UNIVERSAL BIASES IN PHONOLOGICAL LEARNING

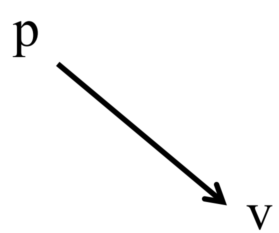
ACTL SUMMER SCHOOL, DAY 3

JAMIE WHITE (UCL)

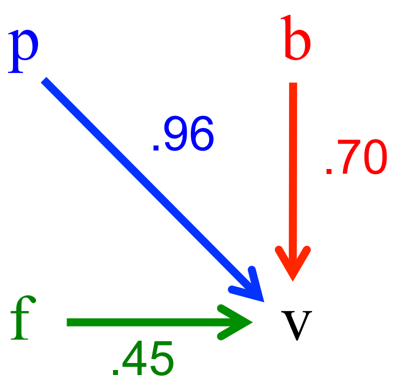
RESULTS (GENERALIZATION PHASE)

Potentially Saltatory condition

Input:

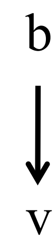


Results:

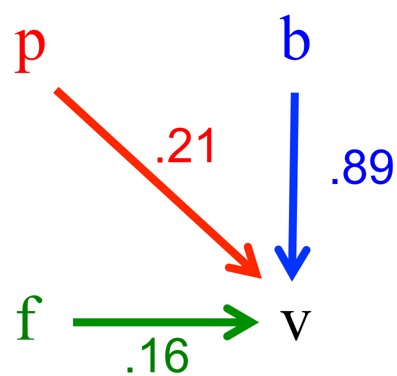


Control condition

Input:

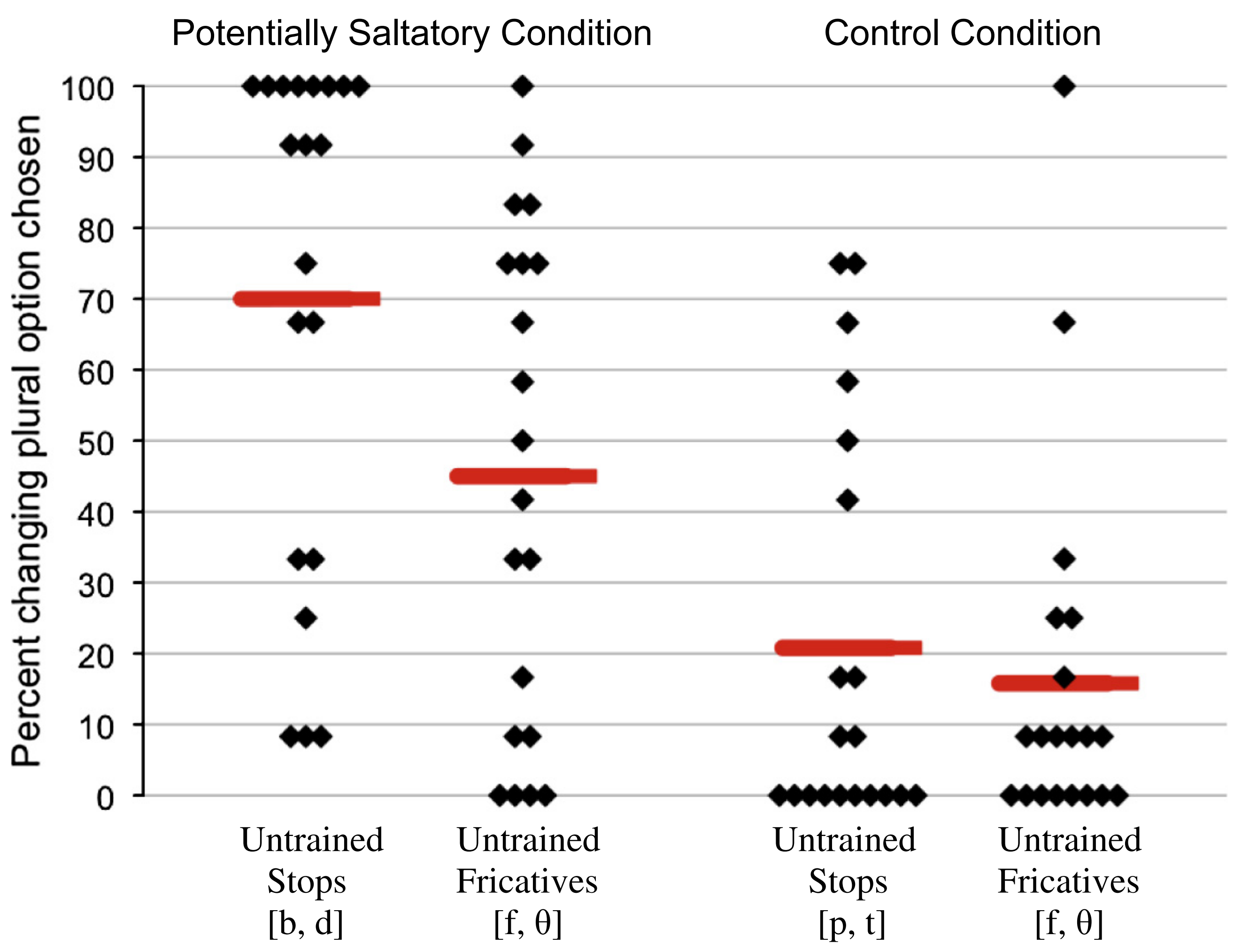


Results:

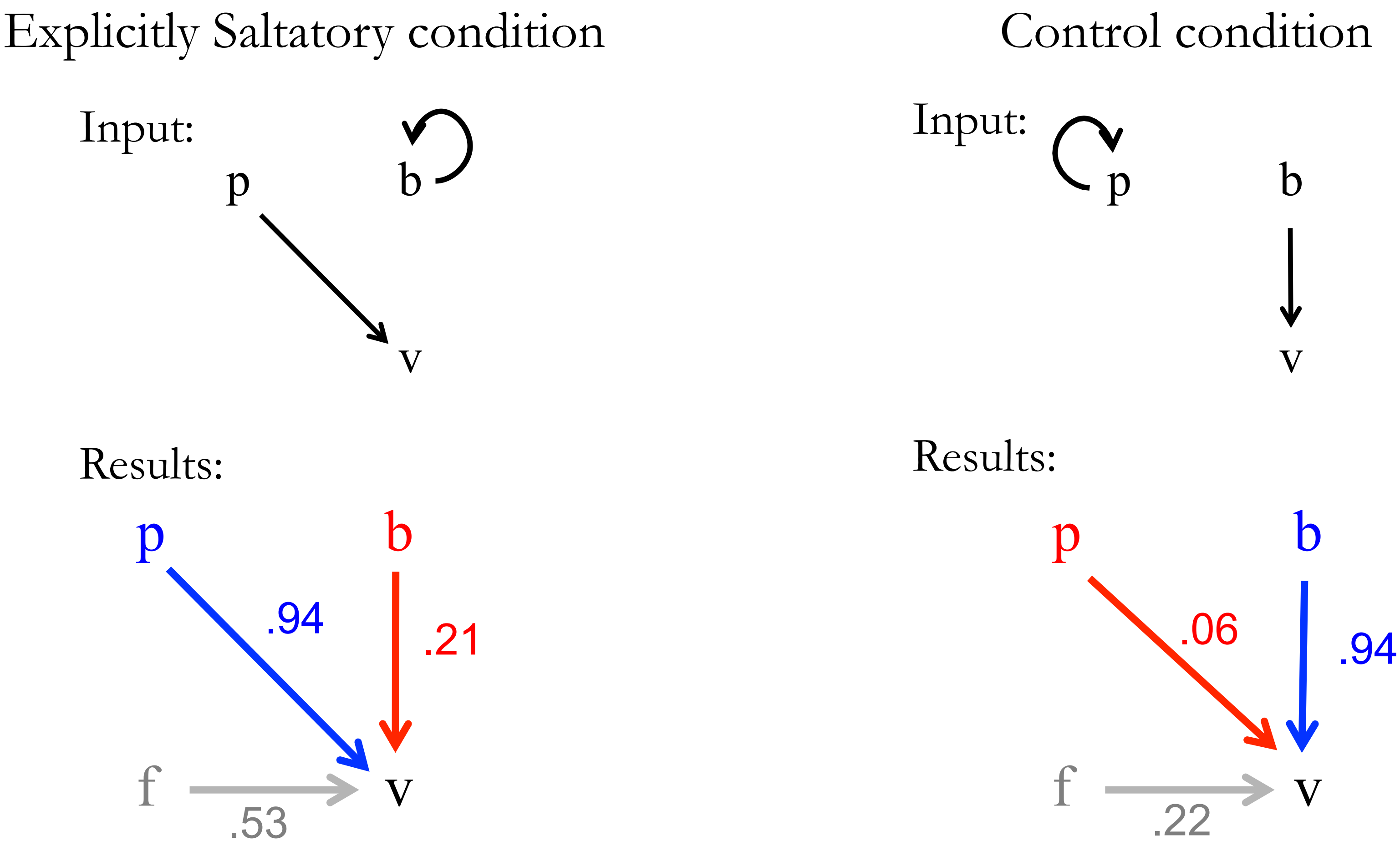


White (2014), *Cognition*

INDIVIDUAL RESULTS



EXP. 2



White (2014), *Cognition*

INFANTS?

12-month-old infants exhibit the same bias in an artificial language learning task!

- See: White & Sundara 2014, *Cognition*

What about in L1 learning?

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.

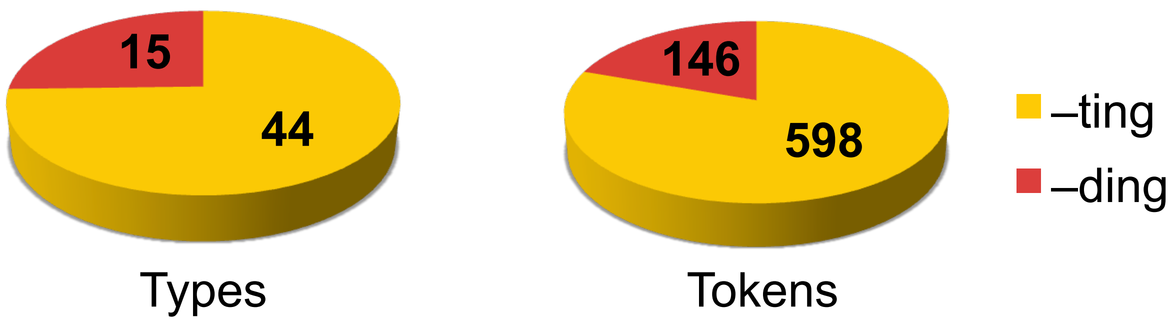
Sundara, Kim, White, & Chong, under review

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,* word-finally*…*)

Sundara, Kim, White, & Chong, under review

EXPERIMENT 1

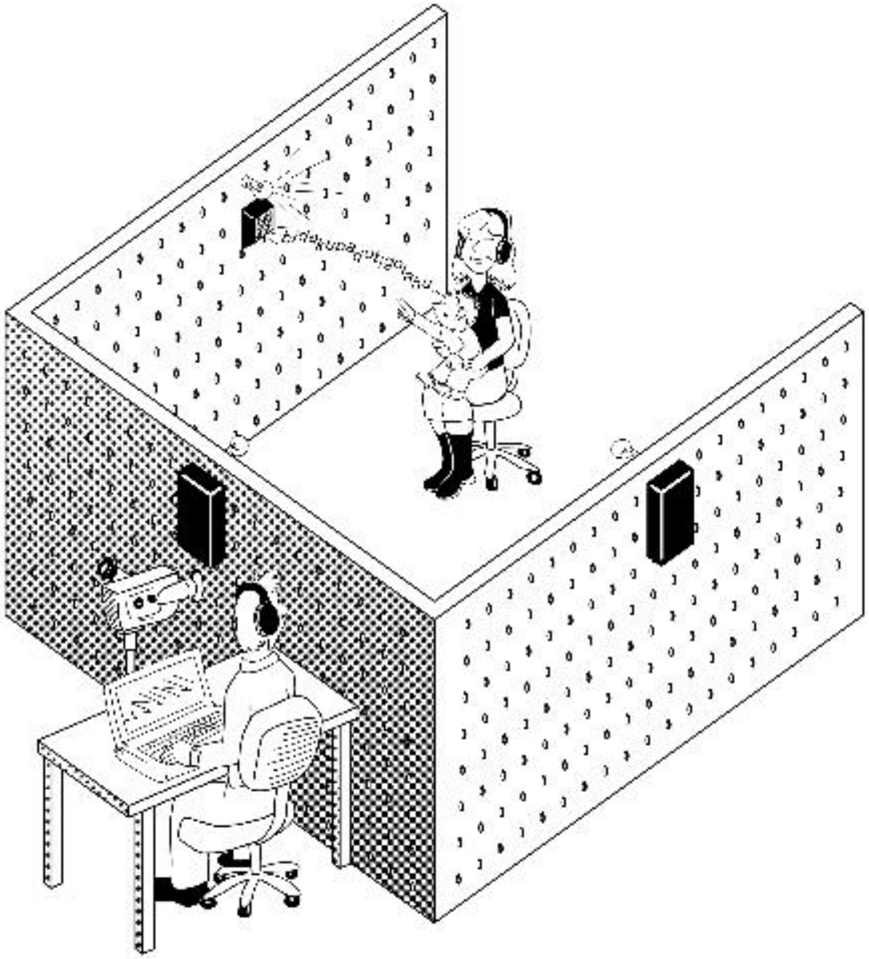
Do 12-month-olds map [ɾ] to /t/?

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

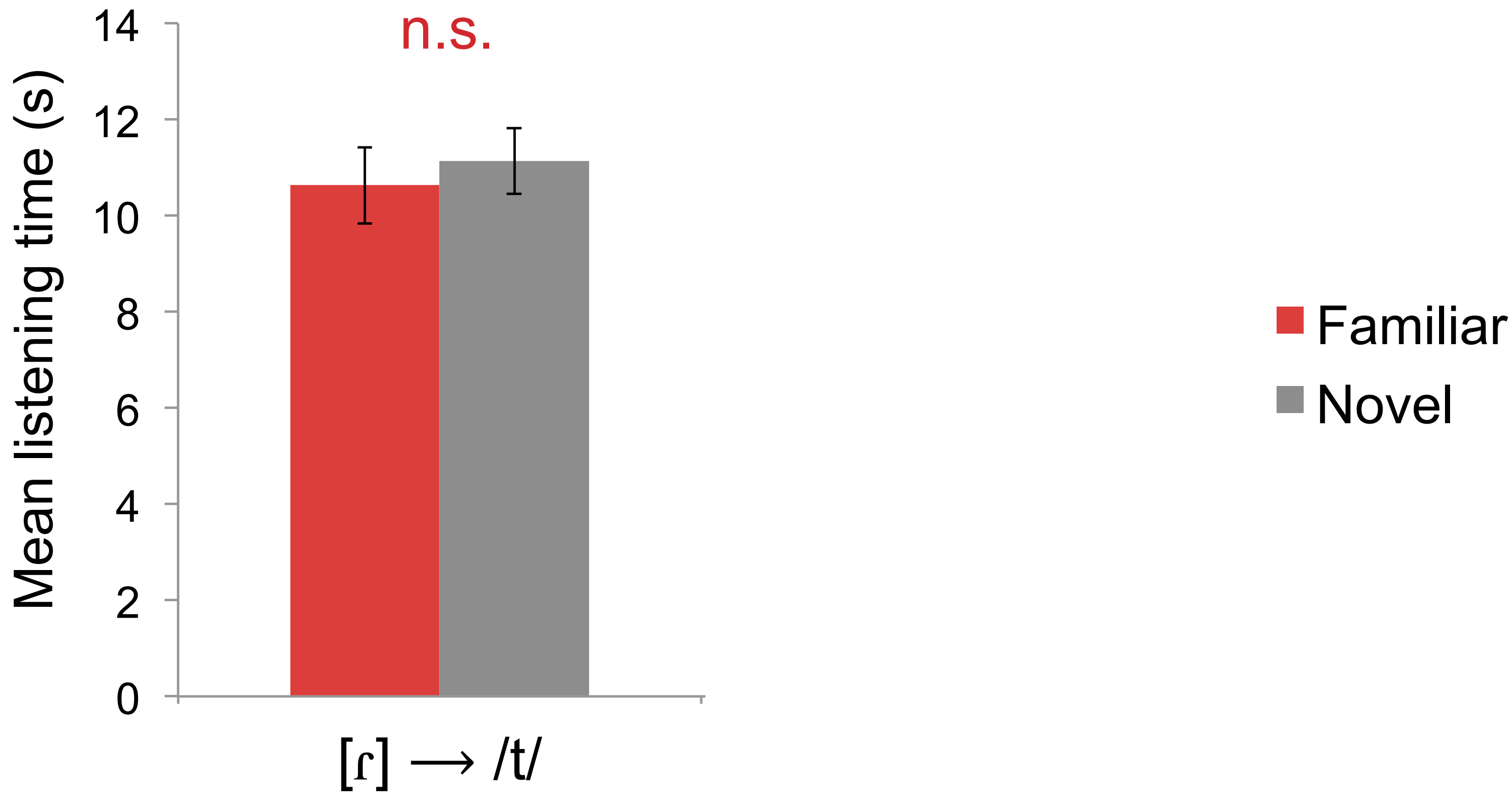
Test phase (4 trials x 2 blocks)

- 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: [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.

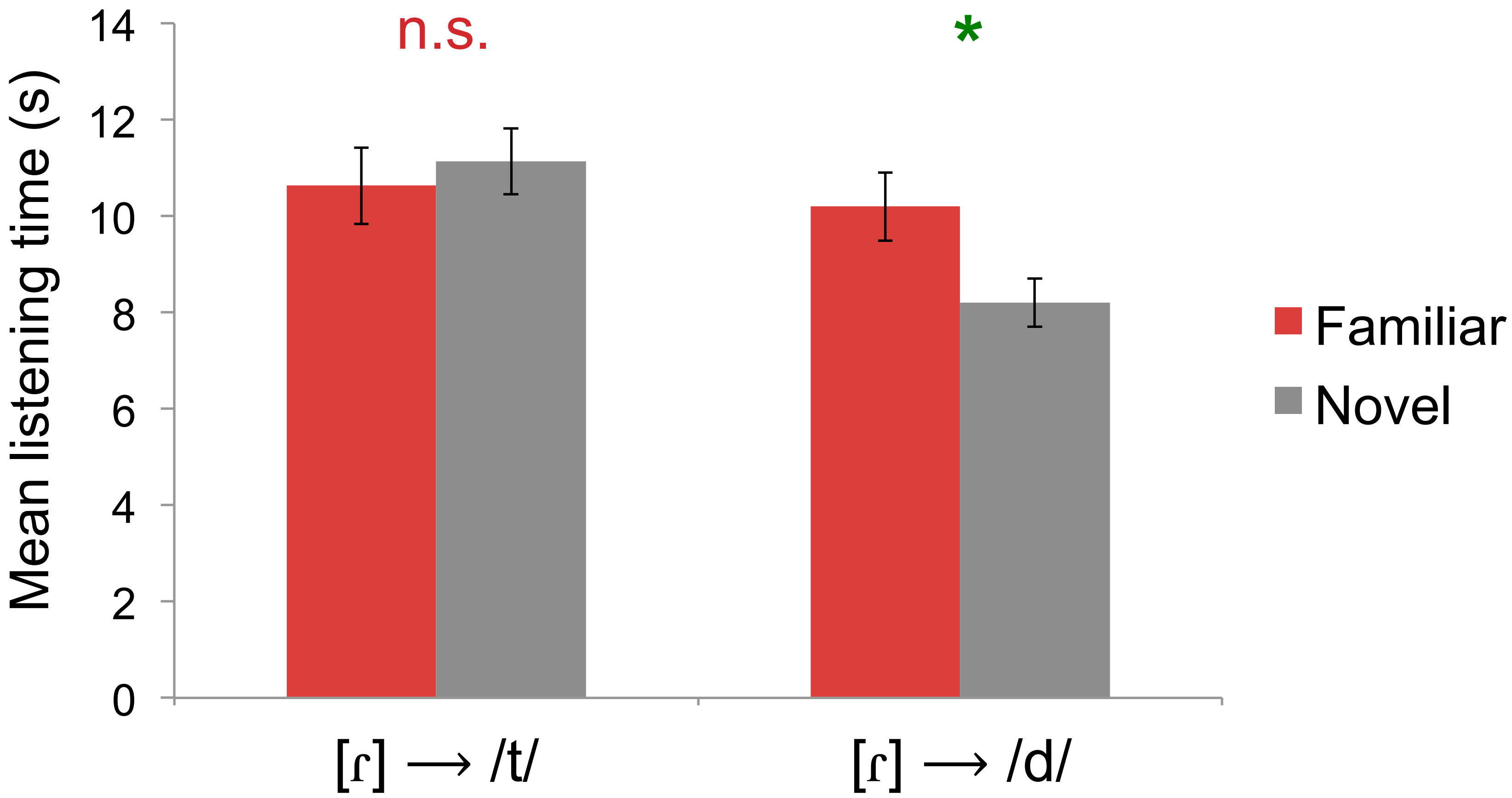
Familiarization phase:

- 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] ⟶ /d/



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

EXPERIMENT 3 – DISCRIMINATION EXP.

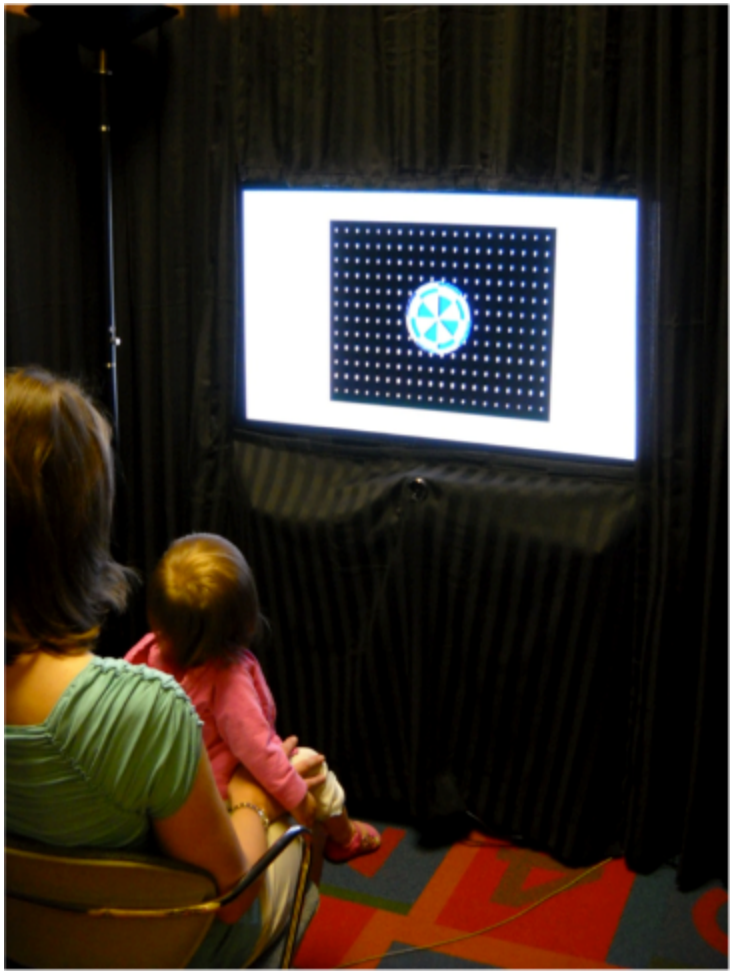
Do 12-month-olds fail to discriminate [d] and [ɾ]?

Participants:

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

Visual fixation procedure

VISUAL FIXATION SETUP



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%.

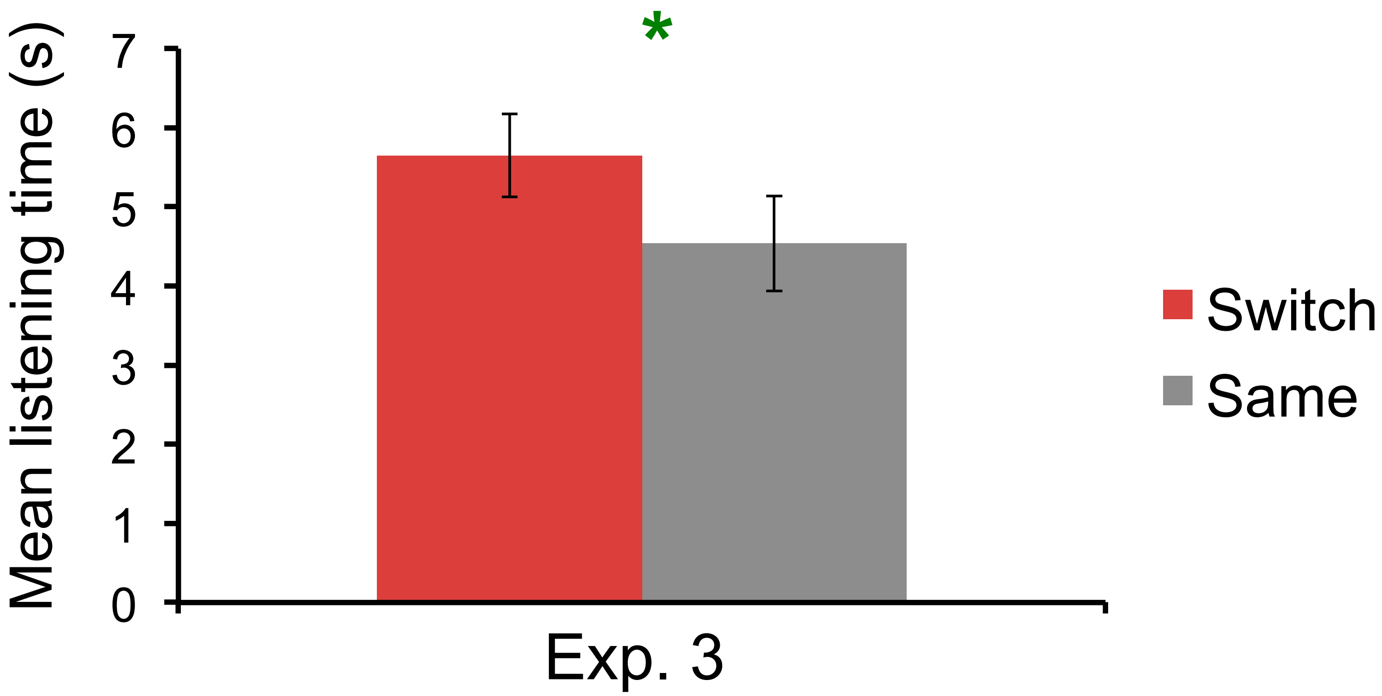
Test phase (2 trials):

- ‘Same’ trial
- ‘Switch’ trial

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

SAMPLE DISCRIM EXPERIMENT

RESULTS



→ **12mo's <u>can</u> discriminate [d] and [ɾ].**

LOOKING FOR BIASES IN NATURAL L1 LEARNING:
CORPUS + EXPERIMENT APPROACH

BASIC IDEA

Two general approaches:

1. Find statistical regularities in a language, using corpora and a statistical model. Then, probe native speaker knowledge to see how well these patterns have been learned.
   - Underlearned or not learned at all → bias against the pattern.
   - Overlearned → pattern bolstered by UG bias.

2. Find crucial cases that happen to be missing in a language. Test speakers on the missing cases.
   - Like a natural ‘poverty of the stimulus’ experiment.
   - E.g., see Zuraw 2007, Berent et al. 2007.

DUTCH VOICING ALTERNATIONS

Dutch voicing alternations

a.	verwijden	[vɛrʋɛidən]	'widen-INF'
	verwijten	[vɛrʋɛitən]	'reproach-INF'
b.	verwijd bijna	[vɛrʋɛid bɛina:]	'widen almost'
	verwijt bijna	[vɛrʋɛid bɛina:]	'reproach almost'
c.	verwijd niet	[vɛrʋɛit nit]	'widen not'
	verwijt niet	[vɛrʋɛit nit]	'reproach not'
d.	verwijd	[vɛrʋɛit]	'widen'
	verwijt	[vɛrʋɛit]	'reproach'

Typical analysis

- Underlying [voice] contrast in obstruents.
- Neutralized to [–voice] word-finally.
- Neutralized to [+voice] before voiced stops (through assimilation).

Ernestus & Baayen 2003, *Language*

WUG TEST

What if we forced speakers to go the other way?

- E.g. give them a nonce word [kyf] and asked them to guess the infinitive, [kyfən] or [kyvən].
- N.B.: [kyf] could correspond to either.
- Ernestus & Baayen did such a task.

Task

- Hear phrase containing novel verb in present: [ɪk tif] ‘I tief…’
- Write down past tense of novel verb: <tief**t**e> or <tief**d**e>
- Allomorph selection driven by voicing of final C: [tə] after underlyingly voiceless; [də] after underlyingly voiced.
- 192 monosyllabic nonce verbs; 28 participants.

Ernestus & Baayen 2003, *Language*

SOME POSSIBLE RESULTS

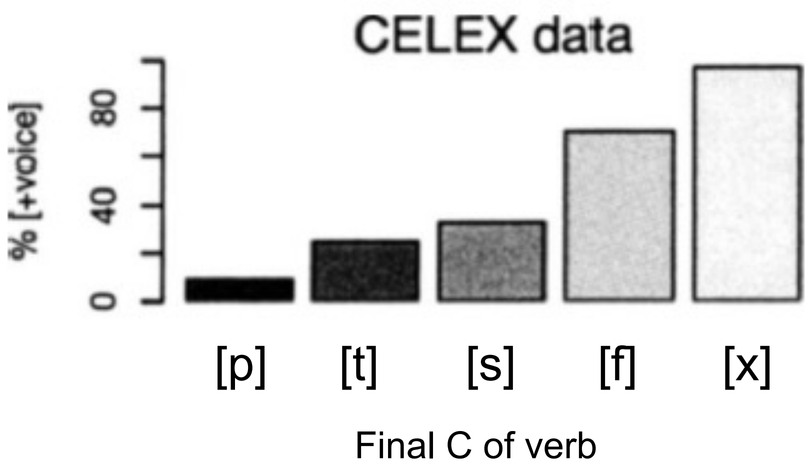
Speakers might…

1. Assume that there are no alternations → only choose voiceless past tense allomorph.
2. Respond randomly → choose voiceless and voiced at roughly chance level.
3. Respond stochastically (broad) → match the overall rate of alternation vs. non-alternation in the full lexicon.
4. Respond stochastically (narrow) → match rate of alternation in the lexicon according to specific phonological factors (e.g. identity of final obstruent).
5. Binary responding → figure out the most likely outcome in the lexicon, and always choose that option.

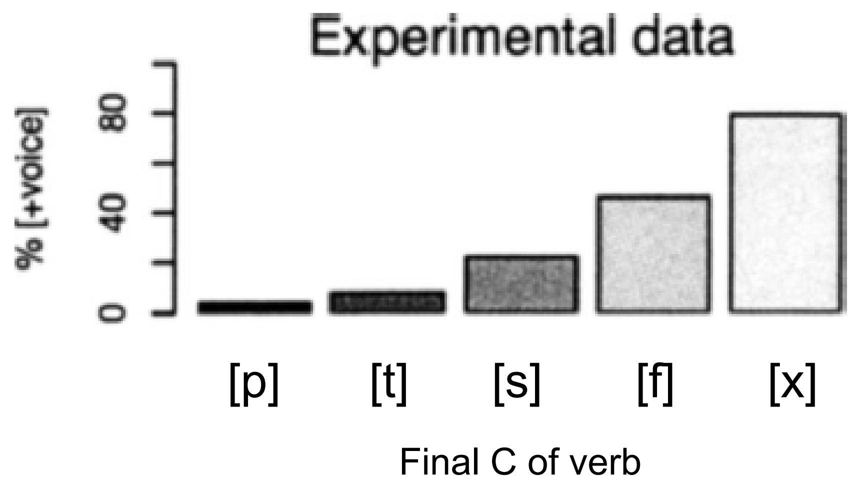
Ernestus & Baayen 2003, *Language*

RESULTS

Results in the Dutch lexicon



Results from wug test



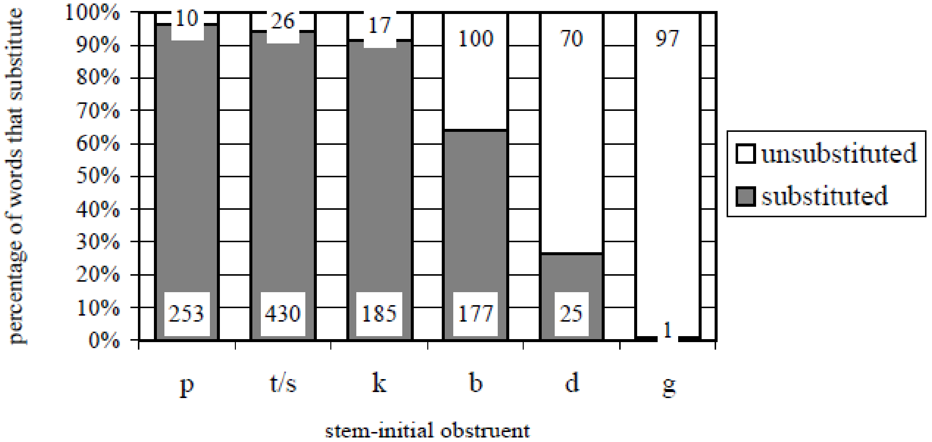
Ernestus & Baayen 2003, *Language*

SIMILAR BEHAVIOR IN TAGALOG

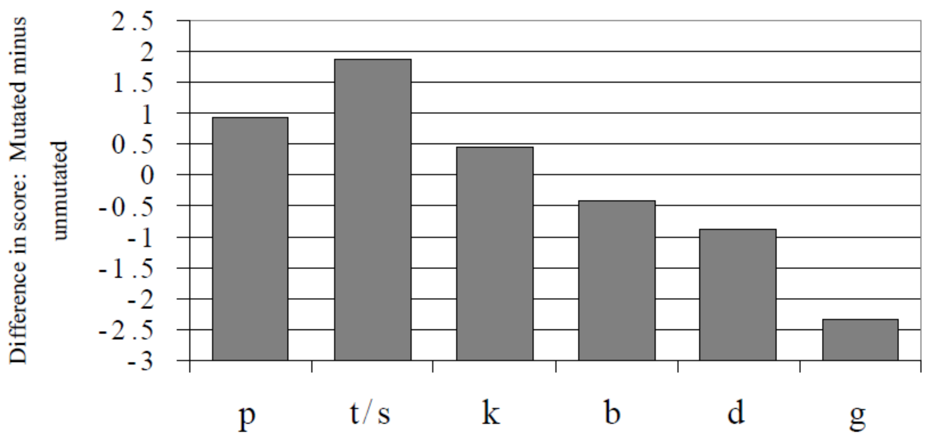
Tagalog nasal substitution

- E.g.: [bigaj] ‘give’ → [mamigaj] ‘to distribute’ (from /maŋ + bigaj/)

In the lexicon



Wug test with nonce forms



Zuraw 2000, dissertation; Zuraw 2010, *NLLT*

FREQUENCY MATCHING

This type of behavior is called frequency matching.

- Presumably domain-general. It occurs in other learning domains and in animals.

Law of Frequency Matching (from Hayes et al. 2009):

- "Speakers of languages with variable lexical patterns respond stochastically when tested on such patterns. Their responses aggregately match the lexical frequencies."

This observation sets the stage for looking for learning biases:

- Null hypothesis: speakers learn statistical patterns in their input and will frequency match when tested.
- Cases where people do NOT frequency match → learning bias

TURKISH LARYNGEAL ALTERNATIONS

Basic pattern:

- Contrast between voiced stops and voiceless aspirated stops neutralized in coda position:

	bare stem	possessive	
a.	atʃ^{h}	atʃ^{h}-ɨ	'hunger'
b.	anatʃ^{h}	anatʃ^{h}-ɨ	'female cub'
c.	gytʃ^{h}	gydʒ-y	'force'
d.	amatʃ^{h}	amadʒ-ɨ	'target'

Traditional analysis (like Dutch final devoicing):

- Underlying contrast.
- Contrast neutralized in coda position, through devoicing and aspiration of the stops.

Becker, Ketrez, & Nevins 2011, *Language*

CORPUS ANALYSIS

Factors affecting the likelihood that a stem alternates in the lexicon (based on Turkish Electronic Living Lexicon):

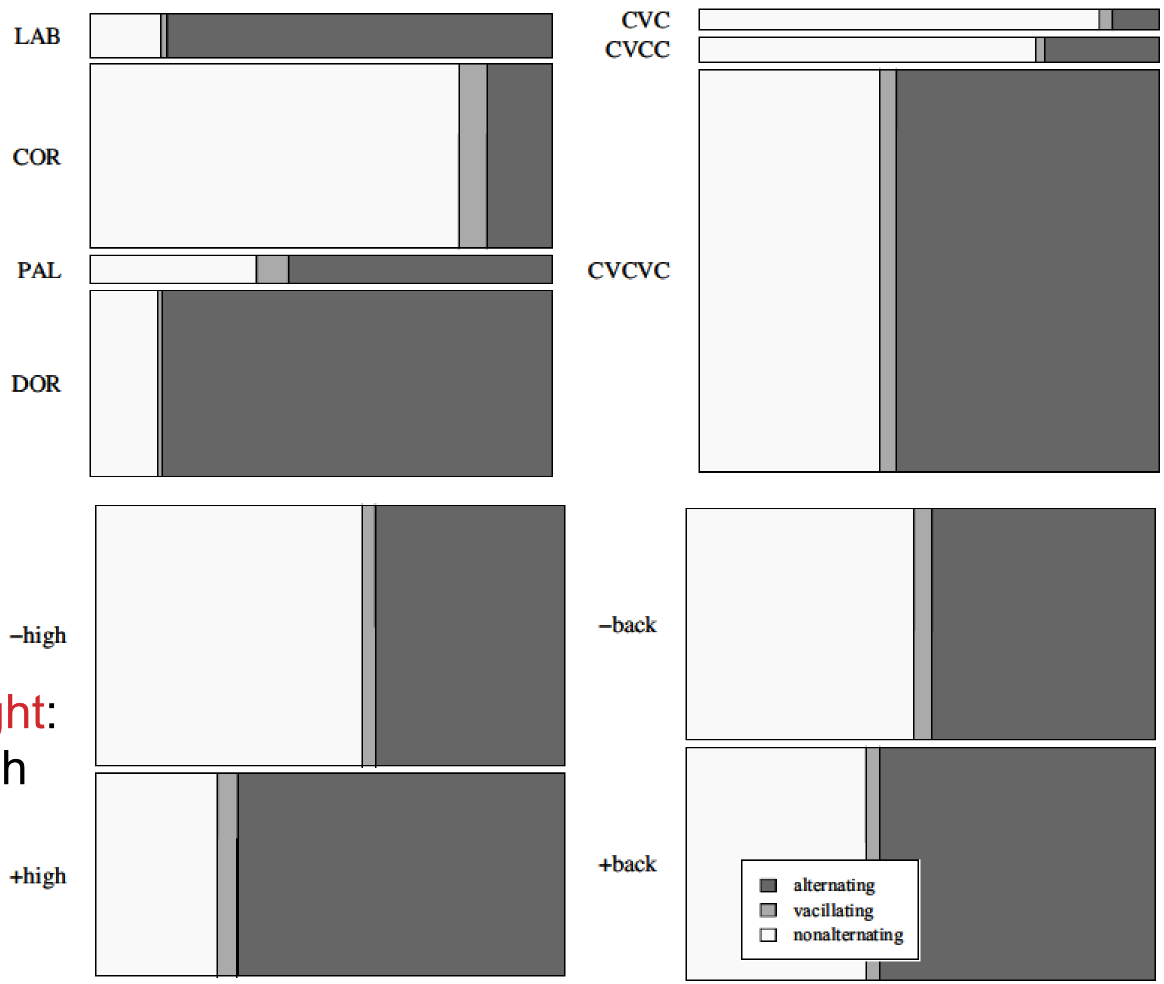
1. Place:
COR < PAL < LAB, DOR

2. Size:
Mono < Poly;

CVC < CVCC

3. Prec V height:
Nonhigh < high

4. Prec V backness:
front < back



Becker, Ketrez, & Nevins 2011, *Language*

NATURALNESS OF THE PATTERNS

Natural:

- Size
  - Faithfulness (lack of alternation) in a prominent position, i.e. the initial syllable. This has typological support (Beckman 1998).
- Place
  - Also has typological support – different places often act differently w.r.t. laryngeal features.

Unnatural:

- Prec V height
- Prec V backness
  - Uncommon for features of V to determine features of following C.

Becker, Ketrez, & Nevins 2011, *Language*

WUG TEST

Participants

- 24 Turkish speakers.

Task

- Self-paced forced-choice task.
- See nonce noun in orthography, e.g. <fet>.
- Hear *Ali’nin* ___ (‘Ali’s ____’) followed by 2 genitive options:
  - E.g. fe**t**$^{\mathbf{h}}$i … fe**d**i (order counterbalanced)
- Choose which is the correct genitive form (button press).
- 72 target items + 36 filler items.

Becker, Ketrez, & Nevins 2011, *Language*

HAVE PARTICIPANTS LEARNED THE LEXICAL TRENDS?

Best model of the corpus

Significant factors:

Place
Size
Prec V height
Prec V backness

Place * Size
Place * Prec V height
Place * Prec V backness

Best model of the experimental results

Significant factors:

Place
Size

Place * Size

Becker, Ketrez, & Nevins 2011, *Language*

‘SURFEIT OF THE STIMULUS’

The authors refer to this as a ‘surfeit of the stimulus’ effect.

- Turkish speakers fail to pick up on some statistical patterns in the Turkish lexicon, even though these patterns have ample support.
- The existence of these patterns is likely due to historical factors, but they have no status in the synchronic grammar.

What type of bias?

- The authors suggest a hard bias approach – the patterns are unlearnable.
- I.e., learners cannot access the constraints that would be necessary to encode such patterns in their grammar.
    - Constraints not part of UG, or are otherwise impossible to induce.

Becker, Ketrez, & Nevins 2011, *Language*

BECKER ET AL.'S (2011) TAKE

"The proposal advanced here is that the results are best understood in light of a theory of universally possible phonological interactions, as encoded in a set of universal constraints. Only factors that can be expressed in terms of constraint interaction can be identified by language learners, with other lexical generalizations going unnoticed."

(See also Becker, Nevins, & Levine 2012, *Language*, for a case in English.)

ANOTHER EXAMPLE: HUNGARIAN

Hungarian has a highly productive pattern of backness harmony in vowels.

3 categories of vowels:

- **Back** (**B**) = [u, uː, o, oː, ɔ, aː]
- **Front** (**F**) = [y, yː, ø, øː]
- **Neutral** (**N**) = [i, iː, eː, ɛ]

Cases of exceptionless harmony:

(5) Closest vowel back: back suffixes

B**B**	[ɔblɔk-nɔk]	'window-DAT'
N**B**	[biːroː-nɔk]	'judge-DAT'
F**B**	[glykoːz-nɔk]	'glucose-DAT'

(6) Closest vowel front rounded: front suffixes

F	[yʃt-nɛk]	'cauldron-DAT'
N**F**	[sɛmøltʃ-nɛk]	'wart-DAT'
B**F**	[ʃoføːr-nɛk]	'chauffeur-DAT'

(7) F + N*: front suffixes

FN	[fyːsɛr-nɛk]	'spice-DAT'
FNN	[øːrizɛt-nɛk]	'custody-DAT'

Hayes, Zuraw, Siptár, & Londe 2009, *Language*

ZONES OF VARIATION

Certain types of stems show variation (‘zones of variation’):

- BN, BNN
- All neutrals (N, NN)

Examples of different outcomes within word of the same type falling in the ‘zones of variation’:

WORD ([o] + [eː])		GLOSS	GOOGLE HITS (Sept. 2008)[7]	%
doménnak	[domeːn-nɔk]	‘domain (on Web)-DAT’	5	2.1
doménnek	[domeːn-nɛk]		234	97.9
bohémnak	[boheːm-nɔk]	‘easy-going-DAT’	433	24.4
bohémnek	[boheːm-nɛk]		1,340	75.6
honvédnak	[honveːd-nɔk]	‘Hungarian soldier-DAT’	8,820	74.1
honvédnek	[honveːd-nɛk]		3,084	25.9
poénnak	[poeːn-nɔk]	‘punch line-DAT’	56,400	99.9
poénnek	[poeːn-nɛk]		36	0.1

TABLE 1. Examples: lexical arbitrariness of harmony within the zones of variation.

Hayes, Zuraw, Siptár, & Londe 2009, *Language*

SOURCE OF THE CORPUS

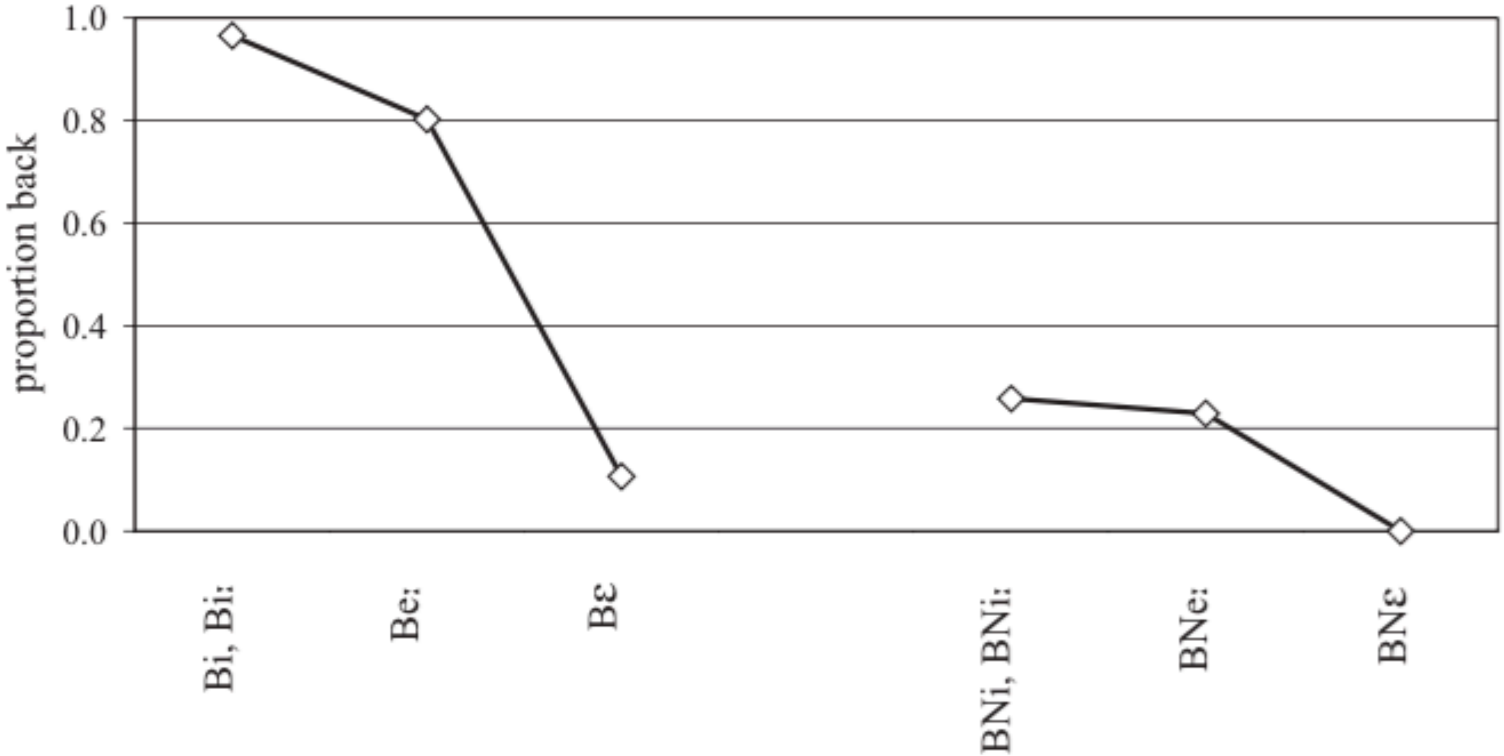
The corpus was collected by way of Google searches.

- (See Hayes & Londe 2006, *Phonology*)
- Searched for the [–nɔk] and [–nɛk] forms of several thousand noun stems.
- Heavily cleaned the corpus, removing potentially problematic cases (e.g. compounds).
- The resulting corpus had 8,915 stems.

Hayes, Zuraw, Siptár, & Londe 2009, *Language*

LEXICAL PATTERNS IN THE ‘ZONES OF VARIATION’

Two effects deemed natural: height and locality



Hayes, Zuraw, Siptár, & Londe 2009, *Language*

FOUR UNNATURAL STATISTICAL EFFECTS IN THE LEXICON

1. **If stem-final C is a labial non-continuant ⟶ Front suffix**
2. **If stem-final C is a sibilant ⟶ Front suffix**
3. **If stem-final C is a coronal non-sonorant ⟶ Front suffix**
4. **If stem ends in CC ⟶ Front suffix**

(All significant in the corpus.)

Hayes, Zuraw, Siptár, & Londe 2009, *Language*

WUG TEST

Participants:

- 131 Hungarian speakers (online)

Hálupem

Choose the best answer to fill in the blank:

Hálupem was a goddess worshipped by the early pagan Hungarians. It is believed that Hálupem was the goddess of weaving. Not just the Hungarians but also neighboring peoples celebrated ___________(-dat.)'s divine powers.

○ *Hálupemnak*
○ *Hálupemnek*

Please rate each item from 1 to 7:

	worst 1	2	3	4	5	6	best 7
Hálupemnak	○	○	○	○	○	○	○
Hálupemnek	○	○	○	○	○	○	○

CONTINUE

This is item 2 (of 13)

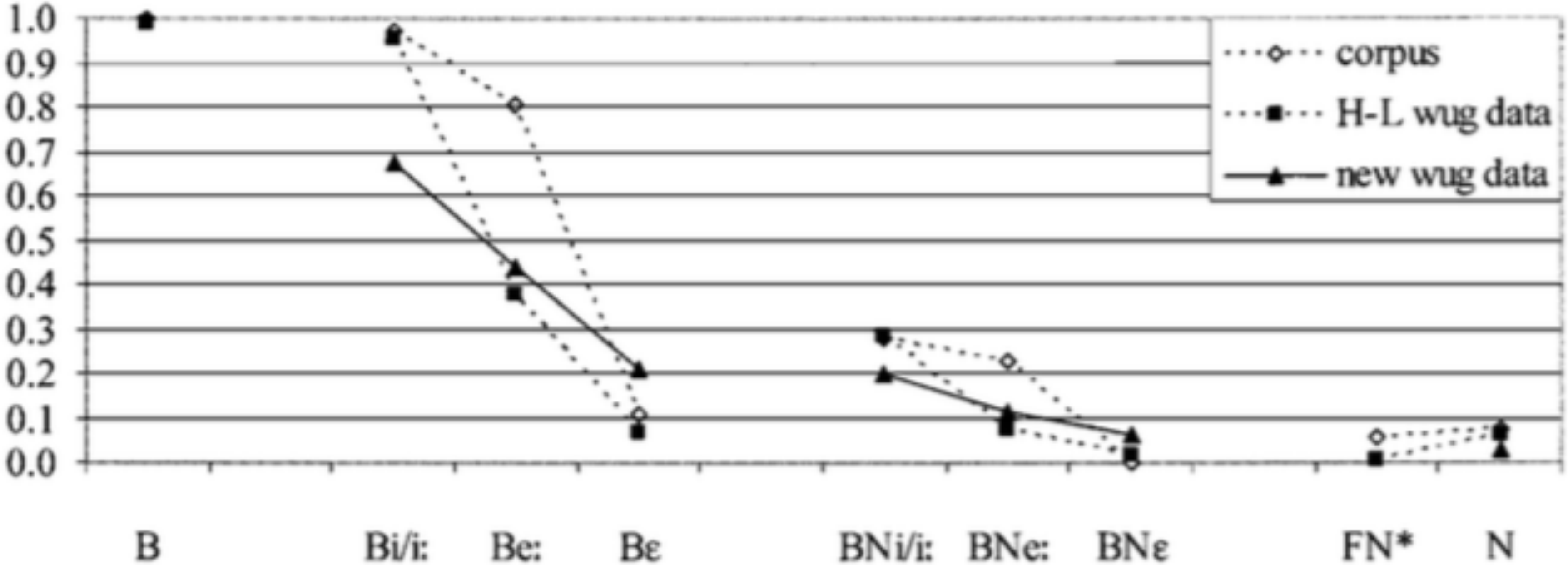
1,703 Wug stems tested in total.

Each stem only seen by one participant.

13 stems per participant.

Hayes, Zuraw, Siptár, & Londe 2009, *Language*

RESULTS (HEIGHT/DISTANCE EFFECTS)



Hayes, Zuraw, Siptár, & Londe 2009, *Language*

RESULTS FOR THE UNNATURAL PATTERNS

They learn them all.

Unnatural constraints	COEFFICIENT	*p*
USE FRONT / bilabial ___	−1.211	< 0.0001
USE FRONT / [+cor, +son] ___	−0.519	0.0074
USE FRONT / sibilant ___	−0.500	0.0230
USE FRONT / CC ___	−0.762	< 0.0001

BUT – are the constraints underlearned?

Hayes, Zuraw, Siptár, & Londe 2009, *Language*

ANSWER: YES

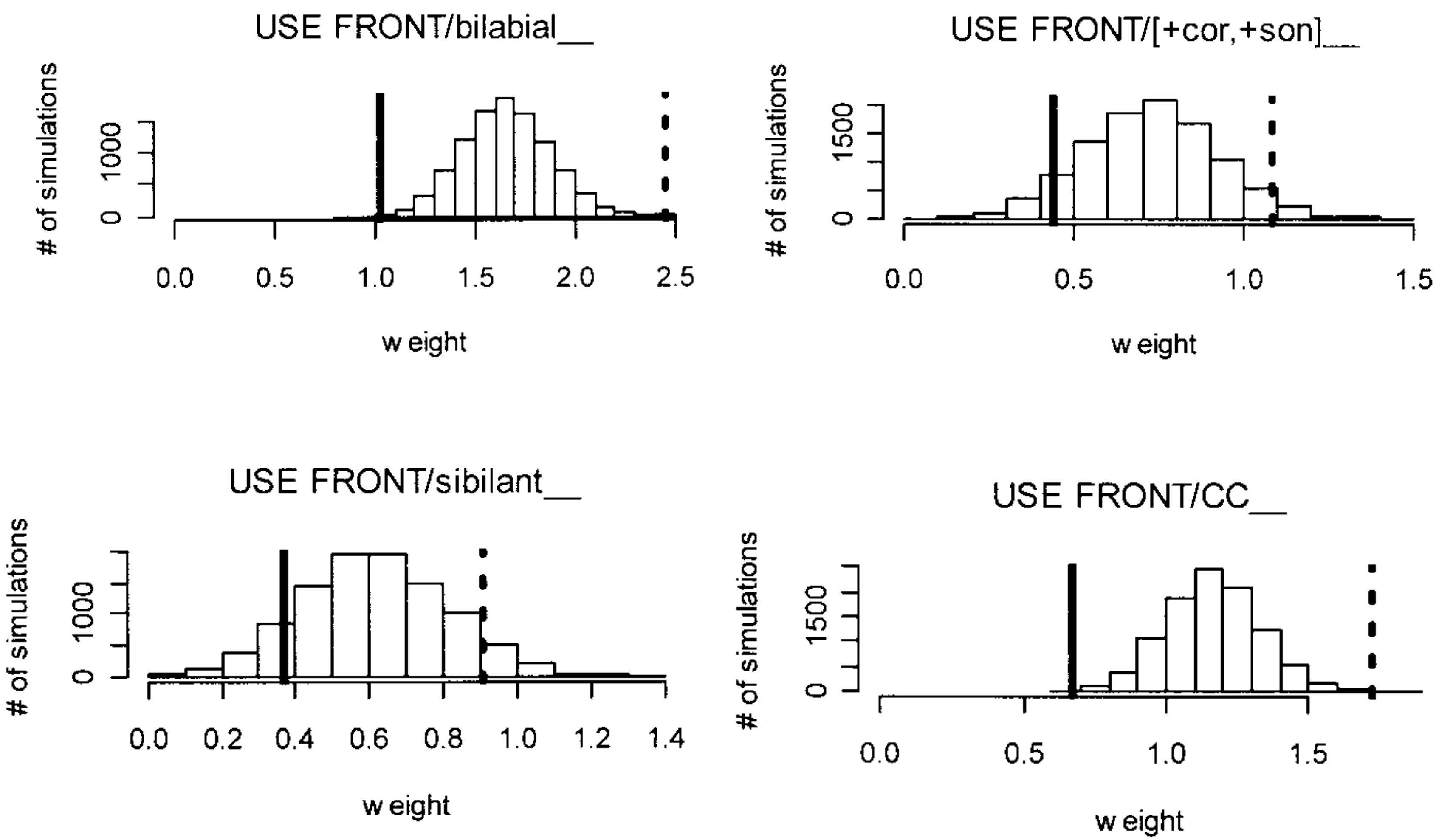
Basic overview of their method:

- Train a MaxEnt grammar on the real wug test results = G_{WUG}
- Train a MaxEnt grammar on the lexicon (corpus data) = G_{LEX}
- We want to compare these – but we can't compare them directly because they are trained on different sets (and amounts) of data.

- So instead…
- Assume that each participant used G_{LEX} as the basis of their wug responses.
- Use the probabilities outputted by G_{LEX} to simulate 10,000 random runs of the wug test (all 1703 words). (=Monte Carlo method)
- This gives you a distribution of the 10,000 Pseudo-G_{WUG} weights for each constraint, assuming people rely on $G_{LEX.}$
- Compare the real weights of each constraint in G_{WUG} to the distribution of the weights.

Hayes, Zuraw, Siptár, & Londe 2009, *Language*

UNDERLEARNING OF UNNATURAL CONSTRAINTS



Hayes, Zuraw, Siptár, & Londe 2009, *Language*

SUMMARY BY HAYES ET AL. (2009)

"We judge that [cases where people learn unnatural rules] indicate an ability in people to locate and internalize phonological generalizations on an inductive basis, without having them prespecified in UG. This does not imply, however, that endogenous factors (i.e. UG, broadly con- strued) could not play a role in phonological learning, and we judge that some of the experimental work cited…above in fact supports this view. Thus, the theory we ultimately advocate is a mixed, bias-based theory, in which learning can be assisted by UG, but is not limited to a strict UG-specified form."

NATURAL AND UNNATURAL PHONOTACTIC GENERALIZATIONS

NATURAL AND UNNATURAL CONSTRAINTS IN ENGLISH PHONOTACTICS

Used the Hayes & Wilson (2008) Phonotactic Learner.

- A MaxEnt model for learning phonotactics from a corpus.
- Induces the phonotactic constraints (in terms of natural classes), using an algorithm that searches through the set of possible constraints and selects them based on search heuristics (simplicity, accuracy, generality).
- Requires few prior assumptions (a key one: a feature set, and we also included syllable structure).
- Resulting grammar of constraints is weighted to maximize the likelihood of the data (MaxEnt learning).

Hayes & White 2013, *Linguistic Inquiry*

NATURAL AND UNNATURAL CONSTRAINTS IN ENGLISH PHONOTACTICS

Corpus:

- Created a corpus consisting of all words appearing both in the CMU Pronouncing Dictionary and in CELEX with a frequency of at least 1.
- Lots of cleaning.

We let the learner run until it had learned 160 constraints.

- Then, we searched for 10 constraints that we deemed natural, and 10 constraints that we deemed unnatural.

Crucially: the weights of the unnatural constraints were, on average, slightly higher than those of the natural constraints.

- Thus: the unnatural constraints represent lexical patterns that are equally strong (or slightly stronger) than the natural constraints.

Hayes & White 2013, *Linguistic Inquiry*

NATURAL CONSTRAINTS

	Constraint	*Violating - Control*	*IPA*
a.	*[−son] [+son] IN CODA	*kipl - kilp*	['kɪpl] - ['kɪlp]
		canifl - canift	[kə'nɪfl] - [kə'nɪft]
b.	*[+cons] [−cons] IN CODA	*tilr - tilse*	['tɪlɹ] - ['tɪls]
		shapenr - shapent	[ʃə'pɛnɹ] - [ʃə'pɛnt]
c.	*[−cons] [+cons] IN ONSET	*hlup - plup*	['hlʌp] - ['plʌp]
		hmit - smit	['hmɪt] - ['smɪt]
d.	*[−cont] [−cont] IN ONSET	*cping - sping*	['kpɪŋ] - ['spɪŋ]
		ctice - stice	['ktaɪs] - ['staɪs]
e.	*[−cont] [+nasal] IN ONSET	*cnope - clope*	['knoʊp] - ['kloʊp]
		pneck - sneck	['pnɛk] - ['snɛk]
f.	*[+labial] [+dorsal] IN CODA	*trefk - treft*	['tɹɛfk] - ['tɹɛft]
		rufk - ruft	['ɹʌfk] - ['ɹʌft]
g.	*[+dorsal] [+labial] IN CODA	*bikf - bimf*	['bɪkf] - ['bɪmf]
		sadekp - sadect	[sə'dɛkp] - [sə'dɛkt]
h.	*[+labial] [+labial] IN ONSET	*bwell - brell*	['bwɛl] - ['bɹɛl]
		pwickon - twickon	['pwɪkən] - ['twɪkən]
i.	$*\begin{bmatrix}-\text{son}\\-\text{voice}\end{bmatrix}\begin{bmatrix}-\text{son}\\+\text{voice}\end{bmatrix}$	*esger - ezger*	['ɛsgɚ] - ['ɛzgɚ]
		trocdal - troctal	['tɹɑkdəl] - ['tɹɑktəl]
j.	$*\begin{bmatrix}-\text{syllabic}\\+\text{high}\end{bmatrix}$ IN CODA	*jouy - jout*	['dʒaʊj] - ['dʒaʊt]
		tighw - tibe	['taɪw] - ['taɪb]

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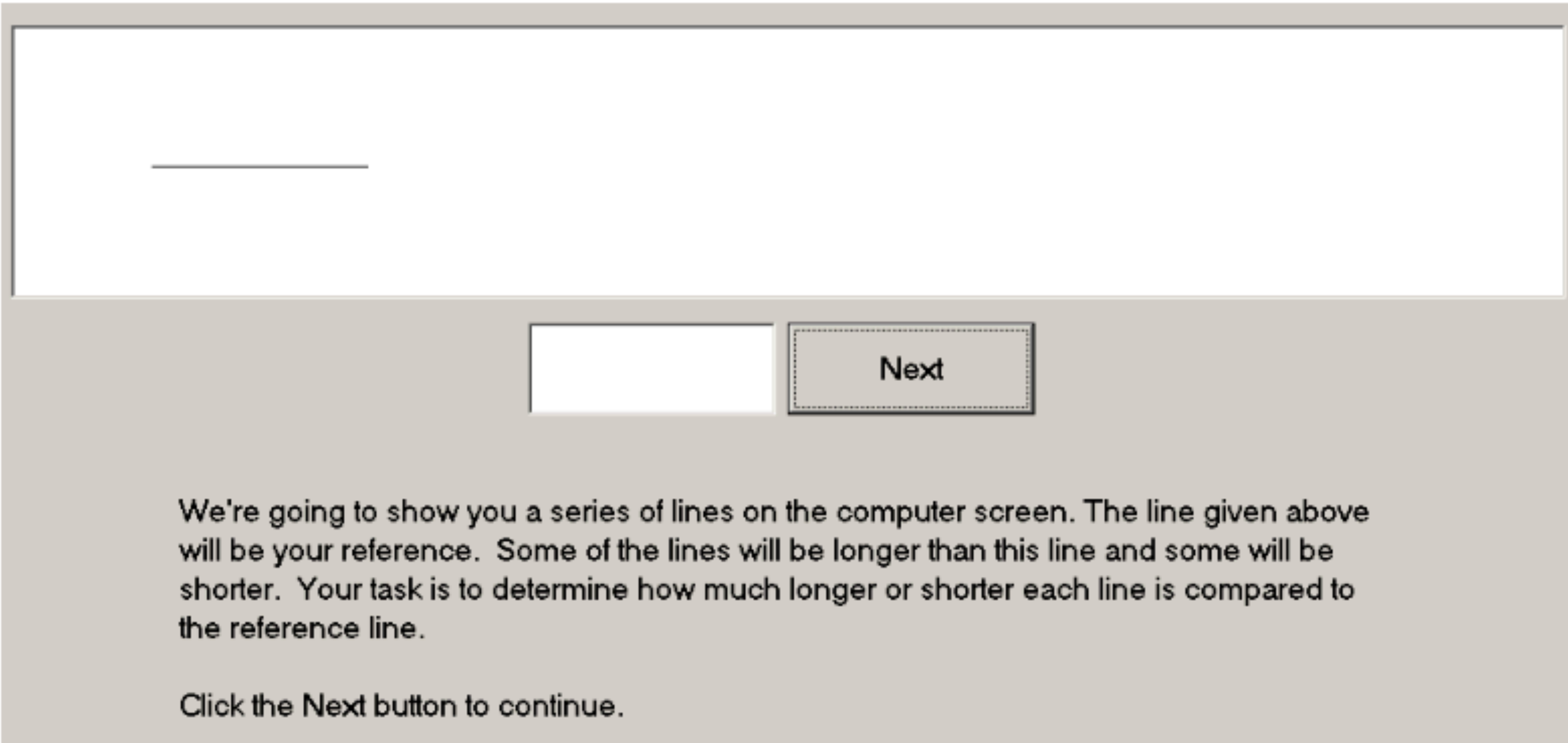
UNNATURAL CONSTRAINTS

	Constraint	*Violating - Control*	*IPA*
No [u, ʊ, w] *before* [h]	a. $*\begin{bmatrix}+\text{round}\\+\text{high}\end{bmatrix}\begin{bmatrix}-\text{cons}\\-\text{son}\end{bmatrix}$	*luhallem - laihallem* *tuheim - towheim*	[lu'hæləm] - [leɪ'hæləm] [tu'heɪm] - [toʊ'heɪm]
[ʃ, ʒ, tʃ, dʒ] *may not precede obstruents*	b. $*\begin{bmatrix}+\text{cons}\\-\text{ant}\end{bmatrix}[-\text{son}]$	*ishty - ishmy* *metchter - metchner*	['ɪʃti] - ['ɪʃmi] ['mɛtʃtɚ] - ['mɛtʃnɚ]
No [j] *before* [aɪ, aʊ, ɔɪ]	c. $*[-\text{back}]\ [+\text{diphthong}]$	*youse - yoss* *yout - yut*	['jaʊs] - ['jɑs] ['jaʊt] - ['jʌt]
No word-initial [u, ʊ]	d. $*[_{\text{word}}\begin{bmatrix}-\text{diphthong}\\+\text{round}\\+\text{high}\end{bmatrix}$	*utrum - otrum* *ooker - ocker*	['utɹəm] - ['oʊtɹəm] ['ʊkɚ] - ['ɑkɚ]
No [aɪ, aʊ, ɔɪ] *before* [ʃ, ʒ]	e. $*[+\text{diphthong}]\begin{bmatrix}+\text{cont}\\-\text{ant}\end{bmatrix}$	*pyshon - pyson* *foushert - fousert*	['paɪʃən] - ['paɪsən] ['faʊʃɚt] - ['faʊsɚt]
No [θ, ð] *before obstruents*	f. $*\begin{bmatrix}+\text{coronal}\\+\text{cont}\\-\text{strident}\end{bmatrix}[-\text{son}]$	*hethker - hethler* *muthpy - muspy*	['hɛθkɚ] - ['hɛθlɚ] ['mʌθpi] - ['mʌspi]
No [θ, ð] *before stressless rounded vowels*	g. $*\begin{bmatrix}+\text{cont}\\-\text{strident}\end{bmatrix}\begin{bmatrix}-\text{stress}\\+\text{round}\end{bmatrix}$	*potho - pothy* *taitho - taithy*	['pɑθo] - ['pɑθi] ['teɪθo] - ['teɪθi]
No [ɔɪ] *before* [ʃ, ʒ, tʃ, dʒ]	h. $*\begin{bmatrix}+\text{diphthong}\\+\text{round}\\-\text{back}\end{bmatrix}[-\text{ant}]$	*noiron - nyron* *boitcher - boisser*	['nɔɪɹən] - ['naɪɹən] ['bɔɪtʃɚ] - ['bɔɪsɚ]
No [ʒ] *before stressed vowel + obstruent*	i. $*\begin{bmatrix}+\text{cont}\\+\text{voice}\\-\text{ant}\end{bmatrix}[+\text{stress}]\ [-\text{son}]$	*zhep - zhem* *zhod - zhar*	['ʒɛp] - ['ʒɛm] ['ʒɑd] - ['ʒɑɹ]
Initial [aʊ, ɔɪ] *may not precede a voiced obstruent*	j. $*[_{\text{word}}\begin{bmatrix}+\text{diphthong}\\+\text{round}\end{bmatrix}\begin{bmatrix}-\text{son}\\+\text{voice}\end{bmatrix}$	*ouzie - oussie* *oid - oit*	['aʊzi] - ['aʊsi] ['ɔɪd] - ['ɔɪt]

DO LEARNERS SHOW AWARENESS OF THE UNNATURAL CONSTRAINTS?

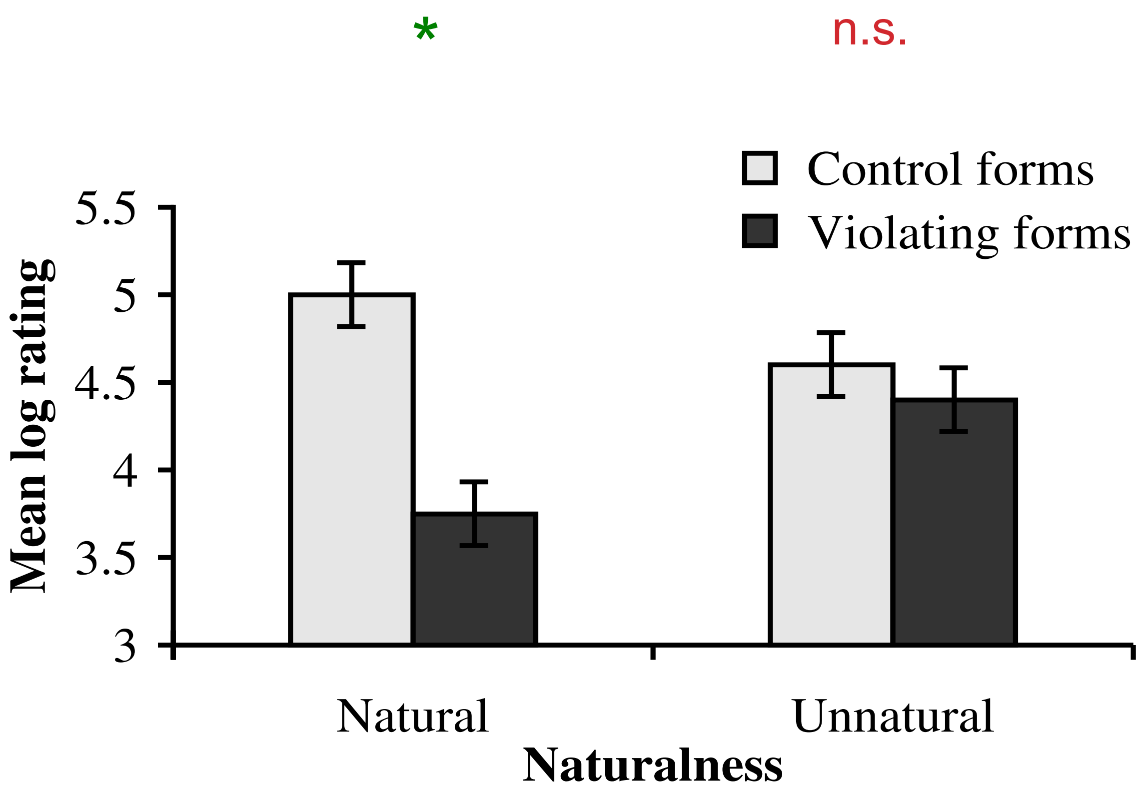
(TO THE SAME LEVEL AS THE NATURAL CONSTRAINTS?)

MAGNITUDE ESTIMATION TASK



Participants: 29 English speakers

RESULTS



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INDIVIDUAL CONSTRAINTS

Effects of individual constraints

Constraint	Status	Pairs	Effect size
*[−cont] [−cont] in onset	natural	*cping/sping*, *ctice/stice*	1.65
*[glide] in coda	natural	*jouy/jout*, *tighw/tibe*	1.56
*[−cons] [+cons] in onset	natural	*hlup/plup*, *hmit/smit*	1.51
*[−cont] [+nasal] in onset	natural	*cnope/clope*, *pneck/sneck*	1.44
*[+labial] [+dorsal] in coda	natural	*rufk/ruft*, *trefk/treft*	1.44
*[+dorsal] [+labial] in coda	natural	*bikf/bimf*, *sadekp/sadect*	1.36
*[+cons] [−cons] in coda	natural	*shapenr/shapent*, *tilr/tilse*	1.34
*[−son] [+son] in coda	natural	*canifl/canift*, *kipl/kilp*	1.31
*[+labial] [+labial] in onset	natural	*bwell/brell*, *pwickon/twickon*	1.23
$*\begin{bmatrix}+\text{coronal}\\+\text{cont}\\-\text{strident}\end{bmatrix}[-\text{son}]$	unnatural	*hethker/hethler*, *muthpy/muspy*	1.14
$*\begin{bmatrix}+\text{cont}\\-\text{strident}\end{bmatrix}\begin{bmatrix}-\text{stress}\\+\text{round}\end{bmatrix}$	unnatural	*potho/pothy*, *taitho/taithy*	1.10
$*\begin{bmatrix}+\text{diphthong}\\+\text{round}\\-\text{back}\end{bmatrix}[-\text{ant}]$	unnatural	*boitcher/boisser*, *noiron/nyron*	1.10
$*[+\text{diphthong}]\begin{bmatrix}+\text{cont}\\-\text{ant}\end{bmatrix}$	unnatural	*foushert/fousert*, *pyshon/pyson*	1.08
$*[_{\text{word}}\begin{bmatrix}-\text{diphthong}\\+\text{round}\\+\text{high}\end{bmatrix}$	unnatural	*ooker/ocker*, *utrum/otrum*	1.03
*[−back] [+diphthong]	unnatural	*youse/yoss*, *yout/yut*	1.02
$*[_{\text{word}}\begin{bmatrix}+\text{diphthong}\\+\text{round}\end{bmatrix}\begin{bmatrix}-\text{son}\\+\text{voice}\end{bmatrix}$	unnatural	*oid/oit*, *ouzie/oussie*	1.02
$*\begin{bmatrix}+\text{cont}\\+\text{voice}\\-\text{ant}\end{bmatrix}[+\text{stress}]\,[-\text{son}]$	unnatural	*zhep/zhem*, *zhod/zhar*	1.01
$*\begin{bmatrix}+\text{cons}\\-\text{ant}\end{bmatrix}[-\text{son}]$	unnatural	*ishty/ishmy*, *metchter/metchner*	0.99
$*\begin{bmatrix}-\text{son}\\-\text{voice}\end{bmatrix}\begin{bmatrix}-\text{son}\\+\text{voice}\end{bmatrix}$	natural	*esger/ezger*, *trocdal/troctal*	0.98
$*\begin{bmatrix}+\text{round}\\+\text{high}\end{bmatrix}\begin{bmatrix}-\text{cons}\\-\text{son}\end{bmatrix}$	unnatural	*luhallem/laihallem*, *tuhaim/towhaim*	0.97

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