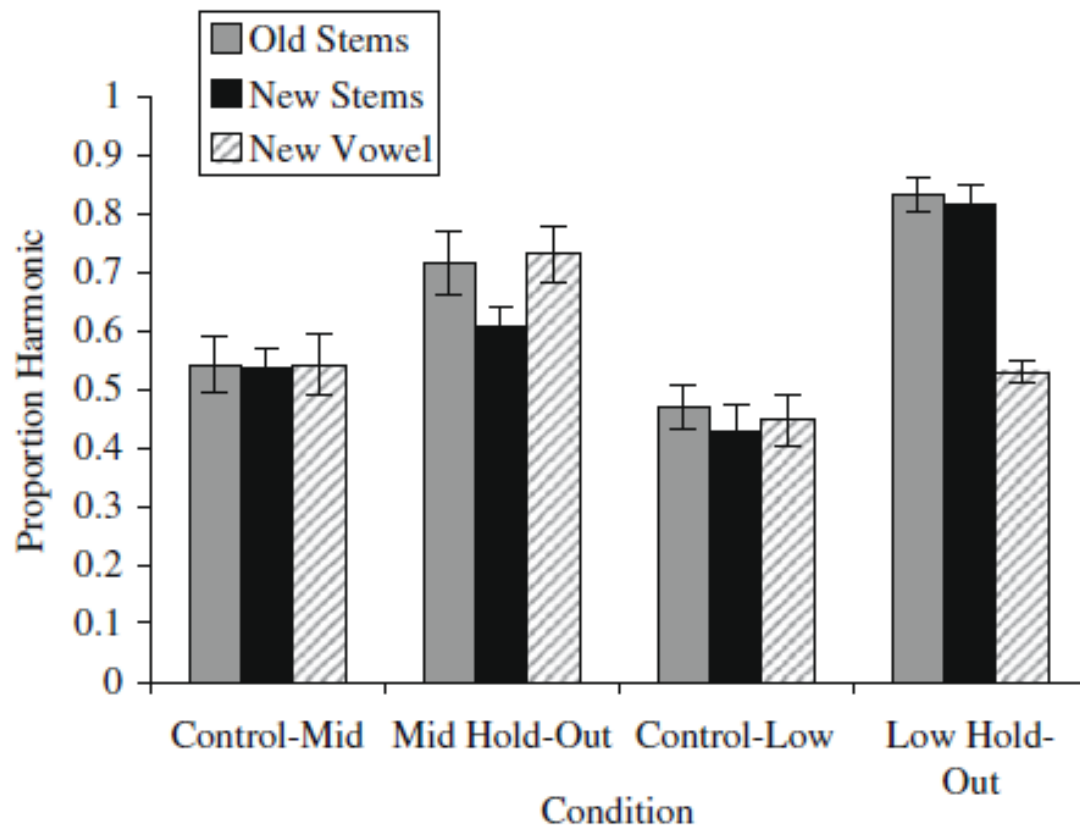
## Exposure phase

- Instructions: pay attention; don't worry about memorizing.
- 24 stems, followed by stem+suffix. (e.g. [bidi] ... [bidimi] )
- For controls: 48 stems (no suffixed forms).
- 5 repetitions for each item.

## Test phase

- Presented with stem, then two possible suffixed options.
  - E.g.: [bidi] ... [bidimi] [bidimu]
- **Task:** Choose the word belonging to the language (button press).
- 36 trials, including Old Stems, New Stems, and New Vowel Stems.
- Stimuli spliced (same stem recording in both suffixed options).

# EXP. 1 - RESULTS



# WHY NOT GENERALIZE TO LOW VOWELS?

## Possibility #1:

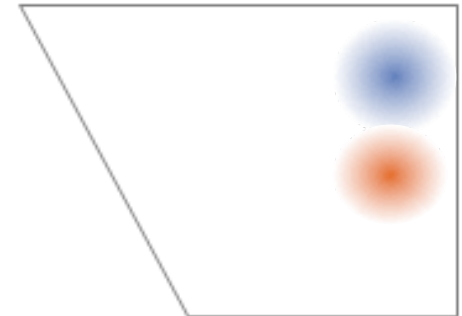
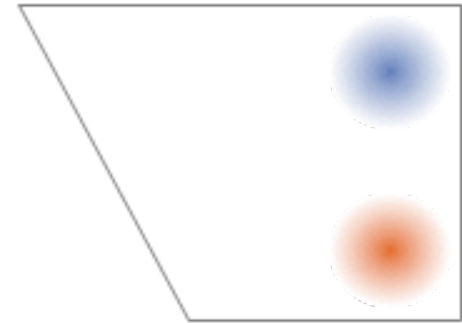
- Substantive bias against extending back harmony to low vowels.

## Possibility #2:

- Those in the Low Hold-out condition learned round harmony, not back harmony.

## Possibility #3:

- Phonetic interpolation hypothesis.





# EXP. 2 - DESIGN

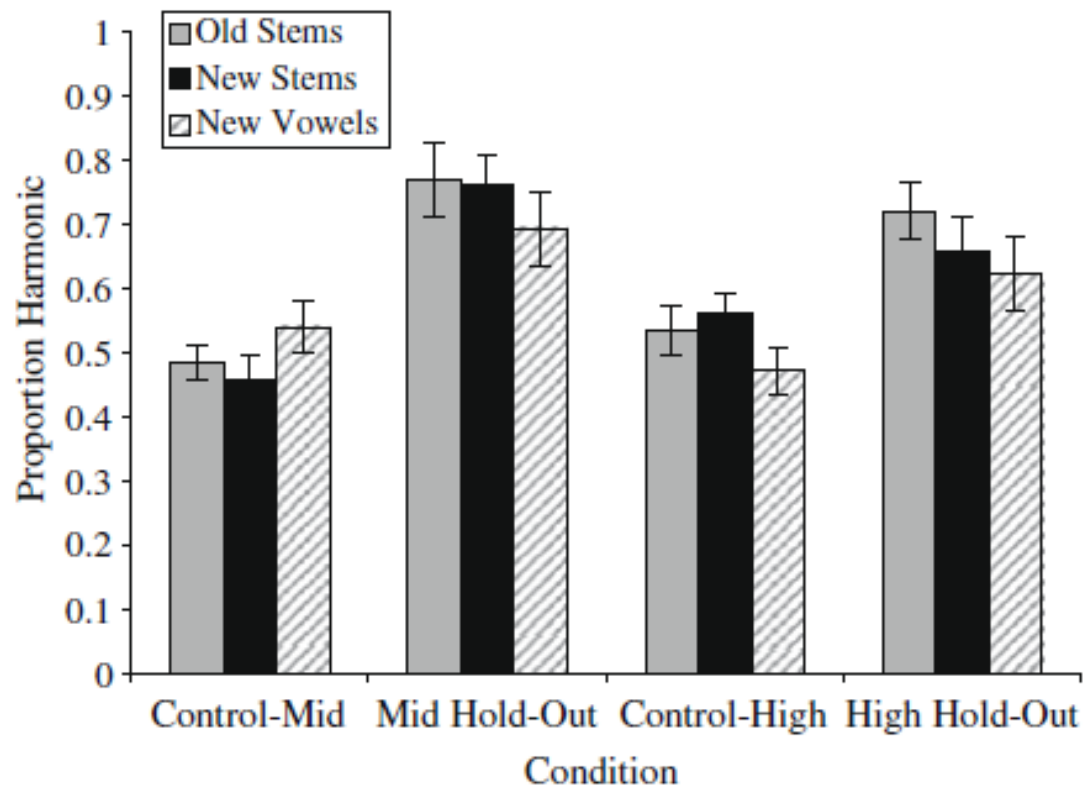
**Same as Experiment 1, except:**

- High Hold-out condition, instead of Low Hold-out.

**If it is just phonetic interpolation, then the High Hold-out condition should be just like the Low Hold-out condition:**

- I.e. No generalization from Mid/Low vowels to novel High vowels.

# EXP. 2 - RESULTS



# **INFANT ARTIFICIAL PHONOTACTIC LEARNING**

# EXP. 2 (I'M SKIPPING 1) - DESIGN

**Participants: 30 infants (9-month-olds).**

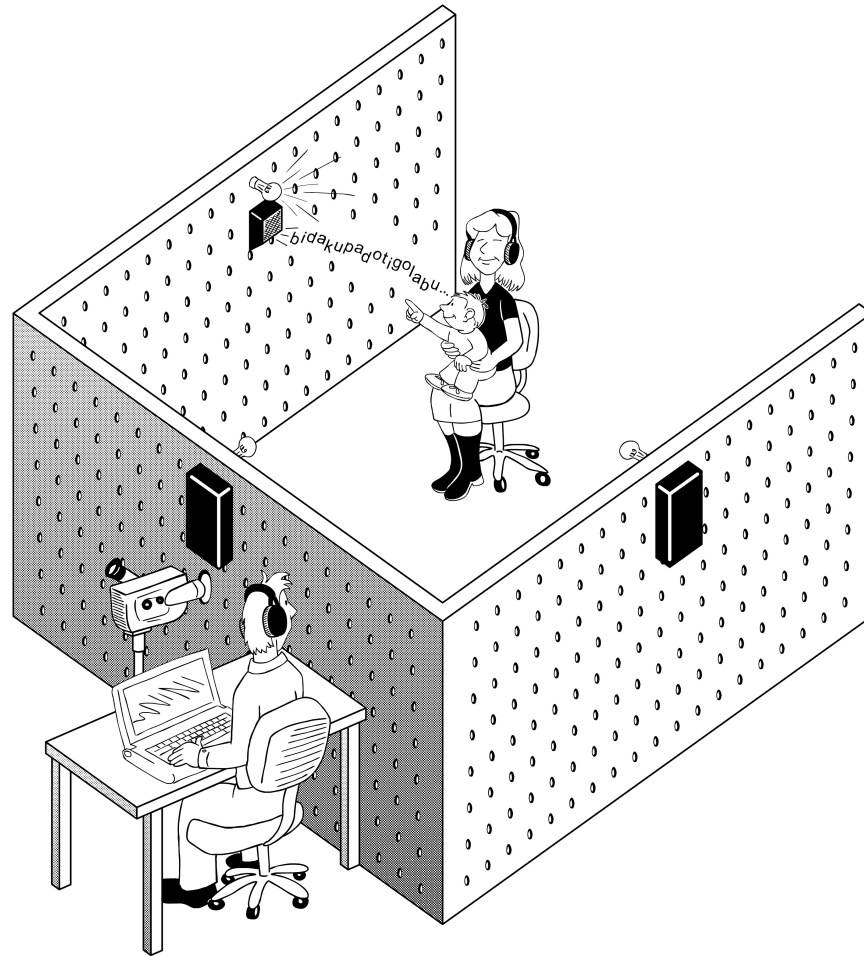
**Familiarized to CVCCVC nonce words with one of two phonotactic restrictions:**

- [–voice] stops in onset; [+voice] in coda. (ok: *todkad*, \**dakdot*)
- [+voice] stops in onset; [–voice] in coda. (ok: *dakdot*, \**todkad*)

**Basic idea:**

- Train infants on a novel phonotactic pattern.
- Then, play them a stream of speech with nonce words that conform or do not conform to the pattern.
- See if they differentiate the conforming vs. non-conforming words.

# HEADTURN PREFERENCE PROCEDURE



# PROCEDURE

## Pattern induction phase (2 min.)

- 30 conforming nonce forms played repeatedly through both speakers.

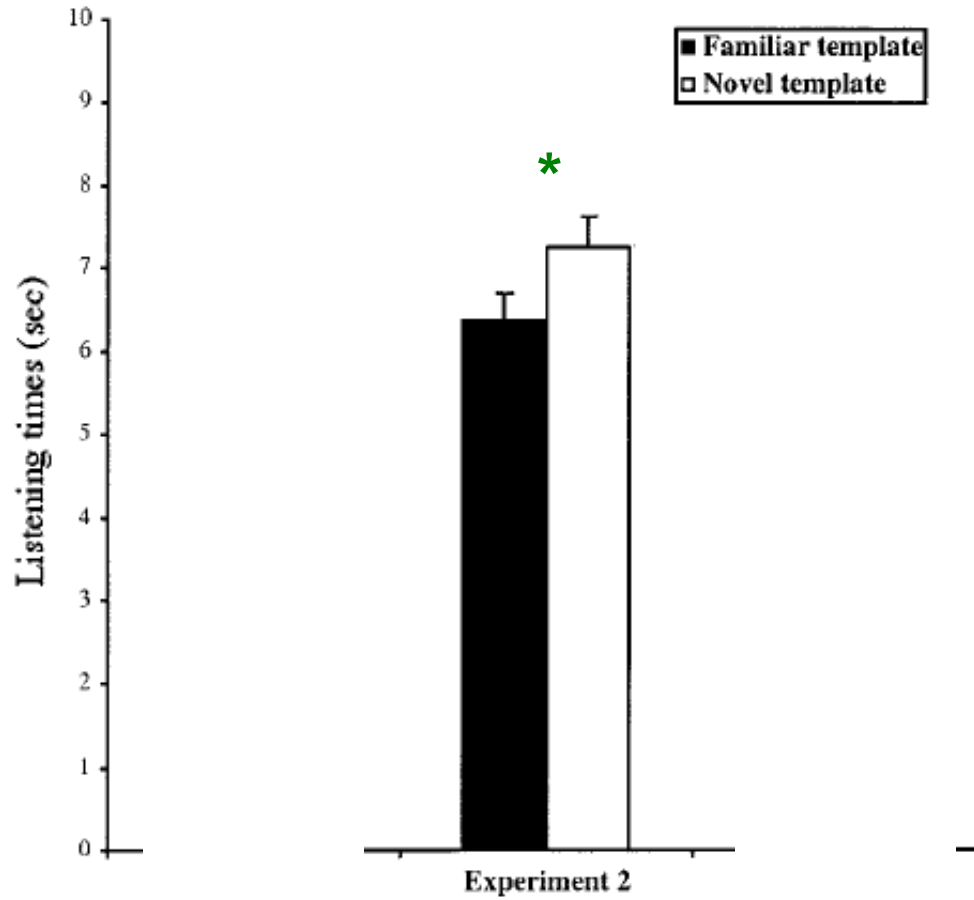
## Segmentation phase (1 min.)

- Listened to 4 new nonce words (2 conforming, 2 non-conforming) presented as a continuous speech stream.
- E.g.: kibpugbupgokpagkobgikbapbupgokkibpug...
- Stimuli synthesized; no acoustic cues for word boundaries.

## Test phase (12 trials)

- 4 words from segmentation; 3 blocks of repetitions.
- Center light flashes until infant looks. Then one side light flashes.
- Once infant looks, a test item is played until infant looks away for more than 2s.

# RESULTS



# EXP. 3

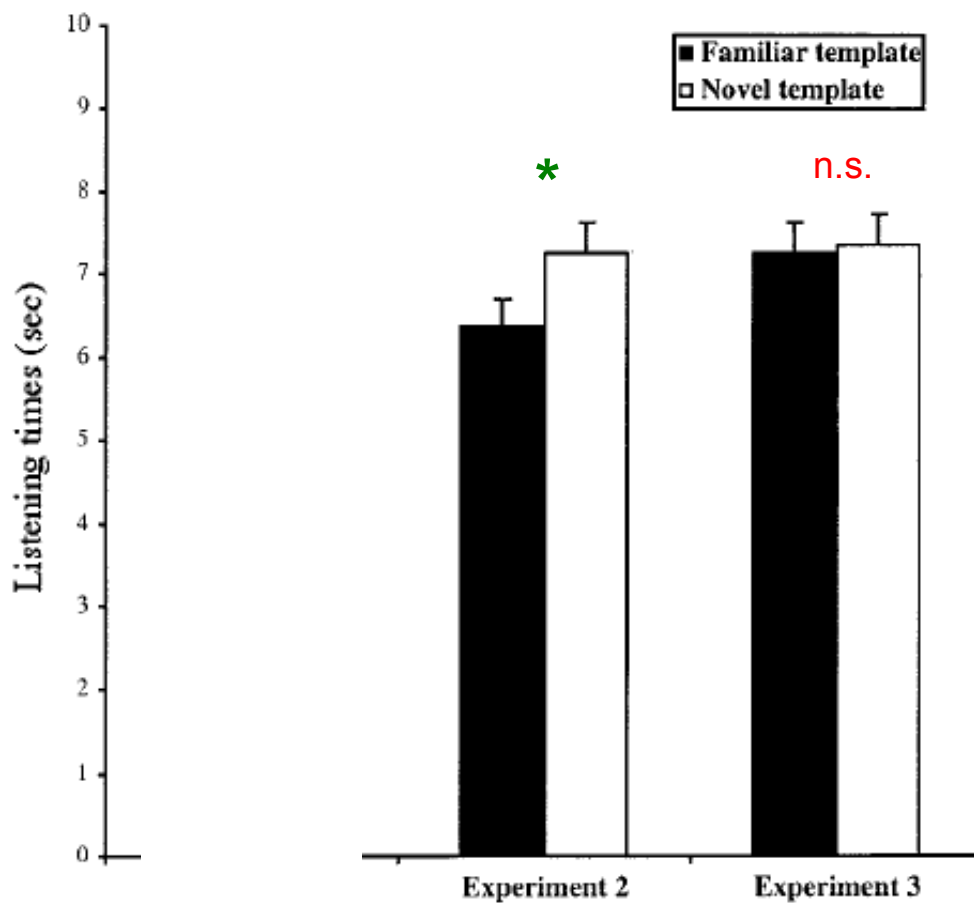
**Same design as Exp. 1, except with phonotactic generalizations that do not follow natural classes:**

- [p, d, k] only in onset; [b, t, g] only in coda.
- Or the opposite pattern.

**Participants: 30 new 9-month-olds**



# RESULTS



# REFERENCES

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