Population-level variation in word and morpheme order is driven by individual-level cognitive biases

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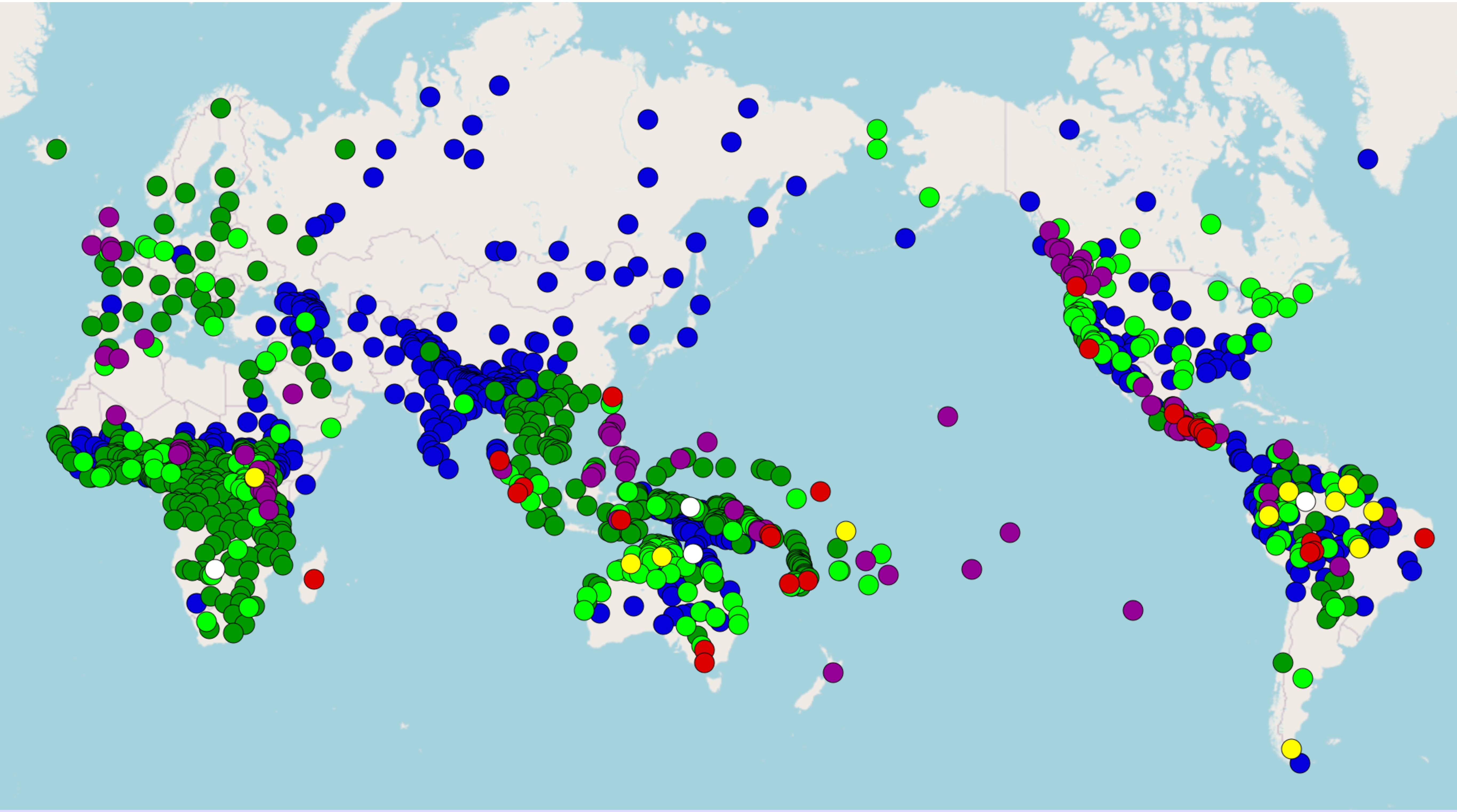
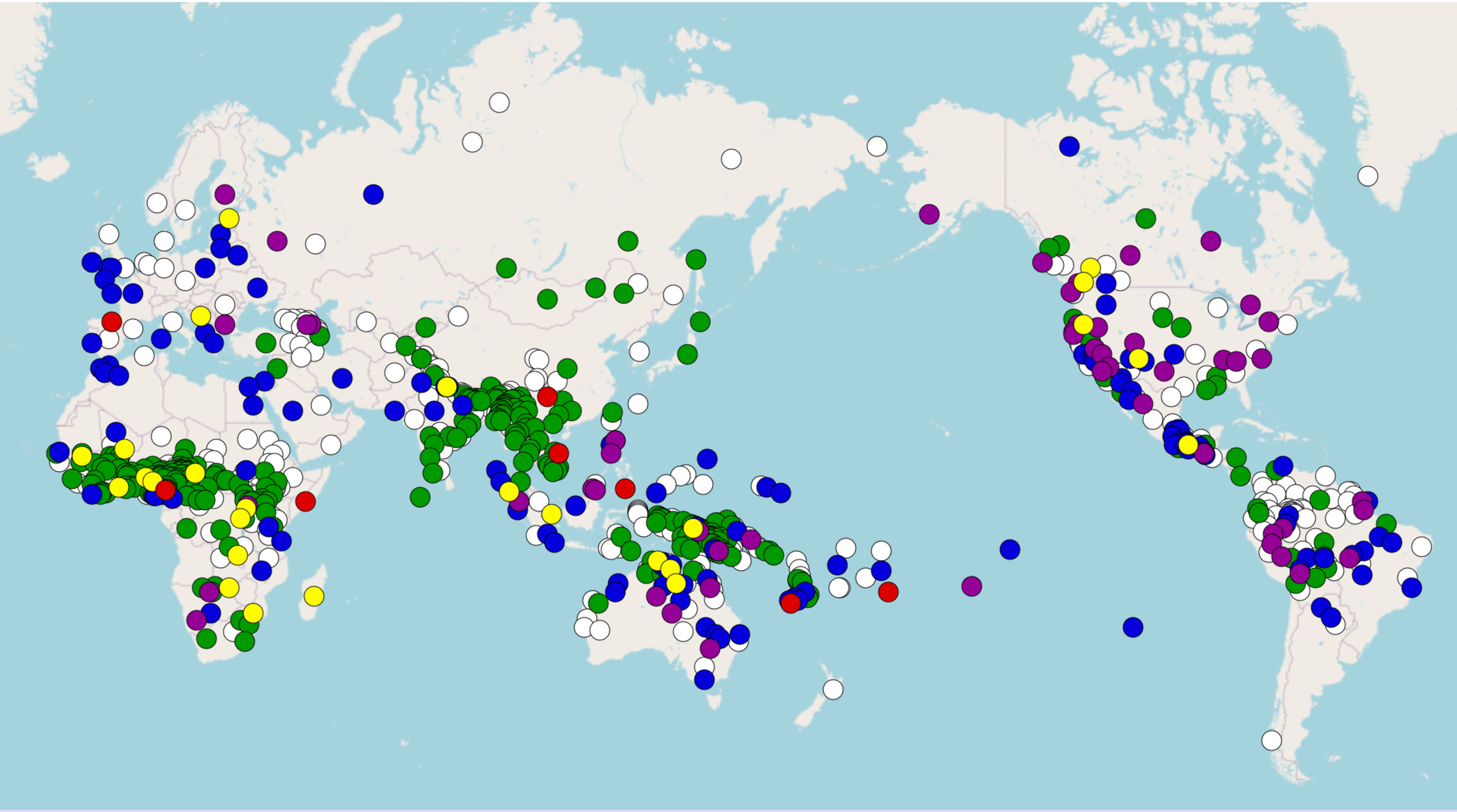
Languages vary, languages are the same

Basic word order



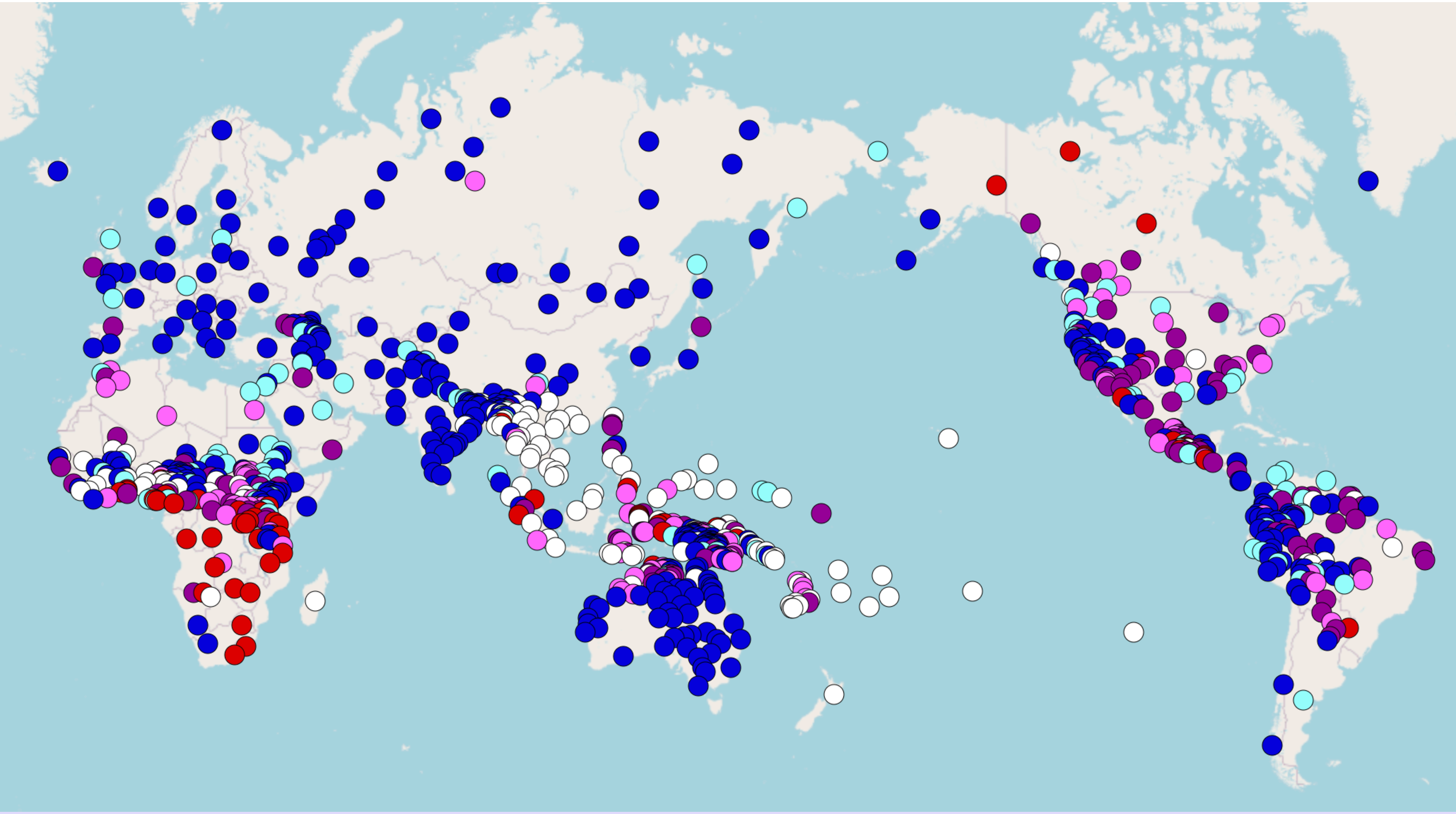
Languages vary, languages are the same

Position of question words



Languages vary, languages are the same

Suffixation vs. prefixation



Languages vary, languages are the same

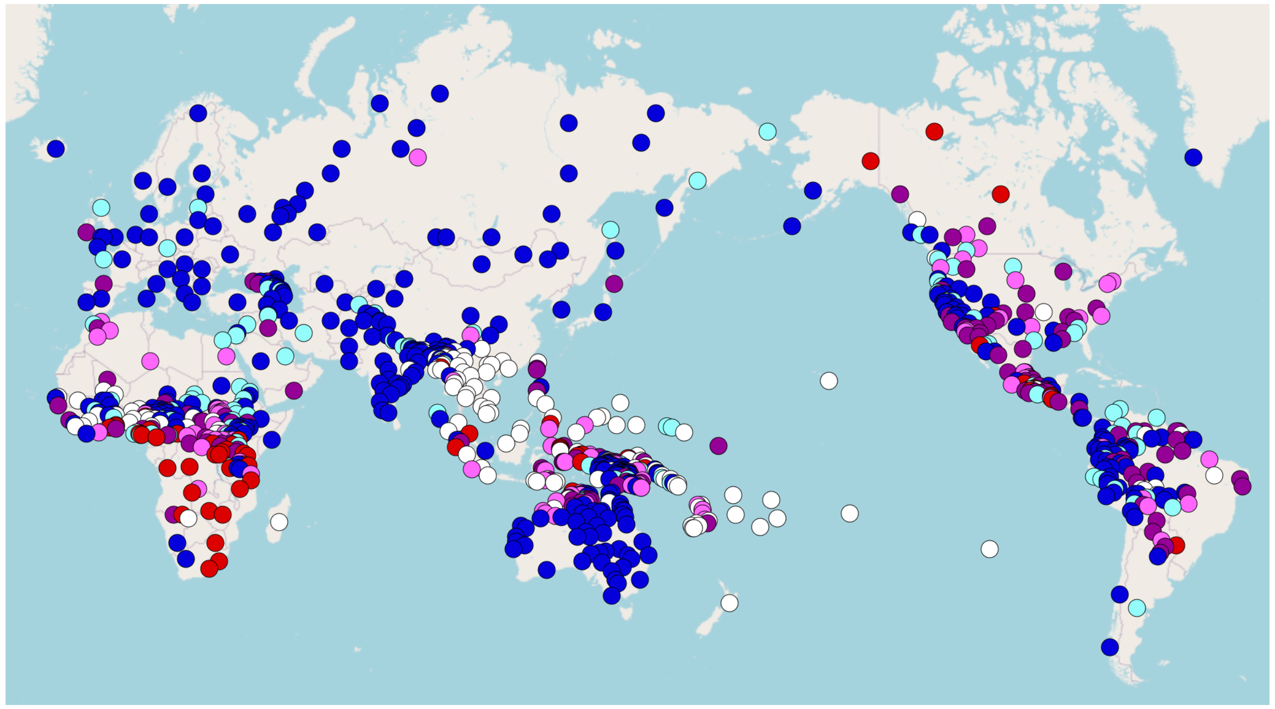
What drives variation and commonalities?

- Culture
- History
- The physical world
- Processes of language change
- Features of cognition (or perception)

How can we tell what role **cognition** plays?

- Typological data…
- Experiments!

An example: the suffixing preference



Type	# langs
mostly suffixes	*406*
more suffixes	*123*
more prefixes	*94*
mostly prefixes	*58*
equal	*147*
neither	*141*

<u>Hypothesis:</u> driven by **universal processing** and **perceptual mechanisms**

① Beginnings of words are special/salient, reserved for lexical content

② Related words are grouped together based on similarities at the start

(Greenberg 1963, Hawkins & Gilligan 1988, Hawkins & Cutler 1988, Hupp et al. 2009, Dryer 2013)

Experimental evidence

Hupp et al. (2009): English-speakers perceive sequences that differ at the end to be more similar

ta-te

base sequence

bo-ta-te

'prefixed' sequence

ta-te-bo

'suffixed' sequence

Experimental evidence

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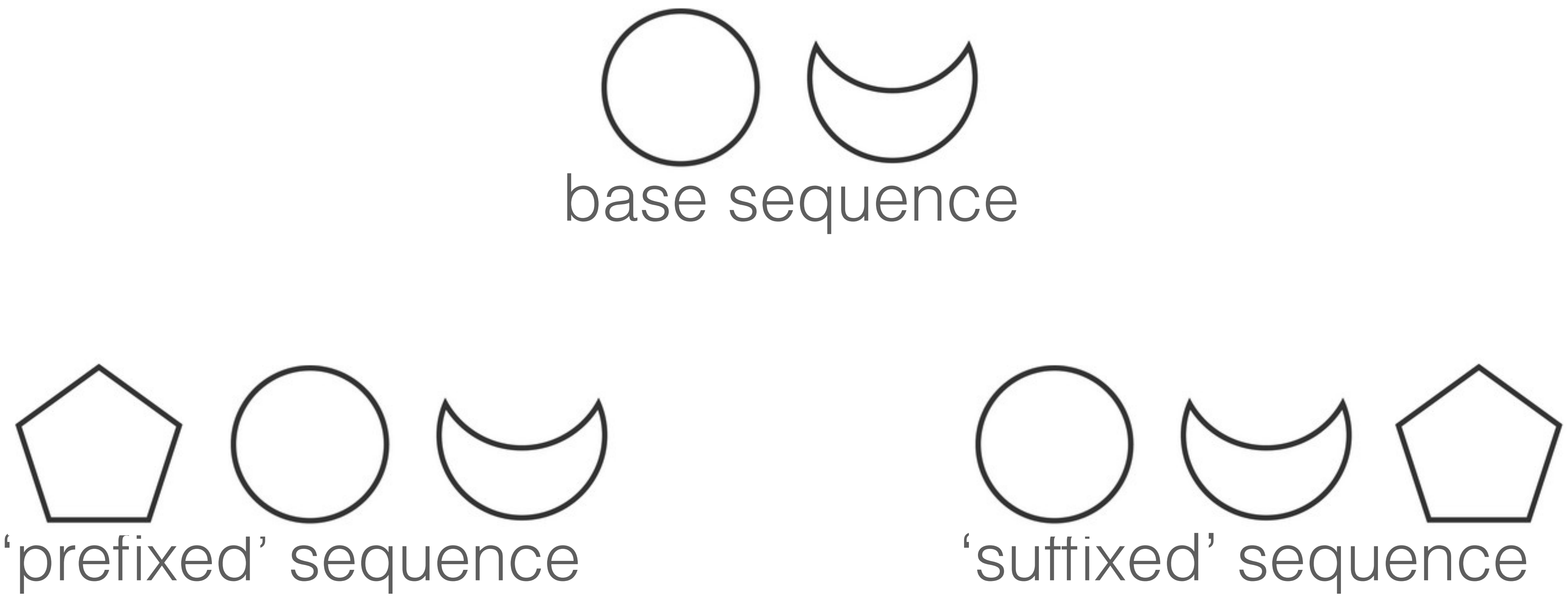
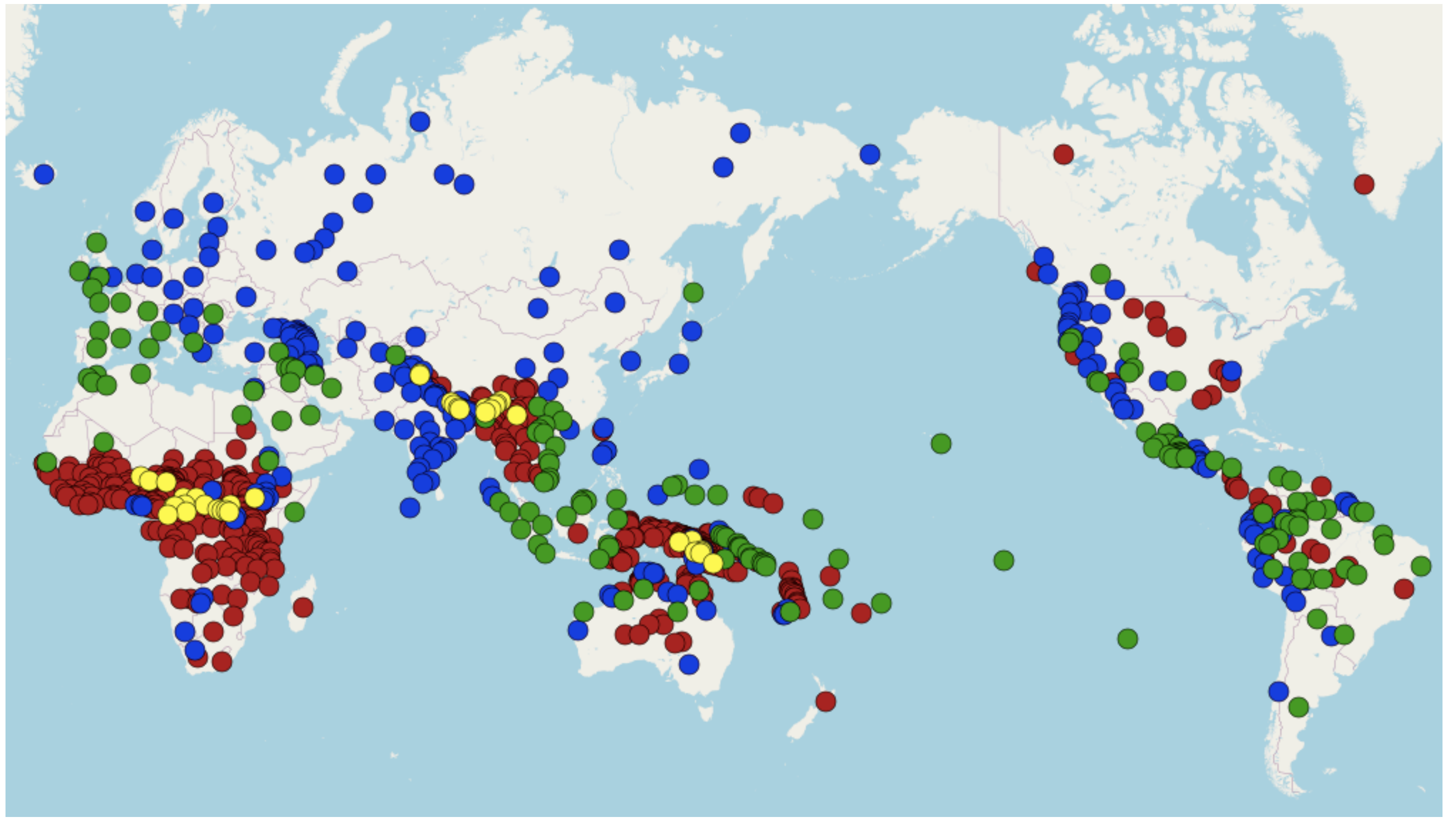


Another example: word order harmony



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Hypothesis: driven by **learned categories** + **universal learning bias** for simplicity

① Heads vs. dependents

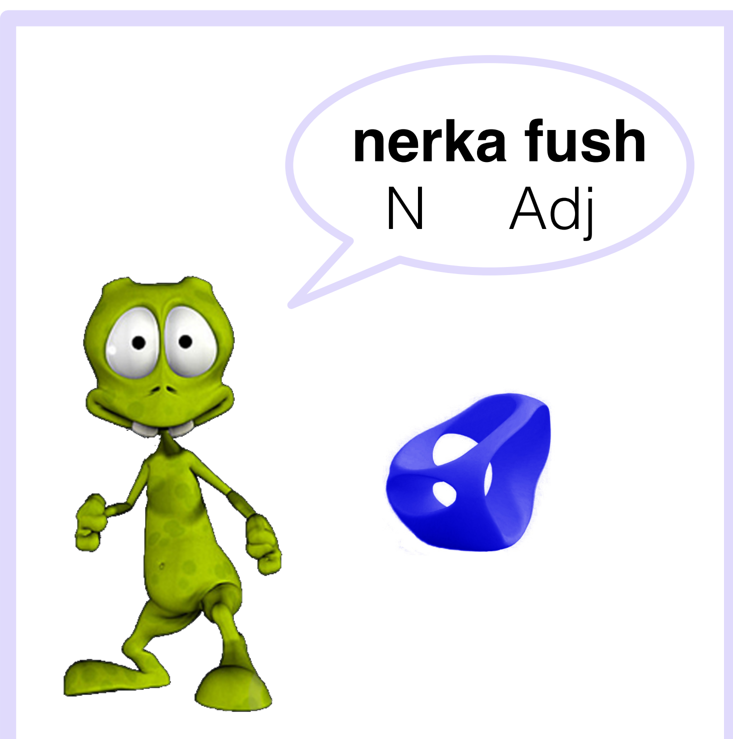
② Single ordering rule > multiple ordering rules

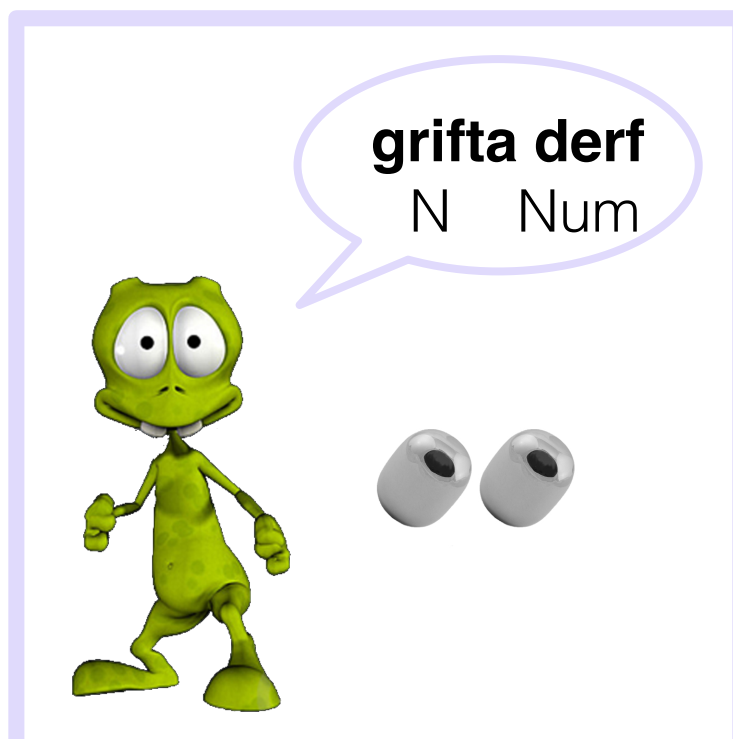
(Greenberg 1963, Vennemann 1973, Culbertson & Kirby 2016 *Frontiers*, Chater & Vitányi 2003)

Experimental evidence

Culbertson et al. (2012): English-speakers regularize variable harmonic orders, not non-harmonic ones

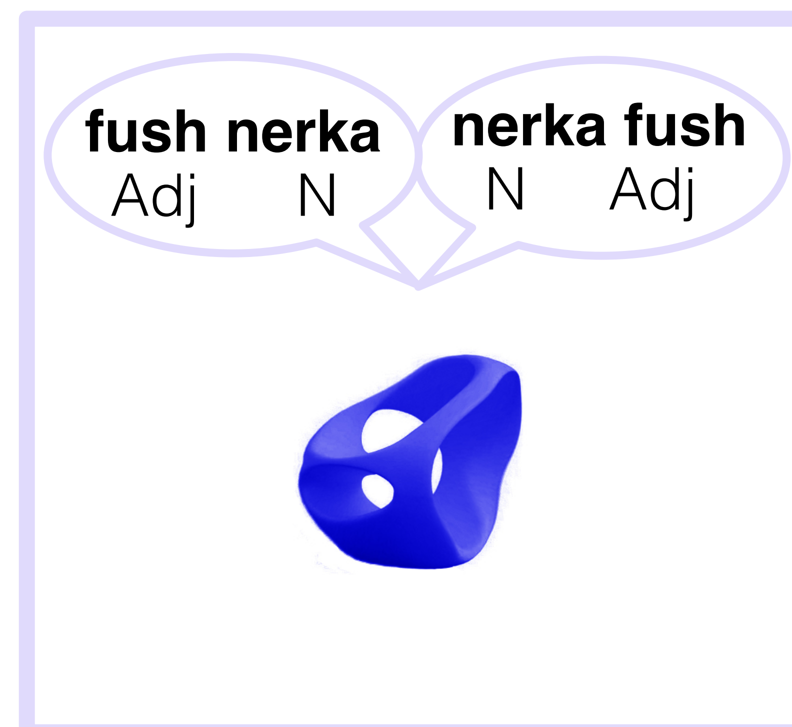
Training: N-MOD or MOD-N





⇒

Testing: MOD+N



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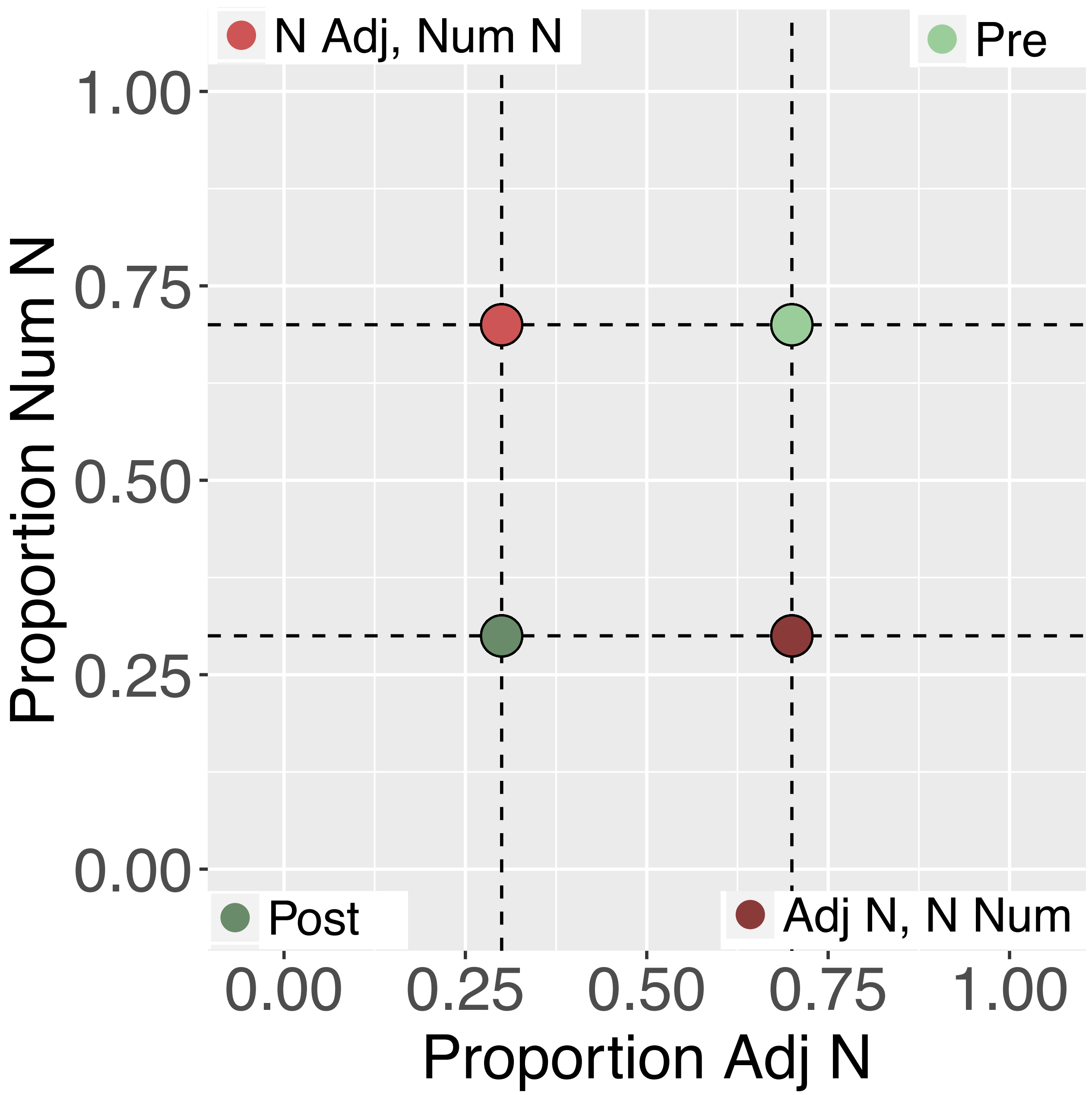
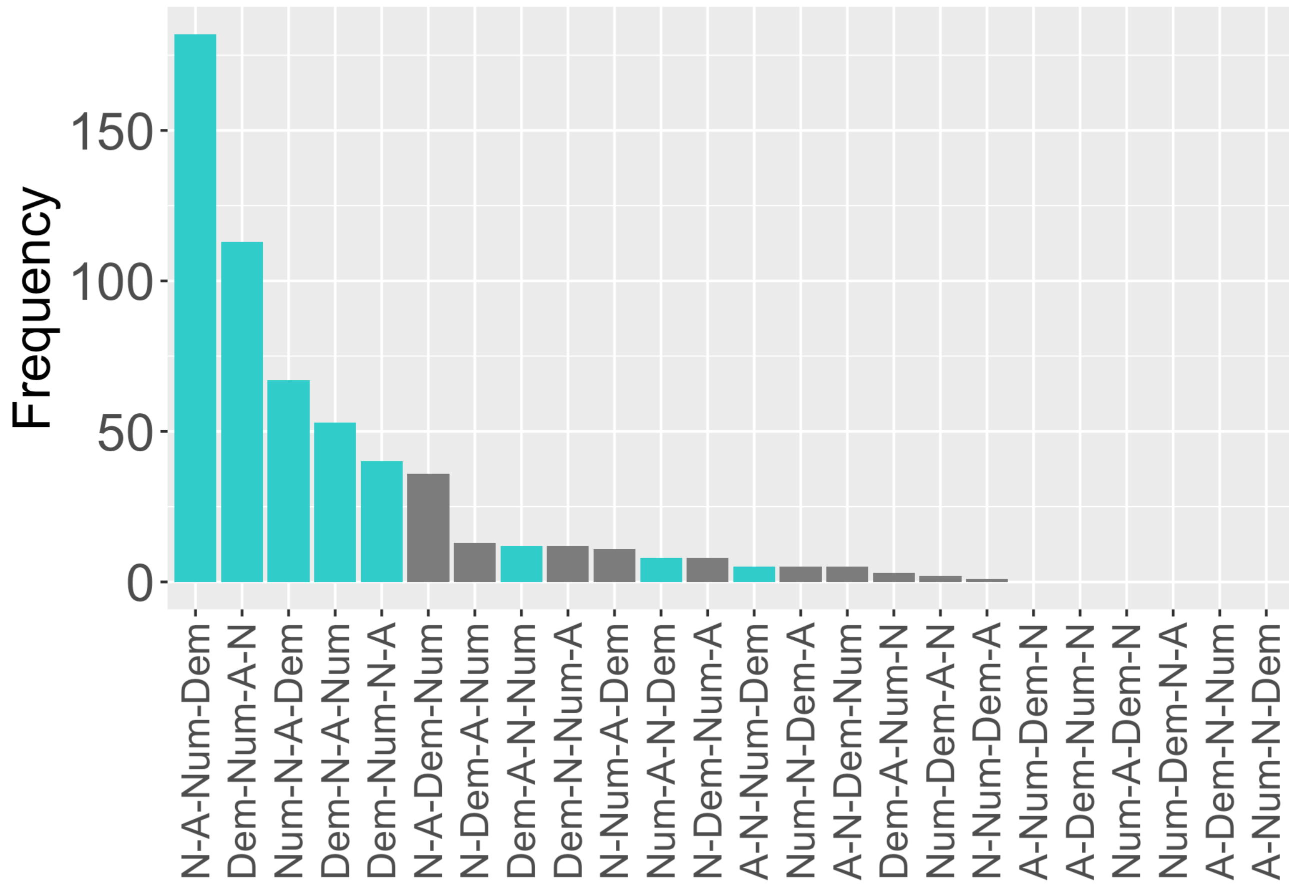
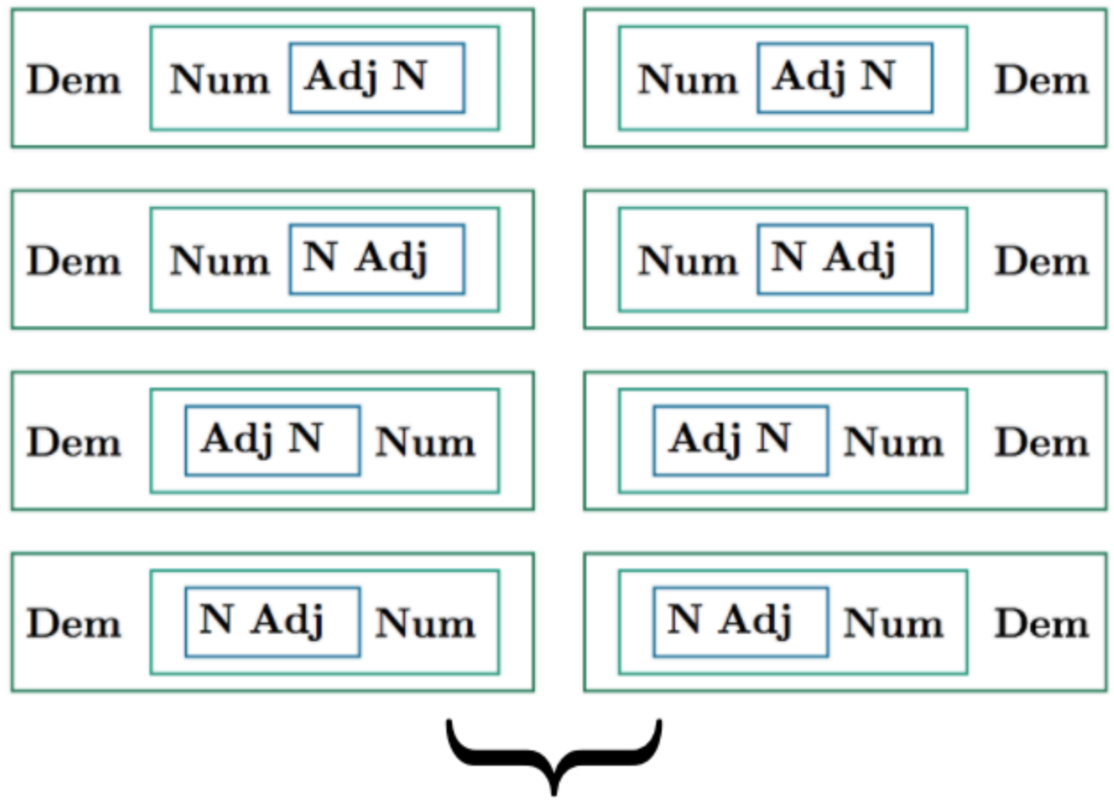


Another example: Complex NP order



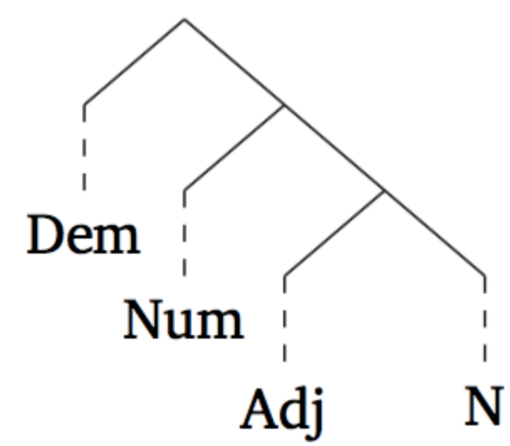


80% of languages

<u>Hypothesis:</u> driven by **universal hierarchy**

① Adj organised closest to Noun, then Num, then Dem

② Orders that are homomorphic to the hierarchy are preferred

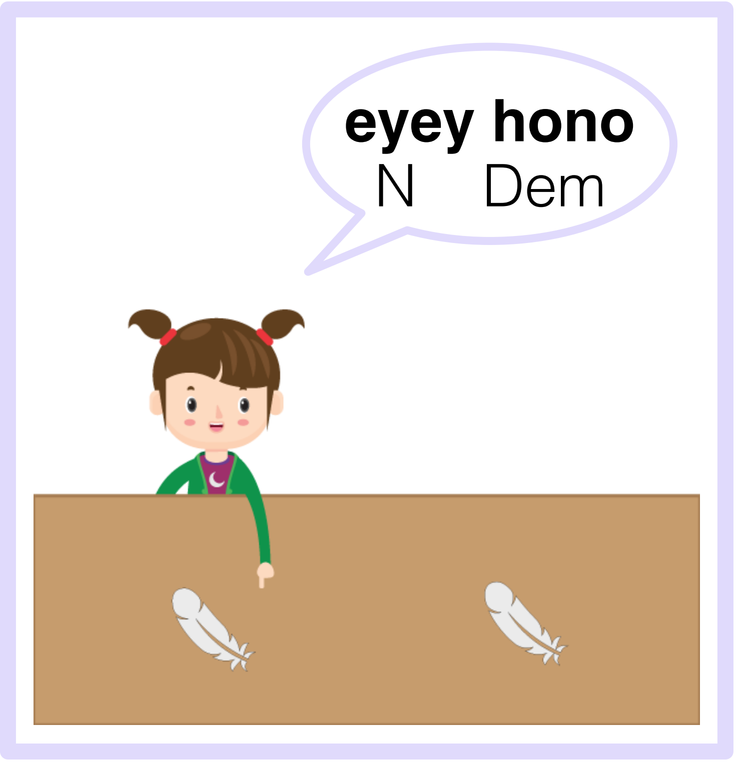


(Cinque 2005, Abels & Neeleman 2012, Culbertson & Adger 2014 *PNAS*)

Experimental evidence

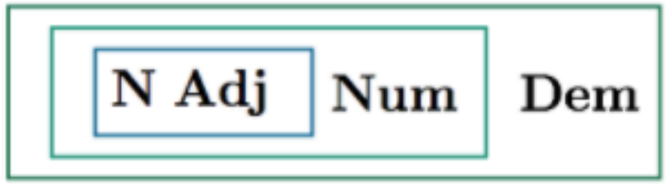
Martin et al. (2020): English-speakers infer Adj closest to N, Dem farthest away given ambiguous input

Training: ADJ or DEM



⇒

Testing: ADJ + DEM



(Martin et al. 2020 *Glossa*)

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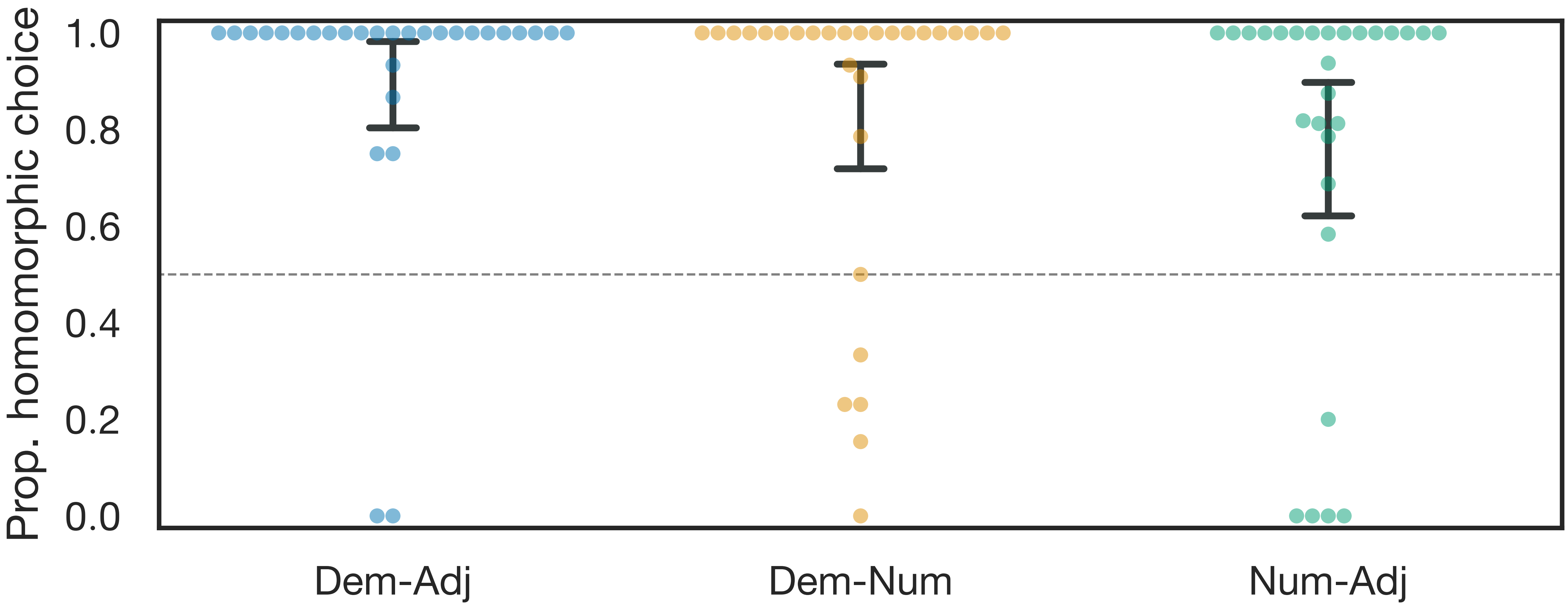

(Martin et al. 2020 *Glossa*)

Languages vary, languages are the same

What drives variation and commonalities?

- Many factors shape typology
- Experiment evidence allows us to connect population-level trends to individual-level biases
    1. Perceptions of similarity —> morpheme order
    2. Preference for simplicity —> harmony
    3. Preference for transparency —> complex NP order

But, where do these biases come from?

- Are they universal?
- Are they influenced by prior language experience?

A crucial missing source of evidence

Variation in language…but not in our participants!

- A general issue in cognitive science

BEHAVIORAL AND BRAIN SCIENCES (2010), Page 1 of 75
doi:10.1017/S0140525X0999152X

The weirdest people in the world?

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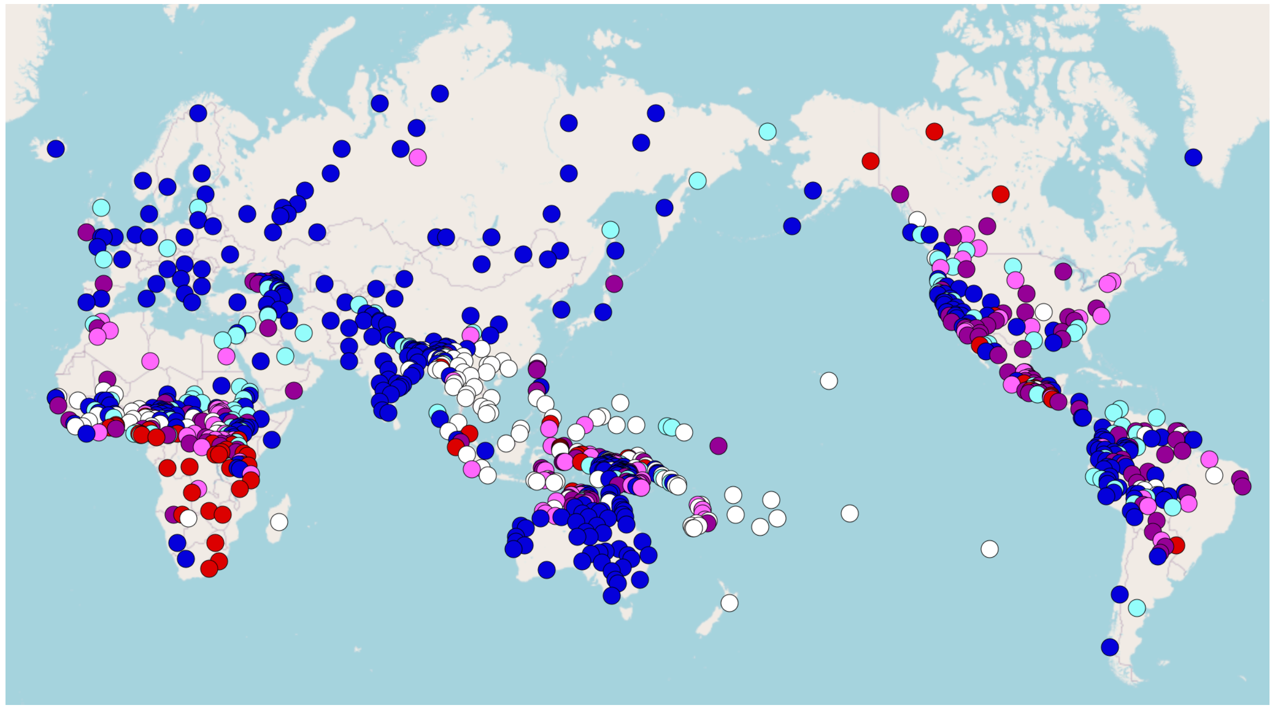
Trends in Cognitive Sciences
CellPress OPEN ACCESS
Feature Review

Over-reliance on English hinders cognitive science

Damián E. Blasi,[1,2,3,*,@] Joseph Henrich,[1] Evangelia Adamou,[4] David Kemmerer,[5,6] and Asifa Majid[7,*,@]

- Particularly problematic when participants have direct experience with the linguistic pattern tested…

Revisiting the suffixing preference



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Hypothesis: driven by **universal processing** and **perceptual mechanisms**

Evidence: Similarity-judgments of **English speakers**

ta-te
base sequence

ta-te-bo
'suffixed' sequence

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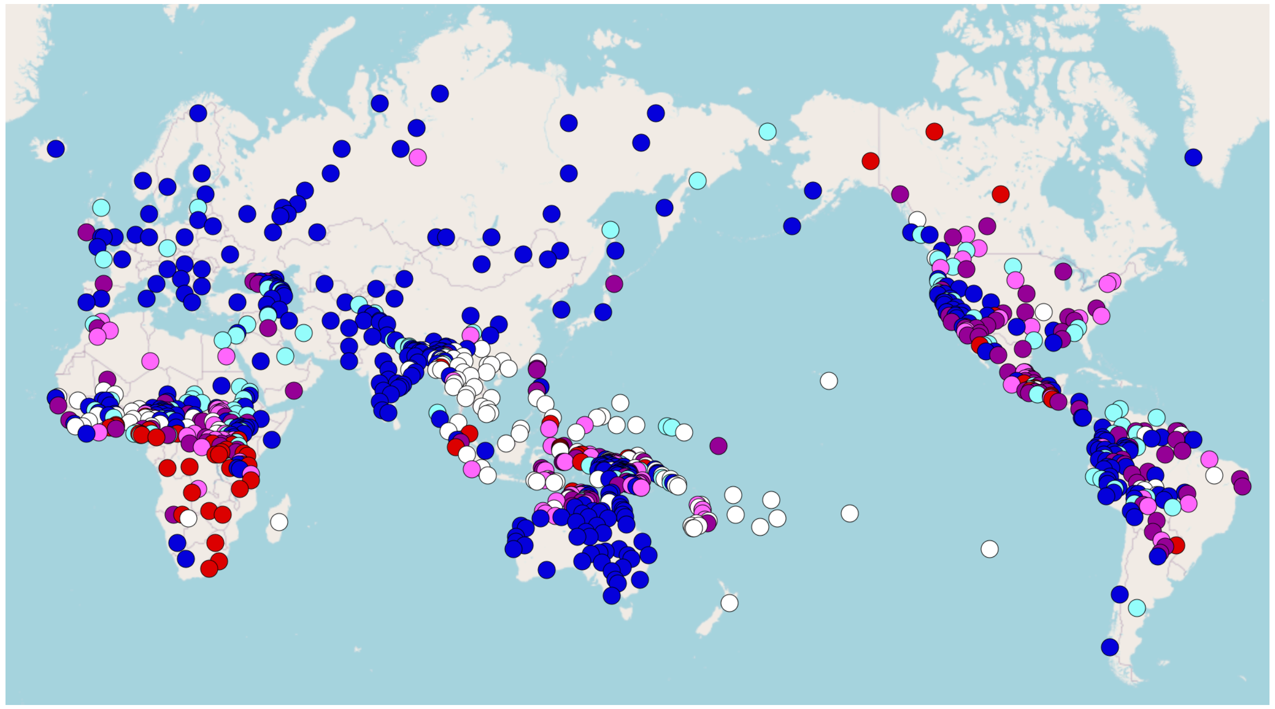
(Hupp et al. 2009,
but also see St. Claire et al. 2009, Bruening et al. 2012)

Revisiting the suffixing preference



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Hypothesis 2: driven by **processes of grammaticalisation**

① Not all affixes tend to be suffixal

② Affix position can be traced back to position of independent word before it fused

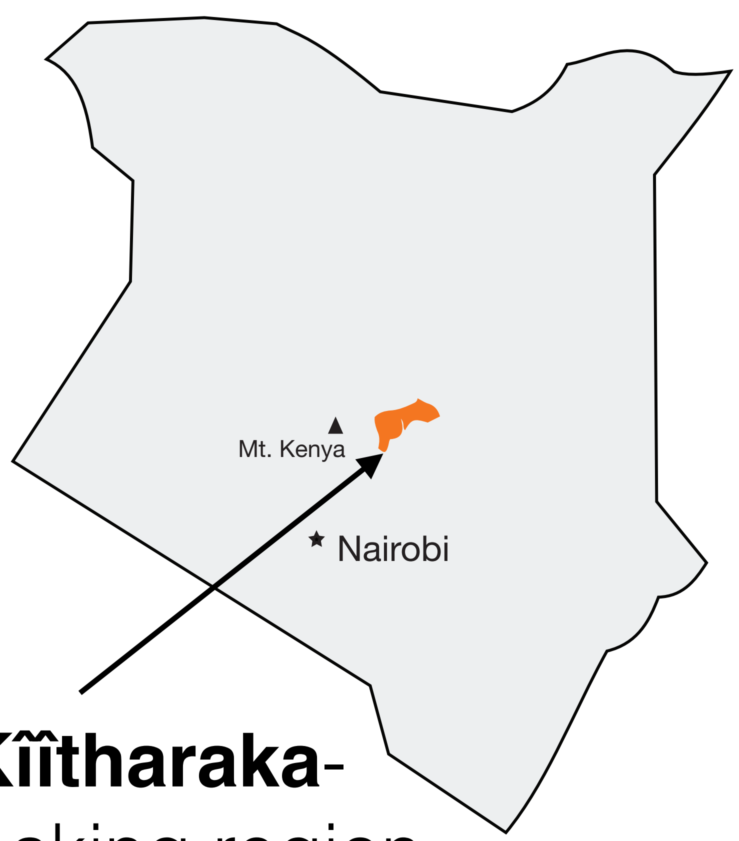
③ Prosodic breaks favor fusion of following words

(Bybee et al. 1990, Enrique-Arias 2002, Himmelmann 2014)

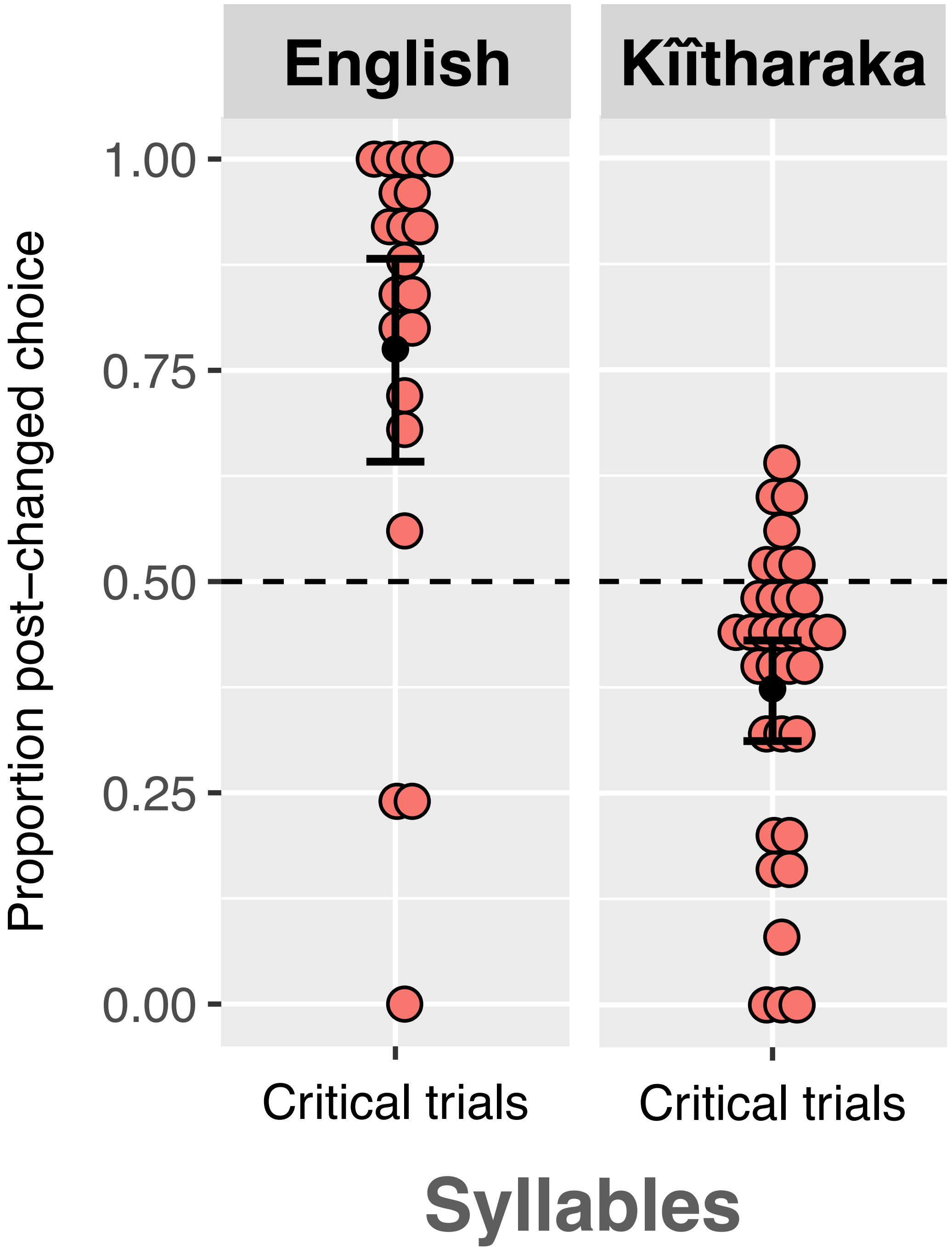
Cross-linguistic experimental evidence

tûbaka **tû**tû **tû**îrî **tû**ûthongî
PL.DIM-cat these two beautiful
these two beautiful kittens

Kenya



Kîîtharaka-
speaking region



(Martin & Culbertson 2020, *Psych Science*)

<u>Cross-linguistic</u> experimental evidence

<u>tû</u>baka	**<u>tû</u>**tû	**<u>tû</u>**îrî	**<u>tû</u>**ûthongî
PL.DIM-cat	these	two	beautiful

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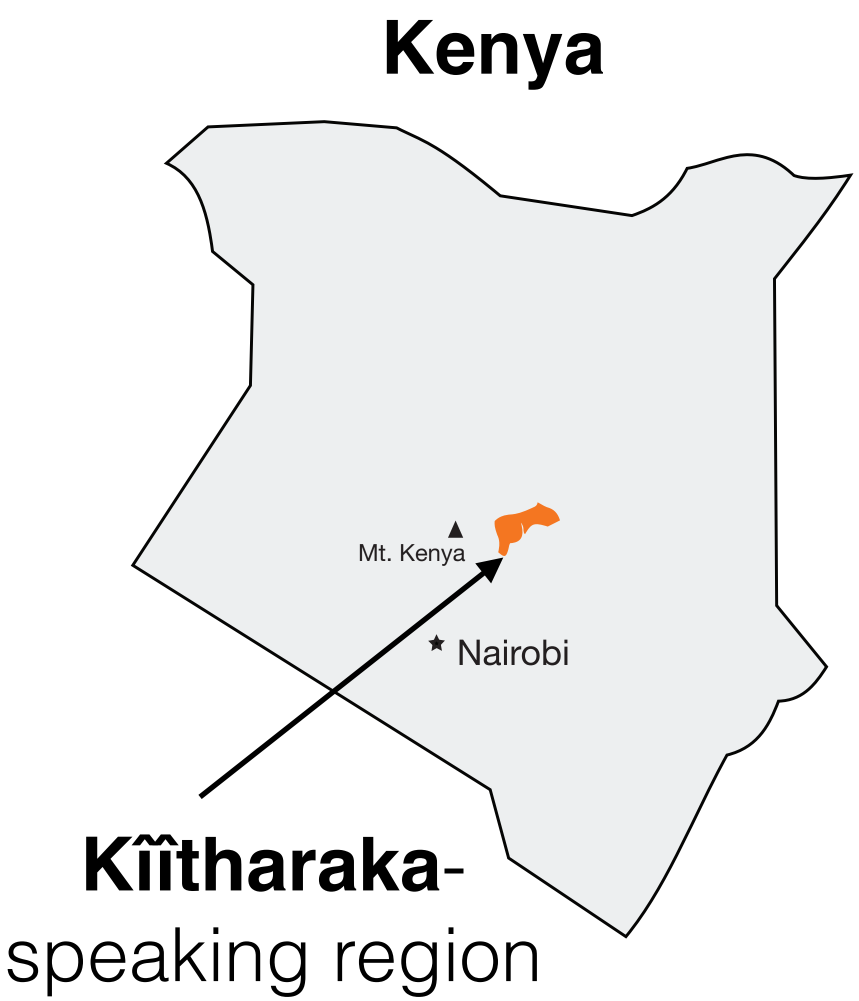
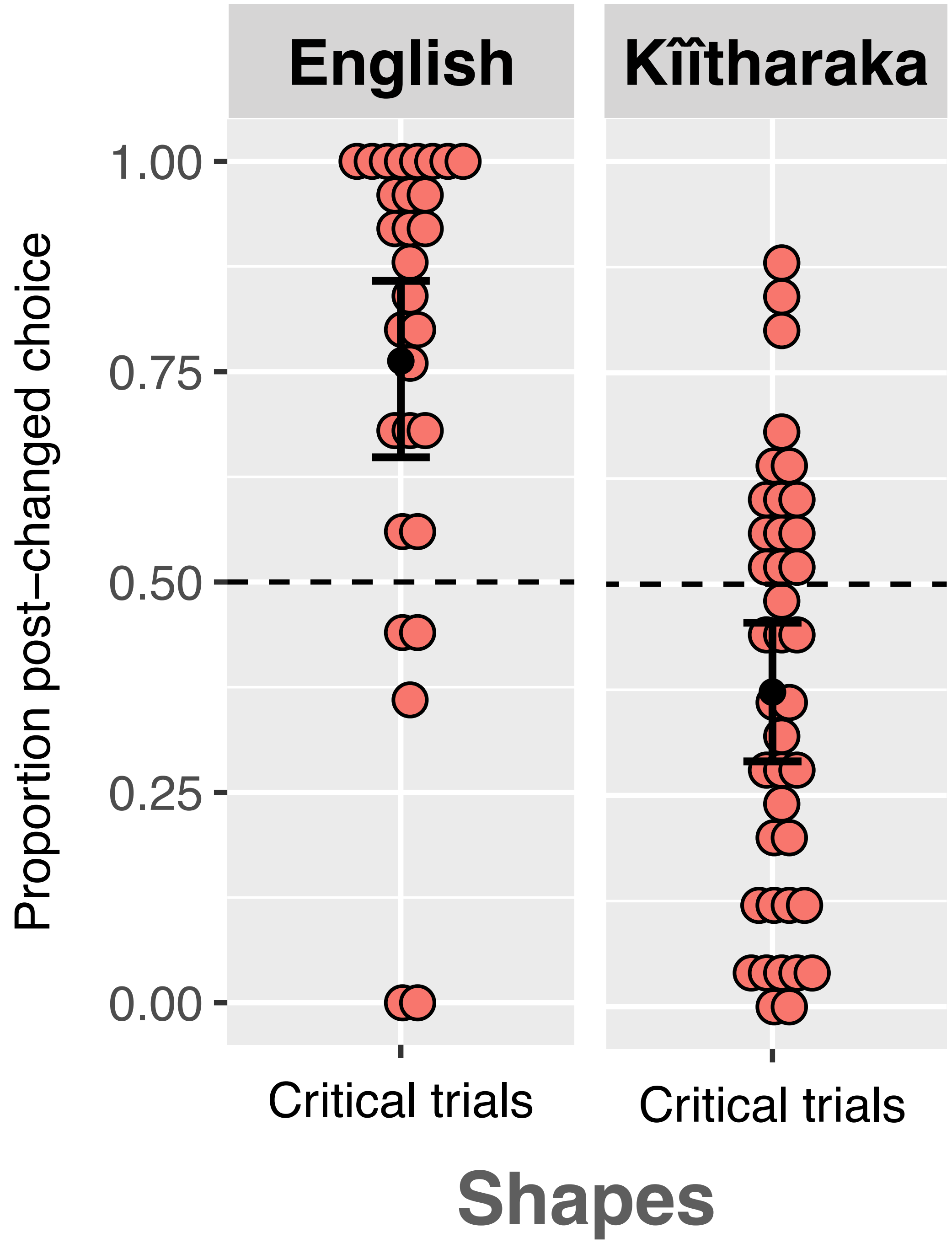




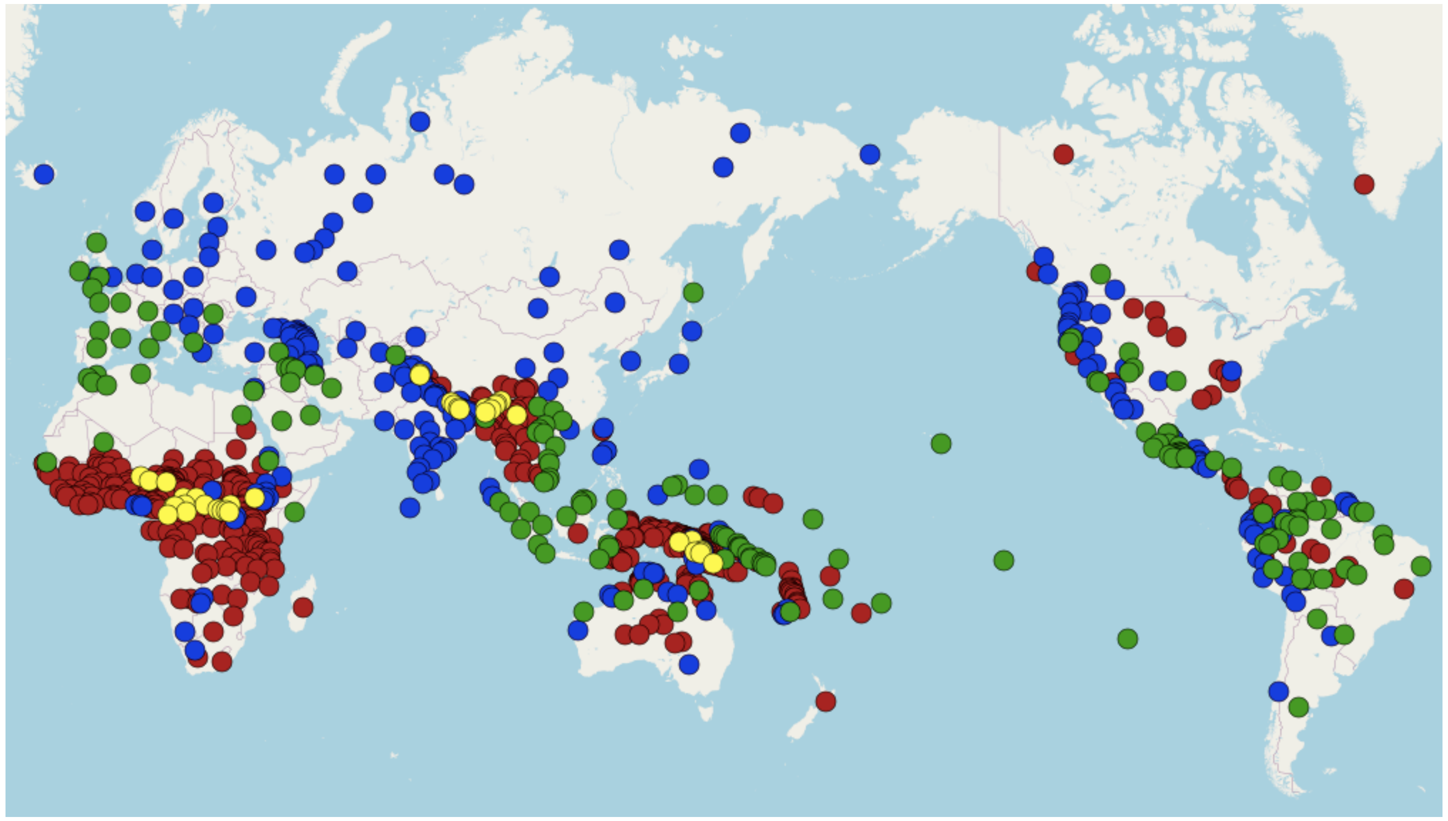
(Martin & Culbertson 2020, *Psych Science*)

Revisiting the suffixing preference

***No evidence* for a universal suffixing preference**

- When we test participants whose language *goes against* a cross-linguistic trend…the bias is reversed
- Best case scenario: perceptual biases are altered by language experience
- Worst case scenario: suffixing is not driven by universal perceptual biases

Revisiting word order harmony



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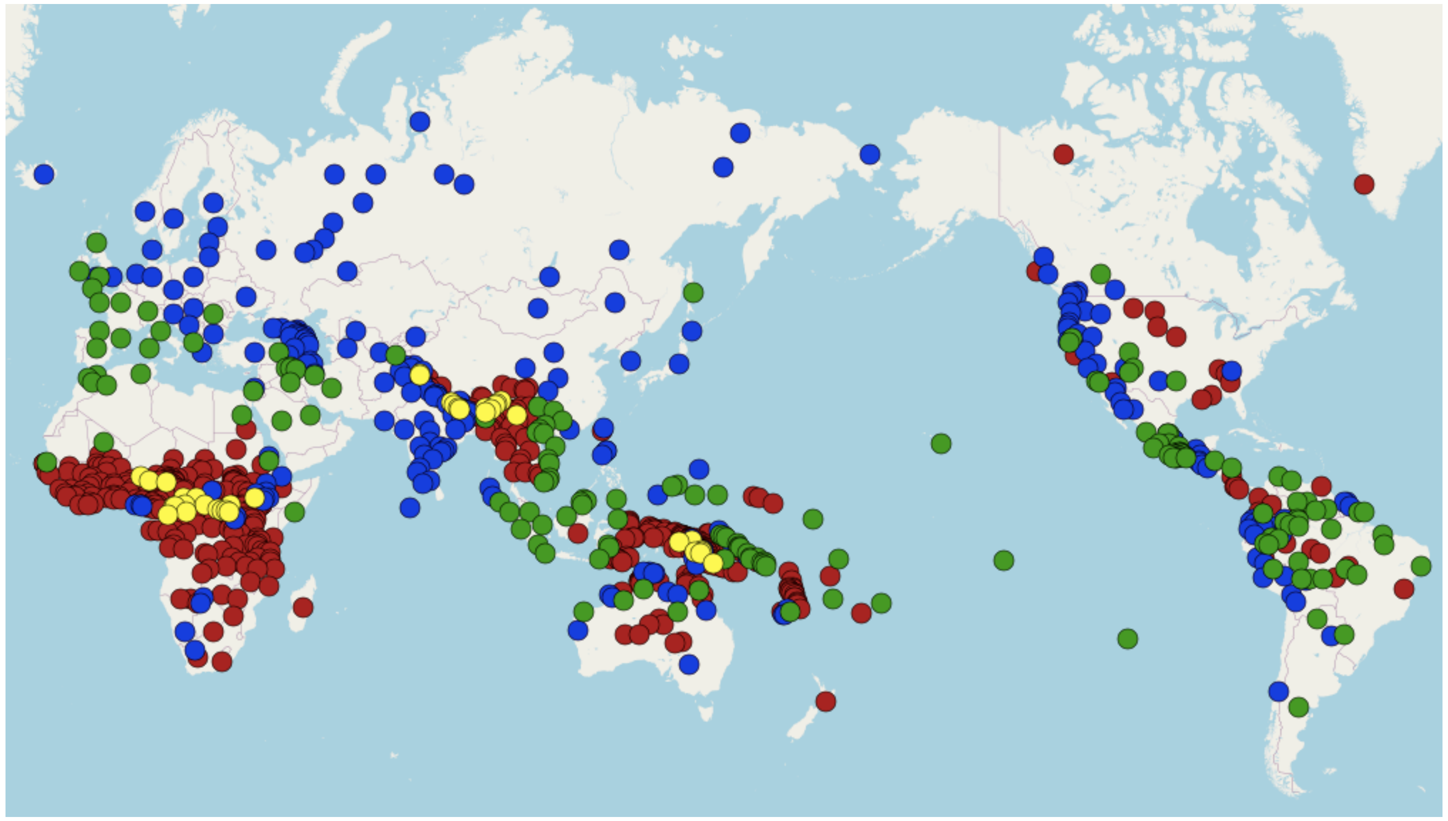
Hypothesis: driven by **universal learning bias** for simplicity

Evidence: Regularization by **English-speaking learners**

N Adj **N Num** trained order	**Adj N** **Num N** trained order	**Adj N** **N Num** trained order	**N Adj** **Num N** trained order

(Culbertson et al. 2012, Culbertson & Newport 2015, 2017 *Cognition*)

Revisiting word order harmony



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<u>Hypothesis 2:</u> words that share a **common historical source** share the same order

Yoruba

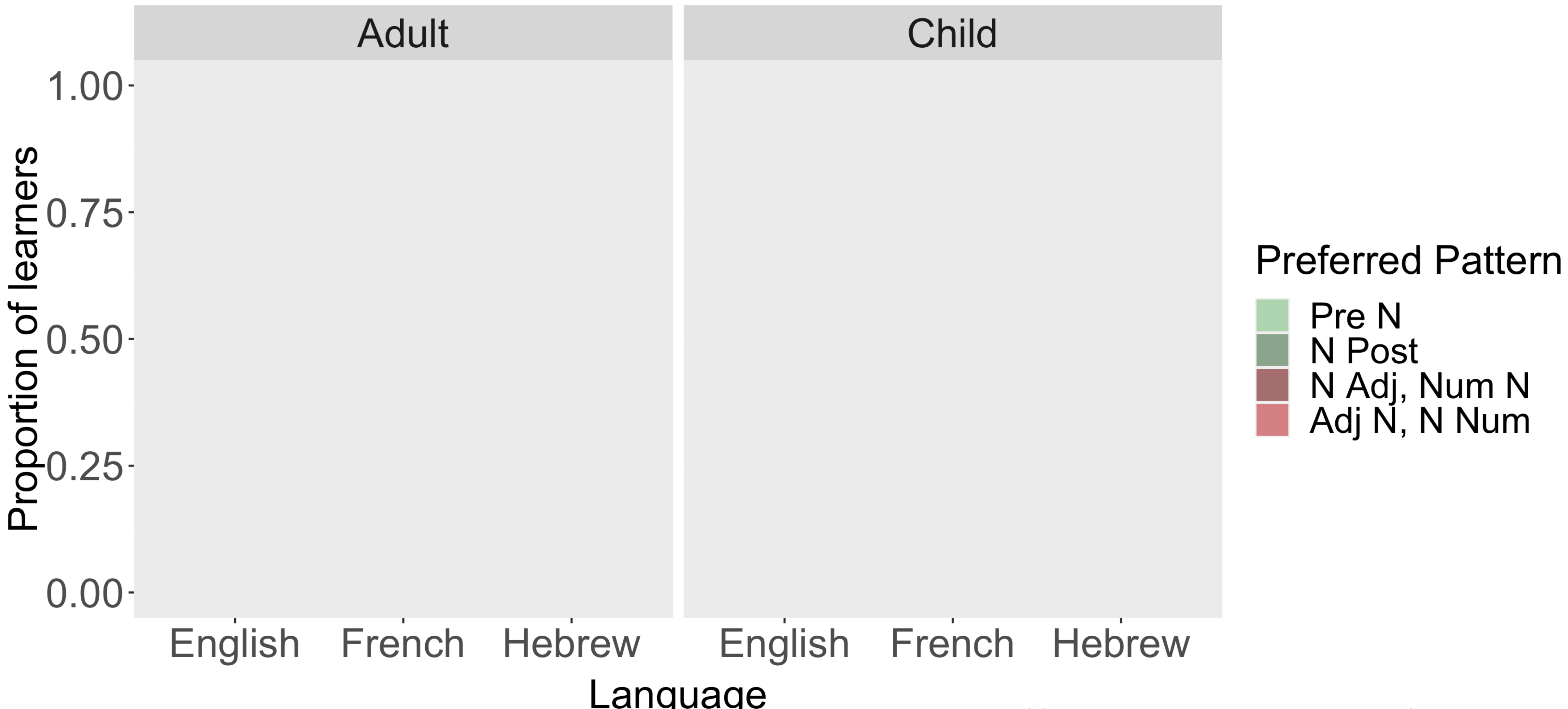
					⇒					
mo	fi	àdé	gé	nạkà		mo	fi	àdé	gé	nạkà
I	took	machete	cut	wood		I	with	machete	cut	wood
	V	N	V	N			Prep	N	V	N

(Givón 1975, Aristar 1991, Kaufman 2009)

Cross-linguistic experimental evidence

French <u>two</u> chairs <u>purple</u>

Hebrew <u>two</u> chairs <u>purple</u>



(Culbertson et al. 2015, Culbertson et al. 2020 *Cognition*)

Revisiting word order harmony

The harmony bias *is* universal

- When we test participants whose language *goes against* a cross-linguistic trend…the bias still holds

Hypothesis: driven by **learned categories** + **universal learning bias** for simplicity

① Heads vs. dependents
② Single ordering rule > multiple ordering rules

A further prediction: preference for consistent alignment of similar *non-linguistic categories*

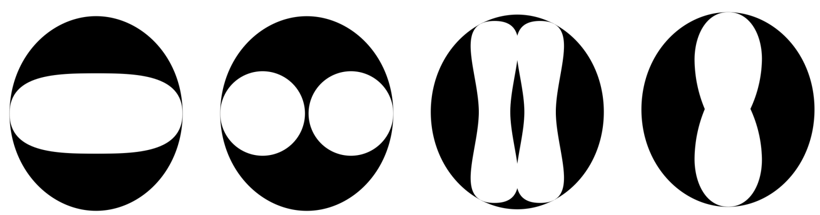
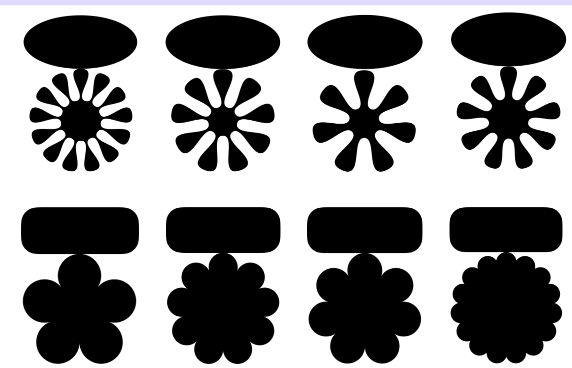
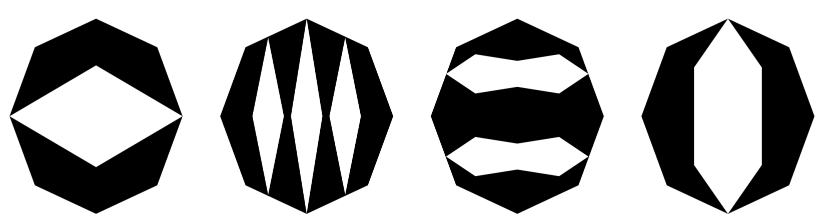
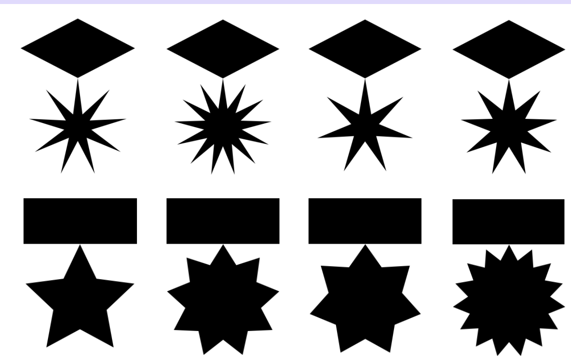
(Greenberg 1963, Vennemann 1973, Culbertson & Kirby 2016 *Frontiers*, Chater & Vitányi 2003)

Cross-domain evidence

- **Categories:** shapes
- Similarities among elements based on:

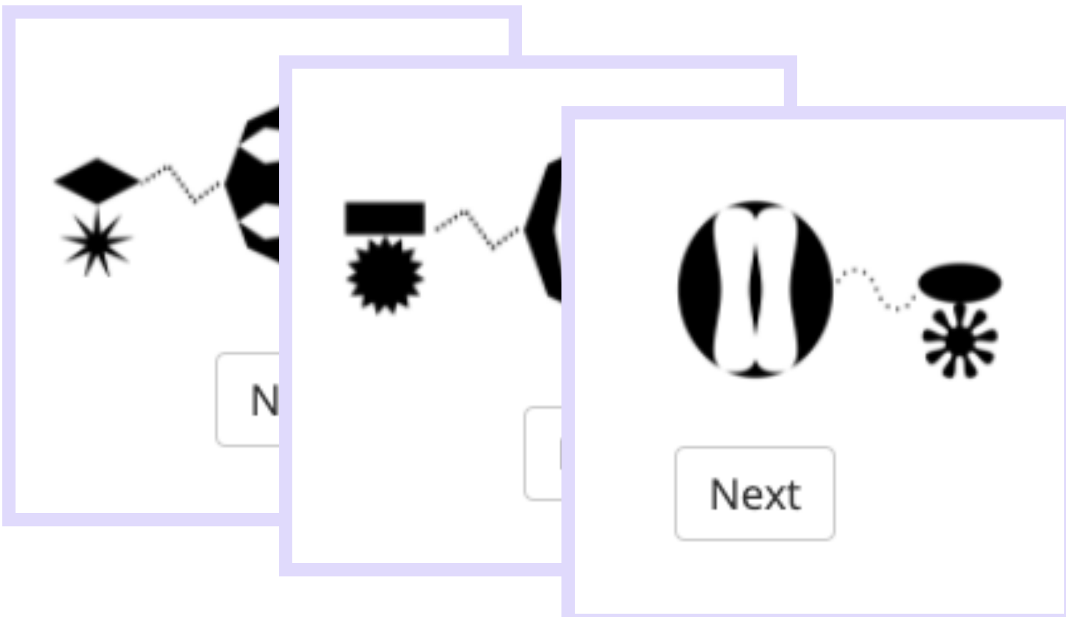
  size (heads vs. deps)

  roundness/fill (distinguishes head/dep categories)

Heads		Dependents	
Head1		Dep1a Dep1b	
Head2		Dep2a Dep2b	

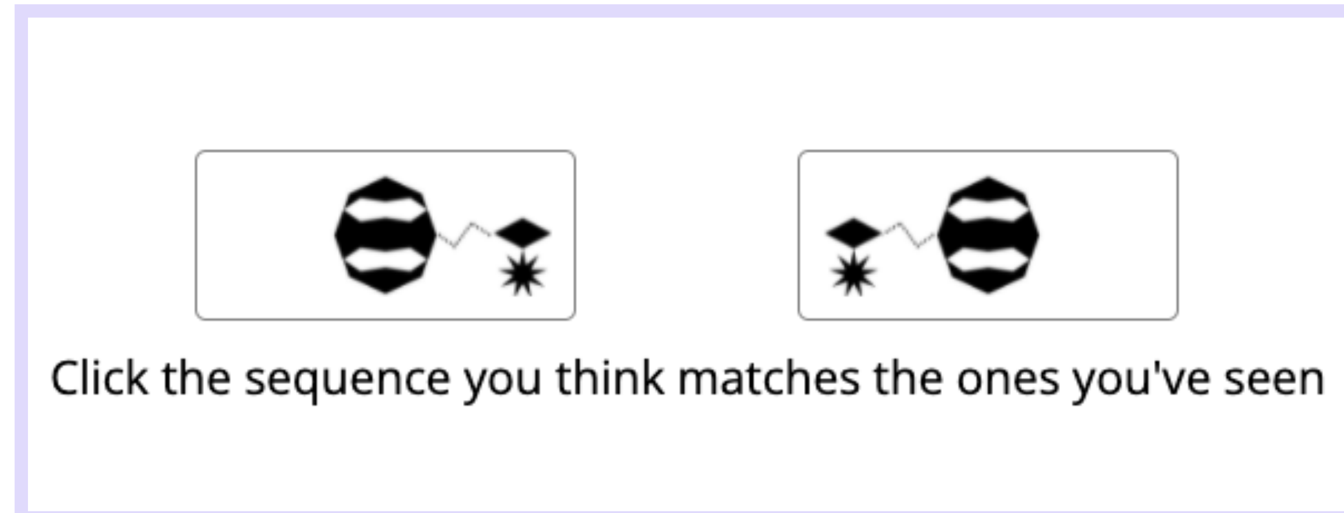
Cross-domain evidence

Training:



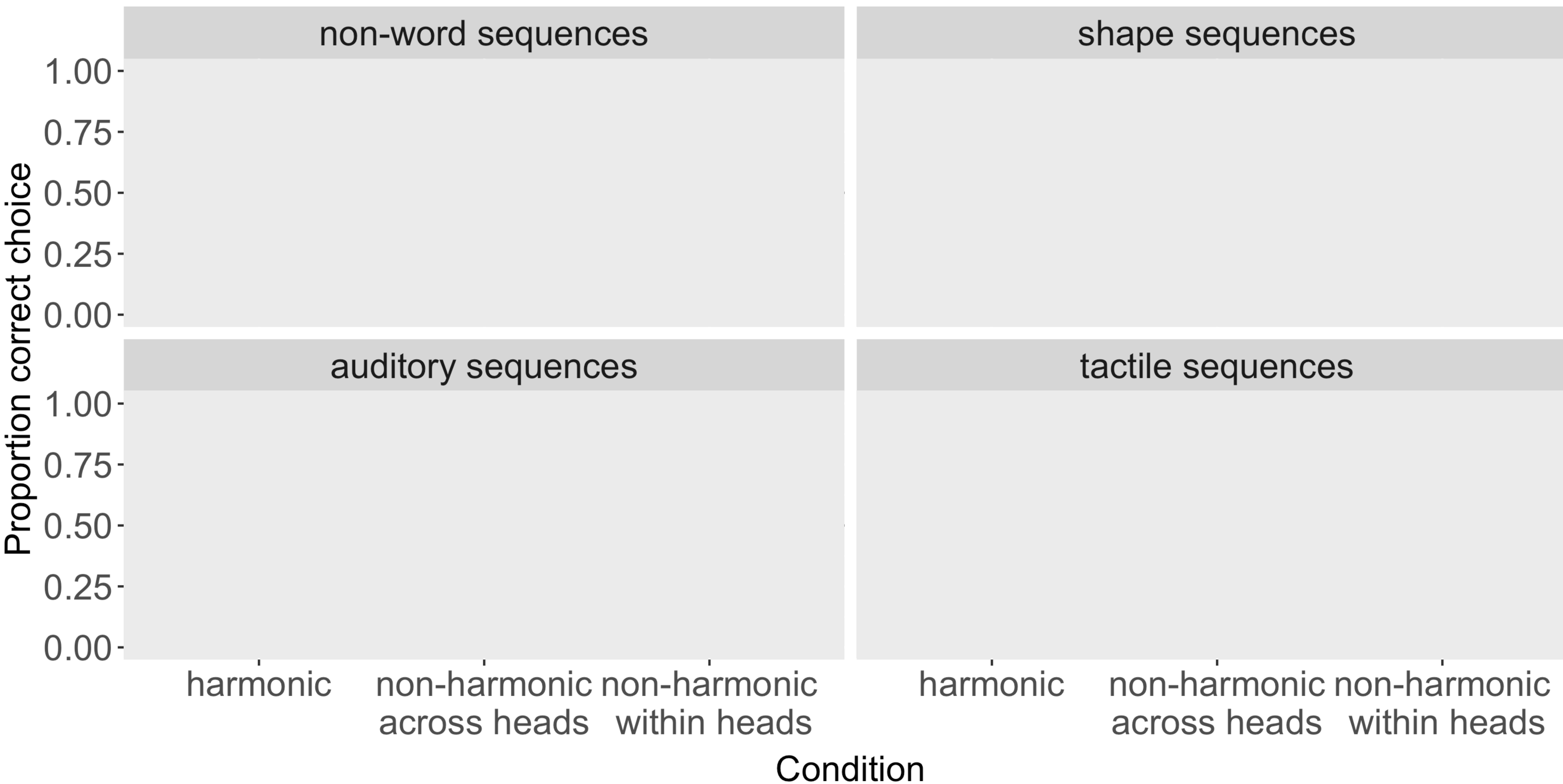
⇒

Testing:



Conditions	
1. Harmonic	• heads first • heads last
2. Non-harmonic *across* heads	• H1 first, H2 last • H1 last, H2 first
3. Non-harmonic *within* heads	• H1 mixed, H2 mixed • …

Cross-domain evidence



(Culbertson & Kirby 2022 *Proc. Cogsci*
Culbertson et al. under review)

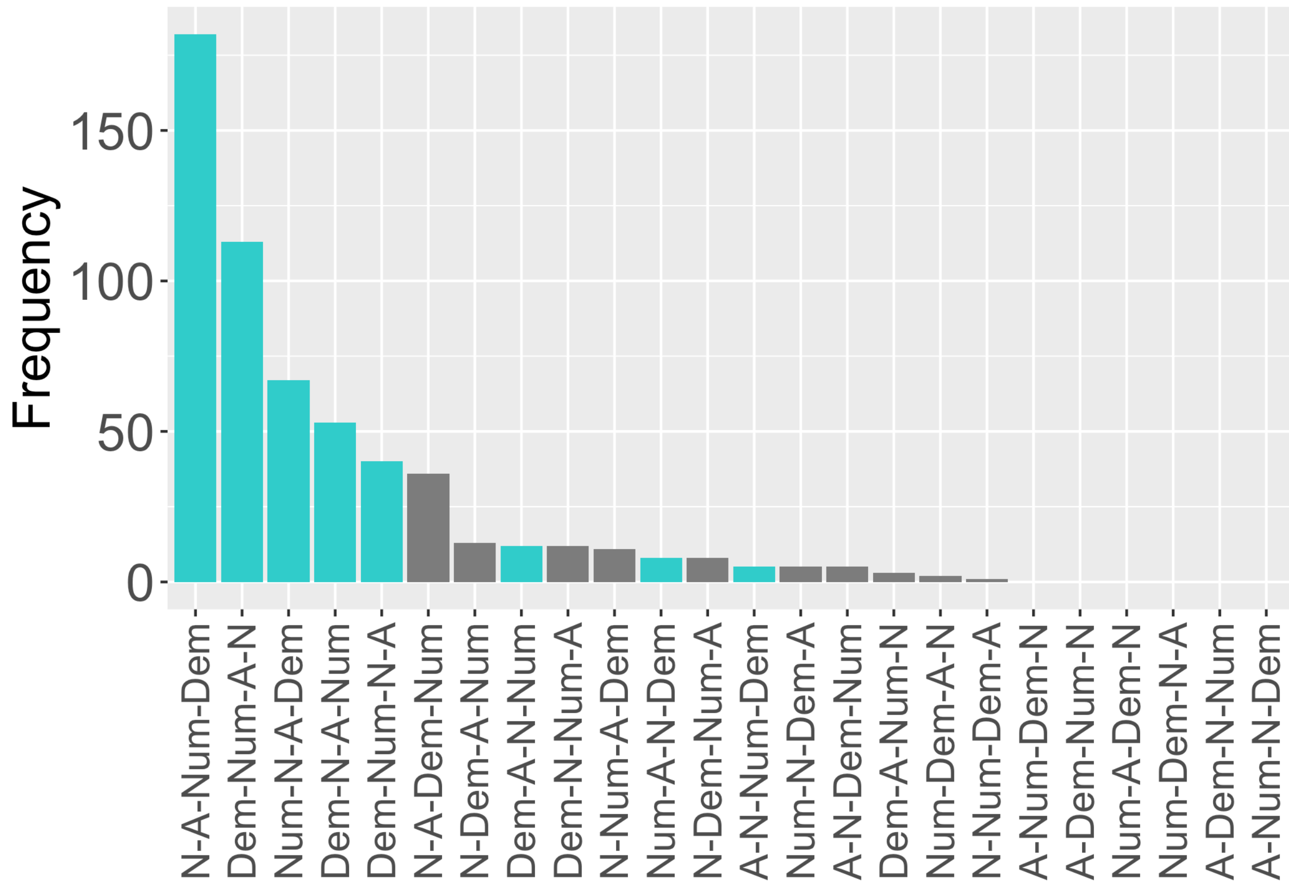
Revisiting word order harmony

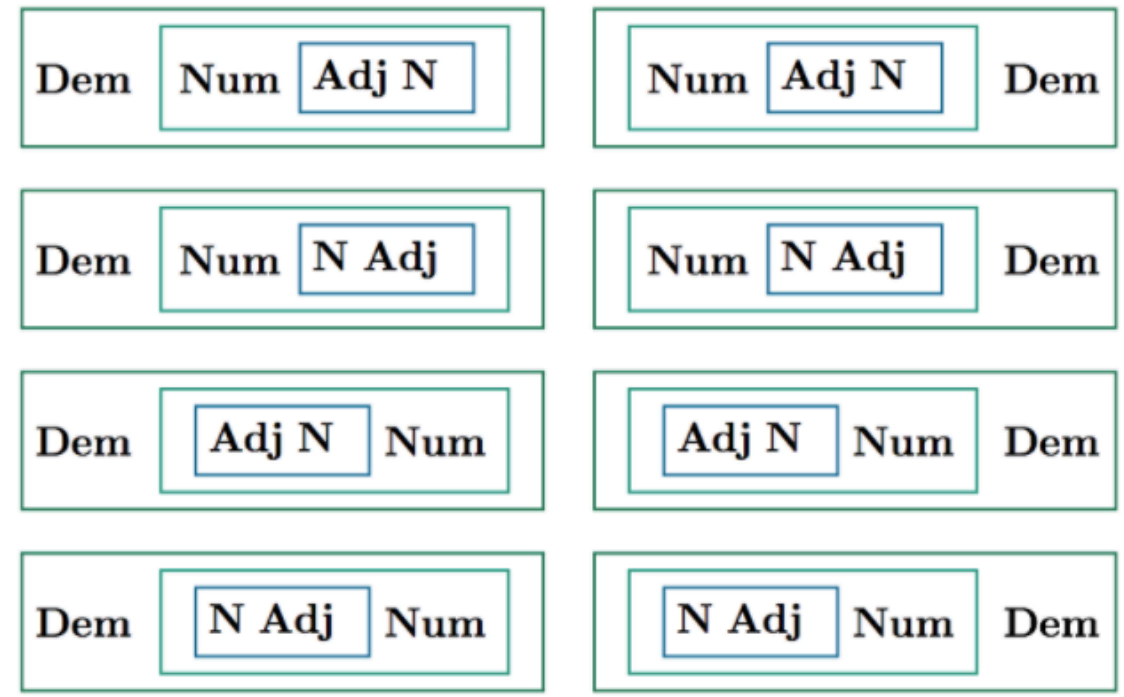
The harmony bias *is* universal and *domain-general*

- When we test participants whose language *goes against* a cross-linguistic trend…the bias still holds
- When we test harmony in the sequential ordering of *non-linguistic* categories…the bias still holds

(Greenberg 1963, Vennemann 1973, Culbertson & Kirby 2016 *Frontiers*, Chater & Vitányi 2003)

Revisiting complex NP order





Hypothesis: driven by **universal hierarchy**

Evidence: inferences of **English-speaking learners**

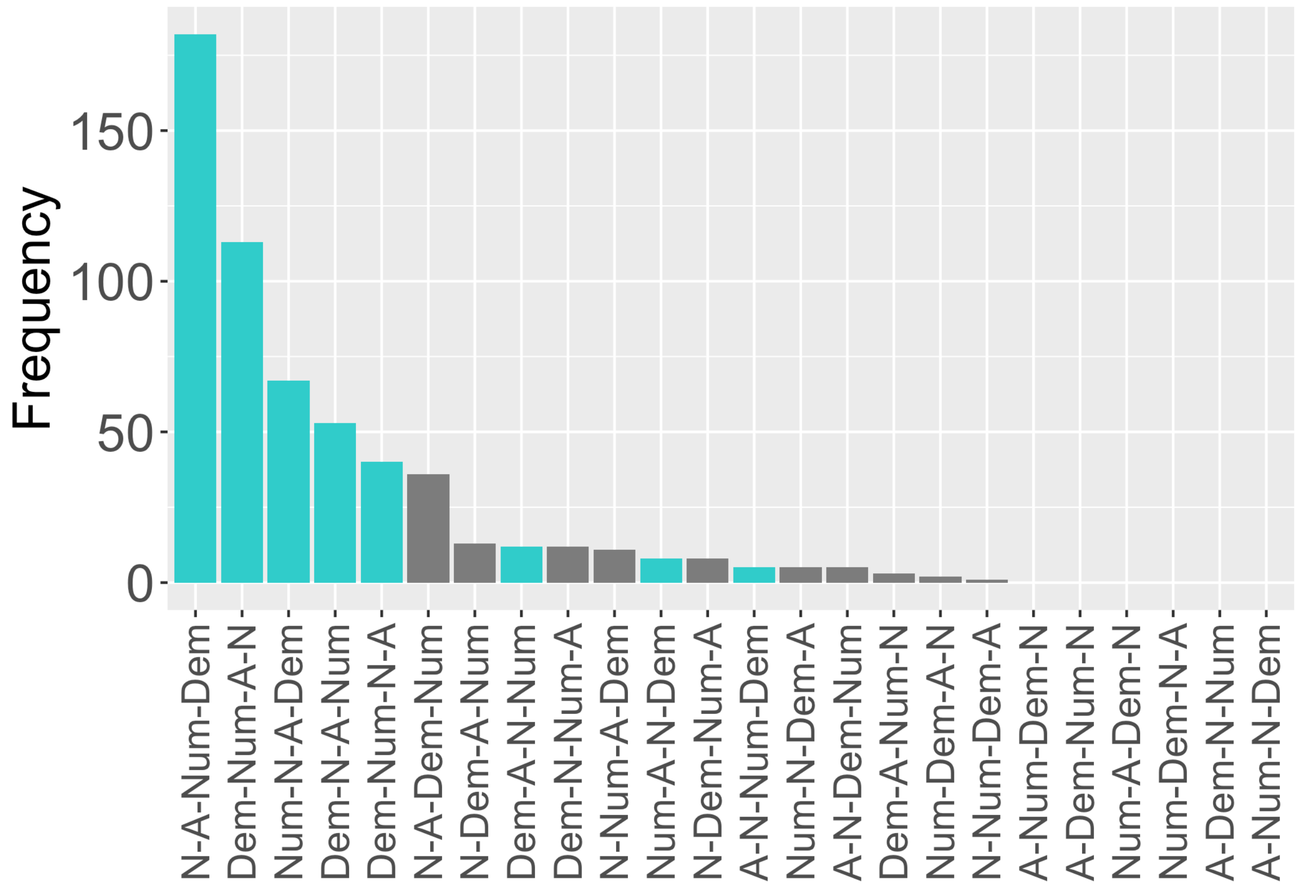
N Adj
N Dem
trained order

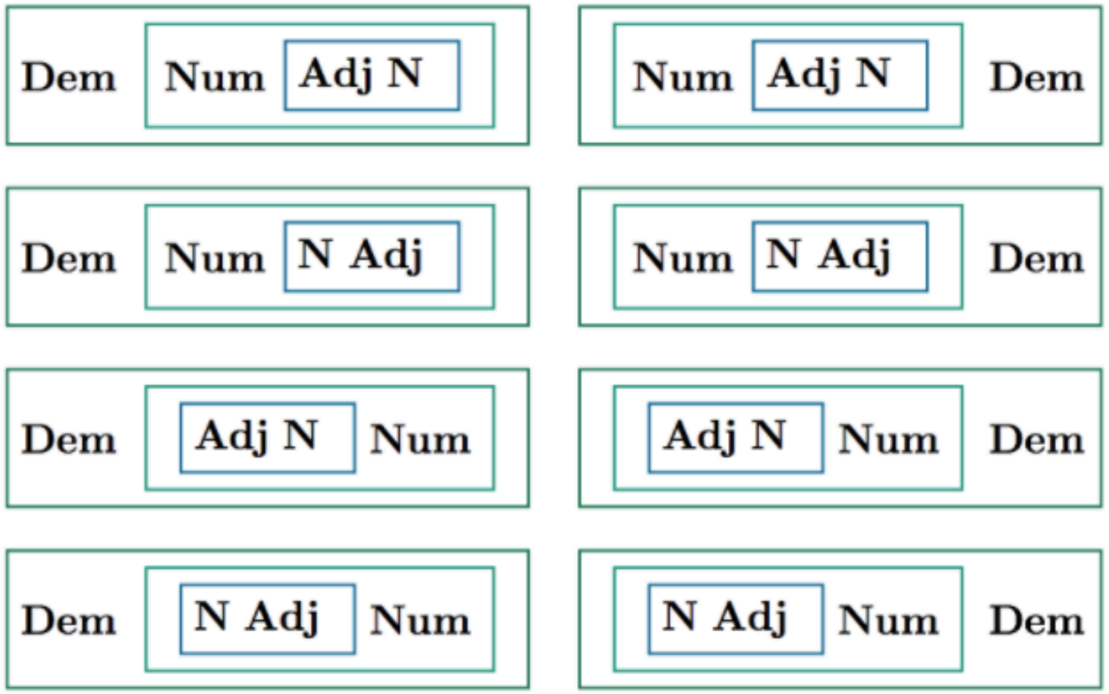
N Adj Dem
homomorphic

N Dem Adj
non-homomorphic

(Martin et al. 2020 *Glossa*, Culbertson & Adger 2014 *PNAS*)

Revisiting noun phrase word order





<u>Hypothesis 2:</u> (harmony +) noise

① Two most common orders are harmonic

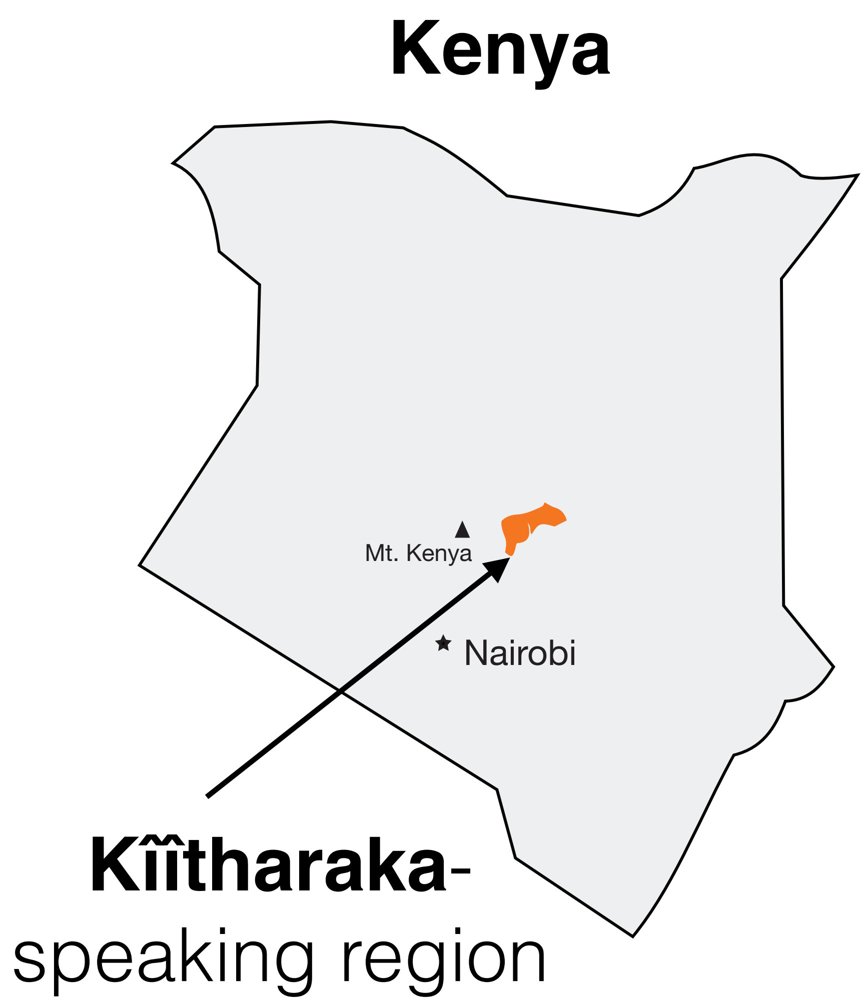
② Zipfian distributions arise naturally via drift

(Gel-Mann & Ruhlen 2011, Martin et al. in prep)

Cross-linguistic experimental evidence

tûbaka	tûtû	tûîrî	tûûthongî
PL.DIM-cat	these	two	beautiful

these two beautiful kittens



Cross-linguistic experimental evidence

tûbaka	tûtû	tûîrî	tûûthongî
PL.DIM-cat	<u>these</u>	<u>two</u>	<u>beautiful</u>

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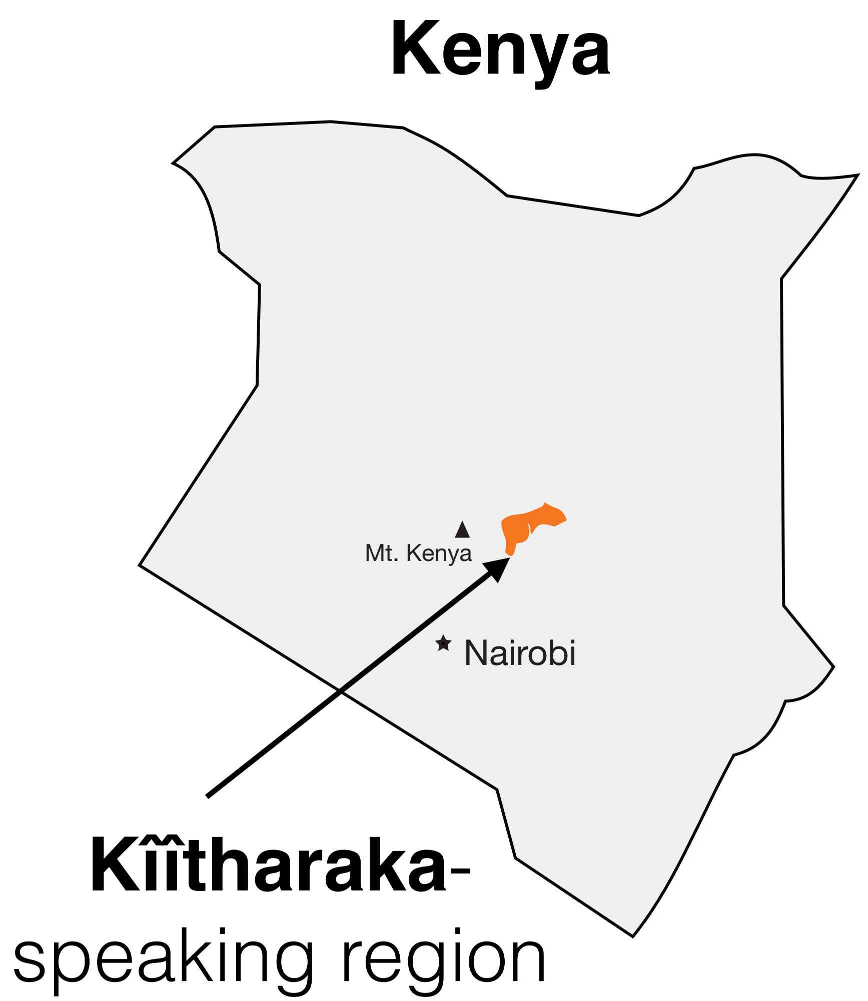
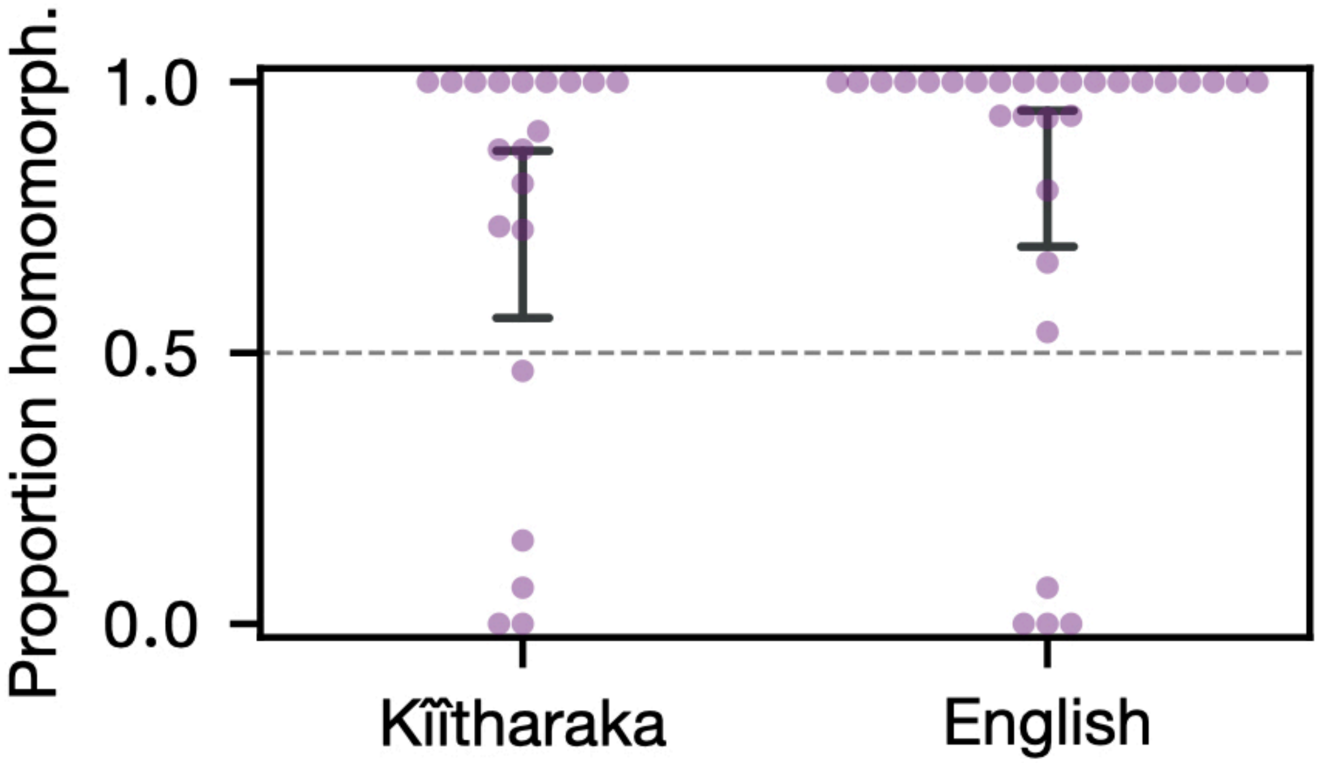




(Martin et al. in prep)

Revisiting complex NP order

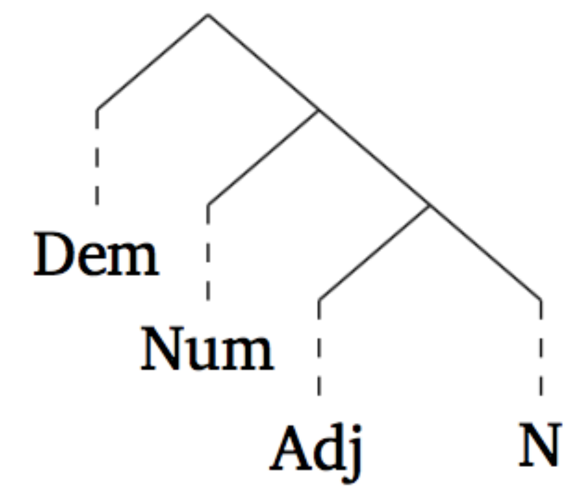
The homomorphism preference *is* a universal bias

- When we test participants whose language *goes against* a cross-linguistic trend…the bias still holds

Hypothesis: driven by **universal hierarchy**

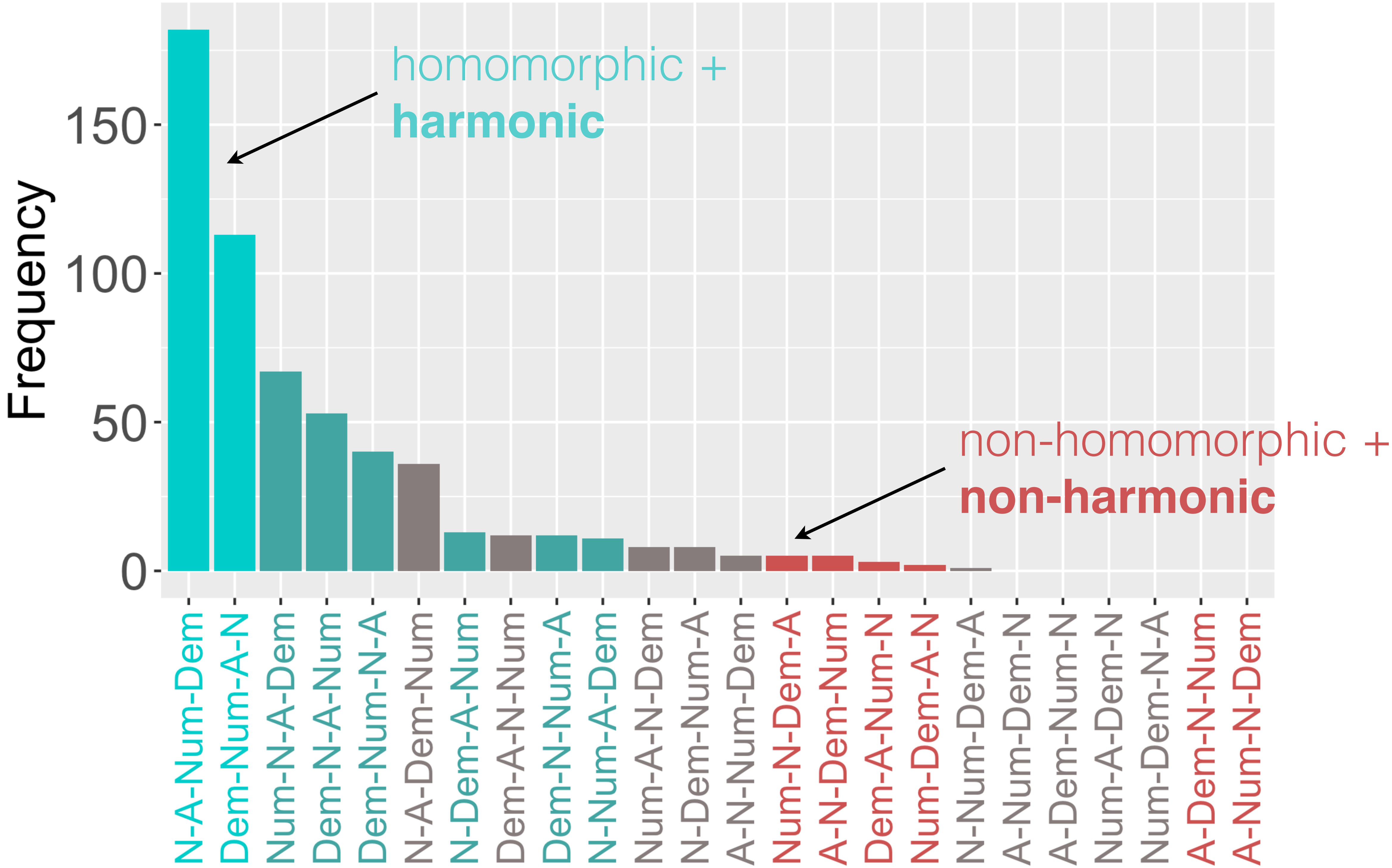
① Adj organised closest to Noun, then Num, then Dem

② Orders that are homomorphic to the hierarchy are preferred



(Cinque 2005, Abels & Neeleman 2012, Culbertson & Adger 2014 *PNAS*)

Hierarchy + harmony



(Corpus data: Dryer 2018)

Revisiting complex NP order

Homomorphism *is* a universal bias

- When we test participants whose language goes against a cross-linguistic trend…the bias still held

<u>Hypothesis:</u> driven by **universal hierarchy**

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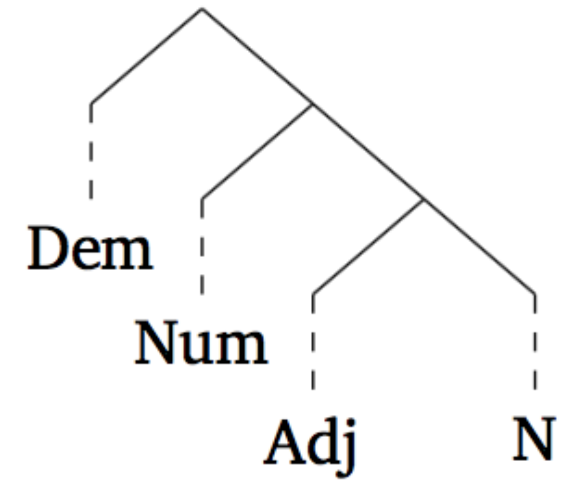


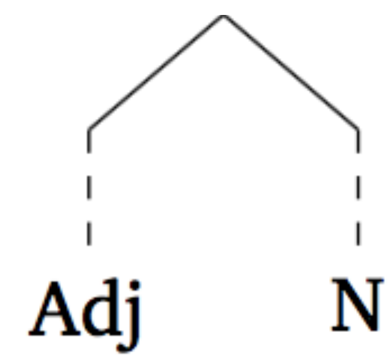
<u>A further question:</u> where does the hierarchy come from?

(Cinque 2005, Abels & Neeleman 2012, Culbertson & Adger 2014 *PNAS*)

An intuition…

{objects,properties} >
{objects,numerosities} >
{objects,discourse status}

⇒



Quantifying the intuition

Underlying structure reflects differences in **conceptual closeness**

- A quantitative measure of strength of association: *pointwise mutual information*

$$pmi(x, y) \equiv \frac{p(x, y)}{p(x)p(y)}$$

← Frequency of pair together

← Frequency of individual elements

- Is co-occurence frequency <u>higher than expected</u> given individual frequencies of elements alone?

(Culbertson et al. 2020, *Language*)

Quantifying the intuition

Prediction:

pmi {objects,properties} >
pmi {objects,numerosities} >
pmi {objects,discourse status}

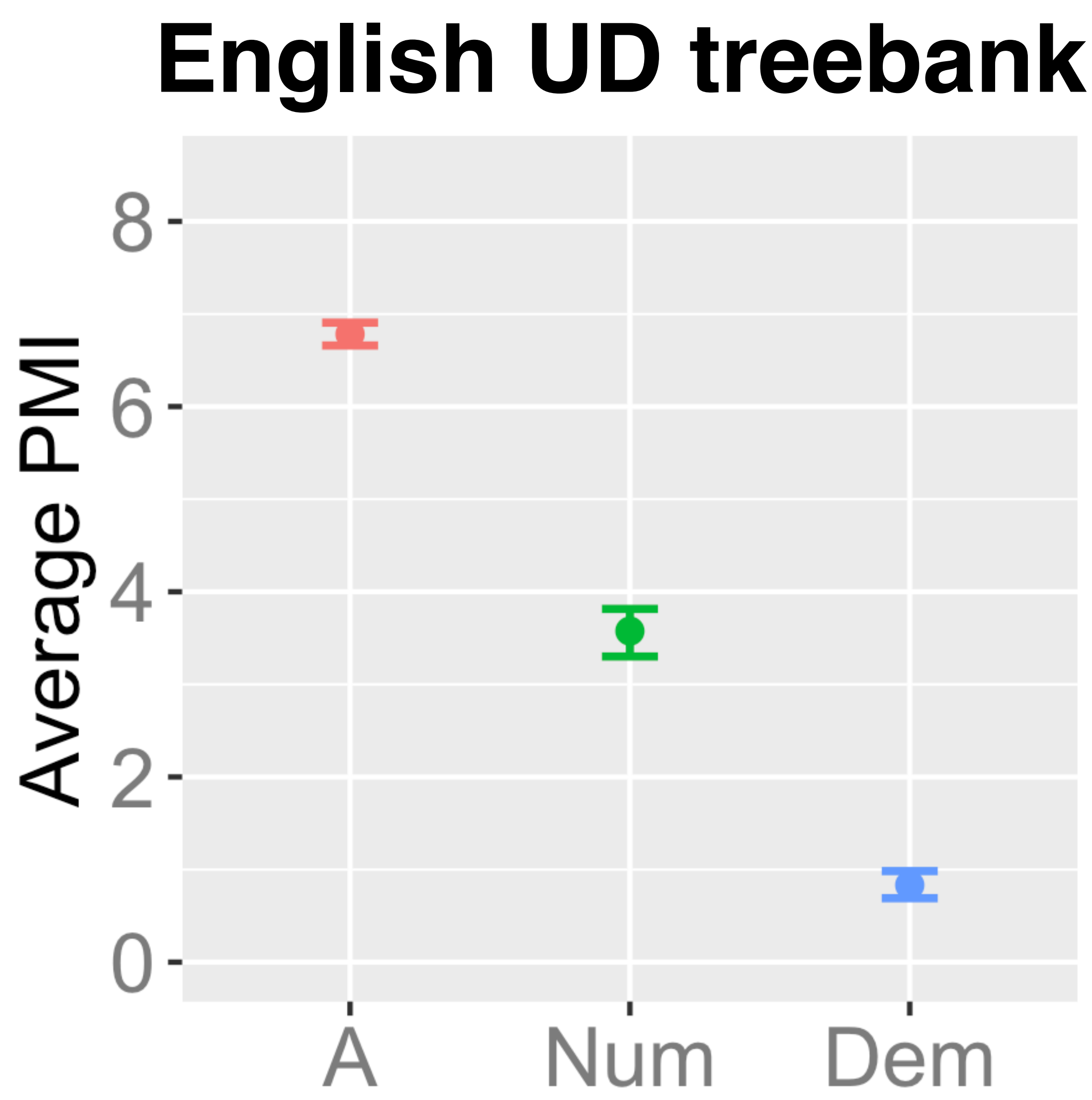
- Test using corpus of…the world??
- Test using **treebank corpora** for 25 different languages
- How it works:

```
1. Get all (N, Mod) bigrams and their frequencies
2. Discard very low frequency pairs
3. Calculate pmi for each pair
4. Average pmi for each modifier type
```

(Culbertson et al. 2020, *Language*)

Evidence from English

Prediction: pmi {N,Adj} > pmi {N,Num} > pmi {N,Dem}



High pmi:

`alcoholic beverage`
`dense vegetation`
`seven founders`

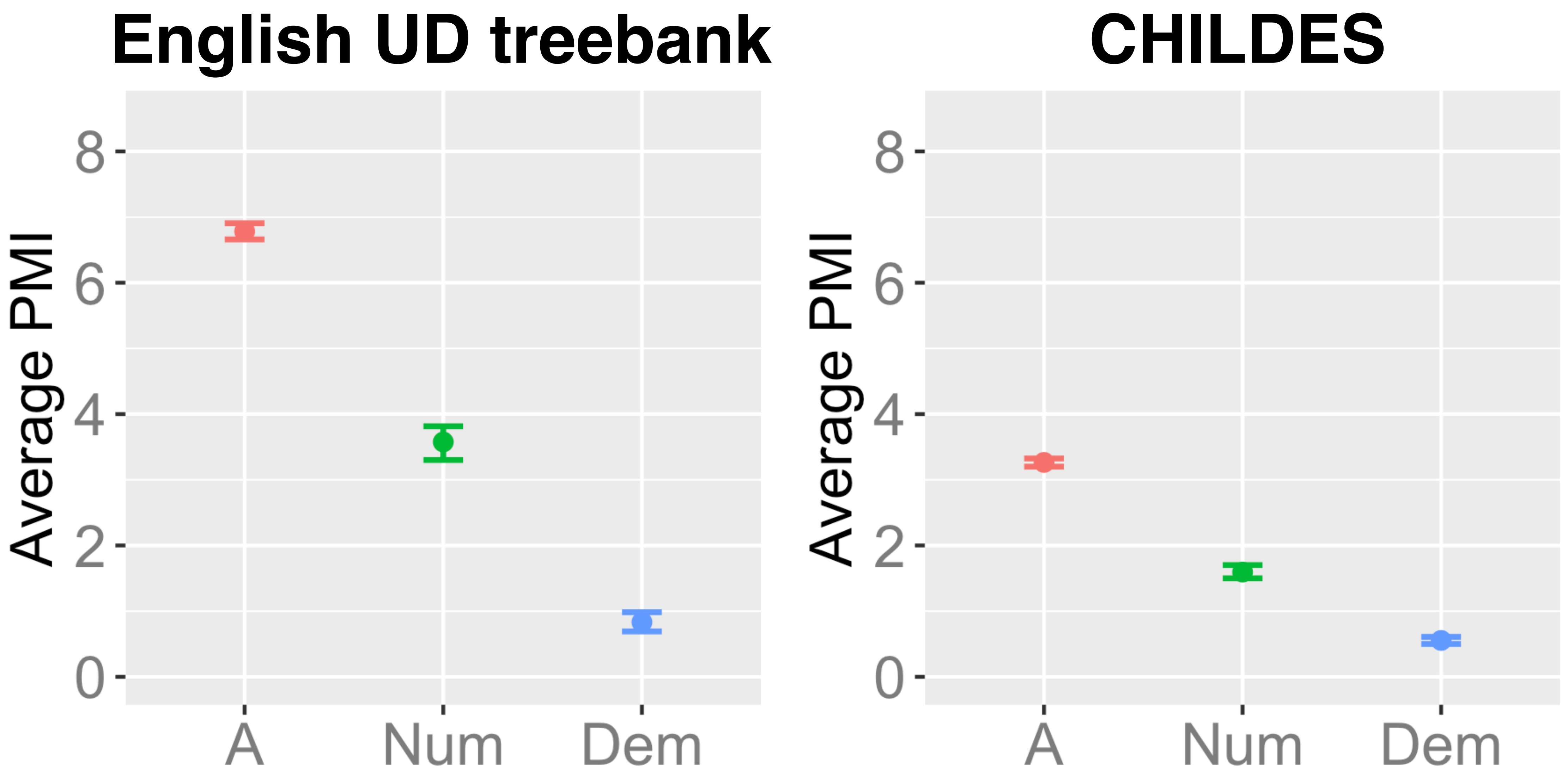
Low pmi:

`that child`
`new fact`
`one program`

(Culbertson et al. 2020, *Language*)

Evidence from English

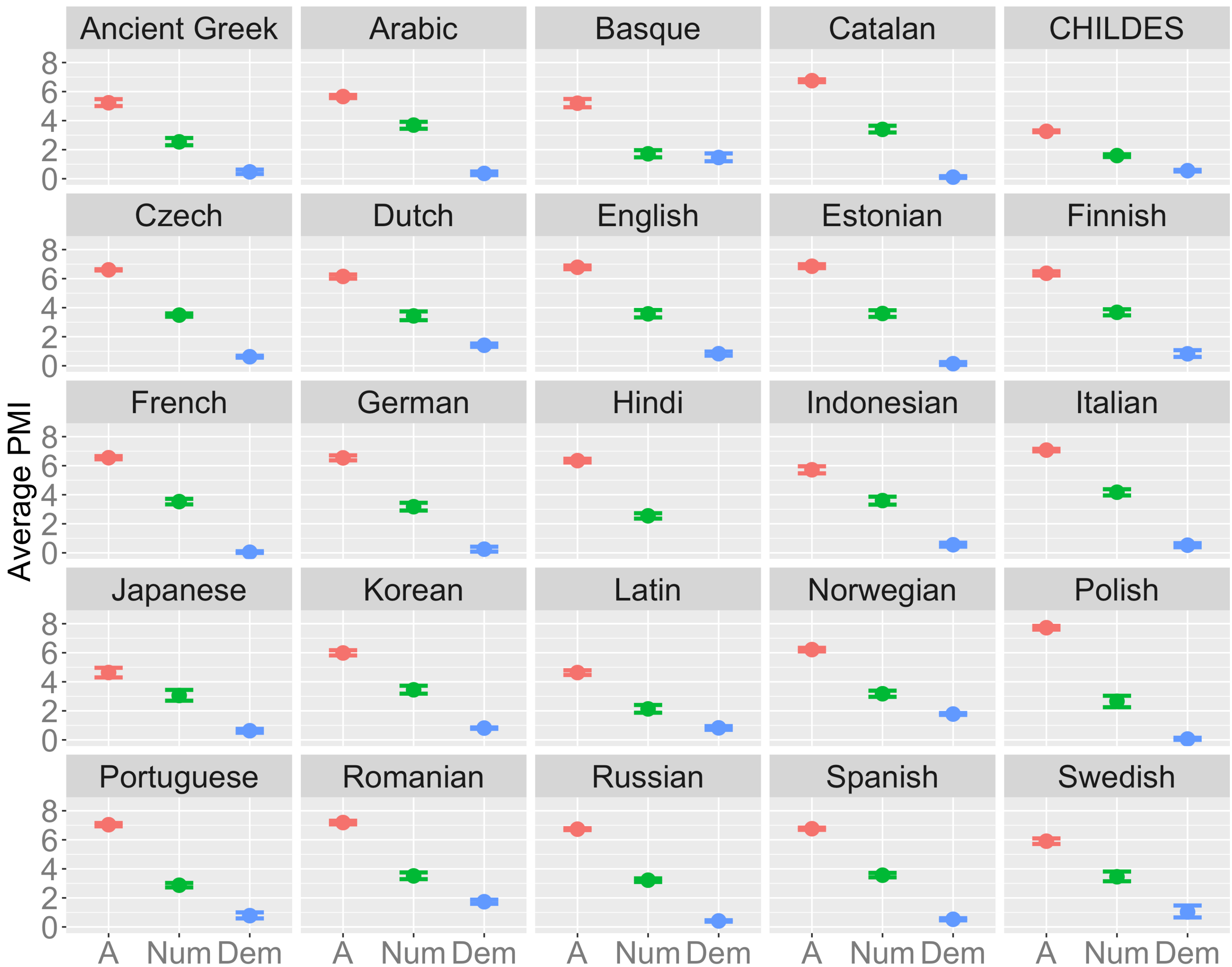
Prediction: pmi {N,Adj} > pmi {N,Num} > pmi {N,Dem}



(Culbertson et al. 2020, *Language*)

Cross-linguistic evidence

Prediction: pmi {N,Adj} > pmi {N,Num} > pmi {N,Dem}

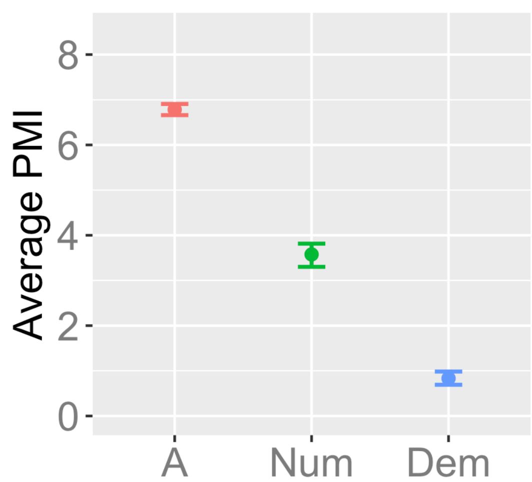


(Culbertson et al. *Language*)

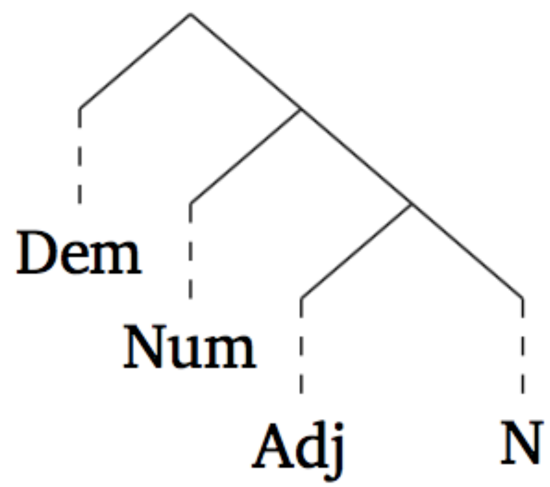
Revisiting complex NP order

Complex NP order:

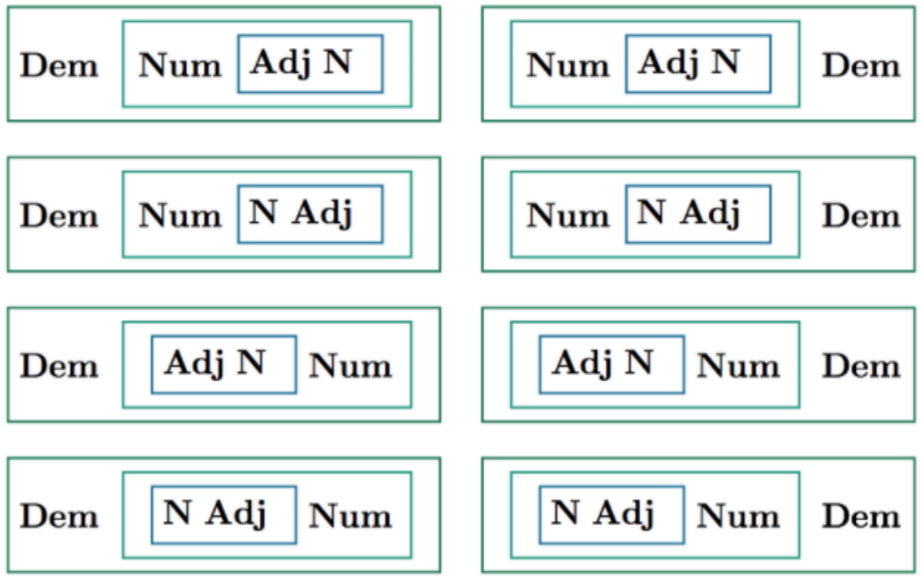
- Universal hierarchy derived from conceptual structure
- Universal bias favouring transparent linearisation



⇒



⇒



<u>A further prediction:</u> preference for homomorphism *without syntax*

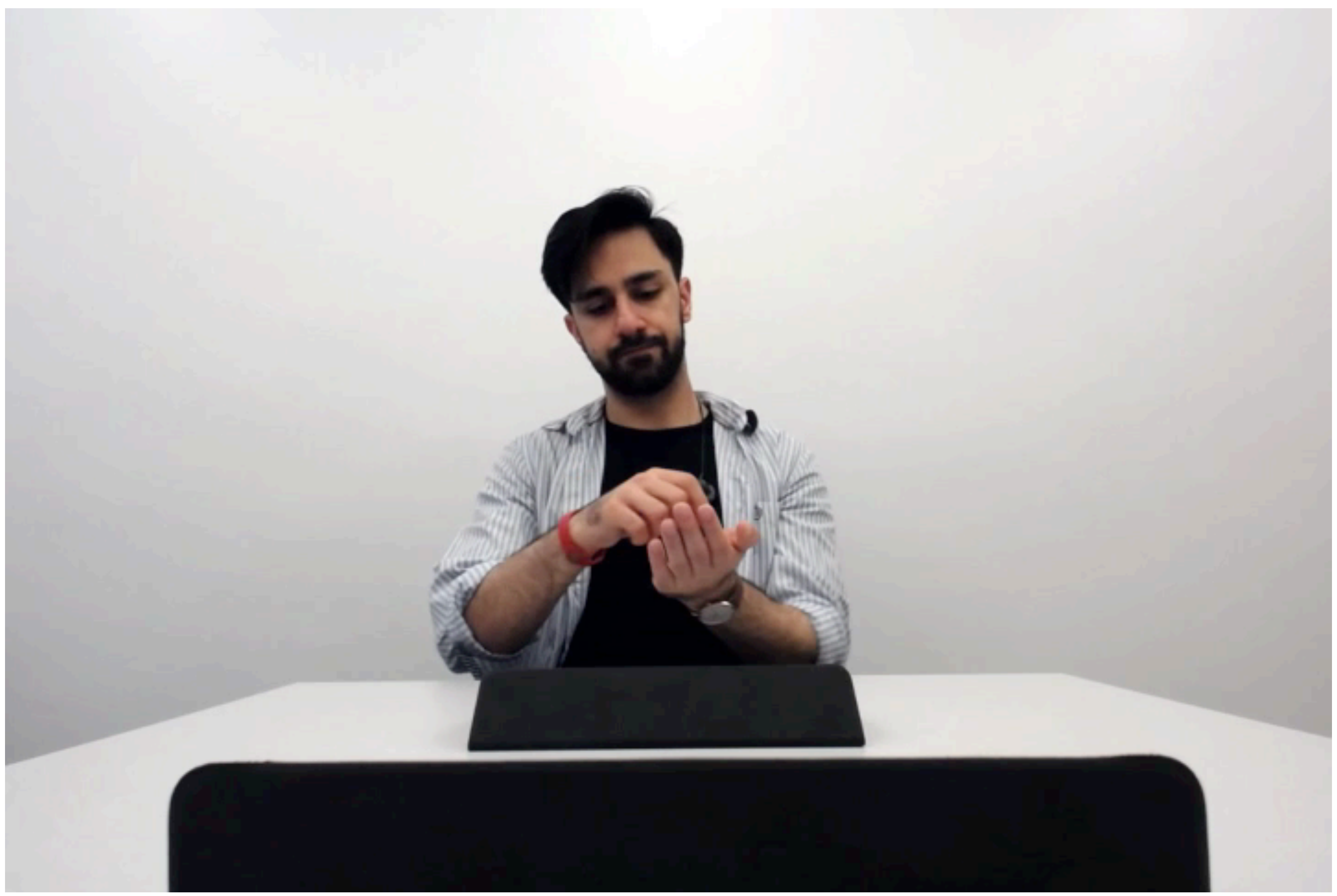
Cross-domain evidence

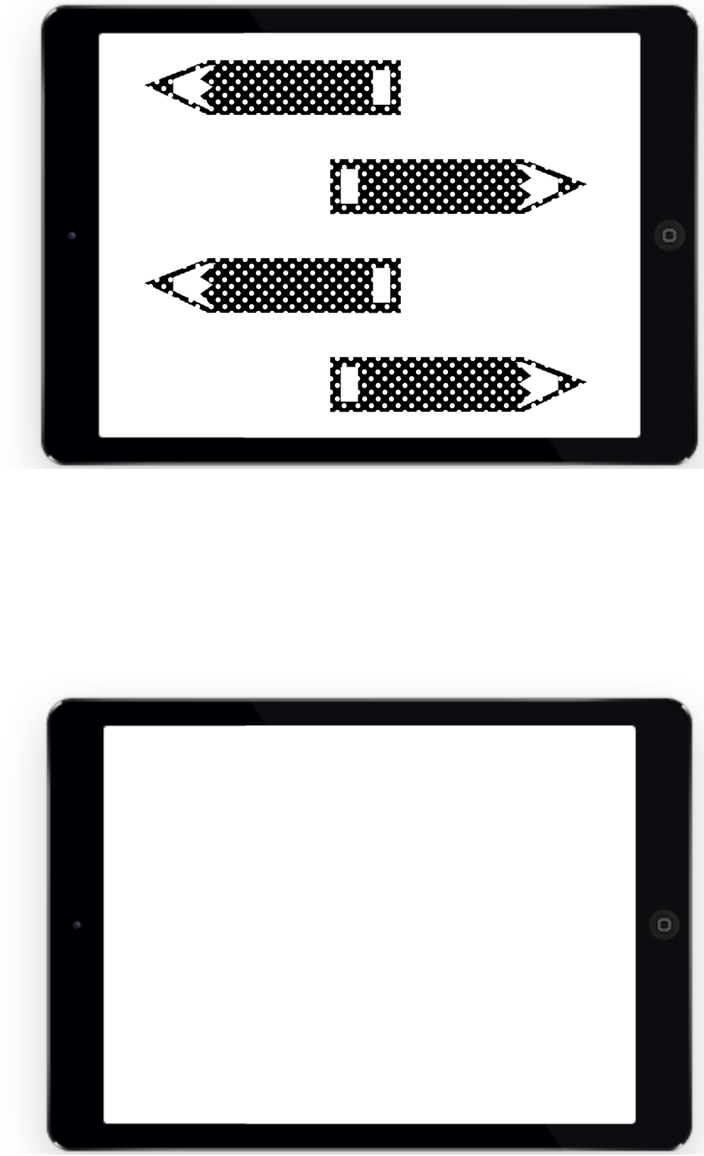
<u>Silent Gesture:</u> participants use an **unfamiliar modality**—their hands—to communicate concepts

(Culbertson et al. 2020, *Language*)

Cross-domain evidence

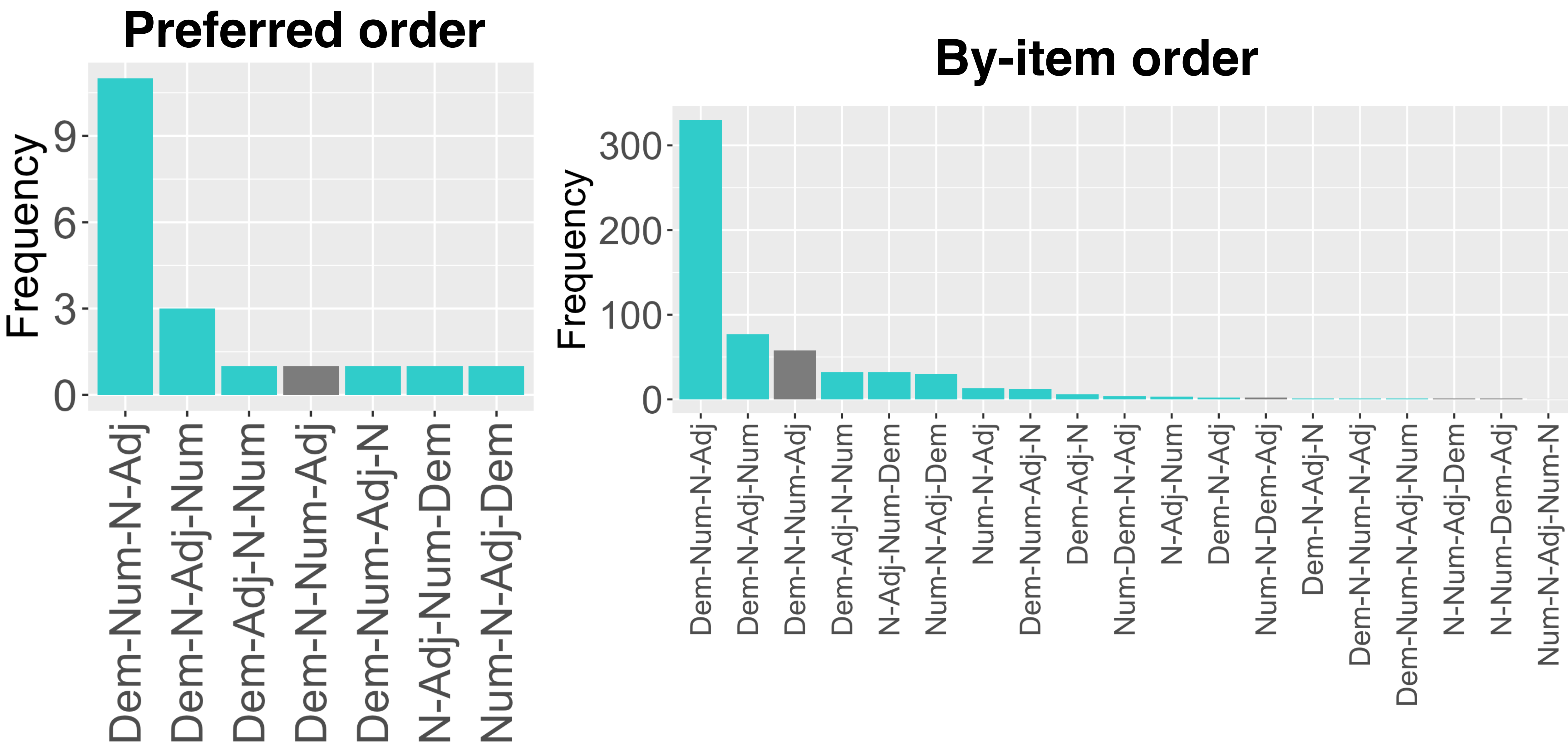
<u>Silent Gesture:</u> participants use an **unfamiliar modality**—their hands—to communicate concepts





(Culbertson et al. 2020, *Language*)

Cross-domain evidence



(Culbertson et al. 2020, *Language*)

Revisiting complex NP order

Homomorphism *is* universal bias

- When we test participants whose language *goes against* a cross-linguistic trend…the bias still holds

The hierarchy is *conceptual*

- When people communicate concept *non-syntactically*… homomorphism to the hierarchy still holds
- Evidence from cross-linguistic corpora suggests conceptual relationships between elements is *learnable*

Conclusion

What drives variation and commonalities?

- Culture, history, the physical world, processes of language change
- Features of cognition (perception)

How can we identify the role **cognition** plays?

- Experiments!
- Cross-linguistic evidence: participants whose language goes against the trend
- Cross-domain evidence: uncover the origins of biases

Thank you!

Many collaborators on this work:

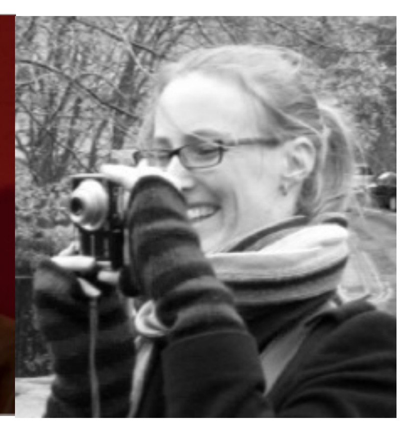
Patrick Kanampiu · David Adger · Alex Martin

Klaus Abels

Theeraporn Ratitamkul

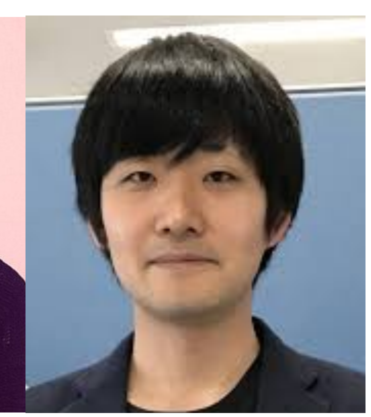
Annie Holtz

Simon Kirby



Marieke Schouwstra

Carmen Saldana

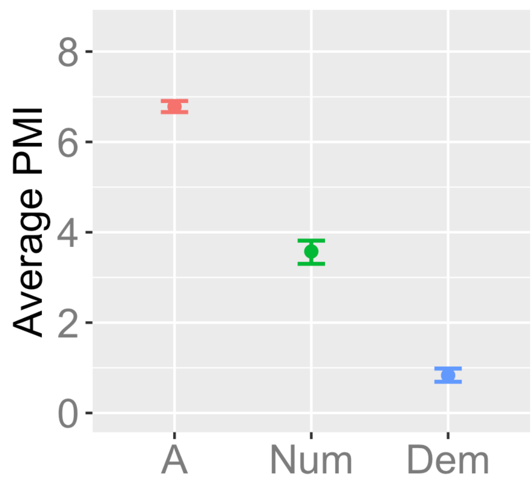


Yohei Oseki

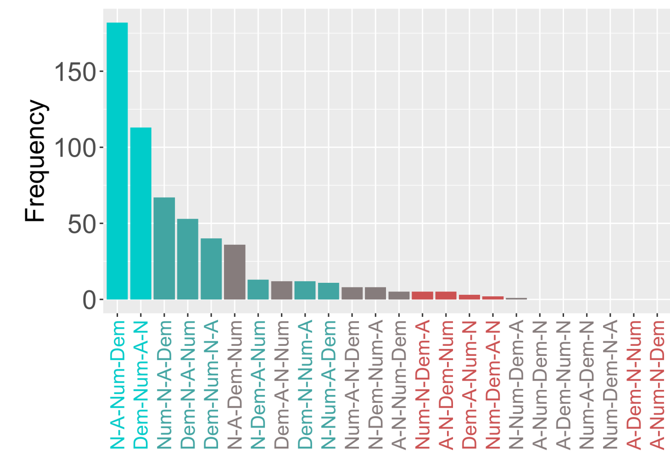
Explaining NP word order

A hypothesis: meaning + transparency + simplicity

Learn by observing objects in the world

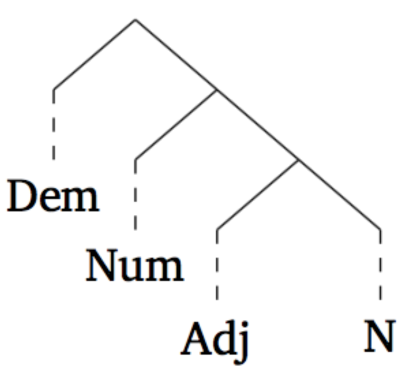


Population-level typology

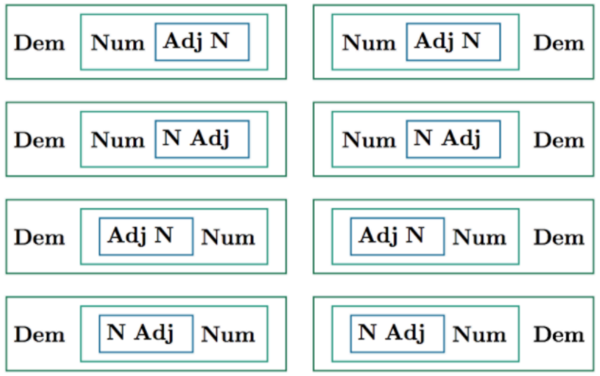


iterated learning

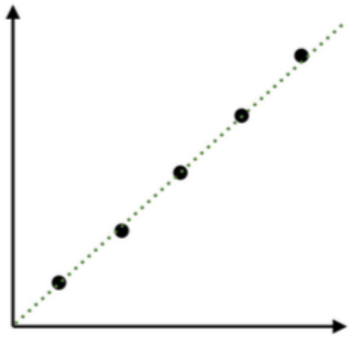
Build a representation



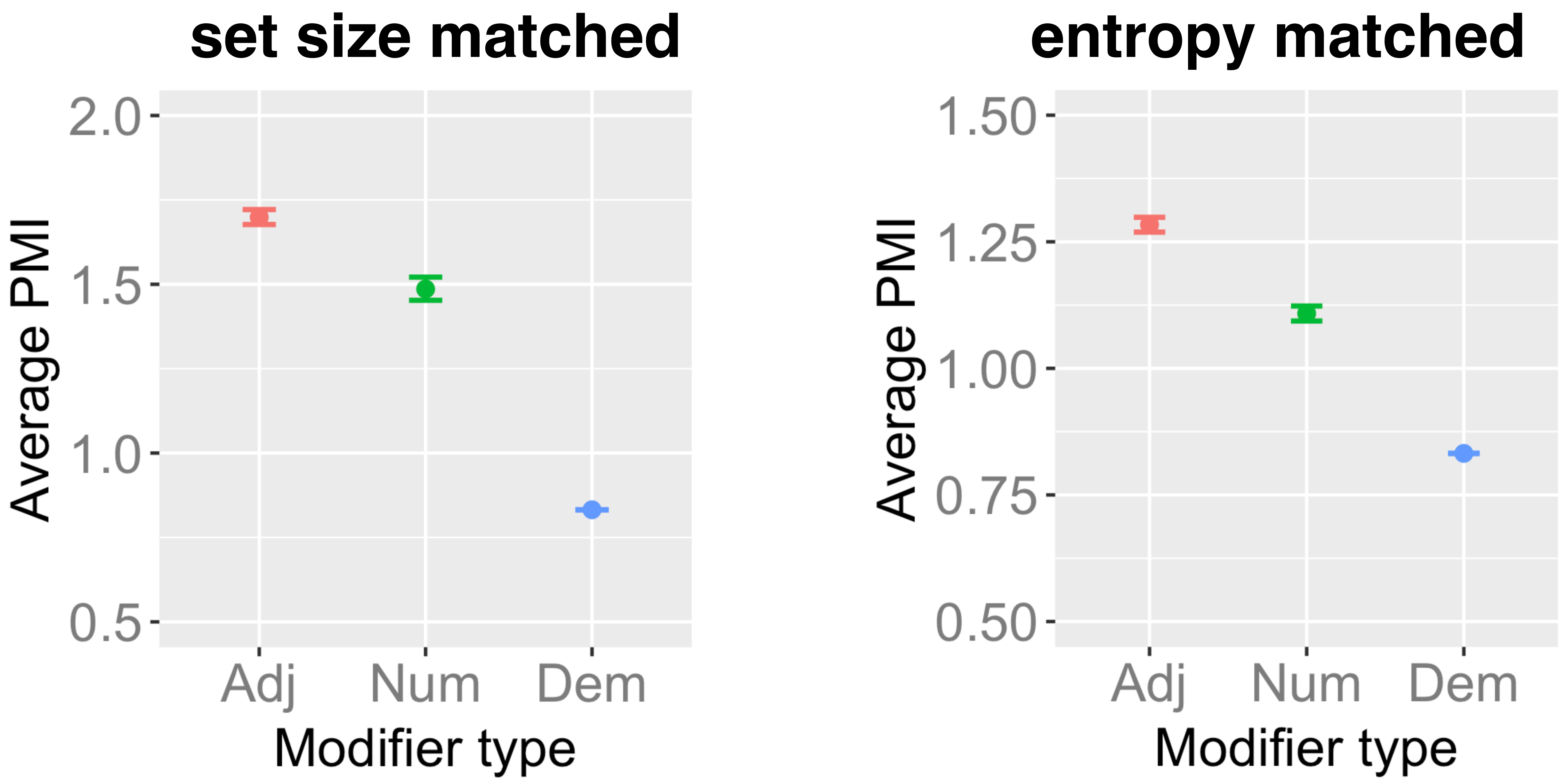
Map to linear order transparently



Filter through simplicity bias



Typically fewer Dems >> lower entropy >> lower PMI



(Culbertson et al. *Language*)

Letter string stimuli

- **Categories:** meaningless strings
- Similarities among elements based on:

  length (heads vs. deps)

  letters (distinguishes head/dep categories)

Heads		Dependents	
Head1	{nageng, negang, genang, ganeng}	Dep1a Dep1b	{bav, baz, dav, daz} {veb, ved, zeb, zed}
Head2	{shukoth,shokuth, koshuth, kushoth}	Dep2a Dep2b	{puf, pus, tuf, tus} {fop, fot, sop, sot}

(Culbertson & Kirby 2022 *Cogsci Proc.*)

Non-linguistic auditory stimuli

- **Categories:** meaningless sounds
- Similarities among elements based on:

  length (heads vs. deps)

  tempo (distinguishes head/dep categories)

Heads		Dependents	
Head1	{·----·, ··---·, ···--·, ····-·}	Dep1a	{-·-·, --·-, -··,--·}
		Dep1b	{·-·, ···, ··-·,·-··}
Head2	{-····-, --···-, ---··-, ----·-}	Dep2a	{-··-, -·—,-·-,---}
		Dep2b	{·--·, ···-,··-, ·—}

dots: tones; **dashes:** noise

Non-linguistic tactile stimuli

- **Categories:** meaningless vibration pulses
- Similarities among elements based on:

  <u>r vs. l thumb</u> (heads vs. deps)

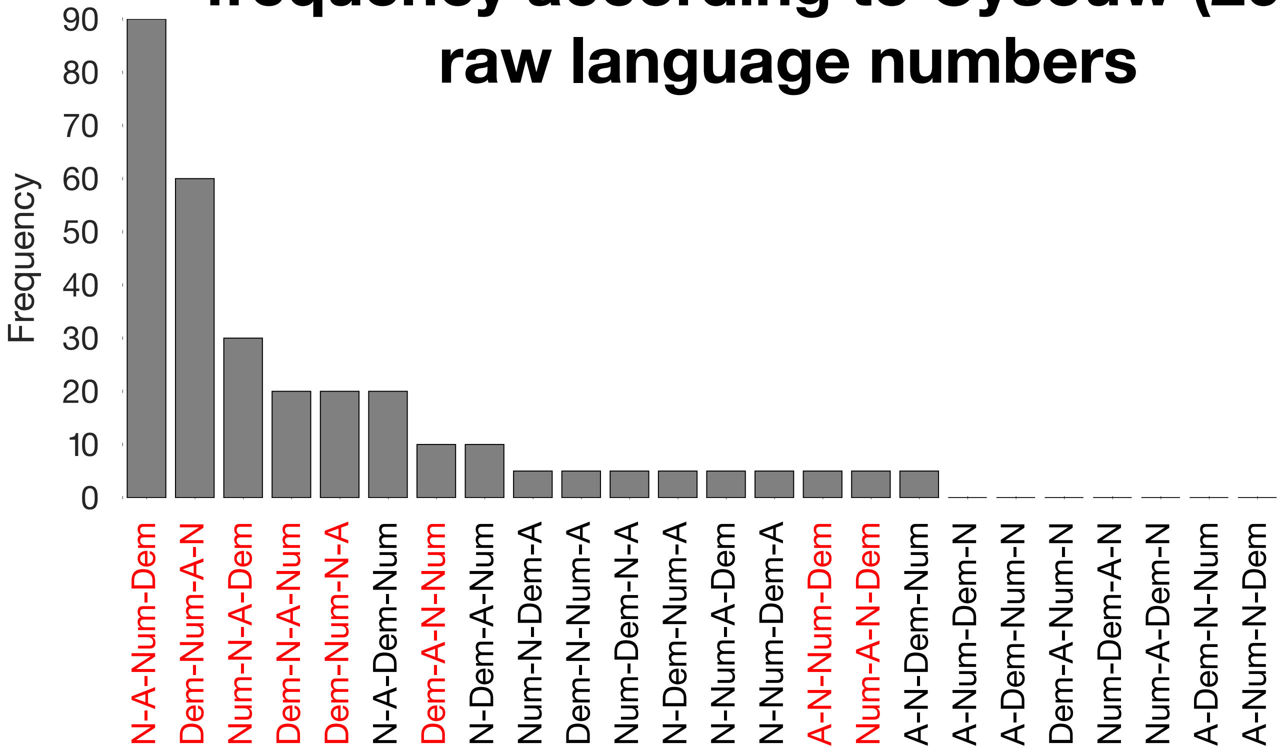
  <u>tempo</u> (distinguishes head/dep categories)

Heads		Dependents	
Head1	{·----·, ··---·, ···--·, ····-·}	Dep1a	{-·-·, --·-, -··,--·}
		Dep1b	{·-·, ···, ··-·,·-··}
Head2	{-····-, --···-, ---··-, ----·-}	Dep2a	{-··-, -·—,-·-,---}
		Dep2b	{·--·, ···-,··-, ·—}

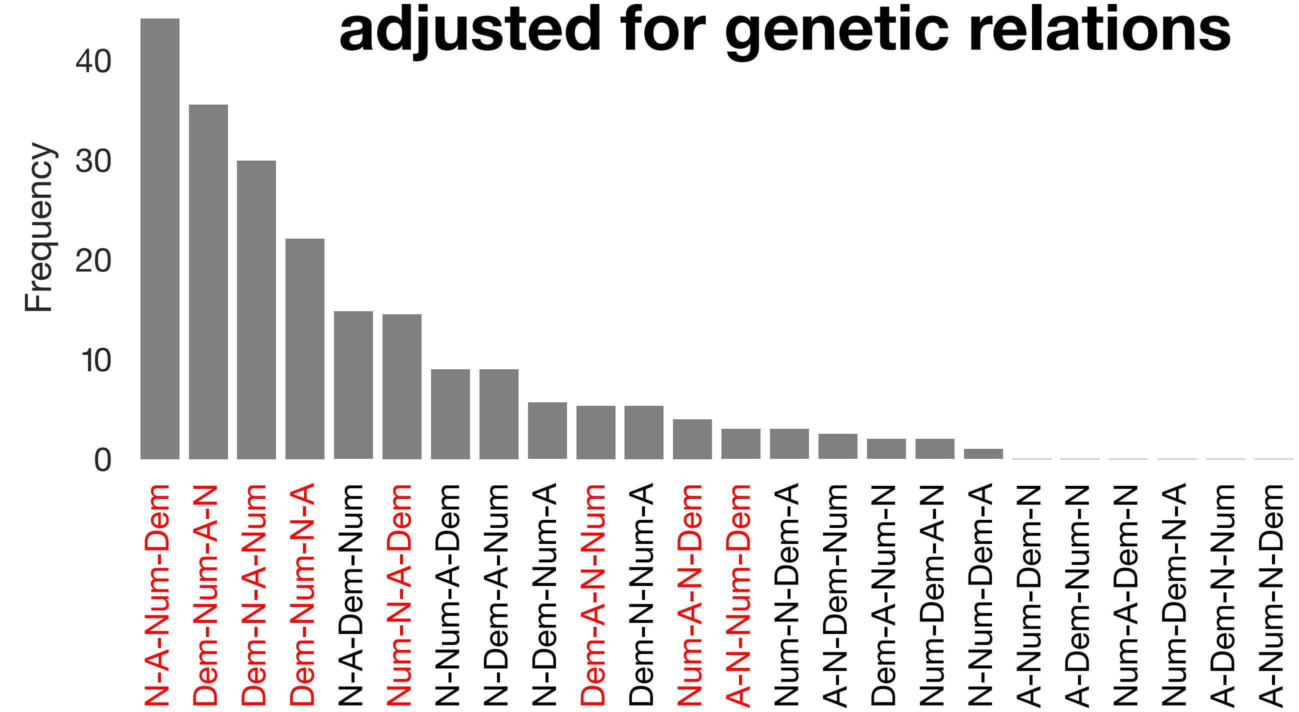
dots: tones; **dashes:** tones

Different typological samples for U20

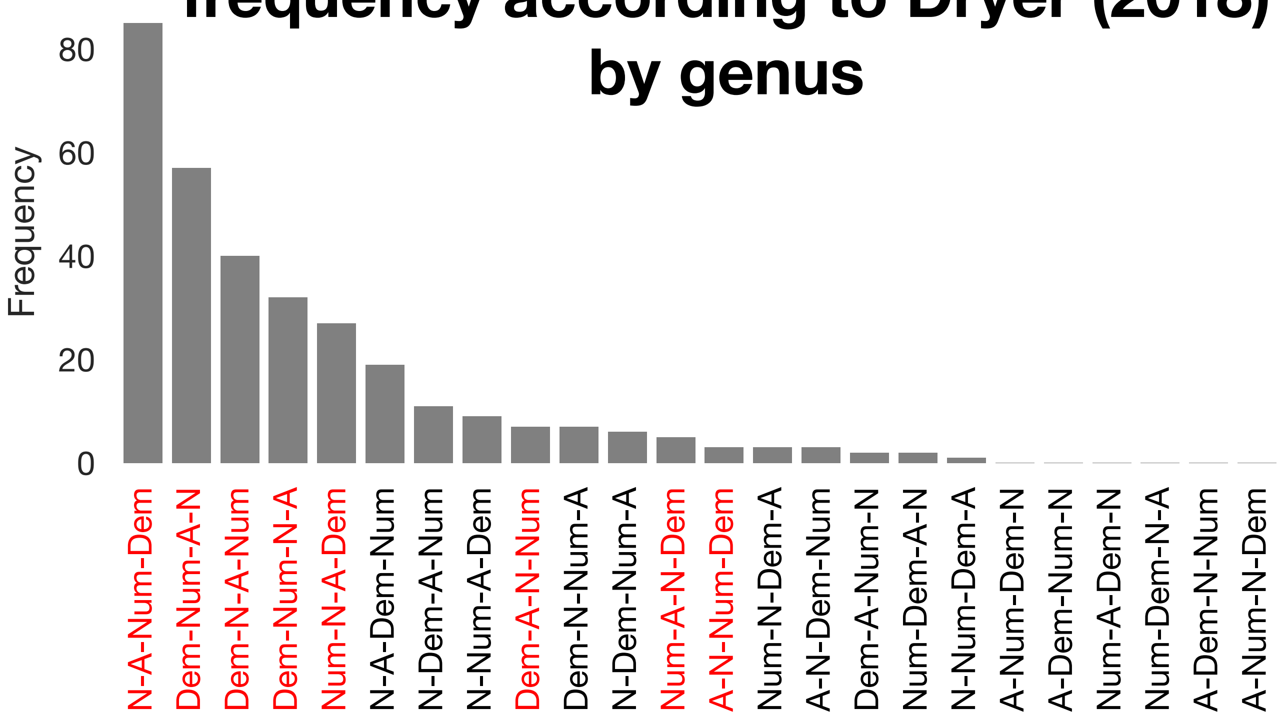
frequency according to Cysouw (2010) raw language numbers



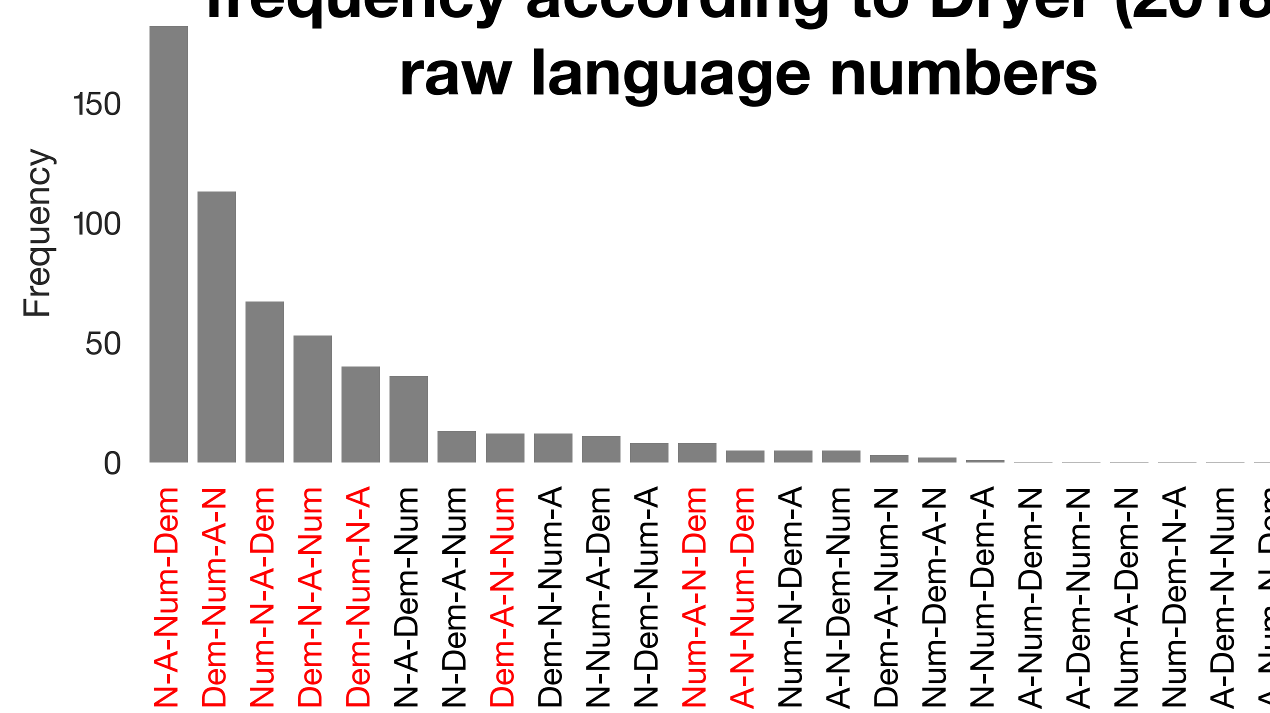
frequency according to Dryer (2018) adjusted for genetic relations



frequency according to Dryer (2018) by genus

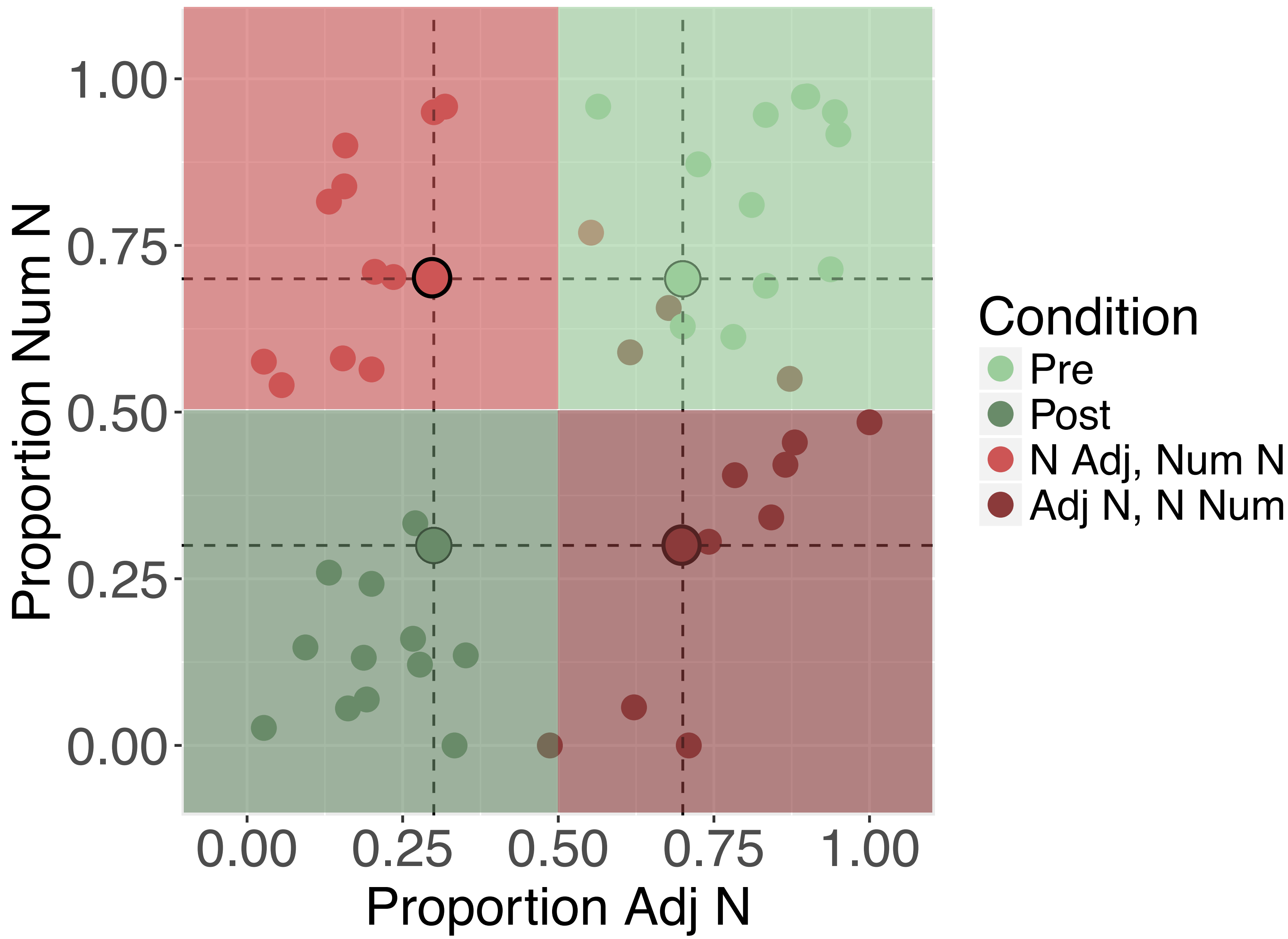


frequency according to Dryer (2018) raw language numbers



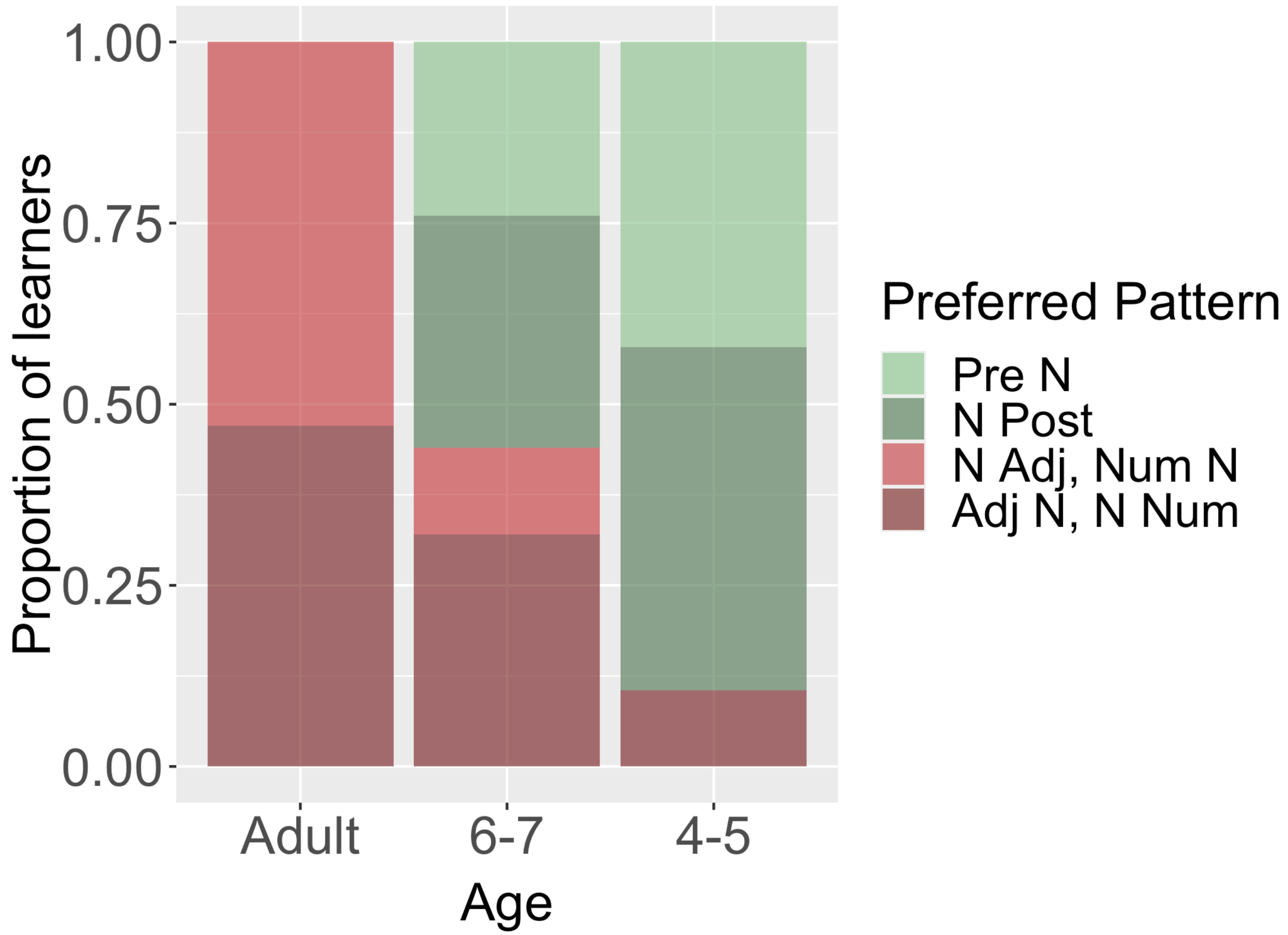
Testing learners' preferences

Categorizing responses…



Improvisation of harmony in children

…even when learning a **perfectly non-harmonic pattern?**



(Culbertson & Newport 2017 *OpenMind*)