Explaining semantic universals: Session 2

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Question

What explains which meanings are lexicalized across languages?

Previous lecture: optimizing the simplicity/informativeness trade-off

The simplicity/informativeness trade-off hypothesis

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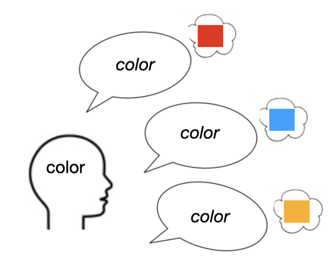
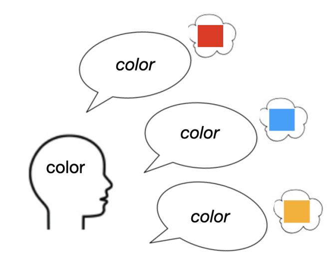
maximize **simplicity**
(minimize **complexity**)

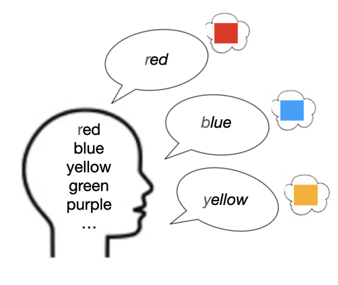


The simplicity/informativeness trade-off hypothesis

Languages are subject to two **competing pressures**:

maximize **simplicity** (minimize **complexity**)	maximize **informativeness** (minimize **communicative cost**)





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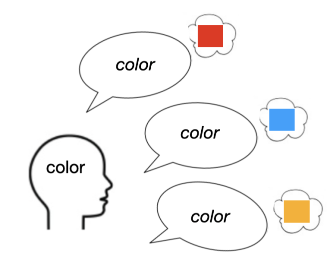

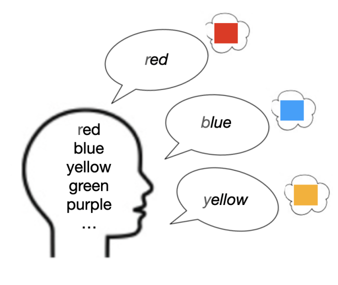

Languages **optimize the trade-off** between these two pressures.

Simplicity/informativeness trade-off optimization: Successes

We discussed (*simplified versions of*) two case studies:

- Connectives: explaining item-level universals (Horn, 1972; Katzir and Singh, 2013; Uegaki, 2022)
- Kinship terms: explaining system-level universals (Kemp and Regier, 2012)

Complexity and informativeness of a language (within a semantic category)

- **Complexity**: number of lexical items

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- **Complexity**: number of lexical items
- **Informativeness**: the probability that the speaker and listener successfully communicate

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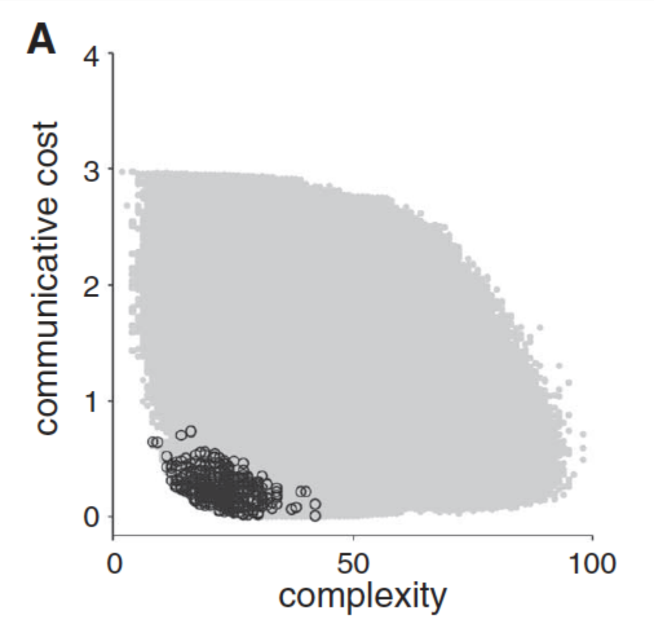

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But the speaker could be more specific and say *paternal grandmother*!

Grandmother vs. paternal grandmother

Simplicity and informativeness not the (only) pressures being optimized?

Pressures shaping lexicons:

The role of morphosyntactic complexity of utterances

Denić and Szymanik (2024), *Cognitive Science*

Due to productive morphosyntax and compositional semantics, lexicon size doesn't always compete with informativeness.

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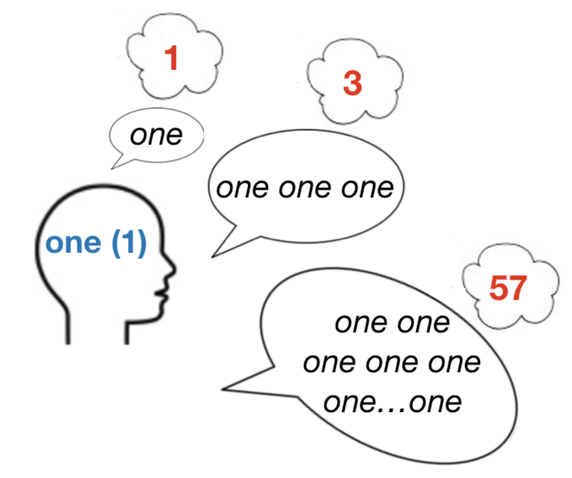
Number	English	Fulfulde
6	*six* (6)	*jowe-* (5) *-e-* (+) *-go* (1)
7	*seven* (7)	*jowe-* (5) *-e-* (+) *-didi* (2)
8	*eight* (8)	*jowe-* (5) *-e-* (+) *-tati* (3)
9	*nine* (9)	*jowe-* (5) *-e-* (+) *-nayi* (4)

Recursive numeral systems are maximally informative.

Despite a small lexicon, any natural number can be referred to precisely.

Simplicity of lexicon/informativeness trade-off optimization makes wrong predictions for recursive numeral systems.



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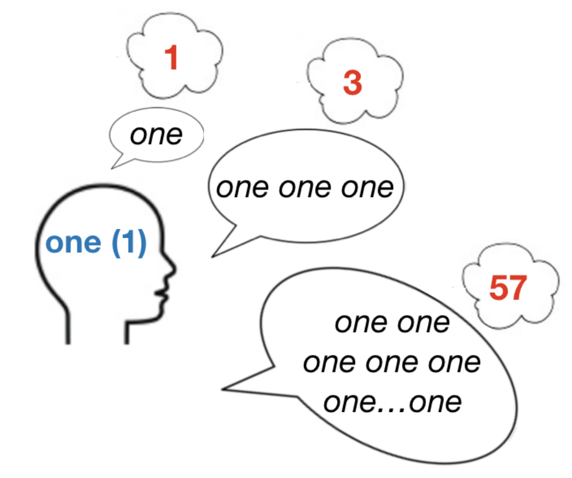


Shortcoming: There is no **utterance complexity** in the model!

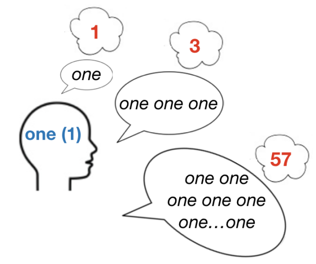
Simplicity of lexicon/simplicity of utterances trade-off

Denić and Szymanik (2024), *Cognitive Science*

Simplicity of lexicon/simplicity of utterances trade-off

Languages' number lexicons are under two **competing pressures**:

(a) minimize **lexicon size**



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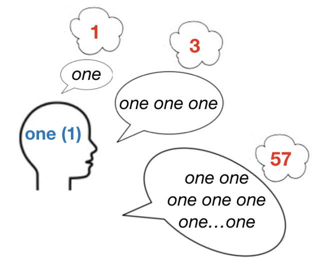
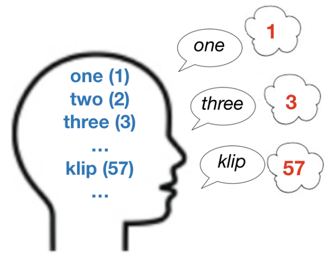


(b) minimize **morphosyntactic complexity of utterances**



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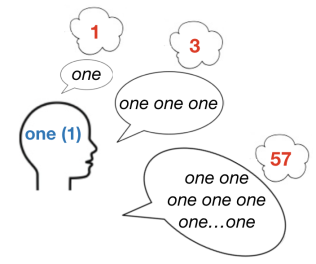

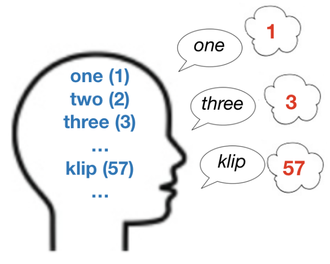

Languages **optimize the trade-off** between these two pressures.

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Natural language data

- 128 **recursive** numeral systems from *WALS* Numeral Bases chapter: genealogically and areally diverse language sample (Comrie, 2013)
- For each language, morphemes in each numeral for numbers 1-99 are identified.

128 languages differ along multiple dimensions.

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- Which numbers are lexicalized:
  - Fulfulde: 1, 2, 3, 4, 5, 10
  - Khanty: 1, 2, 3, 4, 5, 6, 7, 8, 10, 20

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- Which numbers are lexicalized:
  - Fulfulde: 1, 2, 3, 4, 5, 10
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- How morphosyntactically complex numerals are constructed:

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- Which numbers are lexicalized:
  - Fulfulde: 1, 2, 3, 4, 5, 10
  - Khanty: 1, 2, 3, 4, 5, 6, 7, 8, 10, 20
- How morphosyntactically complex numerals are constructed:
  - Fulfulde: $9 = 5 + 4$
  - Khanty: $9 = 10 - 1$

There are **40 different types of numeral systems** among the 128 natural languages examined.

Measuring lexicon size

Lexicon size = **number of lexicalized numbers** in the range 1-99

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Note: multiple morphemes for the same concept are not counted multiple times (e.g., *ten*, *-ty*, *-teen* in English). We'll come back to this!

Measuring morphosyntactic complexity of an utterance

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↓ **1 morpheme**

↓ **3 morphemes**

Measuring average morphosyntactic complexity

$$average\_morpho\_c(L) = \sum_{n=1}^{99} p(n) \cdot number\_of\_morphemes(L\text{'s numeral for } n)$$

Example: English

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$$average\_morpho\_c(English) =$$
$$p(1) number\_of\_morphemes(one) + \cdots + p(99) number\_of\_morphemes(ninety\ nine)$$

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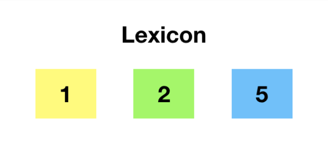

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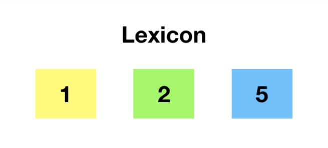

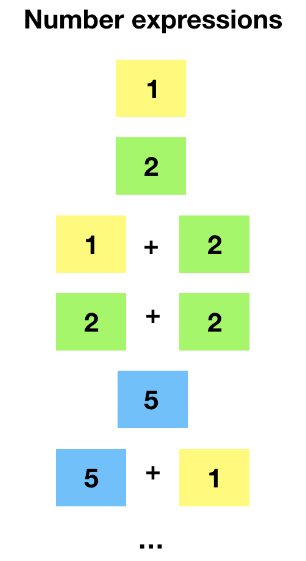

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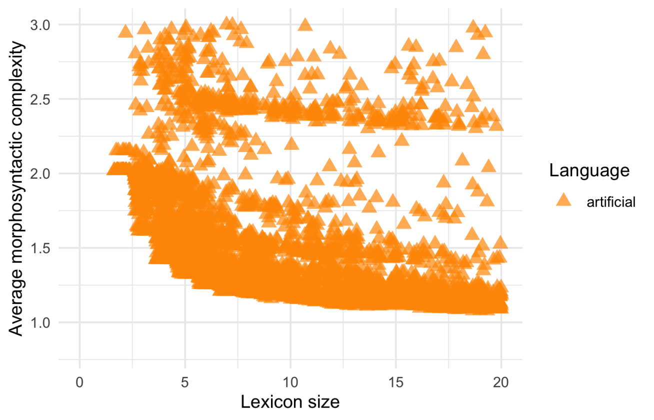
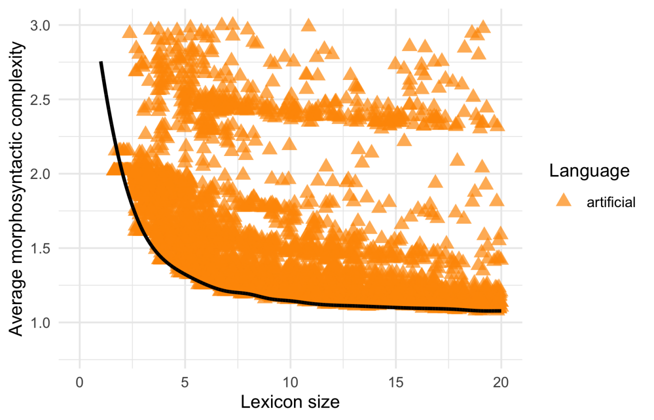
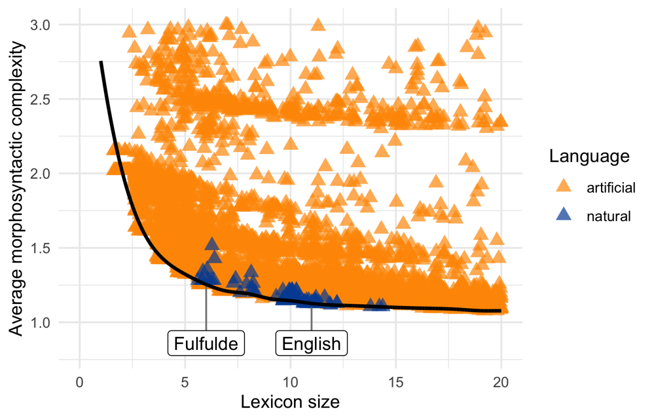


Pareto frontier is a set of Pareto-optimal numeral systems.



Pareto-optimal numeral systems cannot be improved on one dimension without becoming worse on the other.

Natural languages are (near-)optimal solutions to the pressures to minimize lexicon size and complexity of utterances.



Natural languages $N = 128$

Pressures shaping lexicons: Interim summary

Not two, but (at least) three pressures:

1. **minimize lexicon size**
2. **maximize informativeness**
3. **minimize morphosyntactic complexity of utterances**

Going back to other domains?

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For related ideas for **connectives**, see Carcassi and Sbardolini (2023).

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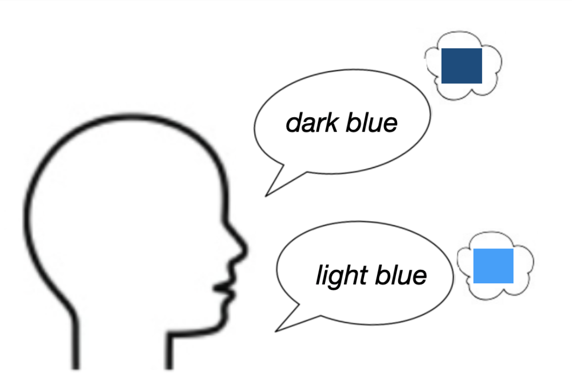

Future directions

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Division is marked/more complex to represent (cognitive bias in language processing)?

Curiosity: *half* is sometimes used! (Hurford, 1975)

What else remains to be explained? Numerals

Serbe

tri : 3, *deset* : 10, *trideset* : 30

Anglais

three : 3, *ten* : 10, *thirty* : 30

How can its existence be reconciled with the idea that languages aim to minimize the size of the lexicon?

What else remains to be explained? Numerals

There are optimal numeral systems with bases other than (multiples) of 5. Why are these not attested among human languages?

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- We started with the simplicity/informativeness trade-off hypothesis.
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Next time:
We will do a parallel exercise for polarity items, and see where it leads us.

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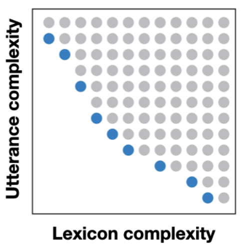
Semantic representations: Evaluating competing hypotheses

Primitives:

$+, \cdot,$ inverse



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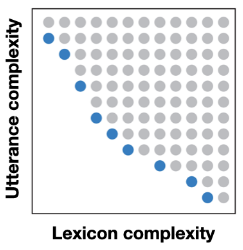

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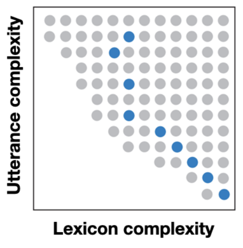

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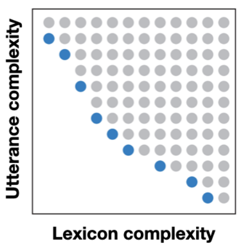

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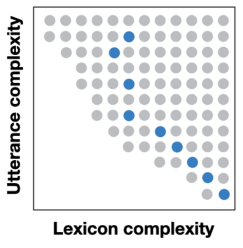

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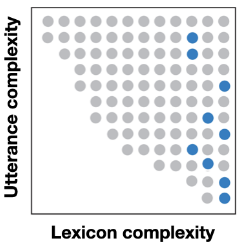

The availability of approximate interpretation is correlated with the morphosyntactic complexity of the numeral.

Example: The numeral for 50 more frequent in Norwegian than in Danish.

Krifka (2007)

Morphosyntax of numerals

Number-denoting morphemes can be digits (D) or bases (in my language sample, max. 5 bases).

NUMBER $\longrightarrow$ D
NUMBER $\longrightarrow$ PHRASE
NUMBER $\longrightarrow$ PHRASE + NUMBER | PHRASE - NUMBER
PHRASE $\longrightarrow$ BASE
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Hurford (2007, 1975)

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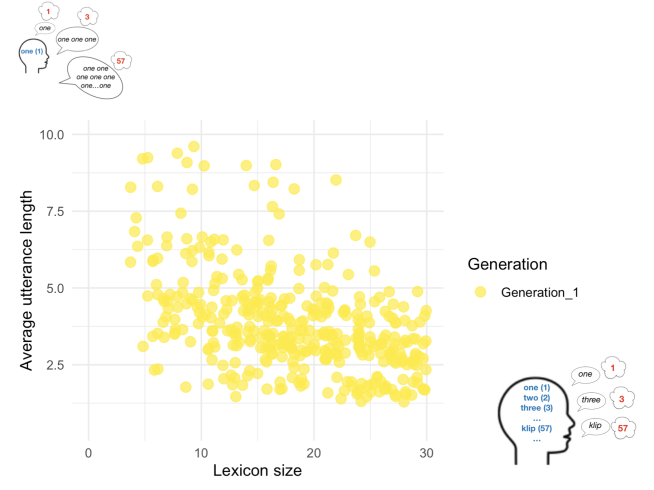
Example:
$D = \{1,2,3,4,5,6,7,8,9\}$, $M = \{10\}$
$40 = 4 \cdot 10$ and not $5 \cdot 8$

Hurford (2007, 1975)

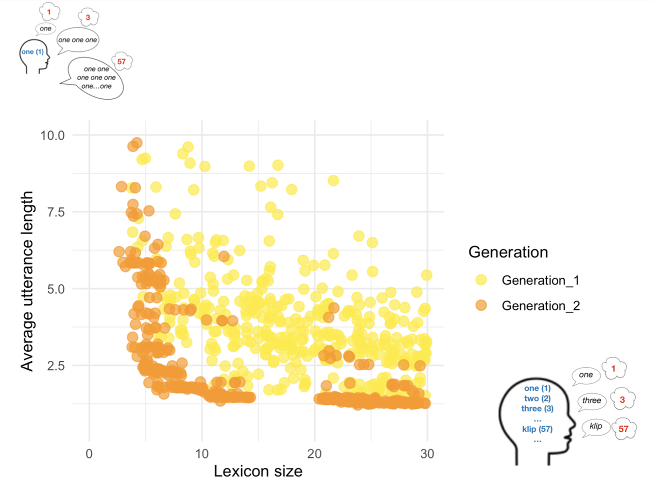
Why seek to reverse-engineer semantic representations? Intersection of semantics and cognitive science.

1. Lexical acquisition (e.g., Piantadosi et al., 2012)
2. Interface between language and reasoning:
    - Successes and failures (e.g., Mascarenhas, 2014)
    - Problem solving (e.g., verification, cf. Hackl, 2009)
3. Pragmatics (e.g., Buccola et al., 2022)

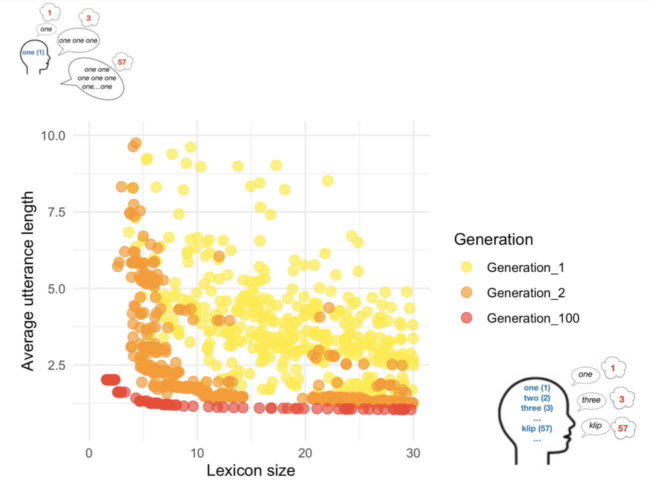
Simulating evolution: Generation 1 of artificial numeral systems



Simulating evolution: Generation 2 of artificial numeral systems



Simulating evolution: Generation 100 of artificial numeral systems



Measuring informativeness

Measure of informativeness of a language based on how likely S and L are to communicate successfully:

$$I(L) = \sum_{m \in M} \sum_{w \in L} P(m) P_S(w|m) P_L(m|w)$$

Complexity/informativeness approach to numeral systems

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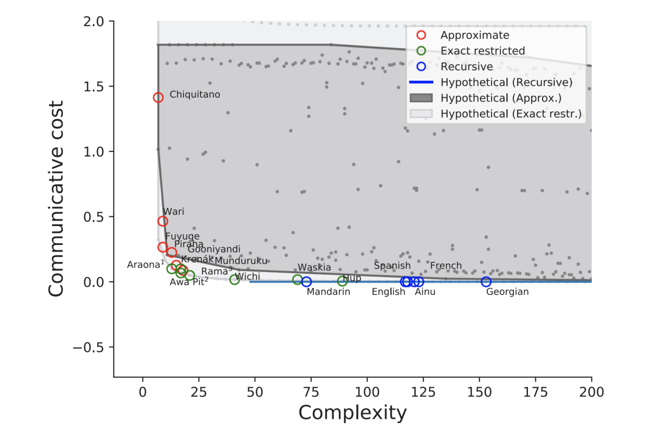
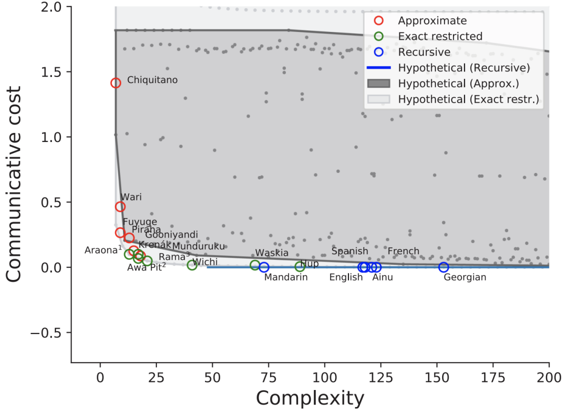


Recursive vs. restricted

In fact, the Pareto frontier for recursive languages is very far!



Languages differ in which meanings they lexicalize.

A	B	A AND B
1	1	1
1	0	0
0	1	0
0	0	0

Bowler (2014)

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English

A and B

Warlpiri (Australia)

A manu B

analysis: exh (exh (A or B))

Bowler (2014)

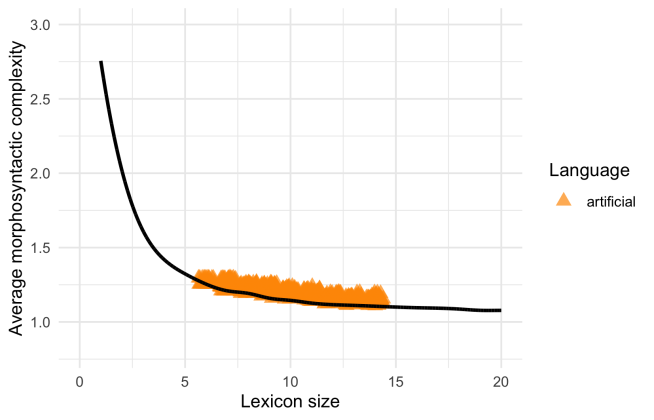
But there are also many similarities in number lexicons.

Number	**English**	**Fulfulde**
1	*one* (1)	*go'o* (1)
2	*two* (2)	*didi* (2)
3	*three* (3)	*tati* (3)
10	*ten* (10)	*sappo* (10)
100	*hundred* (100)	*teemerre* (100)

Explaining semantic universals: Example

All recursive numeral systems (in my sample) lexicalize 1-5.

Explaining semantic universals: Example



≈90% of theoretically possible numeral systems in relative proximity to the Pareto (and all of those on the Pareto) lexicalize 1-5.

Research theme 1: Language and reasoning

How do logical and probabilistic reasoning interact with language interpretation and production?

Research theme 1: Phenomena

- Polarity items (Denić et al., 2018, *Glossa*; Denić et al., 2021, *Cognition*)
- Scalar implicatures (Denić, 2023, *S&P*)
- Donkey anaphora (Denić and Sudo, 2022, *JoS*)
- Proportional quantifiers (Denić and Szymanik, 2022, *JoS*)
- Child language interpretation errors (Denić and Chemla, 2020, *LI*)

Research theme 1: Example result on scalar implicatures

(1) **All 20 of my friends are French or Spanish.**
$\rightsquigarrow$ At least one is French.
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Denić (2023)

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Empirical: Reducing domain size $\rightarrow$ Fewer scalar implicatures

Denić (2023)

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Empirical: Reducing domain size $\rightarrow$ Fewer scalar implicatures
Theoretical: New connection between probabilities and implicatures.

Denić (2023)

Finding what remains to be explained: Example

No morpheme denotes the division operator in any numeral.
(in my language sample)

Finding what remains to be explained: Example

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(in my language sample)

Ket (Werner, 1997)

(3) qol'ep ki
half hundred

Functional pressures (refined)?

Lexicon: Lexicalized numbers and lexicalized arithmetic operators?