USING ARTIFICIAL LANGUAGE LEARNING EXPERIMENTS TO STUDY BIASES IN PHONOLOGICAL LEARNING

EDINBURGH VIRTUAL WORKSHOP ON ARTIFICIAL LANGUAGE LEARNING 2021

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SLIDES

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(or google ‘james white ucl’)

INTRODUCTION

BIG PICTURE

Input (observable)

Learning mechanisms *A priori* biases

Grammar/
Linguistic knowledge

Processing and performance factors

(unobservable)

Output (observable)

LEARNING BIASES

‘HARD’ BIASES

Hard biases: absolute restrictions.

- Grammars/languages that are inconsistent with the bias are not available to the learner ⟶ **not a possible language**.
- Traditional view of Universal Grammar (UG).
- Majorly restricts the hypothesis space thus simplifying the learning problem.

Examples:

- Principles & Parameters: Child only needs to set a limited set of parameter switches – languages outside this set impossible to learn. (Chomsky & Lasnik 1995)
- Classical OT: Child only needs to find a suitable ranking from a universal constraint set – languages with no possible ranking impossible to learn. (Prince & Smolensky 1993)

'SOFT' BIASES

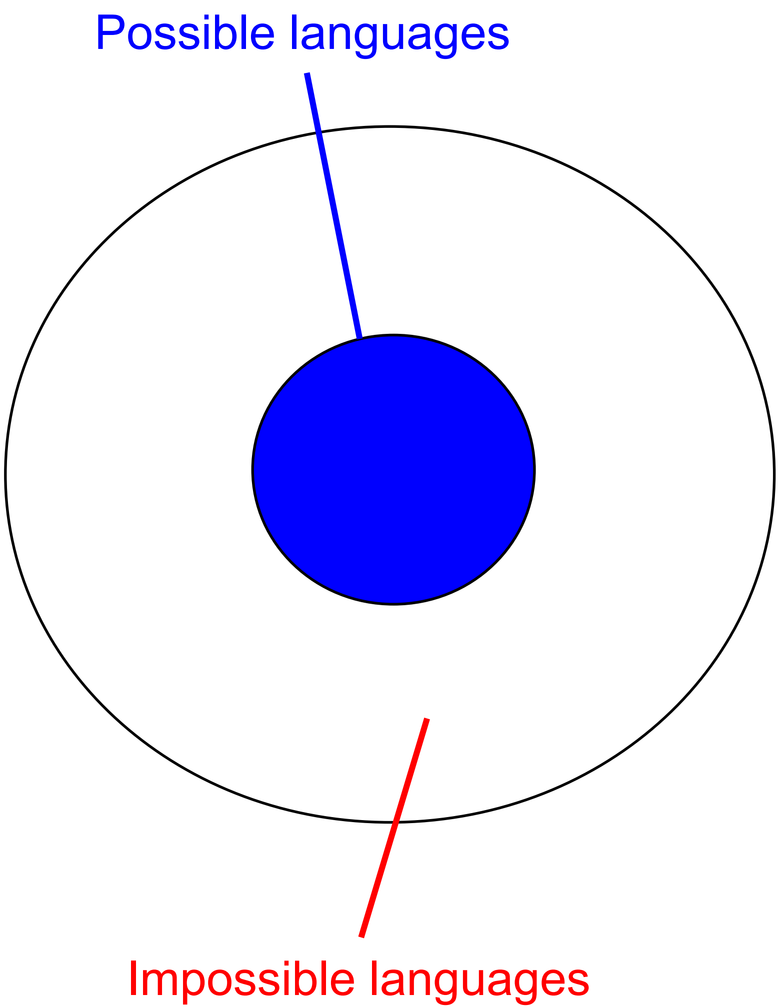
Soft biases: learning preferences

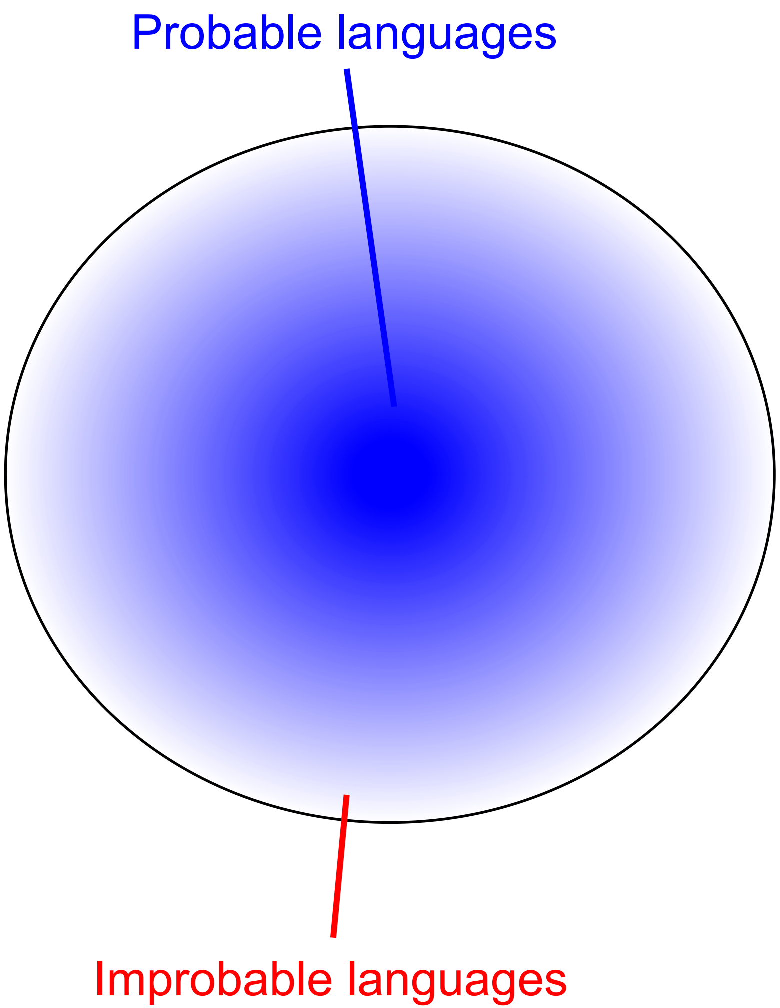
- Grammars/languages inconsistent with the bias are dispreferred by learners, though still available ⟶ **not a likely language**.
- Allows greater leeway in what is a possible language, while still constraining the hypothesis space.
- More easily implemented in a probabilistic model.

Example:

- Priors in maximum entropy (MaxEnt) models (e.g. Wilson 2006,Culbertson et al. 2013, White 2017).

HARD VS. SOFT BIASES





WHY ARTIFICIAL LANGUAGE EXPERIMENTS?

Advantages

- Can test the learnability of any pattern you want, without being restricted to what exists in a real language.
- Can control for potentially confounding properties that may exist in real languages.
- Allows full control over the type and amount of input that participants receive.
- Easy to perform in the lab (or even online).

Disadvantages

- Potential L1 effects.
- Artificial, often very explicit, learning conditions.
- Concerns about whether it uses the same mechanisms as real language learning.
  - So it is ideally used in combination with other sources of evidence.

HOW DO WE SHOW THAT THERE IS A LEARNING BIAS?

‘Null’ hypothesis: **learners learn exactly what is provided in the input, nothing more and nothing less.**

Two basic strategies for demonstrating a learning bias:

1. **Underlearning**:
   - Pattern A and Pattern B are equally supported in the input.
   - Pattern A is learned.
   - Pattern B is not learned, or is not learned as quickly or as completely as Pattern A.
2. **Systematic assumption without evidence**:
   - Input lacks information about certain cases.
   - Learner makes principled assumptions about unseen cases; the behaviour cannot be attributed to the input or chance.
   - E.g.: Generalize Pattern A to some unseen case, but not others.

PHONETIC NATURALNESS VS. SIMPLICITY

VOWEL HARMONY VS DISHARMONY

Harmony

$V_{\alpha} \ldots V \longrightarrow V_{\alpha} \ldots V_{\alpha}$

Disharmony

$V_{\alpha} \ldots V \longrightarrow V_{\alpha} \ldots V_{-\alpha}$

Vowel harmony is:

- Typologically common
- Phonetically motivated

Vowel disharmony is:

- Very rare
- Not phonetically motivated

Pycha, Nowak, Shin & Shosted (2003), *WCCFL*

HARMONY AND LEARNING

(Phonetic) Naturalness hypothesis:

$V_{\alpha} \ldots V \longrightarrow V_{\alpha} \ldots V_{\alpha}$ $\longrightarrow$ **easier to learn**

$V_{\alpha} \ldots V \longrightarrow V_{\alpha} \ldots V_{-\alpha}$ $\longrightarrow$ **harder to learn**

Simplicity hypothesis:

$V_{\alpha} \ldots V \longrightarrow V_{\alpha} \ldots V_{\alpha}$ $\longrightarrow$ **easier to learn**

$V_{\alpha,\beta} \ldots V \longrightarrow V_{\alpha} \ldots V_{\alpha}$ $\longrightarrow$ **harder to learn**

Pycha, Nowak, Shin & Shosted (2003), *WCCFL*

DESIGN

Learned one of three languages:

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

Predictions for learning

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

Pycha, Nowak, Shin & Shosted (2003), *WCCFL*

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]
  - Variety of consonants

- –VC suffix:
  - [ɛk] ~ [ʌk]

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] … [gipɛk] (or [gipʌk] in DH condition)

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

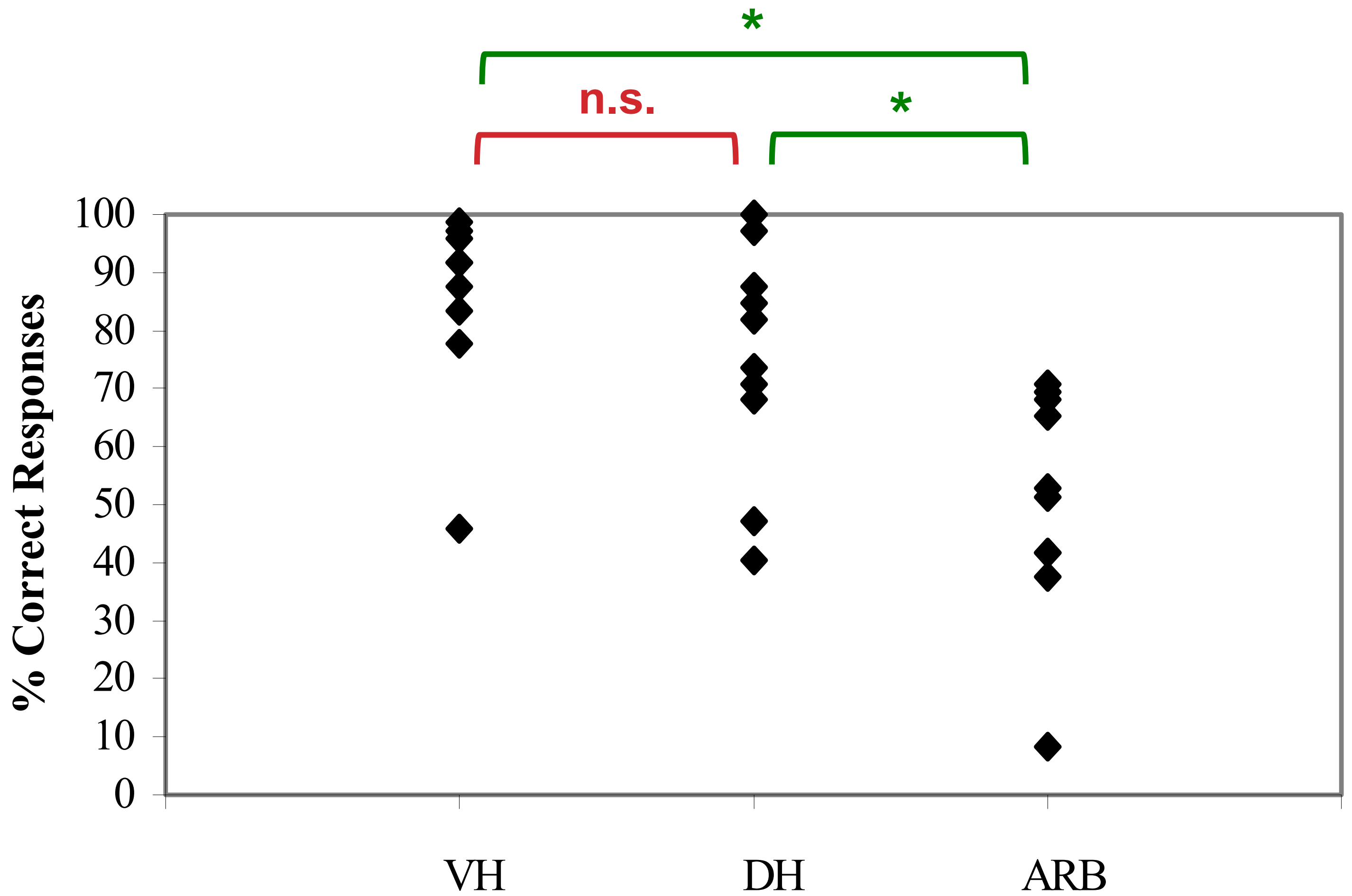
   [gip] … [gipɛk] … Correct plural? ⟶ Feedback

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

   [fig] … [figɛk] … Correct plural? (No feedback)

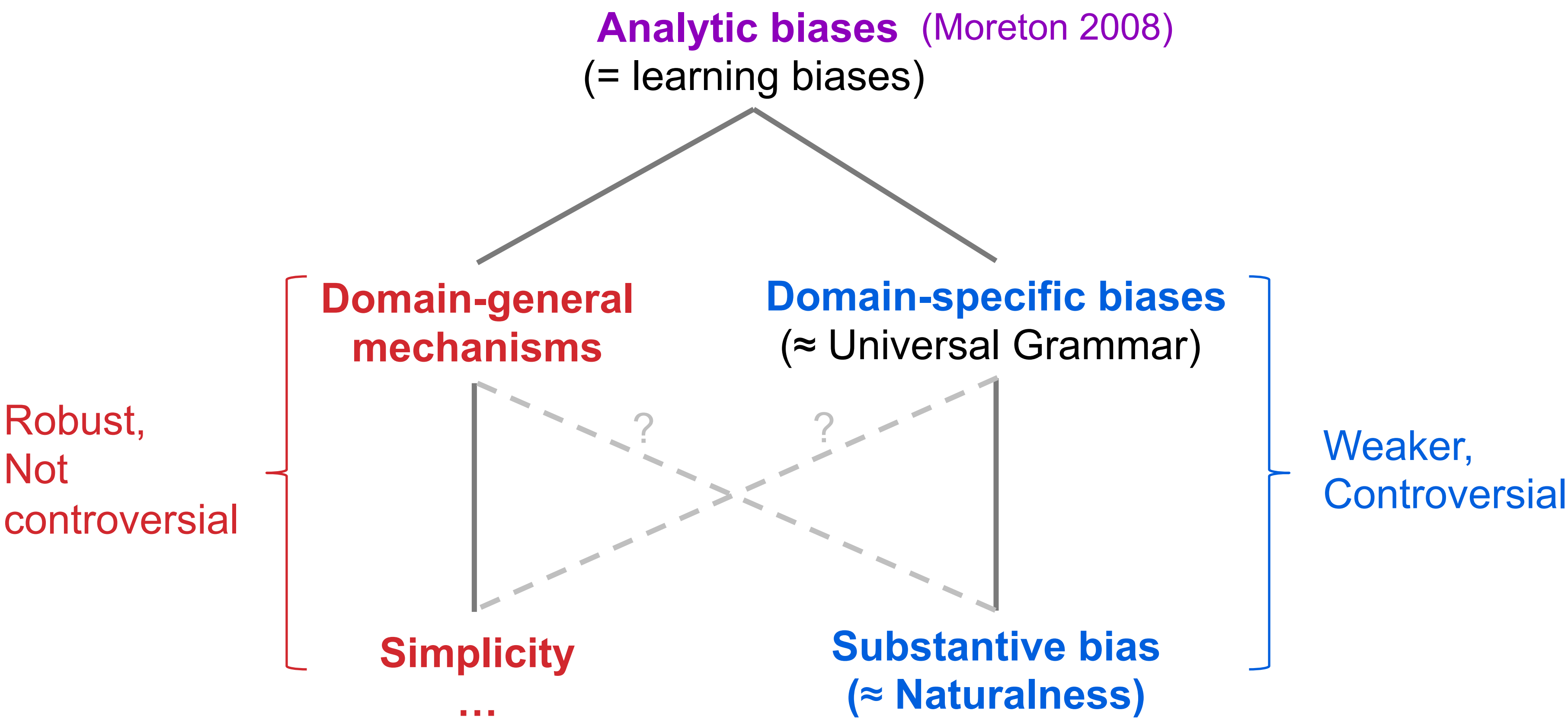
Pycha, Nowak, Shin & Shosted (2003), *WCCFL*

RESULTS



Mean correct: 86% 75% 51%

SIMPLICITY VS. NATURALNESS



See Moreton & Pater (2012a,b) for discussion.

BACK TO HARMONY: NOT SO FAST...

Assumed generalisations learned:

- **Harmony**:

  V ⟶ [αF] / [αF] ___ (or: *[αF][–αF])

  Predicting: **F F F F** and **B B B B**

- **Disharmony**:

  V ⟶ [–αF] / [αF] ___ (or: *[αF][αF])

  Predicting: **F B F B** and **B F B F**

But, if participants learn [gip] ⟶ [gip-ʌk], have they really learned a <u>general</u> disharmony rule?

- Would they extend the pattern to hypothetical [gip-ʌk-ɛb-ʌt]?
- If not, can we really say disharmony is equally learnable?

Martin & White (2021), *Linguistic Inquiry*

DESIGN

Learned one of two languages:

1. **Harmony**:

   [peti] ⟶ [peti-fi], [peti] ⟶ [peti-be]

   [pogu] ⟶ [pogu-fu], [pogu] ⟶ [pogu-bo]

2. **Disharmony**:

   [petu] ⟶ [petu-fi], [petu] ⟶ [petu-be]

   [pogi] ⟶ [pogi-fu], [pogi] ⟶ [pogi-bo]

Test:

- What happens if participants have to add both suffixes at once?

Martin & White (2021), *Linguistic Inquiry*

METHOD

Participants

- 120 American English speakers (who passed attention checks); 60 per group. Recruited online.

Training

- 64 trials (32 stems x 2 suffixes)
- Example: [peti] ⟶ [peti-fi], [peti] ⟶ [peti-be]
- Paired with pictures. Suffixes meant plural or diminutive (counterbalanced).

Test

- 32 single suffix trials (16 novel stems x 2 suffixes).
- 16 critical double suffix trials (1 per stem).

SINGLE SUFFIX TEST TRIALS

Harmony

[gise]

…

[gise-fi] [gise-fu]

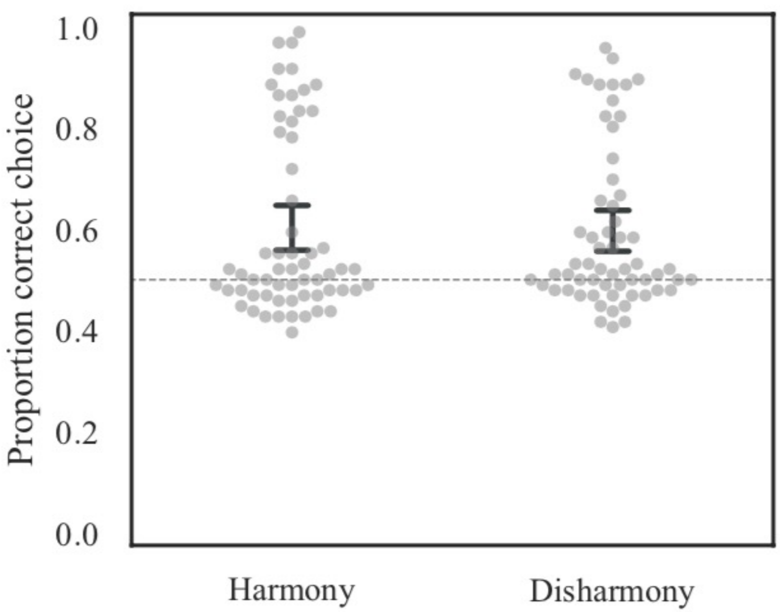
Disharmony

[giso]

…

[giso-fi] [giso-fu]

n.s.



Martin & White (2021), *Linguistic Inquiry*

DOUBLE SUFFIX TEST TRIALS

Harmony

[gise]

…

[gise-fi-be] [gise-fu-be]

[gise-fi-bo] [gise-fu-bo]

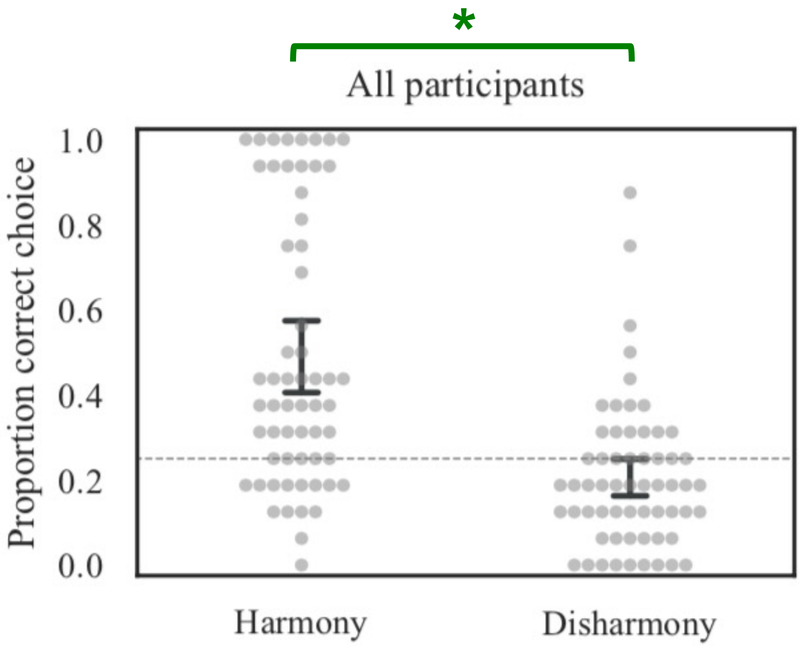
Disharmony

[giso]

…

[giso-fi-be] [giso-fu-be]

[giso-fi-bo] [giso-fu-bo]



Martin & White (2021), *Linguistic Inquiry*

SINGLE SUFFIX TEST TRIALS

Harmony

[gise]

…

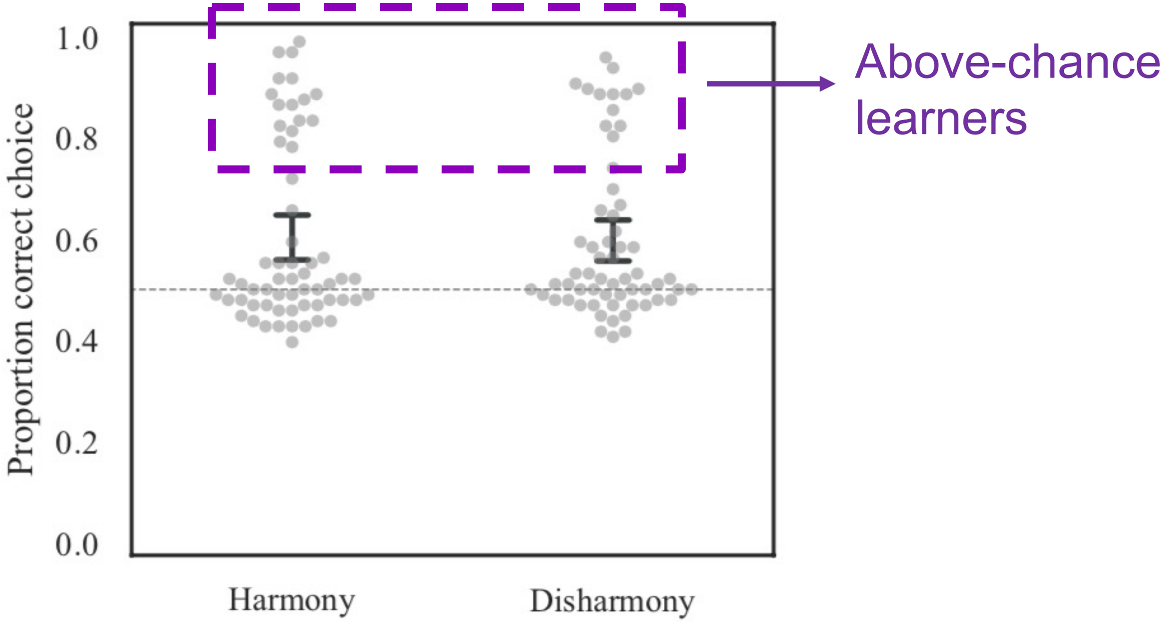
[gise-fi] [gise-fu]

Disharmony

[giso]

…

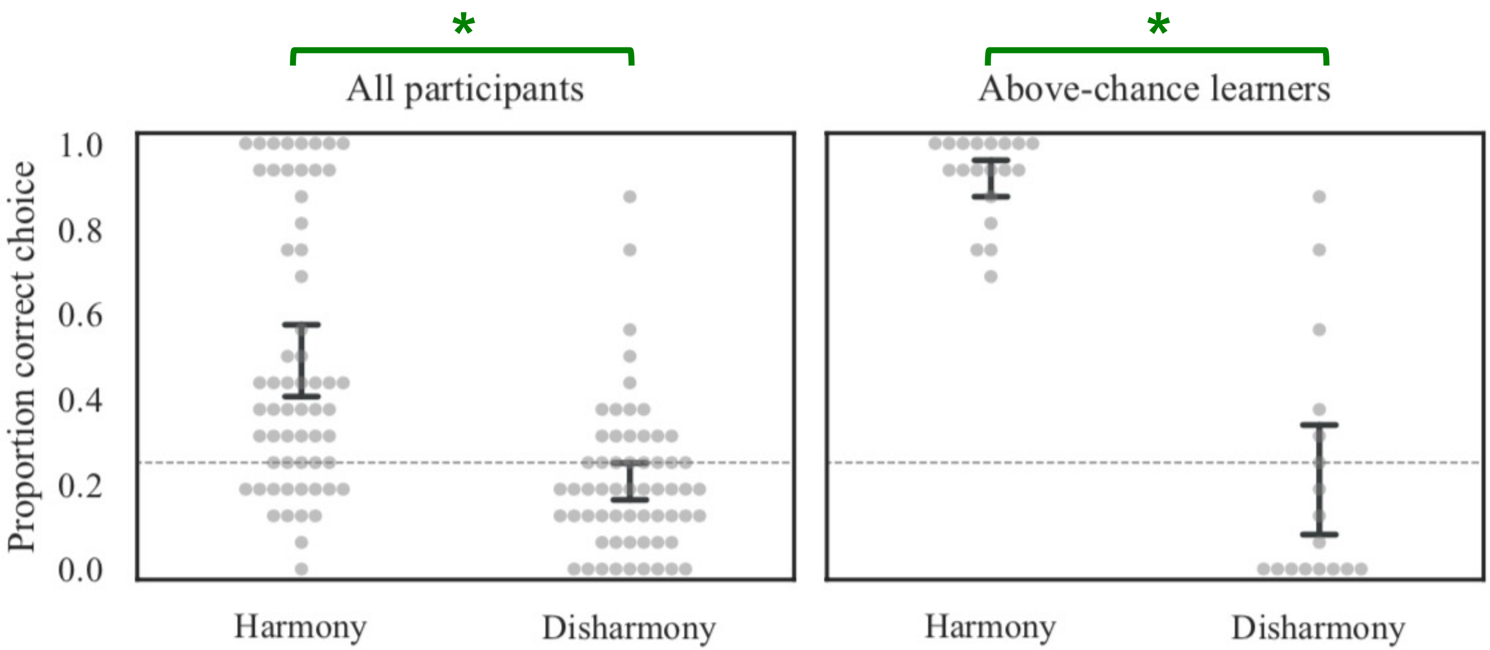
[giso-fi] [giso-fu]



Martin & White (2021), *Linguistic Inquiry*

DOUBLE SUFFIX TEST TRIALS

Harmony		**Disharmony**	
[gise]		[giso]	
…		…	
[gise-fi-be]	[gise-fu-be]	[giso-fi-be]	[giso-fu-be]
[gise-fi-bo]	[gise-fu-bo]	[giso-fi-bo]	[giso-fu-bo]



Martin & White (2021), *Linguistic Inquiry*

TWO MAIN PARADIGMS

Direct learnability

Train 2 groups on minimally different patterns.

→ Is Pattern A learned better than Pattern B?

Pros

- Usually easier to design.

Cons

- Prone to ceiling and floor effects. Amount of training is critical.
- May require a lot of piloting.

‘Poverty of the Stimulus’

(Wilson 2006)

Train with input that is ambiguous between 2 analyses.

→ Is Pattern A preferred to Pattern B?

Pros

- Less prone to ceiling and floor effects. Amount of training more flexible.
- More variables controlled.
- Usually less piloting needed.

Cons

- May be difficult / impossible to design for some questions.

SALTATORY ALTERNATIONS

SALTATORY ALTERNATION

- Example from Campidanian Sardinian (Bolognesi 1998):
  - p ⟶ β/ V __ V, but /b/ remains unchanged

[pãi] ⟶ [s:u βãi] ‘the bread’

[bĩu] ⟶ [s:u bĩu] ‘the wine’

p	2 feature changes ⟶	β
-continuant		+continuant
-voice		+voice
+labial		+labial

White (2014), *Cognition*

SALTATORY ALTERNATION

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  - p ⟶ β/ V __ V, but /b/ remains unchanged

[pãi] ⟶ [s:u βãi] ‘the bread’

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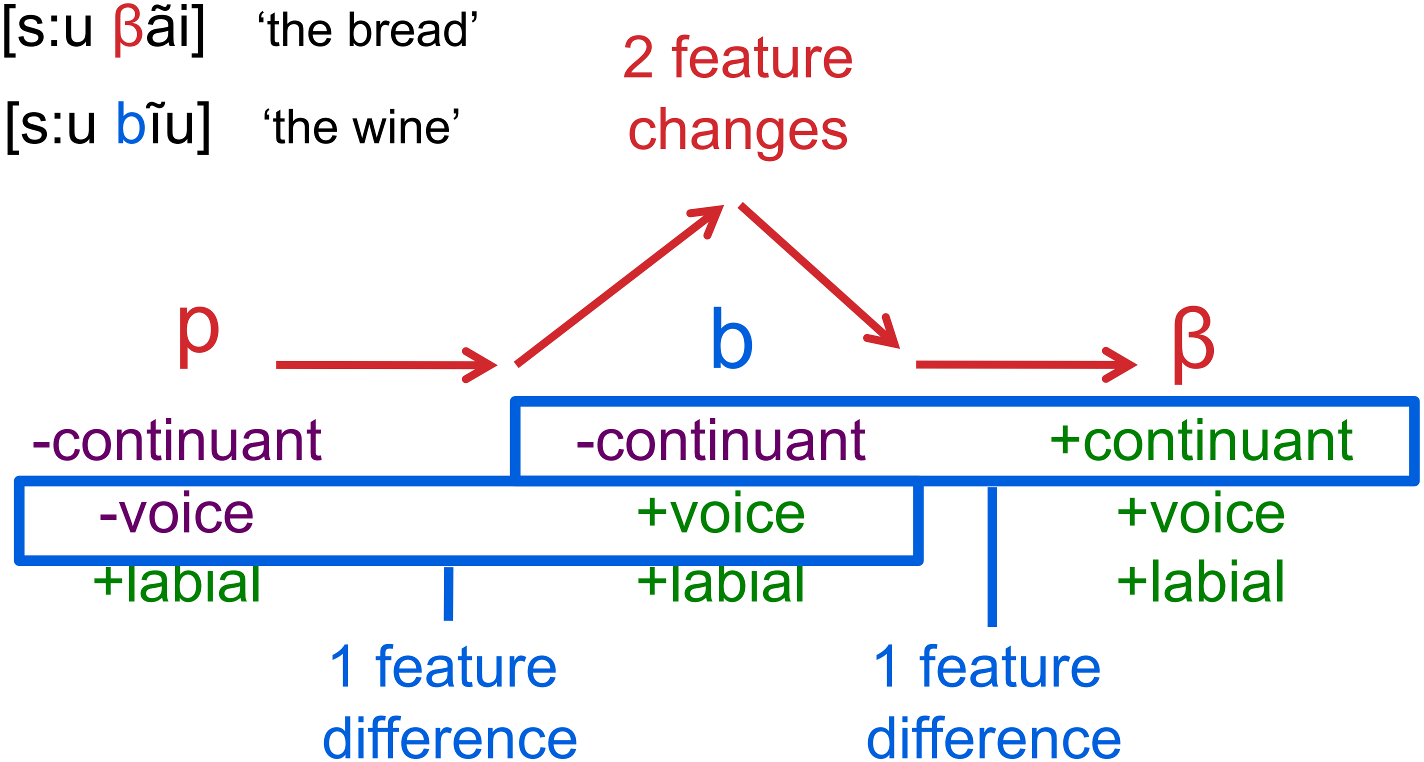
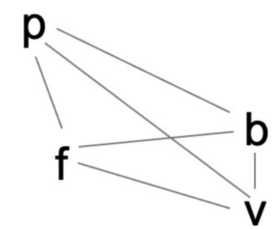


White (2014), *Cognition*

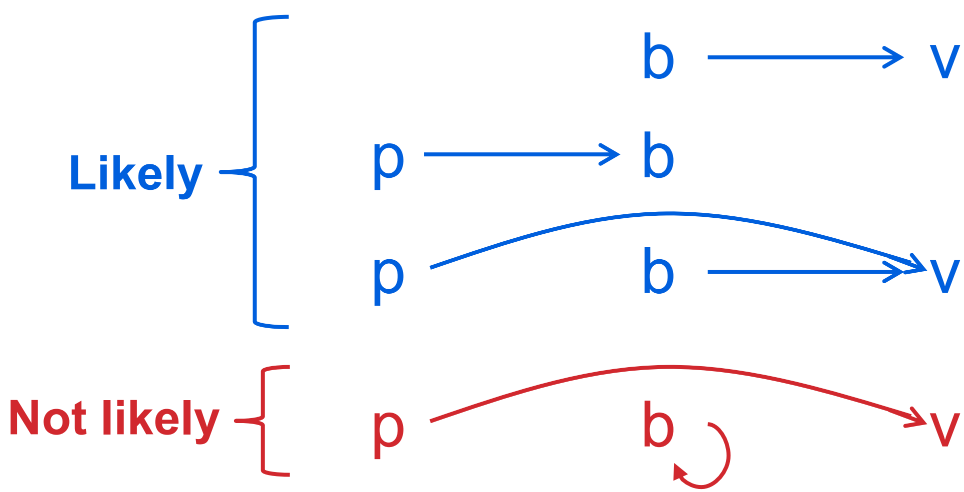
MINIMAL MODIFICATION BIAS

Phonological alternations tend to occur between phonetically similar sounds.



Steriade's (2001/2009) P-map proposal:

- Speakers develop a mental representation of the relative perceptual similarity of speech sounds = the perceptibility map (P-map)
- Learners have a minimal modification bias during learning: they assume phonological processes will involve the smallest possible change.



DO LEARNERS DISPREFER SALTATORY ALTERNATIONS?

PROCEDURE

1. Exposure phase

[kamap]

[kamavi]

White (2014), *Cognition*

PROCEDURE

1. Exposure phase

[kamap]

[kamavi]

2. Verification phase

[kamap]

[kamapi]
or
[kamavi]???

No

Yes ← 80% correct?

3. Generalization phase

[lunub]

[lunubi]
or
[lunuvi]???

EXPOSURE INPUT

Potentially Saltatory condition

$p \rightarrow v$ $\quad$ $t \rightarrow ð$

Control condition

$b \rightarrow v$ $\quad$ $d \rightarrow ð$

<u>Both conditions</u>: non-alternating **<u>filler</u>** sounds [m, n, l, r, s, ʃ]

From now on, I will be representing only the <u>labials</u> for simplicity.

White (2014), *Cognition*

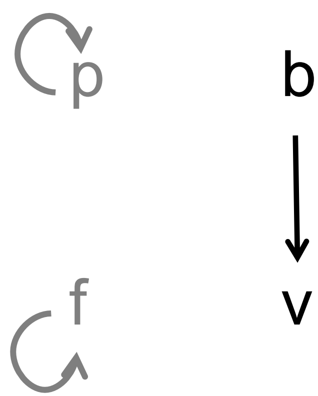
EXPOSURE INPUT

Control condition input:

$$b \longrightarrow v$$

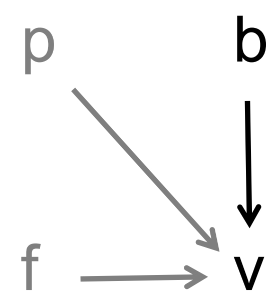
(also: m ⟶ m, n ⟶ n, l ⟶ l ...)

Possible interpretations:



Non-saltatory

No new alternations posited



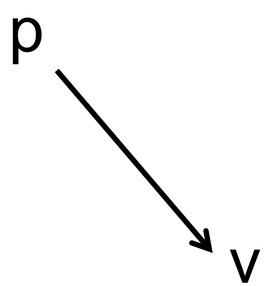
Non-saltatory

New alternations posited

White (2014), *Cognition*

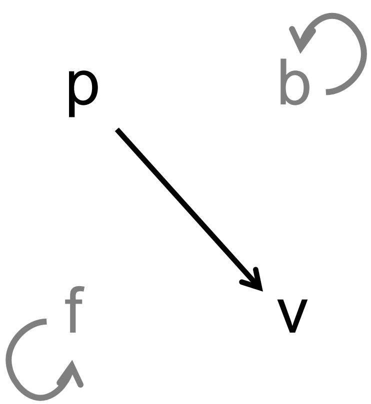
EXPOSURE INPUT

Potentially Saltatory condition input:



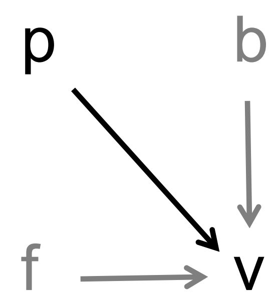
(also: m → m, n → n, l → l ...)

Possible interpretations:



Saltatory

No new alternations posited



Non-saltatory

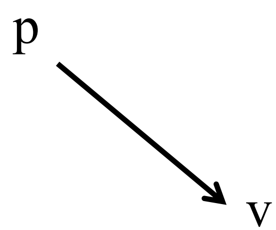
New alternations posited

White (2014), *Cognition*

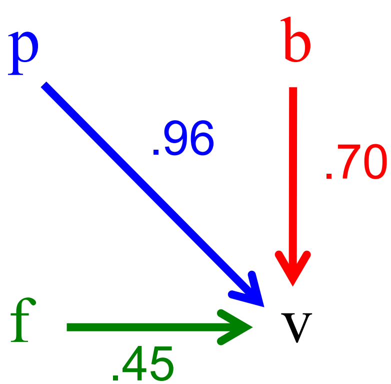
RESULTS (GENERALIZATION PHASE)

Potentially Saltatory condition

Input:

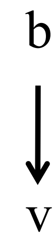


Results:

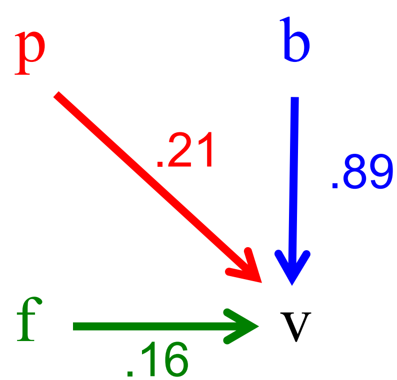


Control condition

Input:



Results:

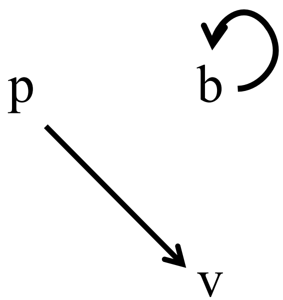


White (2014), *Cognition*

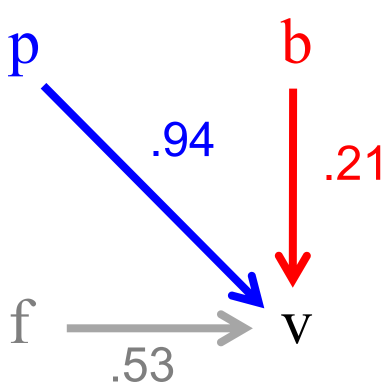
EXP. 2

Explicitly Saltatory condition

Input:

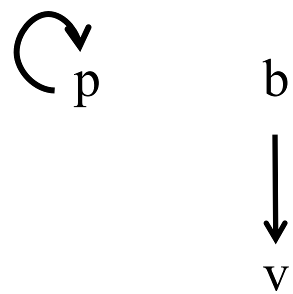


Results:

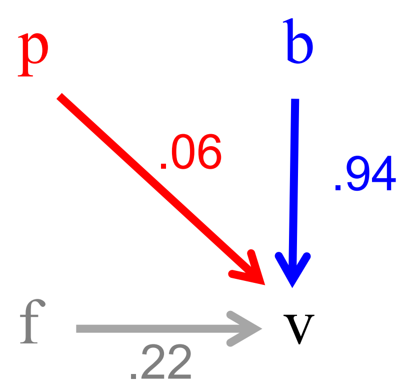


Control condition

Input:



Results:



White (2014), *Cognition*

SUMMARY

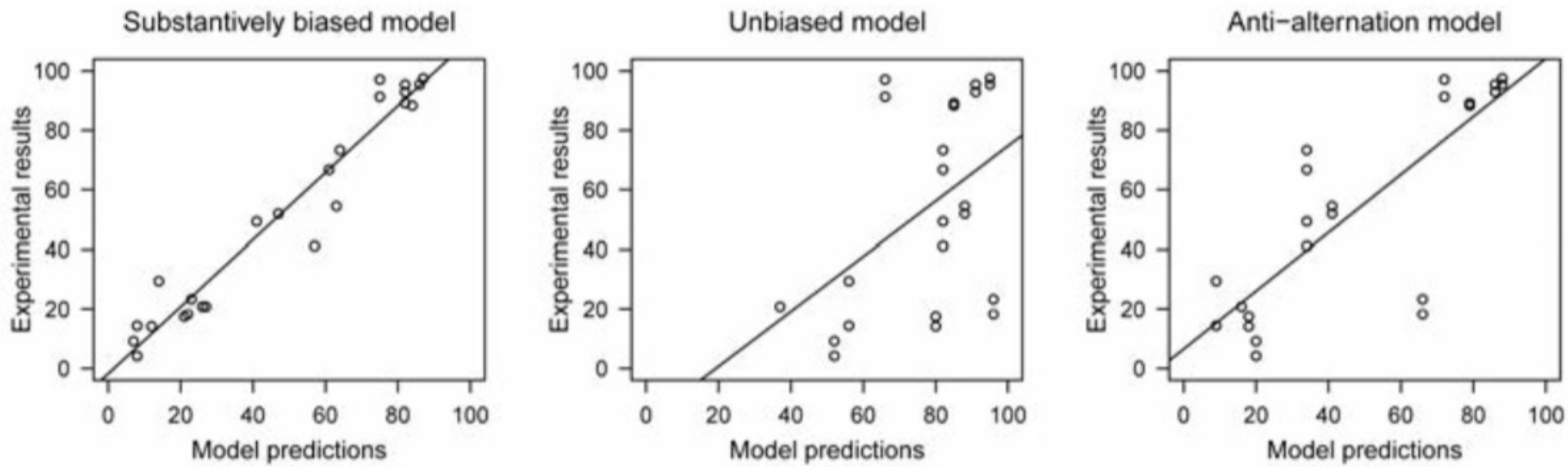
Participants generalised ambiguous alternations in a way that rendered them non-saltatory.

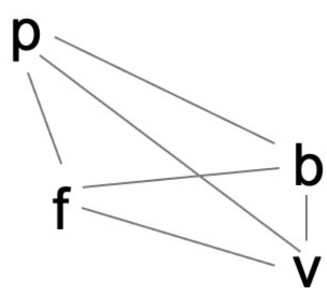
- That is, they generalised an alternation between dissimilar sounds to include more similar sounds (but not vice versa).

Even when they were taught explicitly saltatory alternations, they tended to change the intermediate sounds.

White (2014), *Cognition*

IS IT SUBSTANTIVE BIAS?





White (2017), *Language*

NEUTRALISATION AND HOMOPHONY AVOIDANCE

INTERACTION OF PHONOLOGICAL LEARNING AND LEXICAL LEARNING

NEUTRALISATION

Tapping in American English:

pat [pæt] *pad* [pæd]

[pæɾɪŋ]

patting / padding

Lexical neutralisation / homophony creation

/ t / / d /

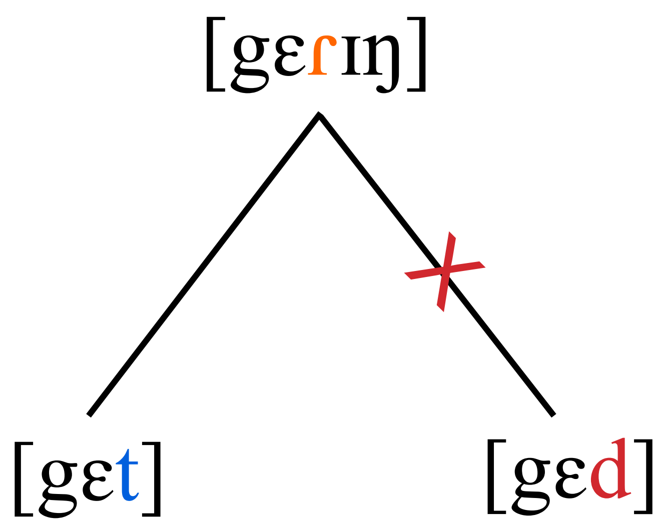
[ɾ]

Phonological neutralisation

Yin & White (2018), *Cognition*

NEUTRALISATION

Phonological neutralisation $\nrightarrow$ lexical neutralisation



<u>Potential</u> homophony, but not actual homophony.

Yin & White (2018), *Cognition*

OVERVIEW

Question: Do people find phonological rules more difficult to learn if they are neutralising?

Basic scheme:

- Teach people a set of novel phonological rules.
- Vary whether the rules result in neutralisation.
- Test whether they find the non-neutralising rules easier to learn than the neutralising ones.
- <u>Exp 2</u>: Also vary whether neutralising rules result in homophony.

Yin & White (2018), *Cognition*

EXP 1: METHOD

Participants:

- 30 Native English speakers (university age)

3 phases:

- Exposure
- Test phase I: Trained items
- Test phase II: Novel items

Learned 4 novel alternations:

/ t, d, s, z / → [tʃ, dʒ, ʃ, ʒ] / __ i

EXP 1: DESIGN

	Language A	Language B
Alternations	/ t / ⟶ [tʃ] / d / ⟶ [dʒ] / s / ⟶ [ʃ] / z / ⟶ [ʒ]	/ t / ⟶ [tʃ] / d / ⟶ [dʒ] / s / ⟶ [ʃ] / z / ⟶ [ʒ]
Critical non-alternating phonemes	/ tʃ, dʒ /	/ ʃ, ʒ /
Filler non-alternating phonemes	/ p, b, k, g, f, v/	/ p, b, k, g, f, v/

Yin & White (2018), *Cognition*

EXP 1: STIMULI

Exposure stimuli: 48 CVCVC singular nonwords with CVCVC-i plural forms.

- 8 alternating [t ~ tʃ] and [d ~ dʒ] (Neutralising in Language A)

  [tusut] ⟶ [tusutʃi]

- 8 alternating [s ~ ʃ] and [z ~ ʒ] (Neutralising in Language B)

  [duvis] ⟶ [duviʃi]

- 8 critical non-alternating trials ending in [tʃ, dʒ] (Language A) or [ʃ, ʒ] (Language B)

  [buvatʃ] ⟶ [buvatʃi] / [buvaʃ] ⟶ [buvaʃi]

- 24 non-alternating filler trials ending in [p, b, k, g, f, v]

  [vatuk] ⟶ [vatuki]

Yin & White (2018), *Cognition*

EXP 1: STIMULI

Illegal sequences never presented.

- *[ti, di] in Language A.
- *[si, zi] in Language B.

Otherwise, C and V distribution roughly balanced across positions.

Yin & White (2018), *Cognition*

EXP 1: PROCEDURE

1. Exposure phase

[tusut]

[tusutʃi]

2. Test phase (2AFC)

[dazat]

[dazatʃi]

…

[dazati]

Yin & White (2018), *Cognition*

TEST PHASE: TRAINED AND NOVEL ITEMS

Test phase 1: Trained items

- 24 items from exposure (2 ending in each phoneme)

Test phase 2: Novel items

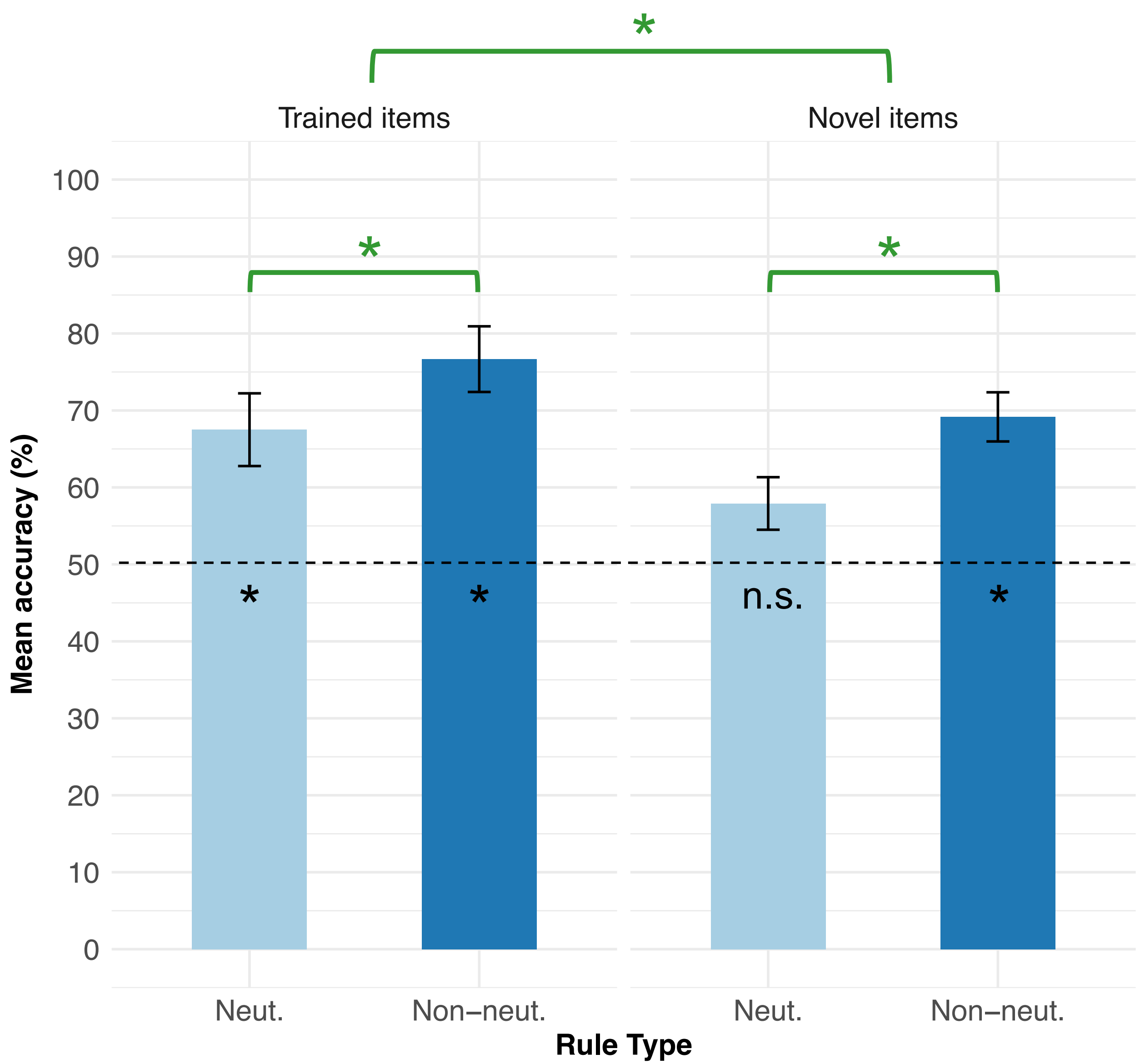
- 48 novel items
- Same type and proportions as in exposure

Main focus here is on Novel items.

- Novel items tell us whether learners have acquired a general rule (necessary to apply the pattern to new forms).
- Trained items can just be memorised/recognised, without learning a pattern.

Yin & White (2018), *Cognition*

EXP 1: RESULTS



Interaction
n.s.

Yin & White (2018), *Cognition*

EXPERIMENT 2

How much of the neutralisation avoidance effect is driven by homophony avoidance?

- In Exp. 1: Neutralising rules resulted in homophony 50% of the time.

In Exp. 2, we manipulated the amount of homophony.

- If homophony matters, more homophony creation ⟶ more difficulty learning neutralising rules.

EXPERIMENT 2

Exp 1: Half lexical neutralisation

/t/-final	tusut	tusutʃi
	buvat	buvatʃi
	tʃuzat	tʃuzatʃi
	faput	faputʃi
/tʃ/-final	tusutʃ	tusutʃi
	buvatʃ	buvatʃi
	pifitʃ	pifitʃi
	gizutʃ	gizutʃi

Exp 2: Homophony condition

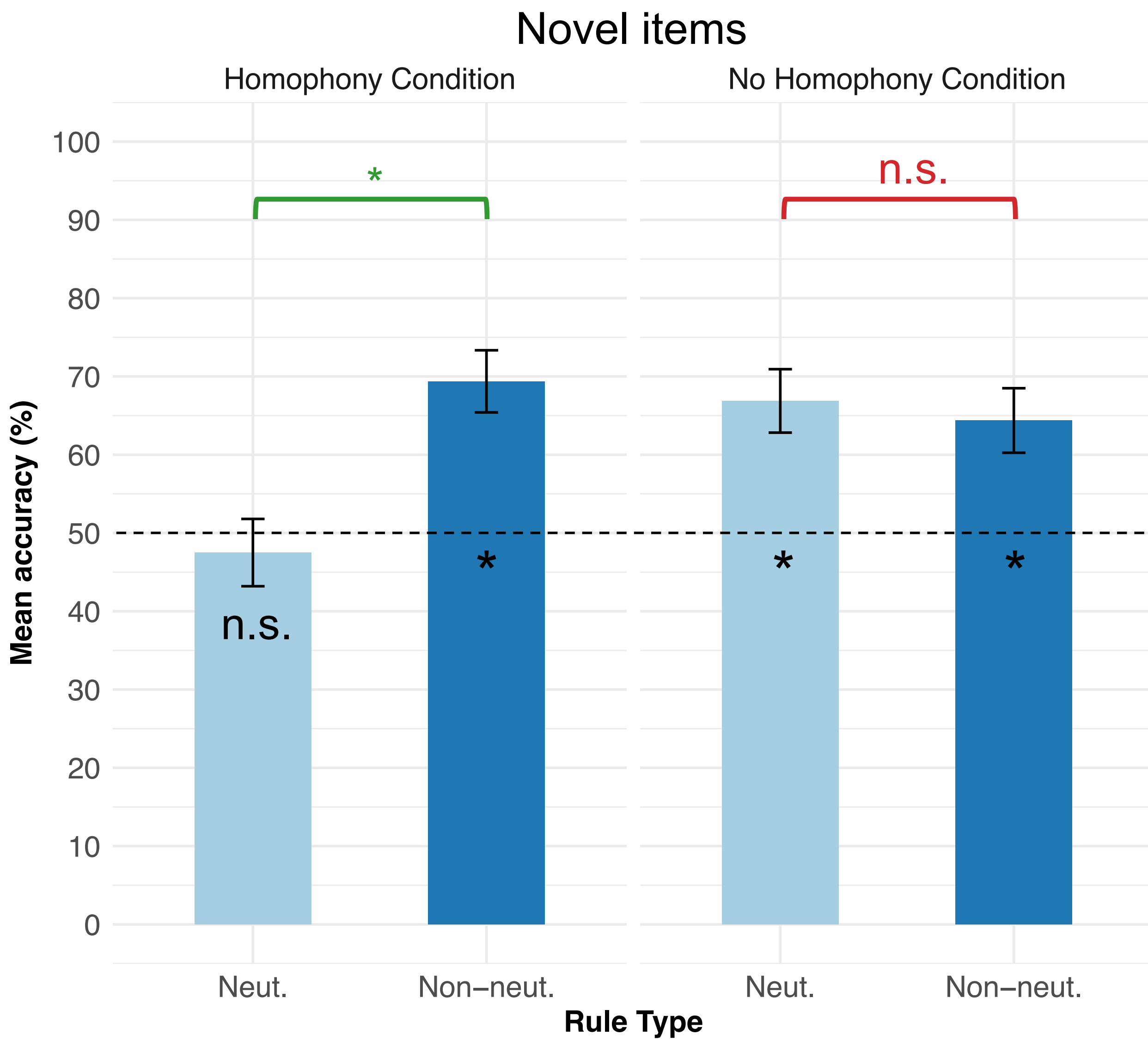
/t/-final	tusut	tusutʃi
	buvat	buvatʃi
	tʃuzat	tʃuzatʃi
	faput	faputʃi
/tʃ/-final	tusutʃ	tusutʃi
	buvatʃ	buvatʃi
	tʃuzatʃ	tʃuzatʃi
	faputʃ	faputʃi

Exp 2: No Homophony condition

/t/-final	tusut	tusutʃi
	buvat	buvatʃi
	tʃuzat	tʃuzatʃi
	faput	faputʃi
/tʃ/-final	busutʃ	busutʃi
	tavutʃ	tavutʃi
	pifitʃ	pifitʃi
	gizutʃ	gizutʃi

Yin & White (2018), *Cognition*

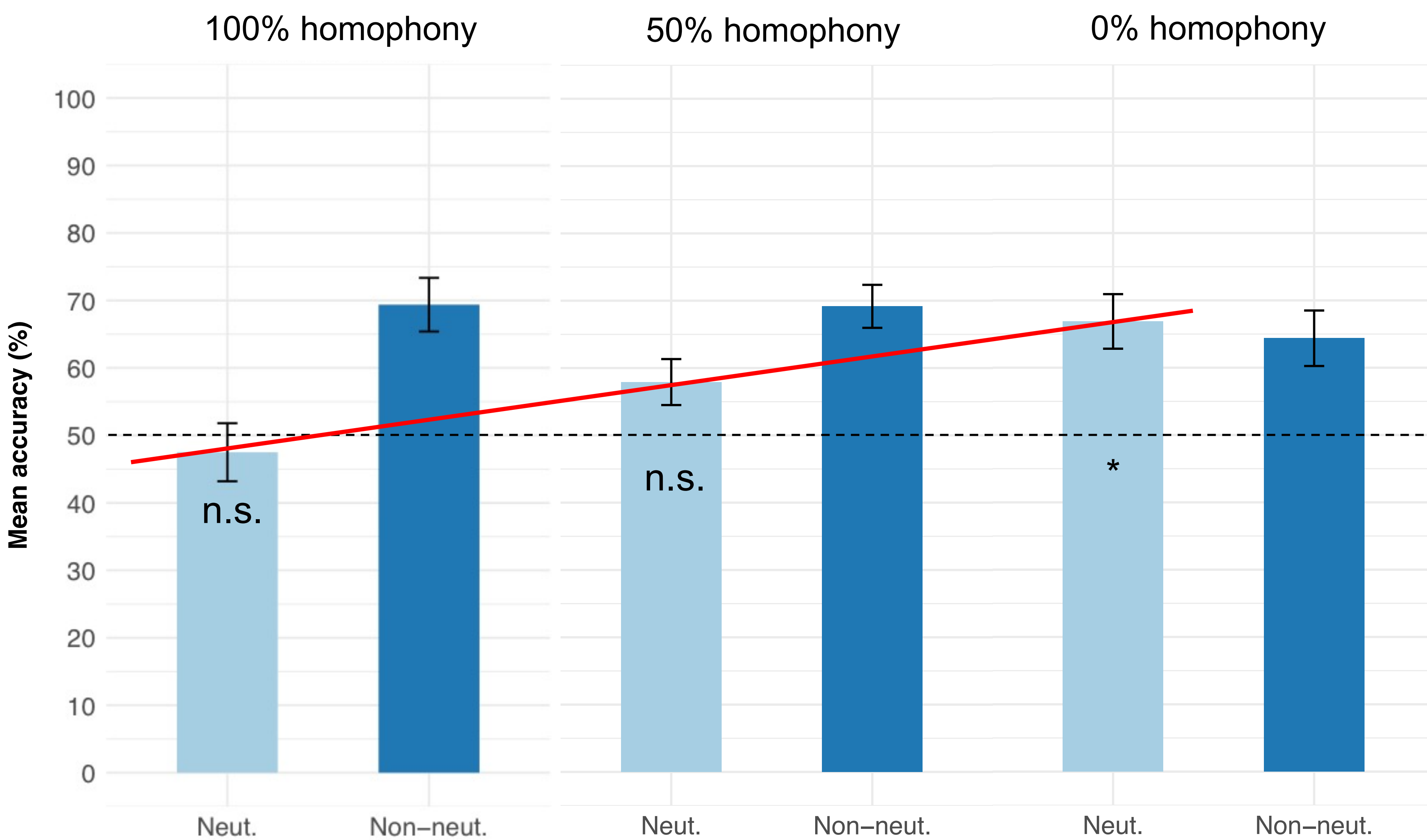
EXP 2: RESULTS



Interaction
$p < .01$

Yin & White (2018), *Cognition*

ACROSS HOMOPHONY LEVELS



SUMMARY

50% Homophony (Exp 1):

- Non-neutralising rules > Neutralising rules
- Neutralising rules @ chance level (novel items).

100% Homophony (Exp 2, Homophony):

- Non-neutralising rules > Neutralising rules
- Neutralising rules @ chance level (novel items).

0% Homophony (Exp 2, No Homophony):

- Non-neutralising rules = Neutralising rules
- All above chance level (novel items).

→ **Effect triggered by homophony avoidance.**

- Rules that cause homophony harder to learn.
- Suggests an interaction between phonological learning and lexical learning.

Yin & White (2018), *Cognition*

THANK YOU!
QUESTIONS?

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