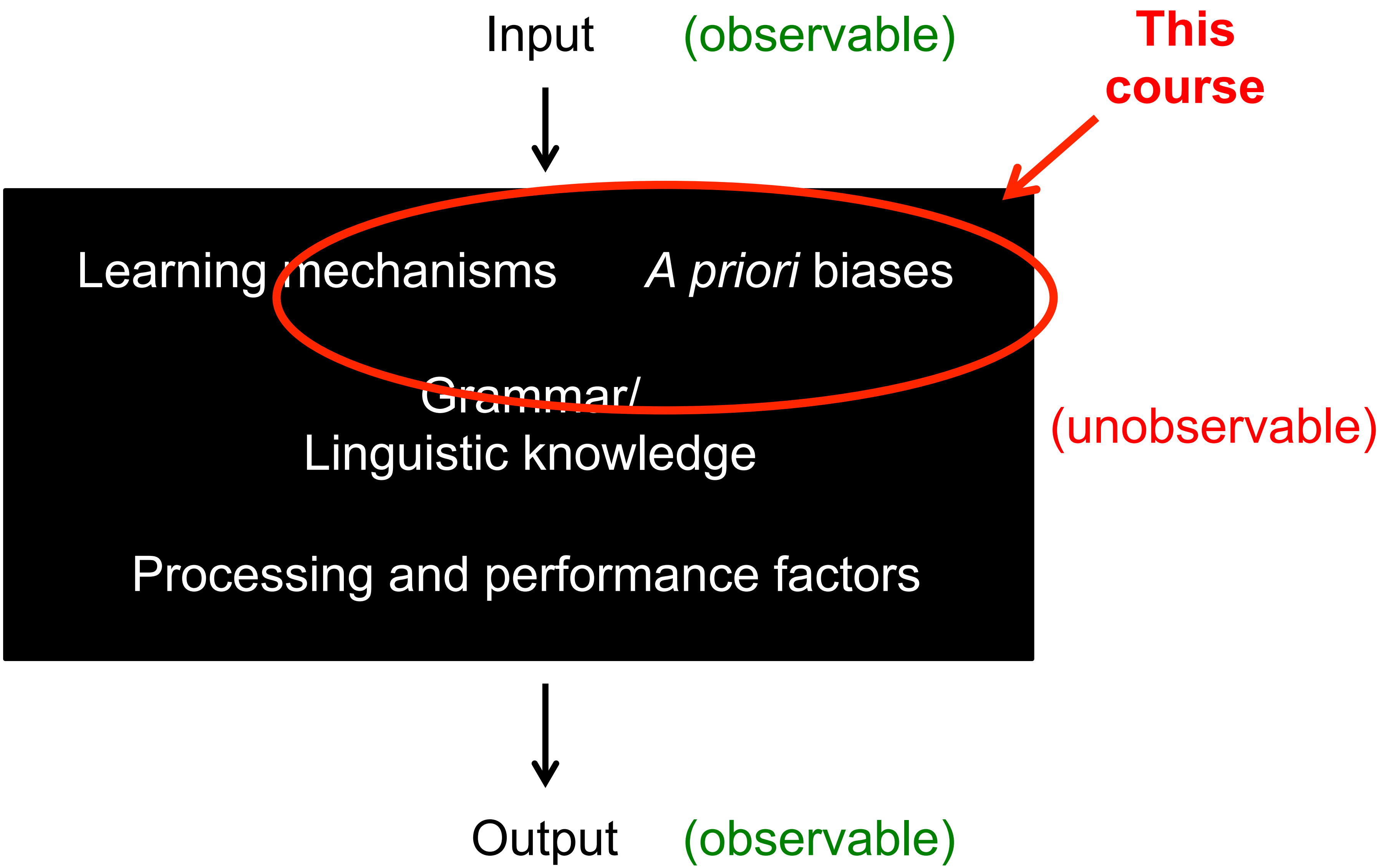
UNIVERSAL BIASES IN PHONOLOGICAL LEARNING

ACTL SUMMER SCHOOL, DAY 1

JAMIE WHITE (UCL)

BIG PICTURE


Input
(observable)
This course
Learning mechanisms
A priori biases
Grammar/
Linguistic knowledge
(unobservable)
Processing and performance factors
Output
(observable)

OVERVIEW OF COURSE

Day 1: Introduction; methods for studying bias; types of biases; analytic and channel bias; complexity and substance (AGL)

Day 2: Complexity and substance (cont.); natural classes and feature-based learning (AGL)

Day 3: P-map bias (primarily AGL)

Day 4: Looking for biases in native language learning (corpus + experiment)

Day 5: Implementing biases in grammar models (primarily MaxEnt)

INTRODUCTION

'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.
- Classical OT: Child only needs to find a suitable ranking from a universal constraint set – languages with no possible ranking impossible to learn.

'SOFT' BIASES

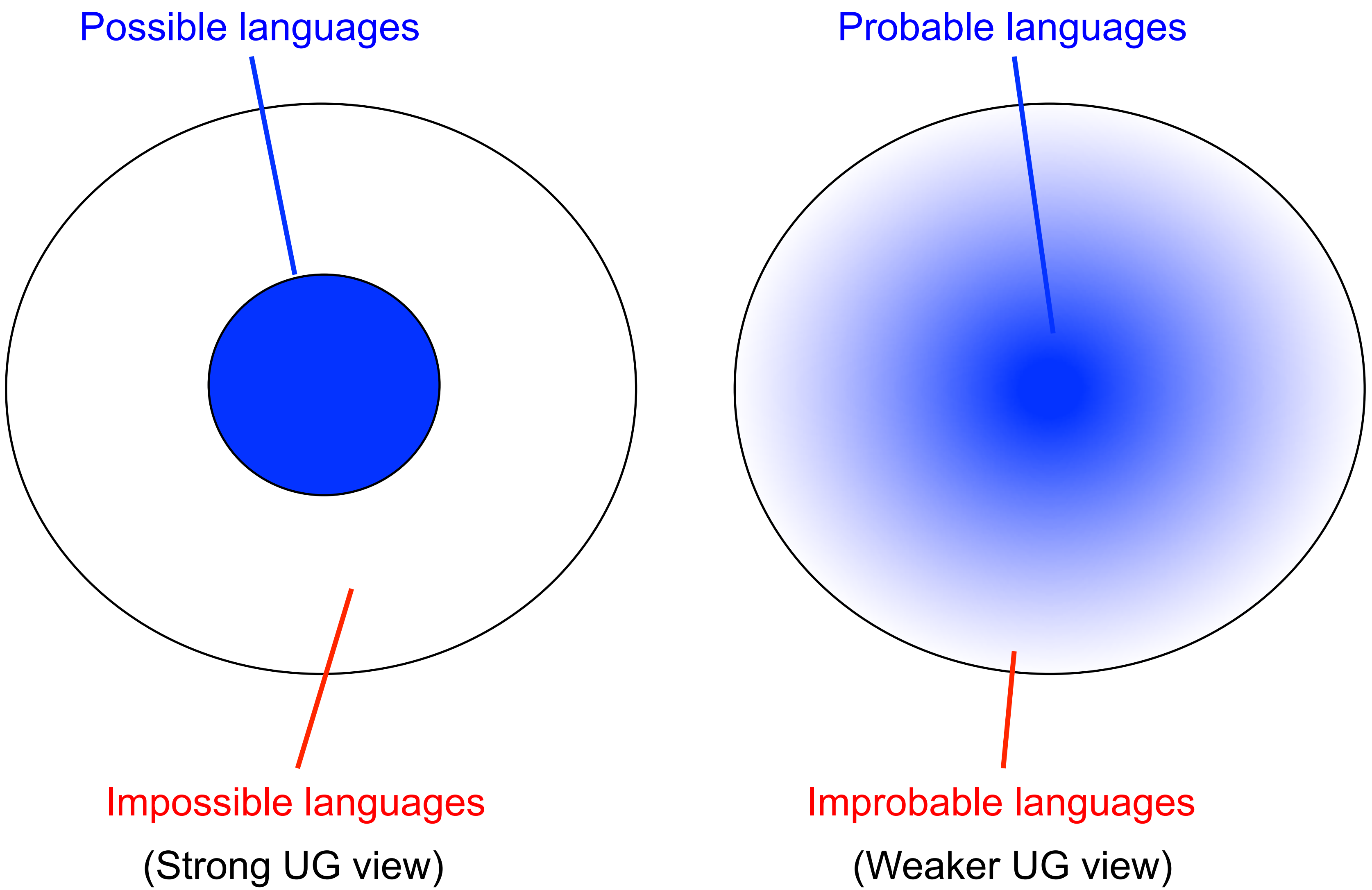
Soft biases: learning preferences

- 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, White 2013).

HARD VS. SOFT BIASES



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. **Assuming 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.

METHODS USED TO STUDY BIASES

Artificial language experiments with adults

- Do people find certain patterns easier to learn than others?
- Do people generalize their learning in a biased way?

Infant learning experiments

- Same questions posed above, but with learners who are in the process of learning a first language.

Testing native language knowledge in adult speakers

- Have people failed to learn (or underlearned) or overlearned patterns present in their language?

Computationally implemented learning models

- Which assumptions/biases allow the model to more closely approximate human performance?

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 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.

ARTIFICIAL LANGUAGE EXPERIMENTS: DESIGN ISSUES

Two main paradigms

1. Compare two patterns: Is pattern A easier to learn than pattern B?
2. 'Poverty of the stimulus' (Wilson 2006): Withhold crucial cases and see if learners respond to the unseen cases in a biased way.

Training method

- Implicit: More like native language learning; may take longer.
- Explicit: Faster, but less like native language learning.

Amount of training

- Particularly relevant in the 'compare two patterns' paradigm. Possible ceiling effects and floor effects.

Response type

- Forced-choice: easier to analyze, but may bias participants' choices.
- Production: Open responses; harder to analyze.

WHERE DO WE LOOK FOR BIASES?

Patterns that are difficult/impossible to derive in certain theoretical frameworks.

- E.g.: Opacity in OT; really complicated rules in SPE.
- Ideally, there should be some connection between what is easy to learn and what is easy to represent in our framework (this idea goes back at least to SPE).

Patterns that are typologically rare.

- Perhaps the rarity is due, in part, to a bias.

WHAT SHAPES TYPOLOGY?

Why are certain patterns typologically common (and others rare)?

- They are likely to be innovated and adopted as part of a language.
- Once adopted, they are likely to remain stable throughout generations rather than dying out.

Mechanisms possibly playing a role:

1. Accidents and non-linguistic events.
2. Language contact and borrowing.
3. Factors affecting the faithful transmission from speaker to listener (**= channel bias**).
4. Factors affecting how a new generation analyzes the input that they receive, and what they learn from it (**= analytic bias**).

Moreton 2008, *Phonology*

MORE ON CHANNEL BIAS AND ANALYTIC BIAS

Channel bias:

- Not a learning bias.
- In production: Factors that might shift a production away from the speaker's intended target.
  - E.g. coarticulation; lenition, deletion, or other alterations due to articulatory difficulty, fast speech rates, etc.
- In perception: Factors that cause the listener to misperceive an utterance.
  - E.g. the nature of our ears and auditory systems; segments having insufficient auditory cues; perceptual similarity between sounds, etc.
- These factors can work in tandem.

Analytic bias:

- Favours certain learning outcomes over others, even assuming perfect input (i.e. no problems with production or perception).

Moreton 2008, *Phonology*

PHONOLOGIZATION

If gradual, phonetic effects become sufficiently noticeable, then they might be interpreted by a new generation of speakers as a regular phonological pattern.

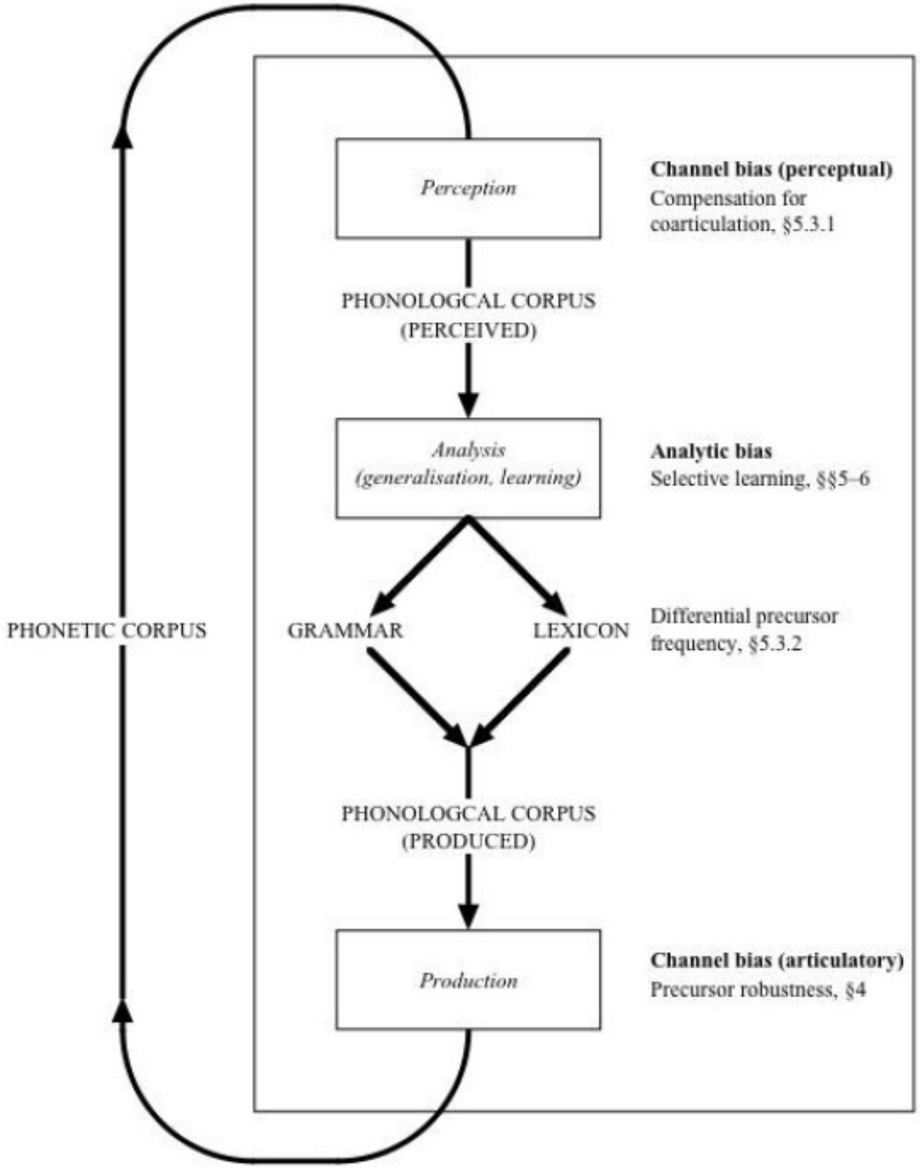
- This is called **phonologization**.

In principle, both channel bias and analytic bias could affect the likelihood (and manner in which) patterns are phonologized.

- **Channel bias**: directly, based on the strength and frequency of the **phonetic precursors** themselves – that is, the phonetic effects that could be phonologized.
- **Analytic bias**: by biasing learners away (or towards) interpreting the precursors in a certain (grammatical) way.

Moreton 2008, *Phonology*

MORETON'S MODEL



Moreton 2008, *Phonology*

CHANNEL BIAS OR ANALYTIC BIAS?

A problem: It's difficult to know whether a typological observation is due to channel bias or analytic bias.

- Often there is an analytic explanation and a channel bias explanation, making hard to tease them apart.

Moreton's approach: Control for channel bias, by looking for two phonological patterns with:

- Equally strong phonetic precursors.
- Different typological frequencies.

→ Thus, if a learning bias is found against the rarer pattern, then it seems that the only remaining explanation could be analytic bias.

Moreton 2008, *Phonology*

THE PATTERNS

HH pattern:

- Height of one V is predictable from the height of another V with at least one intervening C.
- E.g.: vowel harmony

HV pattern:

- Predictable relationship between the height of a V and the voicing (or other laryngeal category) of an adjacent C.
- E.g.: Canadian Raising (-ish).

Moreton 2008, *Phonology*

THE PATTERNS

Typological survey: HH common; HV uncommon.

- Counting the # of language families with each type of pattern.

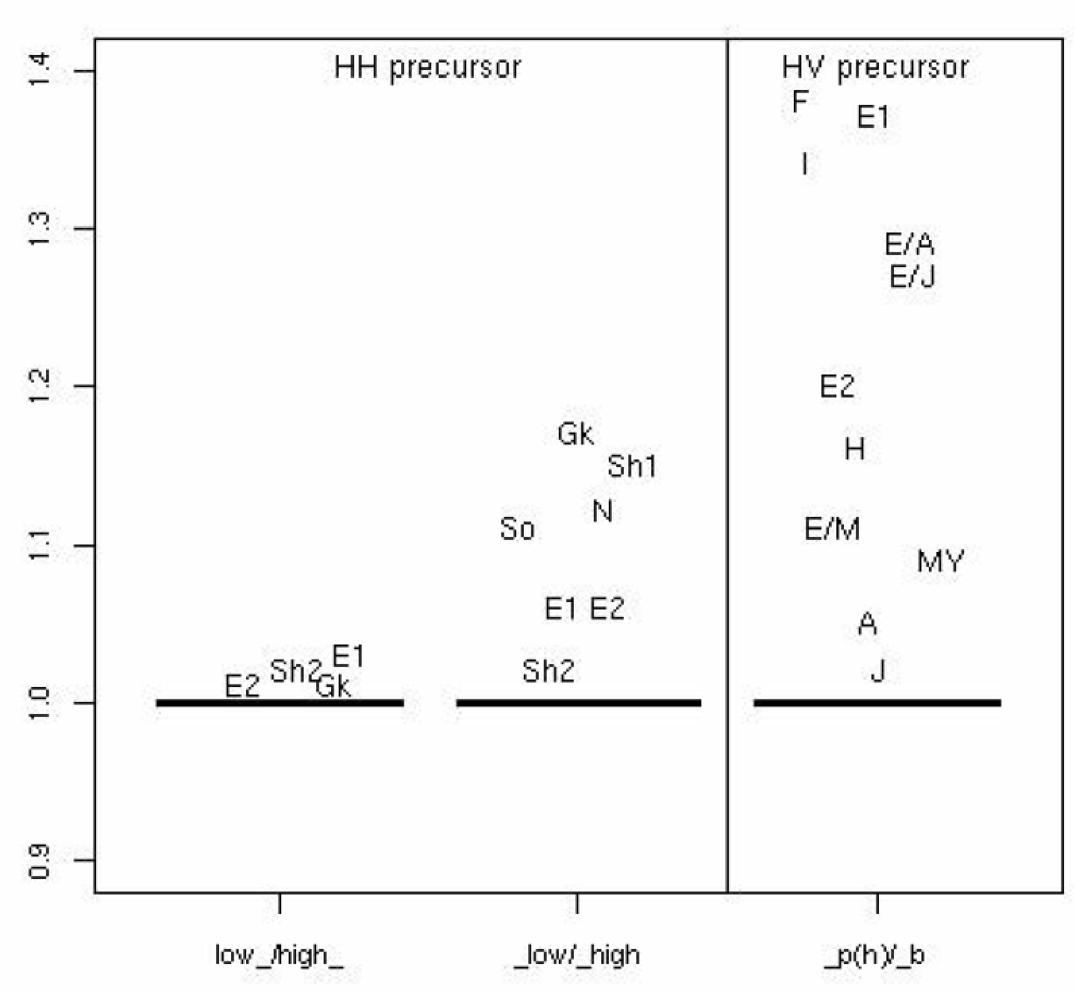
Survey of phonetic precursors: HV (at least) equal in strength to HH (but see Yu 2011 for a critique)**.**

- Meta-analysis of previous phonetic studies.
- **HH**: Lower F1 next to high vowels.
  - Coarticulation between nearby vowels.

- **HV**: Lower F1 before voiceless obstruents due to:
  - Exaggerated vowel articulations before voiceless obstruents.
  - Expansion of the pharynx when producing voiced obstruents.

Moreton 2008, *Phonology*

PRECURSOR ROBUSTNESS



Moreton 2008, *Phonology*

IS THERE AN ANALYTIC BIAS? ARTIFICIAL LANGUAGE EXP DESIGN

Participants familiarized to two languages:

- **HH language**
  - Familiarization words (all C**V**C**V**) had V_1 and V_2 with the same height (both high or both non-high).
- **HV language**
  - Familiarization words (all C**VC**V) had V_1 and C_2 that were high and voiced, or non-high and voiceless, respectively.
- Participants learned both languages (order counterbalanced).
- Num. participants = 24

Stimuli

- CVCV nonce words (e.g. [tiku]).
- Limited to vowels [i, u, æ, ɔ] and consonants [t, d, k, g].
- Synthesized speech.

Moreton 2008, *Phonology*

PROCEDURE

Familarization phase

- Heard auditory nonce words, which they then produced back into a microphone as accurately as possible.
- 32 forms (all either HH or HV conforming, depending on language).

Test phase

- Each trial: ‘conforming’ word … ‘non-conforming’ word (order counterbalanced).
- Task: Click a button to choose the one that is part of the language that was studied.
- 32 test trials (all words were novel, i.e. not heard in familiarization).
- Non-conforming items did not conform to HH or HV, in either language.

Moreton 2008, *Phonology*

RESULTS

		0 (HV Condition)		1 (HH Condition)	
		HH-non-conformity		HV-non-conformity	
Same-Vowel	Order	0 (vowels agree in height)	1 (vowels disagree in height)	0 (V1 high iff C2 voiced)	1 (V1 high iff C2 voiceless)
0 ($V1 \neq V2$)		[tidu] (8)	[tidæ] (16)	[tidu] (8)	[titu] (8)
	0 (1st half)	50·0	55·7	67·7	63·5
	1 (2nd half)	53·1	55·7	70·8	57·3
1 ($V1 = V2$)		[tidi] (8)	*impossible*	[tidi] (8)	[titi] (8)
	0 (1st half)	57·3		75·0	56·3
	1 (2nd half)	50·0		51·0	63·5

*

Moreton 2008, *Phonology*

EXPERIMENT 2

If analytic bias is the only underlying source of typological differences that we see, typology should almost entirely mirror learnability results.

Follow-up experiment:

- Same design, procedure as Exp. 1.

Compare different two patterns:

- **HV pattern**: same as in Exp. 1.
- **VV pattern**: relationship between voicing of two consonants separated by a vowel.
    - Typologically uncommon (like HV).
    - No clear phonetic precursor.

Moreton 2008, *Phonology*

RESULTS – EXP. 2

		0 (HV Condition)		1 (VV Condition)	
		VV-non-conformity		HV-non-conformity	
Same-Conso-nant	Order	0 (consonants agree in voicing)	1 (consonants disagree in voicing)	0 (V1 high iff C2 voiced)	1 (V1 high iff C2 voiceless)
0 (C1, C2)	0 (1st half) 1 (2nd half)	[gidi] (8) 54·1 55·0	[kidi] (16) 57·3 53·8	[kidi] (8) 65·8 51·8	[kiti] (8) 59·1 43·6
1 (C1=C2)	0 (1st half) 1 (2nd half)	[didi] (8) 50·0 43·3	*impossible*	[didi] (8) 55·6 57·0	[titi] (8) 68·1 51·5

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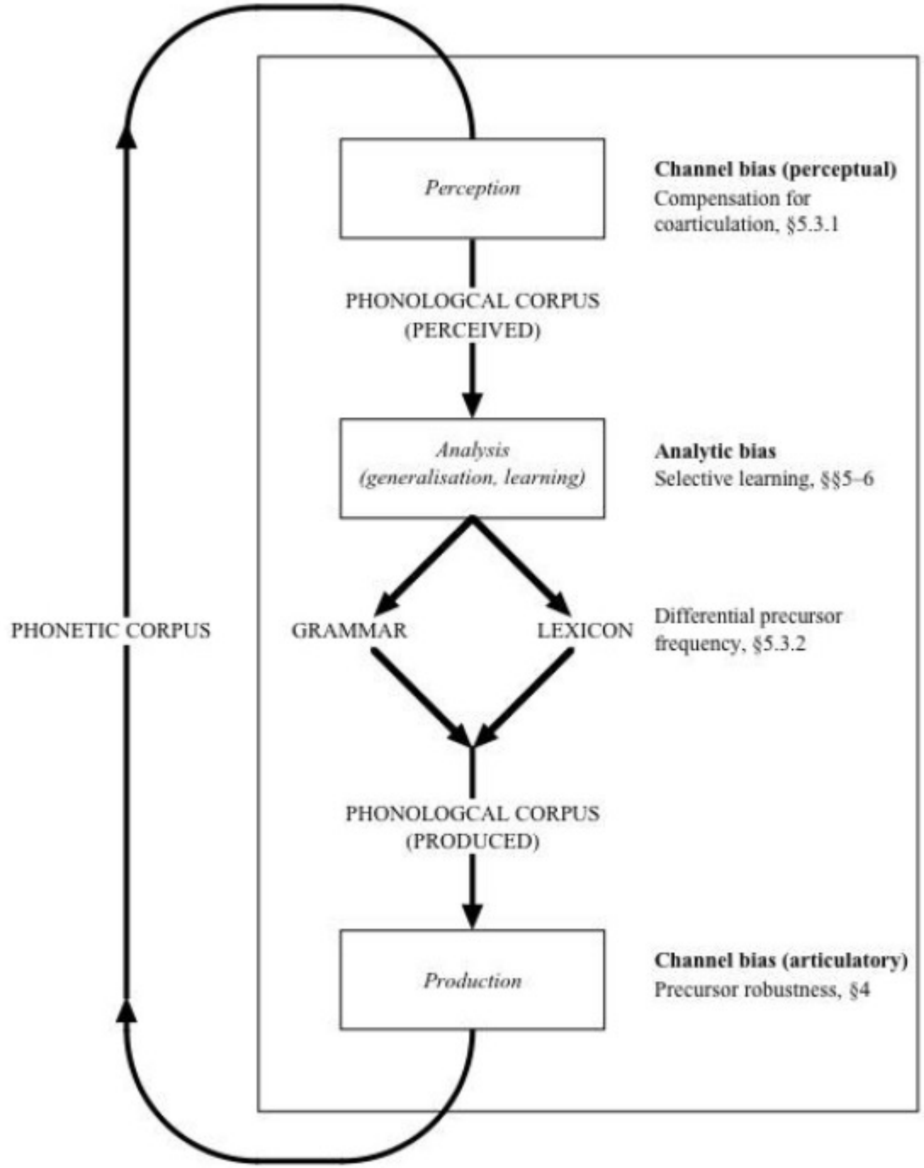
Moreton 2008, *Phonology*

MORETON'S CONCLUSION

We need both channel bias and analytic bias.

Both play a role in shaping typology.



Moreton 2008, *Phonology*

BROADLY, UNCONTROVERSIAL THAT SOME COGNITIVE BIASES PLAY A ROLE

Quote from Blevins (2006, p.246):

- “Though EP challenges the existence of *phonological* universals, it does not deny, and, indeed, it embraces work in phonetics and cognitive sciences more generally which demonstrates synchronic effects of innate knowledge or processing effects in those two domains.”

- EP = Evolutionary Phonology, which represents perhaps the most forceful argument that channel bias is the primary means of shaping phonological typology (see also work by Ohala, e.g. 1981).

Which biases?

- That is a much more controversial question…

TWO BIASES THAT HAVE RECEIVED A LOT OF ATTENTION

Complexity/simplicity bias (sometimes 'structural' bias)

- Simple patterns preferred to complex patterns.
- Idea has been around in phonology for a long time (e.g. SPE's feature counting metric).
- Similar effects found in other cognitive domains (e.g. visual pattern learning).
- Moreton's (2008) explanation for the results we just saw.
    - HH and VV easier to learn because they involve a single feature. HV more difficult because it involves tracking two features.

Substantive bias (term from Wilson 2006)

- Phonetic substance plays a role in the grammar and in learning.
- Phonetically motivated (sometimes called 'natural') patterns are preferred by the grammar (and thus easier to learn).

Complexity bias less controversial; substantive bias more so.

- Moreton & Pater (2012a,b) have suggested that all putatively substantive biases might really be complexity biases.

VOWEL HARMONY

SIMPLICITY VS. PHONETIC NATURALNESS IN VOWEL HARMONY

Simplicity hypothesis:

1. $X_{\alpha} \ldots X \rightarrow X_{\alpha} \ldots X_{\alpha}$ ⟶ **easy to learn**
2. $X_{\alpha,\beta} \ldots X \rightarrow X_{\alpha,\beta} \ldots X_{\alpha}$ ⟶ **hard to learn**

(Phonetic) Naturalness hypothesis:

3. $X_{\alpha} \ldots X \rightarrow X_{\alpha} \ldots X_{\alpha}$ ⟶ **easy to learn**
4. $X_{\alpha} \ldots X \rightarrow X_{\alpha} \ldots X_{-\alpha}$ ⟶ **hard to learn**

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

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, ʊ] ⟶ front suffix; stem vowel [ɪ, u, ɑ] ⟶ back suffix.

Predictions for learning

- Simplicity: **VH , DH > ARB**
- Phonetic naturalness: **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]
  - Wide variety of Cs
- –VC suffixes:
  - [ɛk] ~ [ʌk]
- Stimuli were spliced (controls for coarticulation).

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

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) … [gipɛk]

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

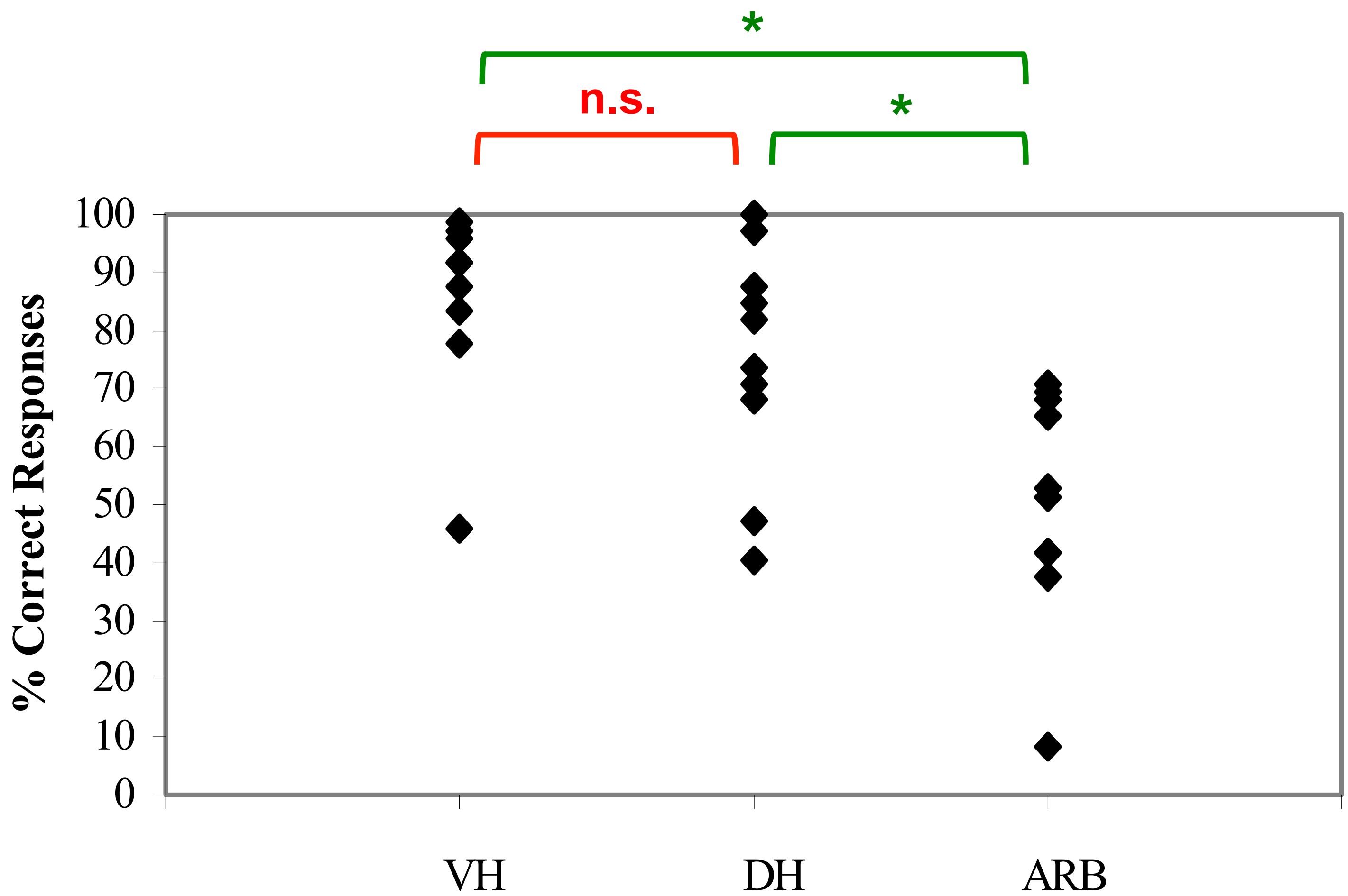
   [gip] … [gipɛk] … Correct plural? ⟶ Feedback

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%

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

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’.

Skoruppa & Peperkamp 2011, *Cognitive Science*

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]	**pudère**	[pydɛʁ]	pudeur	[pydœʁ]
High	eunuque	[ønyk]	**eunique**	[ønik]	**eunique**	[ønik]
Disharmonic						
Mid	**liquère**	[likɛʁ]	liqueur	[likœʁ]	**liquère**	[likɛʁ]
High	**laitie**	[lɛti]	laitue	[lɛty]	laitue	[lɛty]

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**

Skoruppa & Peperkamp 2011, *Cognitive Science*

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.

Skoruppa & Peperkamp 2011, *Cognitive Science*

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 **pudère**, il se versa un verre de **liqueur**.
Mixed French:	(mid vowels: harmonic; high vowels: disharmonic)

Skoruppa & Peperkamp 2011, *Cognitive Science*

METHOD

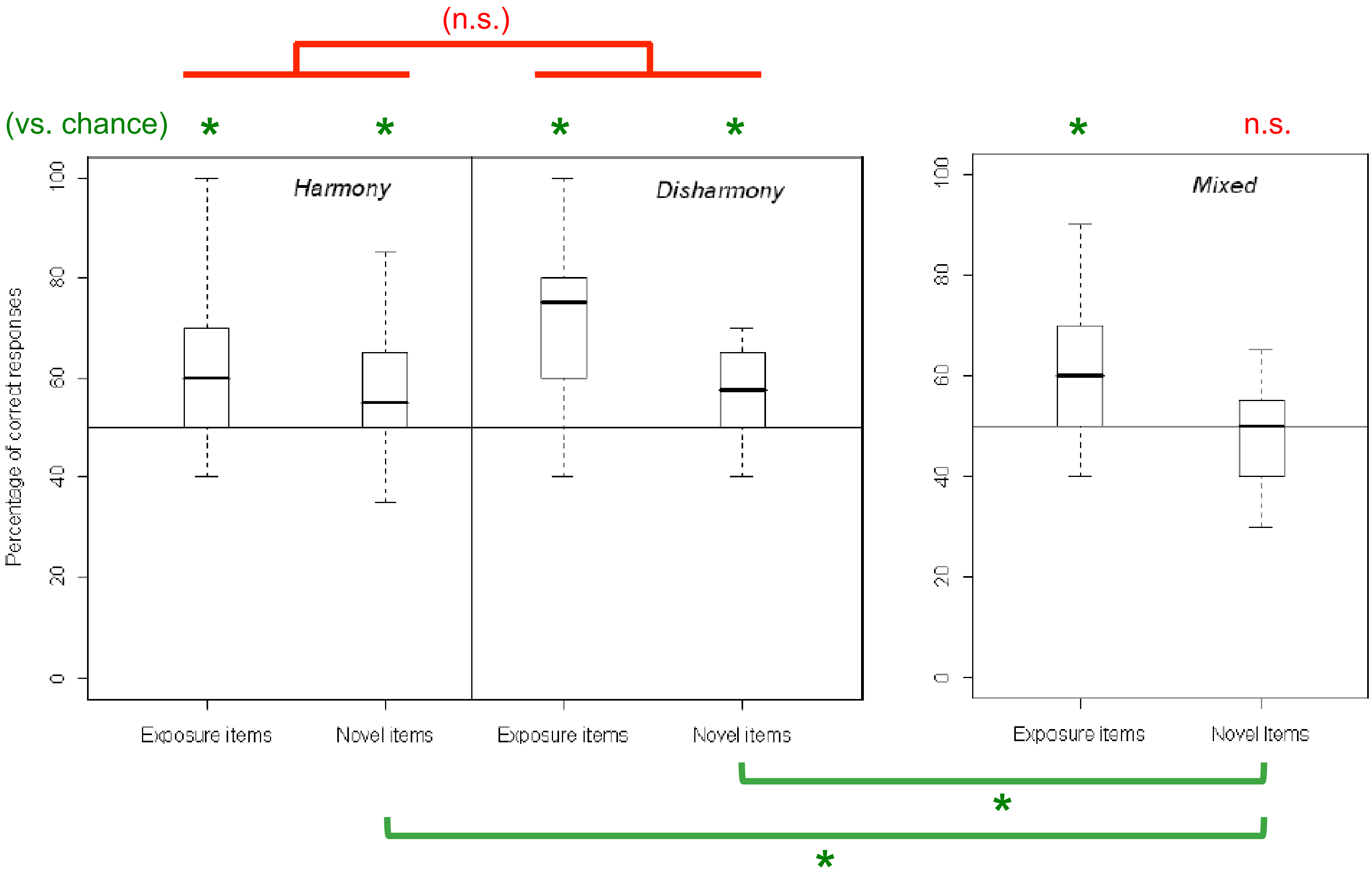
Procedure

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 1st word or 2nd word is pronounced in the same accent as exposure (button press).

Skoruppa & Peperkamp 2011, *Cognitive Science*

RESULTS



Skoruppa & Peperkamp 2011, *Cognitive Science*

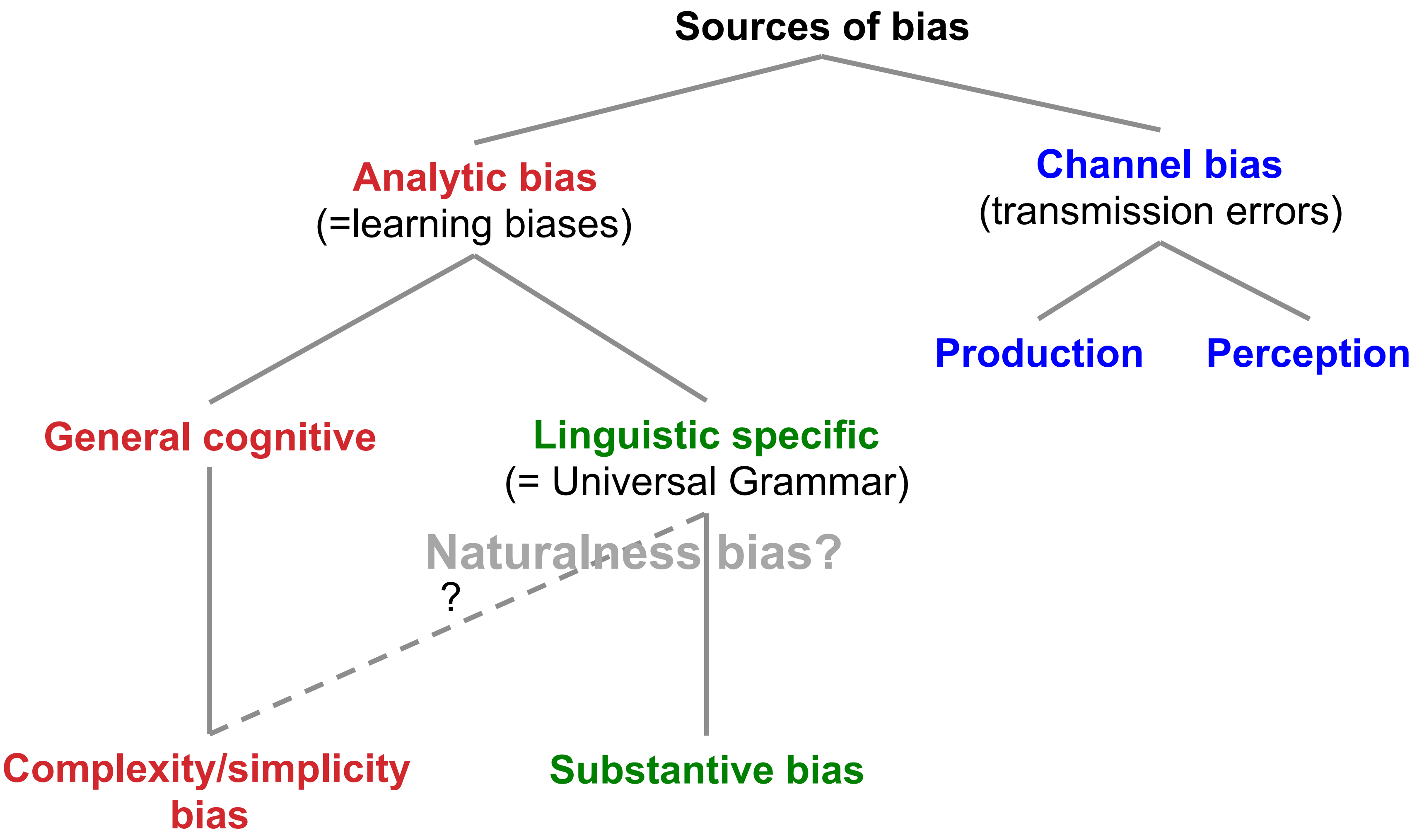
ON THE HORIZON

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!

TYPES OF BIASES*



*Note: some connections are controversial or not fully understood.

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