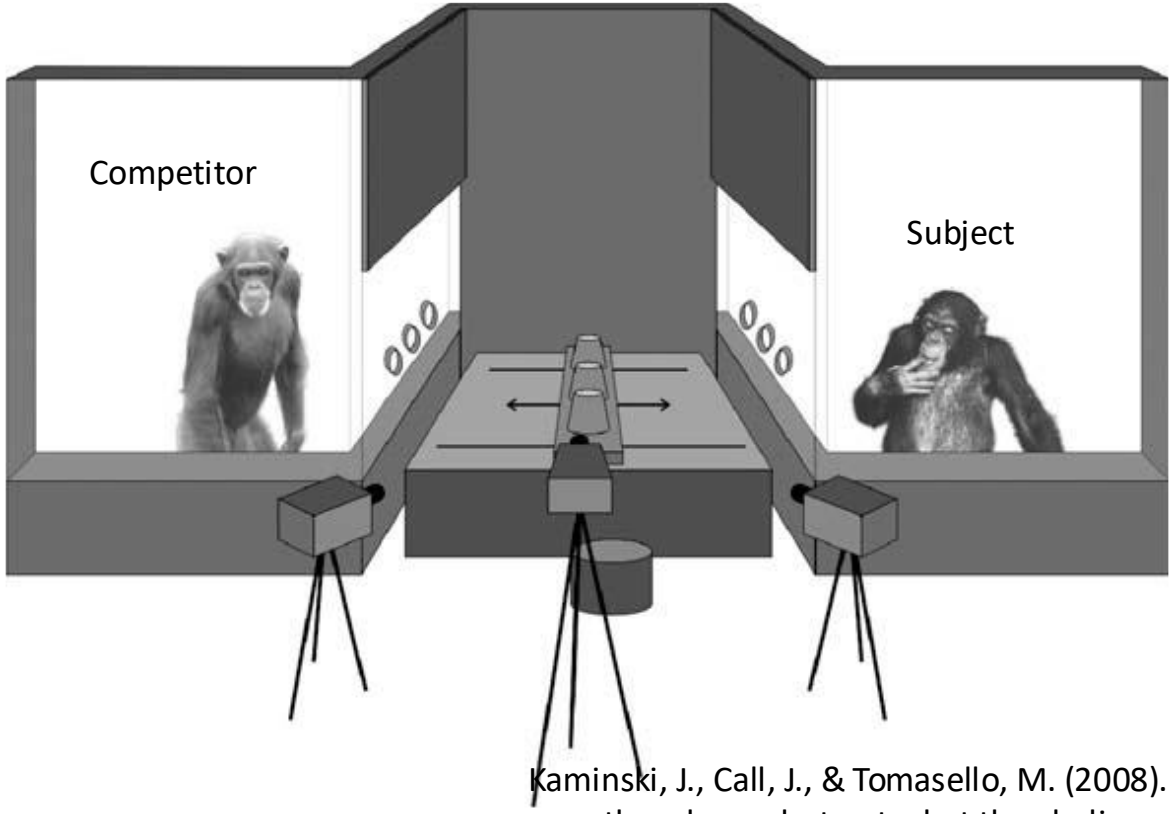
Origins and Evolution of Language
Week 8: The cultural evolution of language

Kenny Smith
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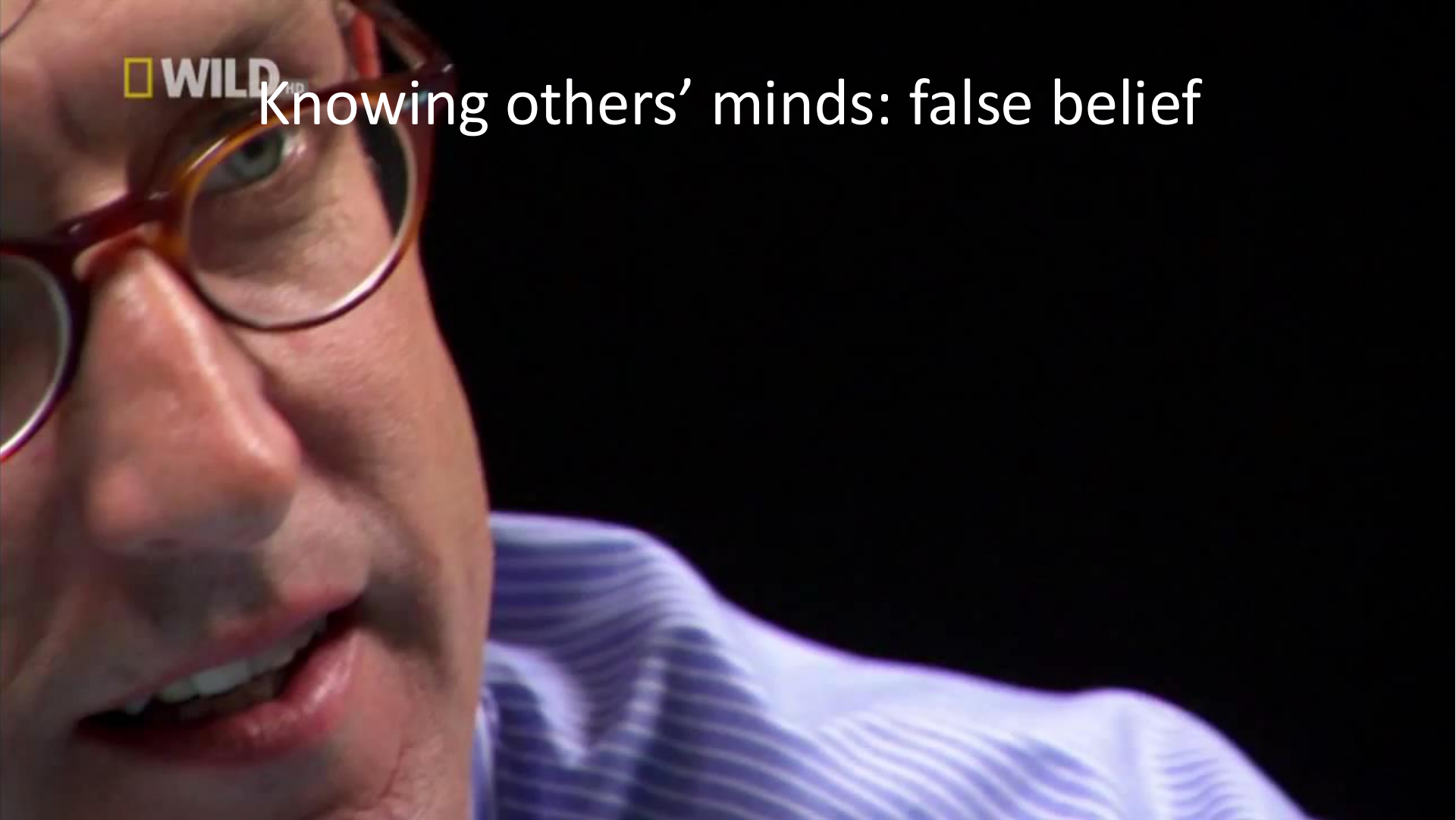
Plan for today

- Rattle through false belief understanding from last week
- Cultural evolution of language
  - Uniformitarianism
  - Learning, use, and language change
  - Cultural transmission and the evolution of structure
  - Questions from the reading quiz

Knowing others' minds: knowing what others know



Kaminski, J., Call, J., & Tomasello, M. (2008). Chimpanzees know what others know, but not what they believe. *Cognition, 109*, 224–234.



Knowing others' minds: false belief

A question from the pre-lecture quiz

`I think there's a difference between these two explanations from the paper:

1) False belief "requires an understanding that other minds contain representations of the world *that can be different from reality*".
2) False belief requires individuals to "represent another's mental state in a way that is *independent from their own representation of reality*".

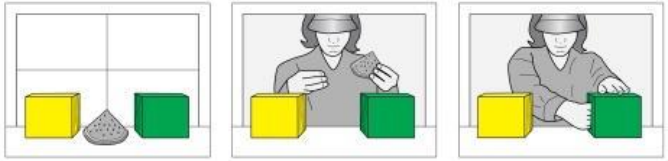
I actually prefer the second explanation because phrased like this, it is consistent with the idea that we might not be able to perceive an objective reality (if there is one at all), because we will only ever be able to see our representation of reality. Rather than defining false belief as "holding the belief that someone else has a belief that *you know is not true*", I would then opt for something along the lines of "holding the belief that someone else has a belief that *does not align with yours*".'

A question from the pre-lecture quiz

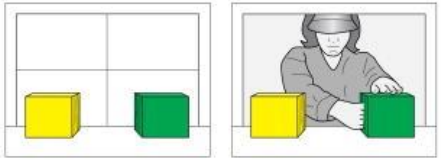
`Apart from my confusion about the definition of false belief, I'm also not quite sure how false belief relates to second-order intentionality in communication. Why would it be necessary for an individual to believe someone else's belief to be false in order to reason about their communicative intentions? Wouldn't it just be enough for an individual to recognise that someone else has beliefs/representations/intentions that may differ from their own (just because they're different, they don't have to be false, or judged to be false)? **Or is it just that if an individual believes someone else's beliefs to be false, we basically have definite proof that the individual REALLY understands that someone else's beliefs are different from their own?'**

Familiarization trials

Trial 1



Trials 2 and 3



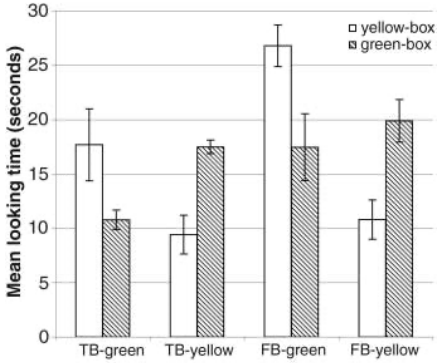
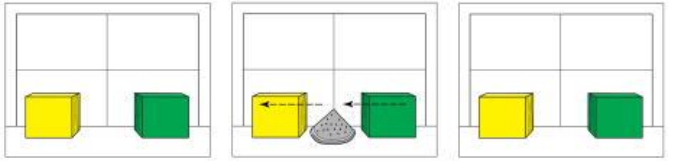


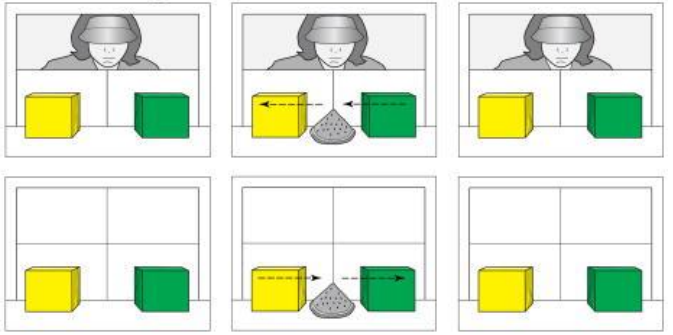
Fig. 4. Mean (±SE) looking times during the test trial (after the actor reached into the green or yellow box) in the four belief conditions.

Belief-induction trial

False-belief-green condition

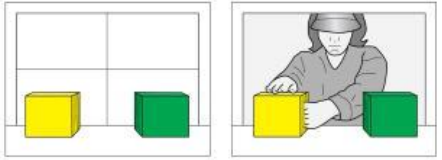


False-belief-yellow condition

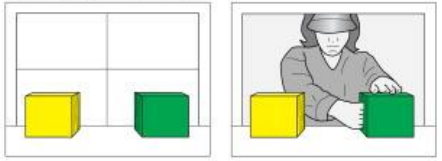


Test trial

Yellow-box event



Green-box event



Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science, 308*, 255–258



Krupenye, C., et al. (2016). Great apes anticipate that other individuals will act according to false beliefs. *Science, 354,* 110-114.

Familiarization

Bonobo Jasongo

Krupenye, C., et al. (2016). Great apes anticipate that other individuals will act according to false beliefs. *Science, 354,* 110-114.

Knowing others' minds: false belief

Table 1. Number of participants who made first looks to either the target or the distractor during the agent's approach in experiments one (N = 40) and two (N = 30). Values in parentheses indicate the number of participants who did not look at either.

Condition	Target	Distractor	Total
	Experiment one		
FB1	10	4	14 (6)
FB2	10	6	16 (4)
Total	20	10	30 (10)
	Experiment two		
FB1	8	2	10 (6)
FB2	9	3	12 (2)
Total	17	5	22 (8)

Krupenye, C., et al. (2016). Great apes anticipate that other individuals will act according to false beliefs. *Science, 354,* 110-114.

So why are we so good at it?

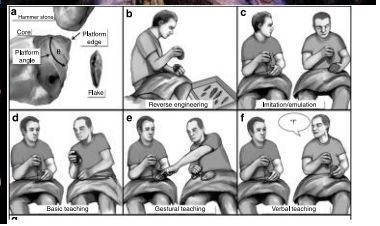
What selective pressures drive the evolution of mind sharing and mind reading?

- We occupy a uniquely social niche?
- We occupy a uniquely technological niche?
- …









Reminder: communication in the Last Common Ancestor of chimps and humans

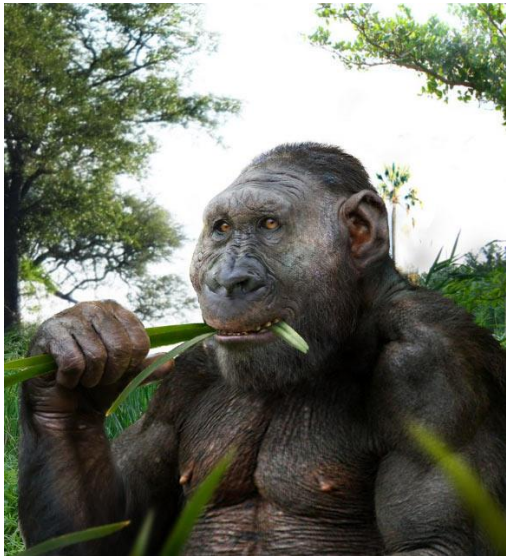
- Not 2nd order intentional?
- No/minimal use of structure subserving meaning?
- Probably not learned?

But remember Fitch's point: their communication system may underrepresent their cognitive capacities!



How about these other capacities?

- The ability to learn complex grammars?
  - No/little capacity for complex vocal imitation
  - Some ability to learn complex sequencing constraints?
  - Some ability to learn compositional meaning-form mappings?
- Little motivation to mindshare??
- Some ability to mindread



On to this week’s content

What you've seen so far (1/2)

Human linguistic communication has unusual properties (see week 3)

- Evidence for 2nd order intentionality in communication is rare in other animals
- Lots of structured communication out there, but structure is simpler and typically not meaning-related

Human capacity to sustain complex non-linguistic cultures (e.g. tools) is also unusual (see week 5)

- Language implicated in maintenance of stone tool technology?
- We do a lot of social learning, and cultural evolution is largely responsible for our behavioural and technological sophistication

What you've seen so far (2/2)

Human capacity for learning complex meaning-bearing communicative signals is unusual (see weeks 6-7)

- Vocal learning seen in other animals, but limited in our closest relatives?
- Other animals can learn sequencing constraints, but only simple ones have been tested
- Other animals can learn rules of meaningful combination, but few systematic studies

Human motivation to share mental states and aptitude to reason about the mental states of others is unusual (weeks 3 and 7)

- Mitteilungsbedürfnis is weird!
- Evidence for 2nd order intentionality in communication is rare in other animals
- Some evidence of capacity to reason about knowledge, ignorance and false belief in other apes, but only in competitive contexts
- Complex social living a possible selection pressure driving human brain expansion?

The human package

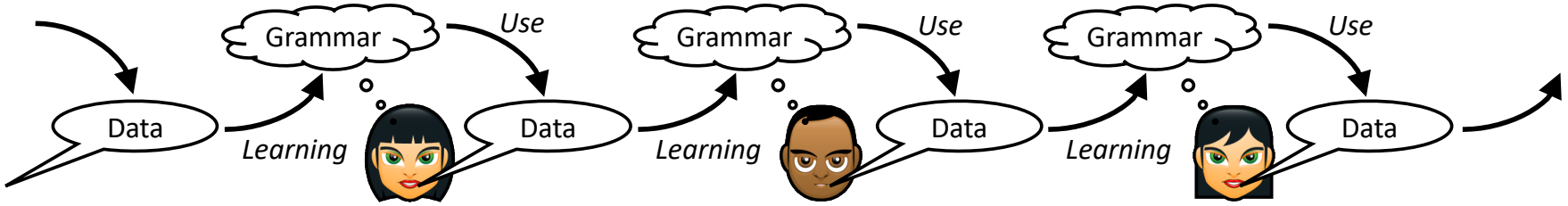
Somehow, we ended up with

- The ability to learn complex grammars
  - capacity for complex vocal imitation
  - ability to learn complex sequencing constraints
  - ability to learn compositional meaning-form mappings
- The ability and motivation to mindread and mindshare

This sets up the preconditions for the **cultural transmission of learned, meaning-bearing communication**

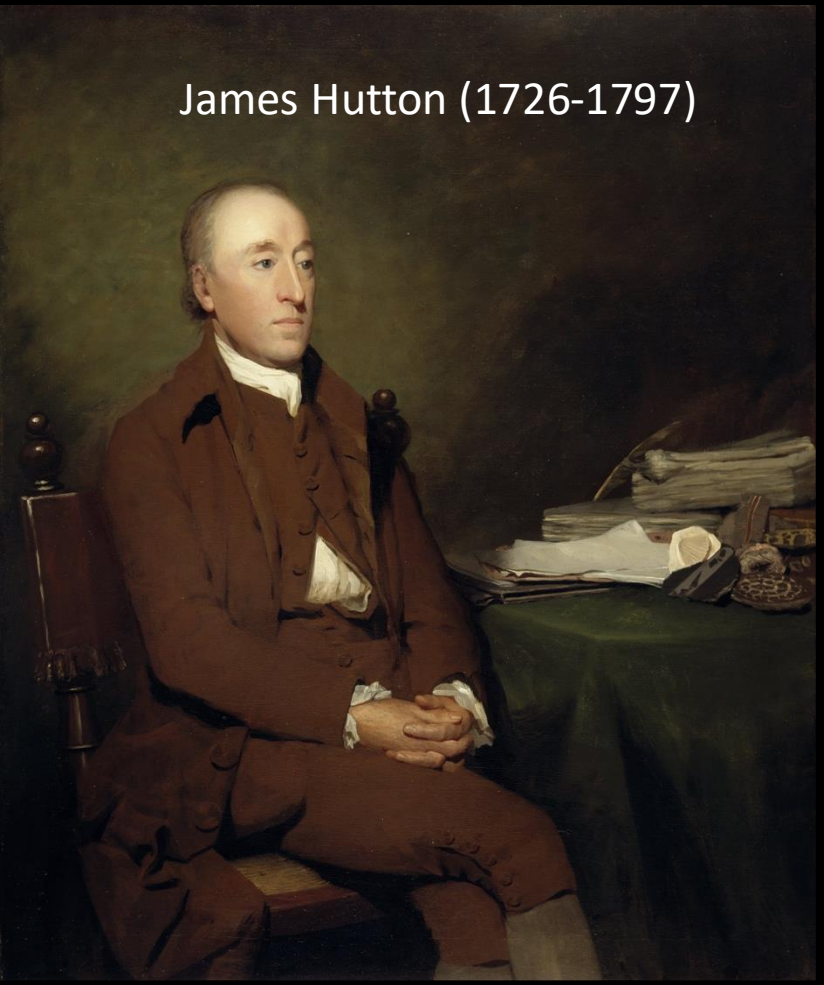
- Once that's in place, exciting stuff happens

The cultural evolution of language



- Language is passed from person to person by **learning**
- People learn from language as it is **used in communication**
- Language **evolves** in response to its learning and use

Uniformitarianism (in geology)



Uniformitarianism: **the present is the key to the past**



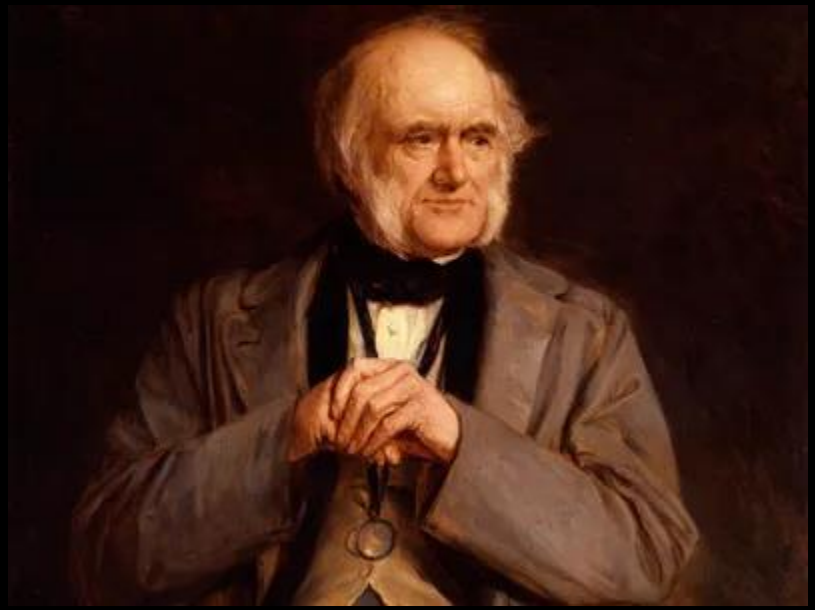
"On us who saw these phenomenon for the first time the impression will not easily be forgotten…We felt necessarily carried back to a time when the schistus on which we stood was yet at the bottom of the sea, and when the sandstone before us was only beginning to be deposited, in the shape of sand or mud, from the waters of the supercontinent ocean… The mind seemed to grow giddy by looking so far back into the abyss of time; and whilst we listened with earnestness and admiration to the philosopher who was now unfolding to us the order and series of these wonderful events, we became sensible how much further reason may sometimes go than imagination may venture to follow."

John Playfair
(1748-1819)





Lyell on **catastrophism**



Charles Lyell (1797-1875)

“Never was there a doctrine more calculated to foster indolence, and to blunt the keen edge of curiosity, than this assumption of the discordance between the former and the existing causes of change... The student was taught to despond from the first. Geology, it was affirmed, could never arise to the rank of an exact science... [With catastrophism] we see the ancient spirit of speculation revived, and a desire manifestly shown to cut, rather than patiently untie, the Gordian Knot”

Lyell, C. (1854). *Principles of Geology: Being an Attempt to Explain the Former Changes of the Earth's Surface, by Reference to Causes Now in Operation*

Uniformitarianism in evolutionary linguistics

The present is the key to the past

The more we can explain in terms of processes we can observe in the present day, the happier we should be

- Learning and use explain language change visible in the present and the recent historical record
- Can we explain (some of) language origins in terms of the same processes?
- Rather than catastrophism, e.g. language evolved in a single dramatic step due to some single magical event or macromutation

Importantly, uniformity of **process**, not of state: we don't have to say languages have always looked as they do now! (see e.g. Heine & Kuteva, 2002)

Heine, B., & Kuteva, T. (2002). On the Evolution of Grammatical Forms. In. A. Wray (Ed.) The Transition to Language (pp. 376-397). Oxford: Oxford University Press.

Language change

Language change (as attested in the historical record / inferable from synchronic data) is a consequence of:

- Speakers trying to convey meaning efficiently
- Hearers trying to infer speaker meaning
- Language learners (and everyone else) seeking regularities in the linguistic data they encounter

These processes are inherent to the transmission of language via learning and (ostensive-inferential) use

Ad-hoc extension to meet communicative needs





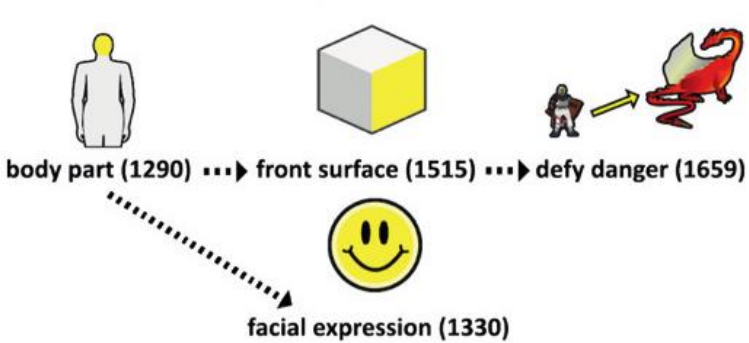








“A reef of dead metaphors” (Deutscher, 2005)



From Ramiro, C., Srinivasan, M., Malt, B. C., & Yu, X. (2018). Algorithms in the historical emergence of word senses. *Proceedings of the National Academy of Sciences, USA, 115,* 2323-2328.

“She was *thrilled* to *discover* that the *assessment board* had *decided* to make her *rival redundant*”

thrill: from thirl, “to pierce”

discover: remove the cover from

assessment: from *assidere,* “to sit by” (in judgment)

board: plank

decided: from *de-caedere, “cut off”*

rival: from *rivalis*, someone who shares the same river

redundant: from redundantem, “overflow”

From p. 125 of Deutscher, G. (2005). *The Unfolding of Language*. New York, NY: Picador.

Grammaticalization

E.g.: development of future tense markers from verbs of motion

I am going to Gothenburg	MOTION
I am going to stay at home	INTENTION
It is going to rain	FUTURE

Grammaticalization

E.g.: development of future tense markers from verbs of motion

I am going to Gothenburg	MOTION (+ INTENTION)
I am going to stay at home	INTENTION
It is going to rain	FUTURE

Grammaticalization

E.g.: development of future tense markers from verbs of motion

I am going to Gothenburg	MOTION (+ INTENTION)
I am going to buy you a gift!	MOTION + INTENTION
I am going to stay at home	INTENTION
It is going to rain	FUTURE

Grammaticalization

E.g.: development of future tense markers from verbs of motion

I am going to Gothenburg	MOTION (+ INTENTION)
I am going to buy you a gift!	MOTION + INTENTION
I am going to stay at home	INTENTION (+ FUTURE)
It is going to rain	FUTURE

Grammaticalization

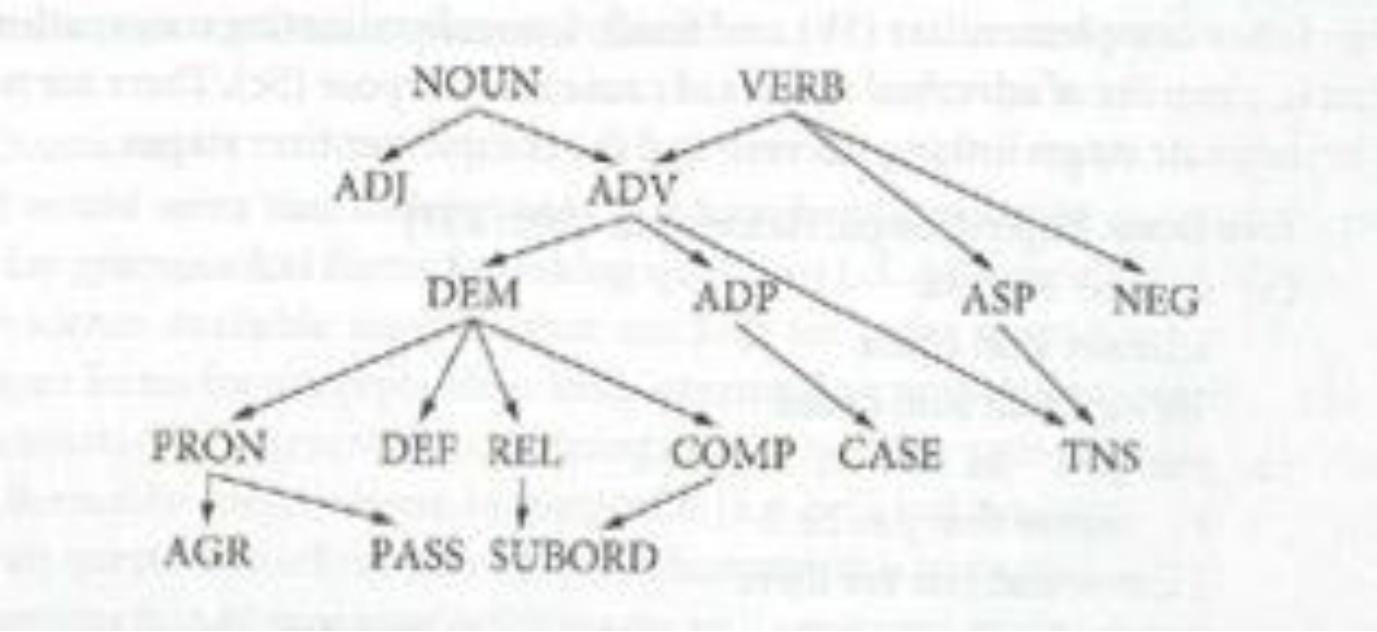
E.g.: development of future tense markers from verbs of motion

I am going to Gothenburg	MOTION (+ INTENTION)
I am going to buy you a gift!	MOTION + INTENTION
I am going to stay at home	INTENTION (+ FUTURE)
I am going to stay at home tomorrow	INTENTION + FUTURE
It is going to rain	FUTURE

Grammaticalization

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I am going to Gothenburg	MOTION (+ INTENTION)
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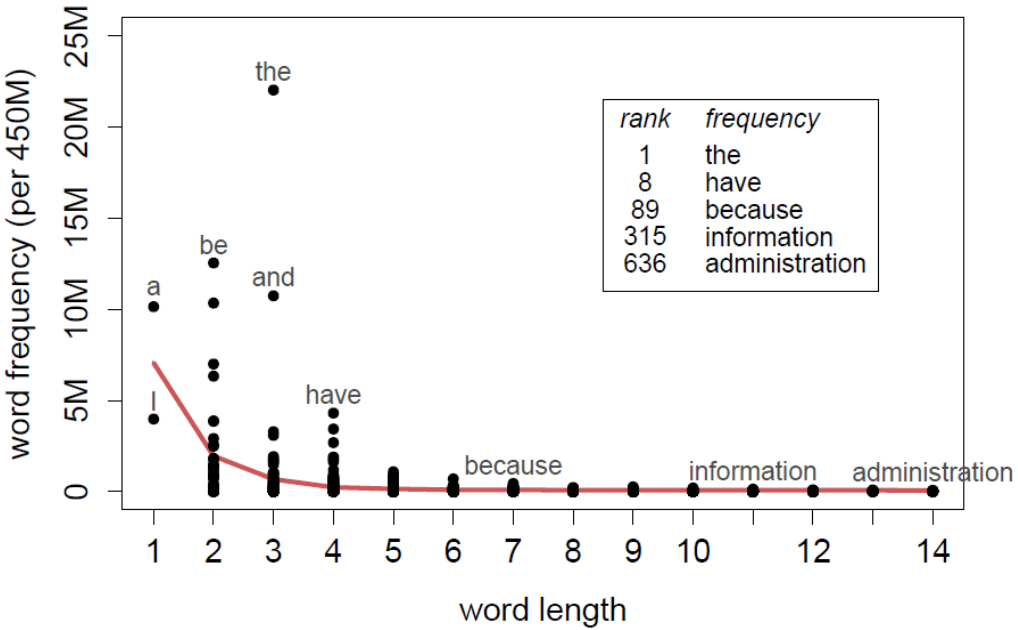


Analogical extension & "system pressure"

Cover of issue featuring Lieberman, E., Michel, J. B., Jackson, J., Tang, T., & Nowak, M. A. (2007). Quantifying the evolutionary dynamics of language. *Nature, 449,* 713-716.

Analogical extension & “system pressure”

Frequent words tend to be short (Zipf’s Law of Abbreviation)



From Kanwal, J., Smith, K., Culbertson, J., & Kirby, S. (2017). Zipf’s Law of Abbreviation and the Principle of Least Effort: Language users optimise a miniature lexicon for efficient communication. *Cognition, 165*, 45-52.

Analogical extension & “system pressure”

Frequent words tend to be short (Zipf’s Law of Abbreviation)

But system-level pressures favor **regularity**

Table 12.9. An unattested system

English	SG	PL	Percentage of singular	Hypothetical language
house	49295	9840	83	
hare	488	136	78	
bear	1182	611	66	
window	9936	8506	54	
feather	487	810	38	
parent	3706	15956	19	

From Haspelmath, M. (2014). On system pressure competing with economic motivation. In MacWhinney, B., Malchukov, A., & Moravcsik, E. (Eds) *Competing Motivations in Grammar and Usage* (pp. 197-208). Oxford: Oxford University Press.

Analogical extension & "system pressure"

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Table 12.9. An unattested system

English	SG	PL	Percentage of singular	Hypothetical language
house	49295	9840	83	*house-Ø/house-ssss*
hare	488	136	78	*hare-Ø/hare-sss*
bear	1182	611	66	*bear-Ø/bear-ss*
window	9936	8506	54	*window-Ø/window-s*
feather	487	810	38	*feather-one/feather-Ø*
parent	3706	15956	19	*parent-oneone/parent-Ø*

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Language change

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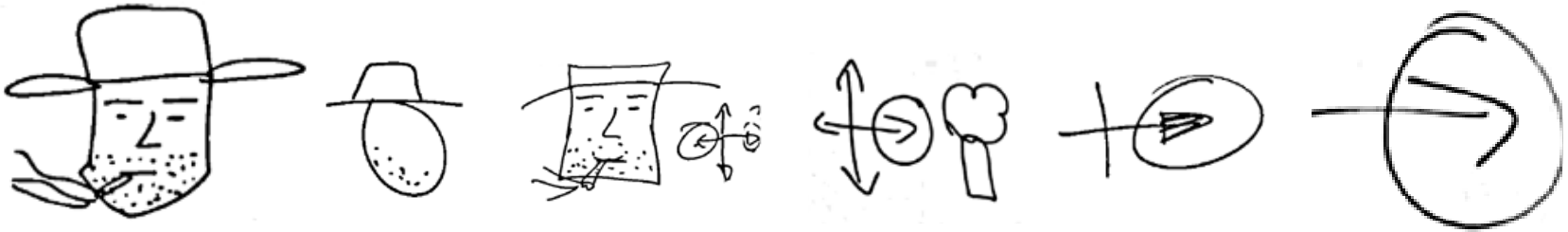
- Speakers trying to convey meaning efficiently
- Hearers trying to infer speaker meaning
- Language learners (and everyone else) seeking regularities in the linguistic data they encounter

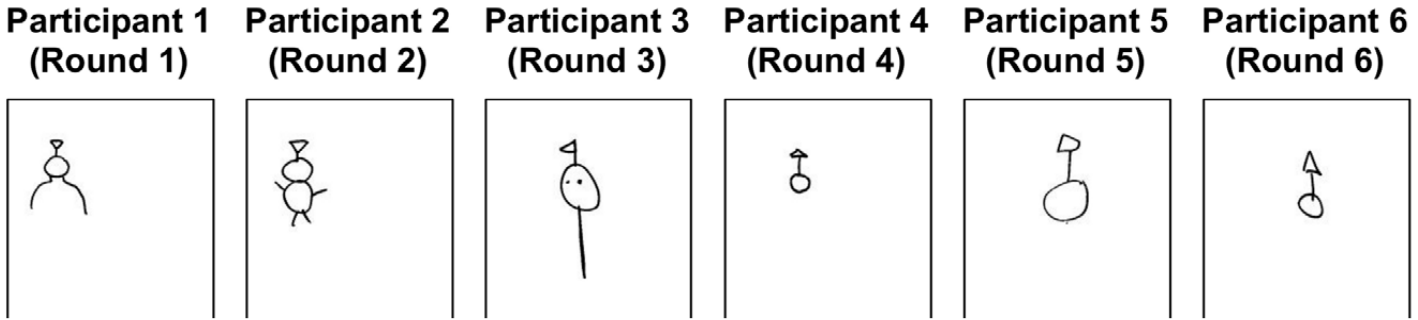
These processes are inherent to the transmission of language via learning and (ostensive-inferential) use

To what extent can these same processes explain the origins of fundamental properties of linguistic systems?

Example: the evolution of symbols

The evolution of arbitrary symbols in the lab (from week 1)





Garrod, S. et al. (2007). Foundations of Representation: Where Might Graphical Symbol Systems Come From? *Cognitive Science, 31*, 961-987

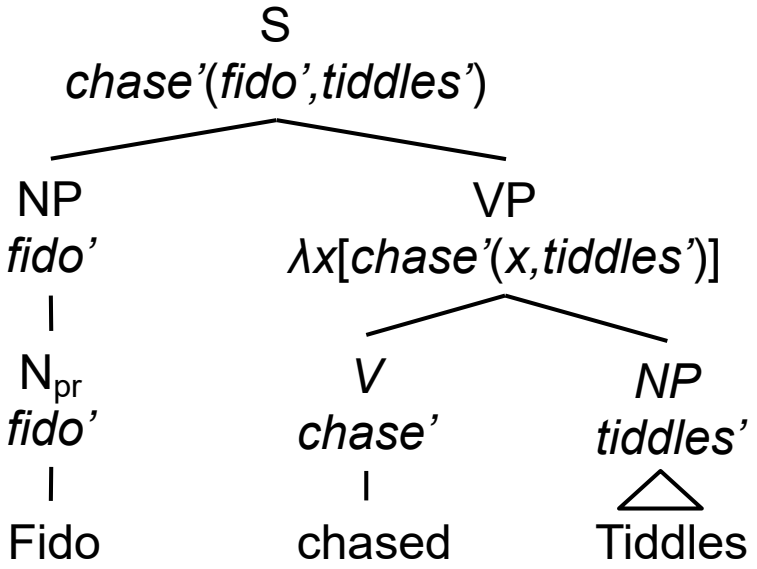
Caldwell, C. A., & Smith, K. (2012). Cultural evolution and the perpetuation of arbitrary communicative conventions in experimental microsocieties. *PLoS ONE, 7,* e43807.

Example: the evolution of structure

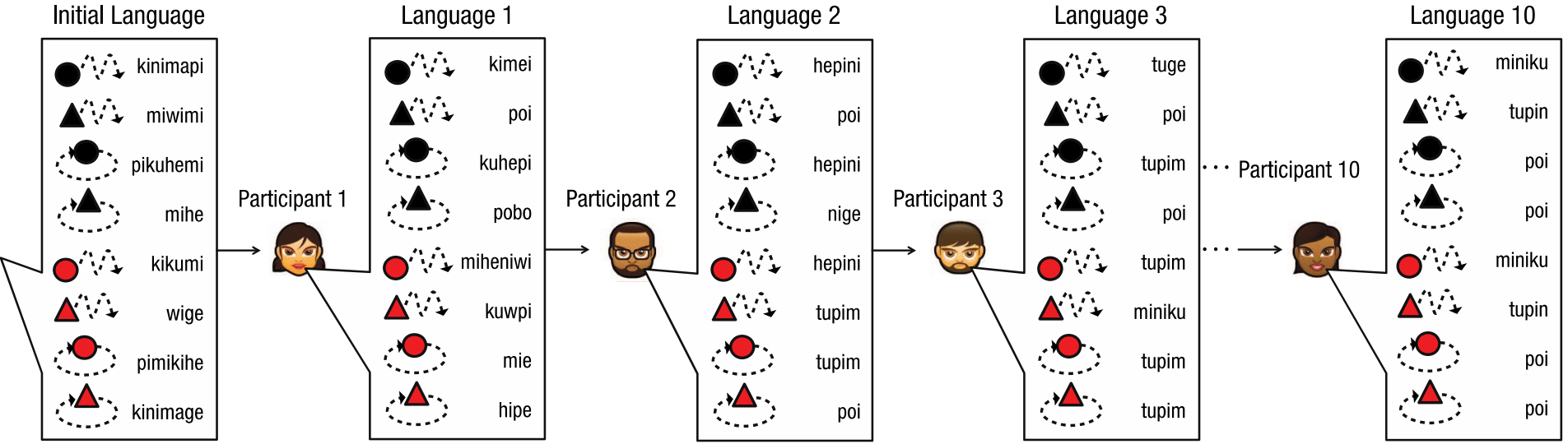
Reminder: Language's communicative power comes from its **structure**

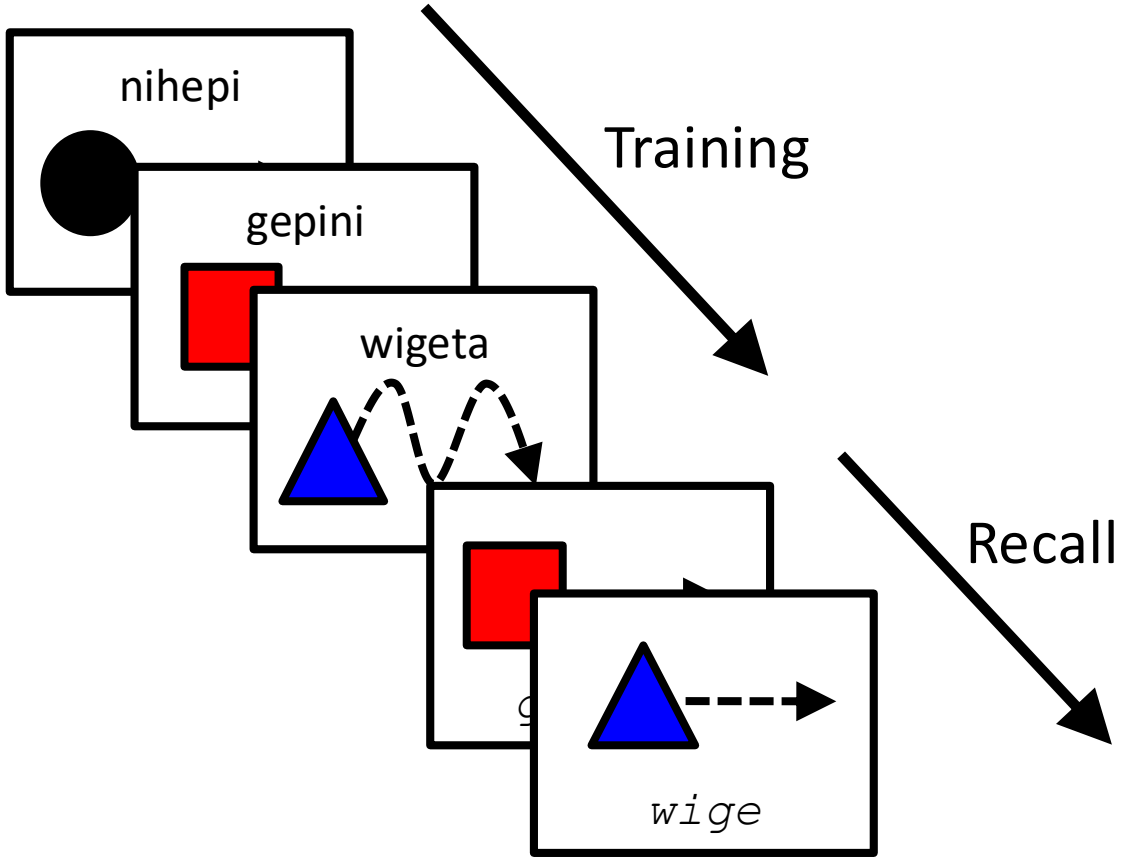
Compositionality: the meaning of an expression is a function of the meaning of its parts and the way in which they are combined

S → NP VP	*VP'*(*NP'*)
NP → N_{pr}	N'_{pr}
N_{pr} → Fido	*fido'*
N_{pr} → Tiddles	*tiddles'*
VP → V NP	*V'*(*NP'*)
V → chased	*λx* [*λy* [(*chase'*(*x,y*)]]



Iterated Learning





Kirby, S., Cornish, H., & Smith, K. (2008). Cumulative cultural evolution in the laboratory: An experimental approach to the origins of structure in human language. *PNAS, 105,* 10681-10686.

Your questions from the pre-lecture quiz

“I was wondering why you used the terms 'string' and 'meaning' as opposed to 'words' and 'symbols' or something similarly intuitive?”

An initial **holistic** language from chain 4



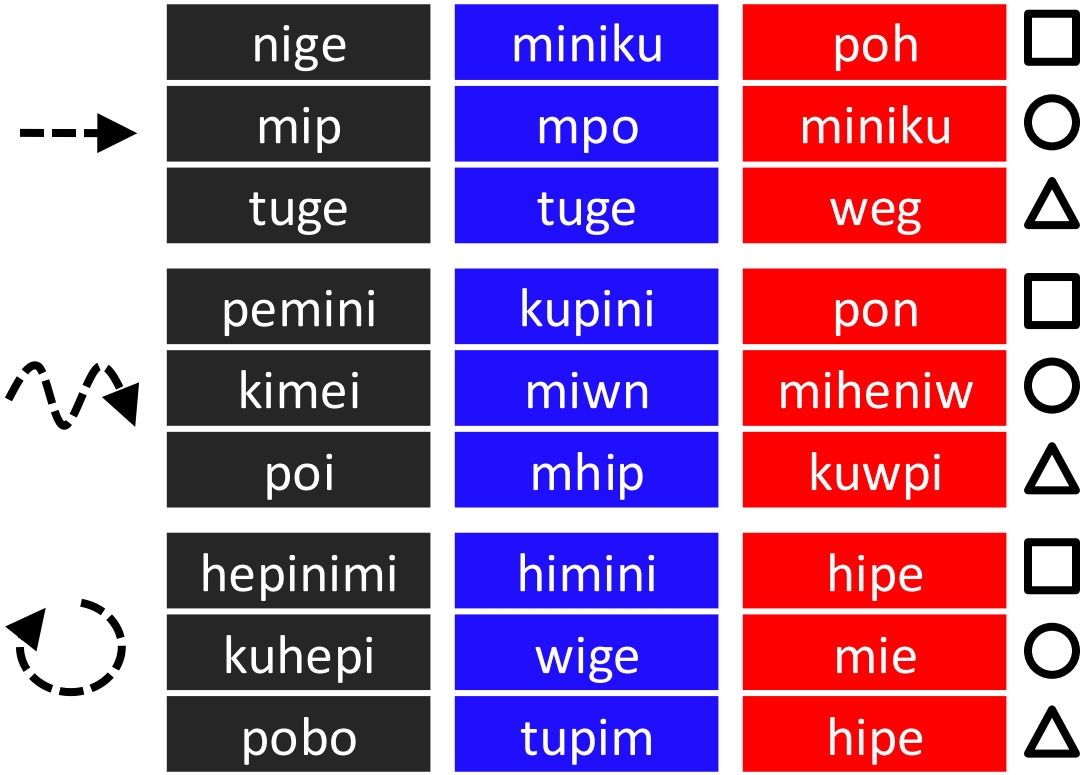
Seen vs unseen



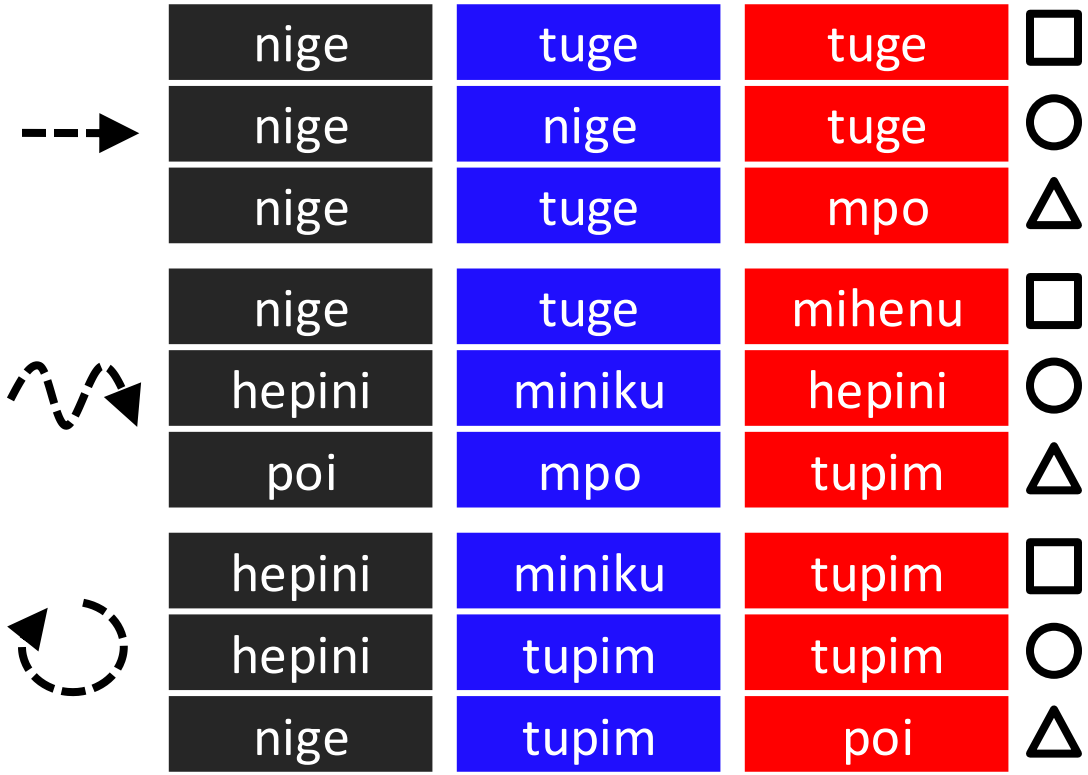
An initial **holistic** language from chain 4



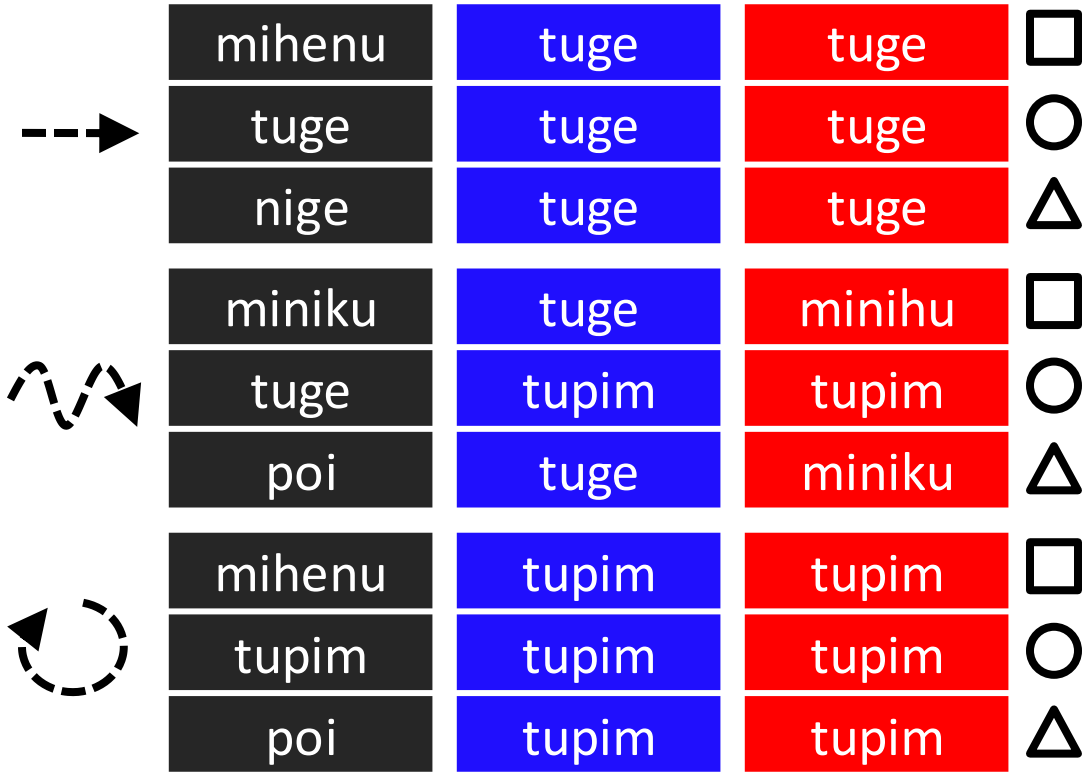
Generation 1 language from chain 4



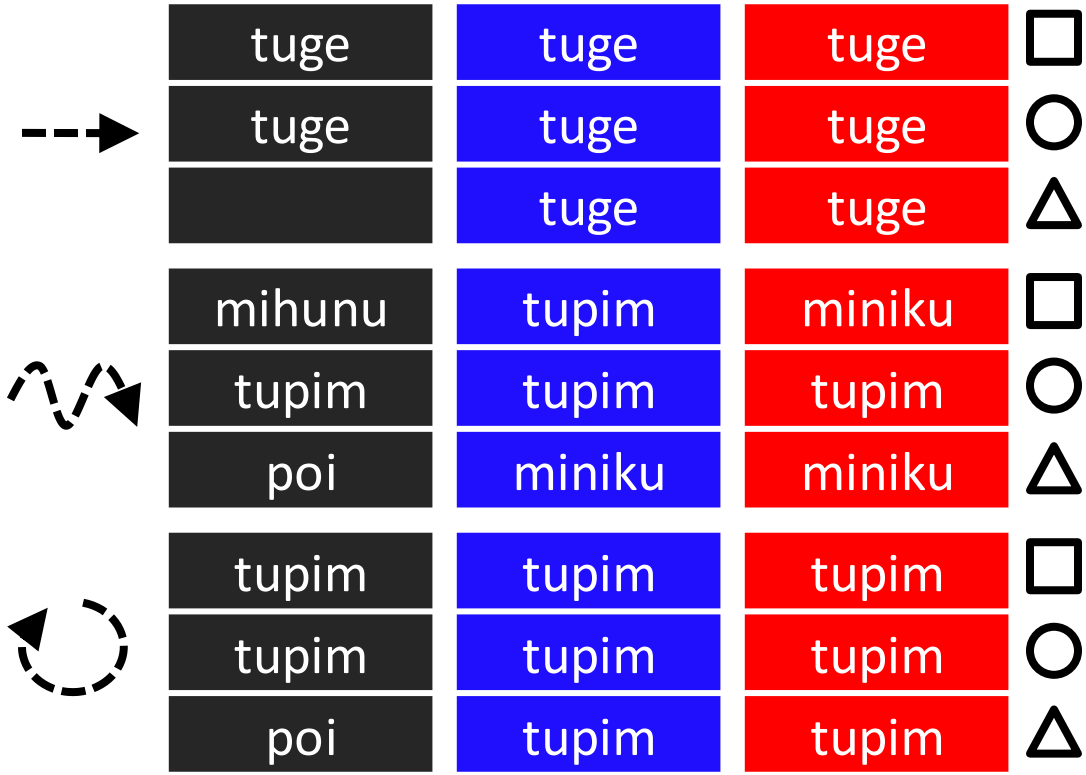
Generation 2 language from chain 4



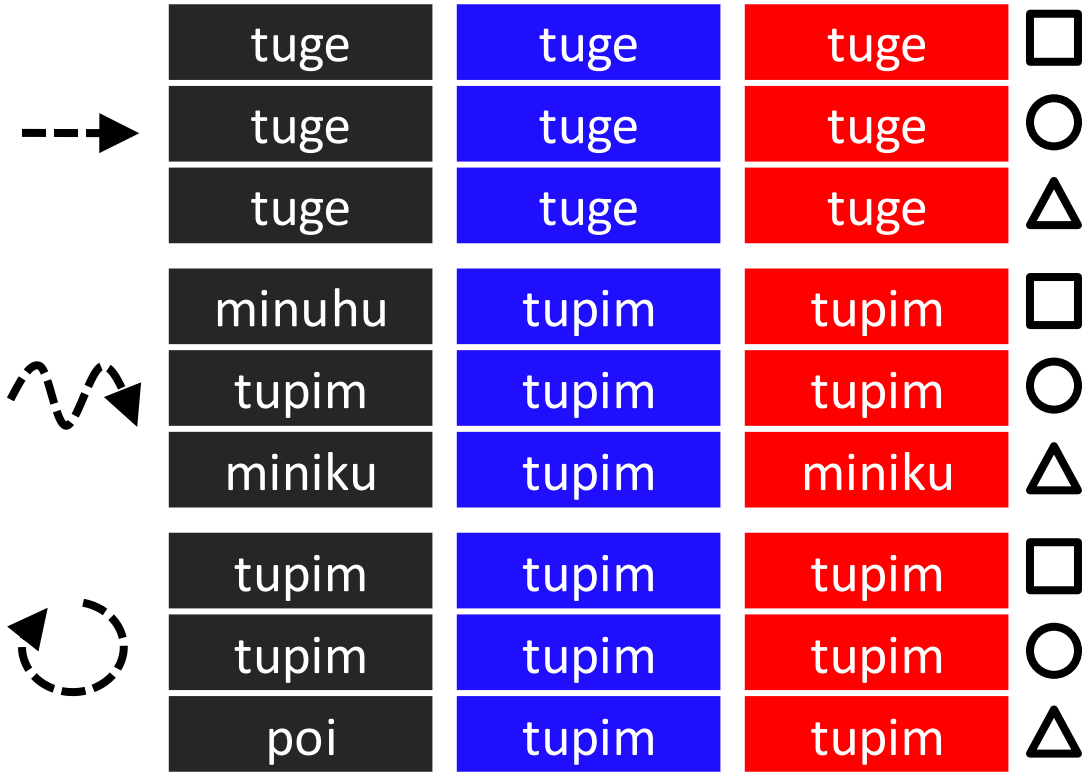
Generation 3 language from chain 4



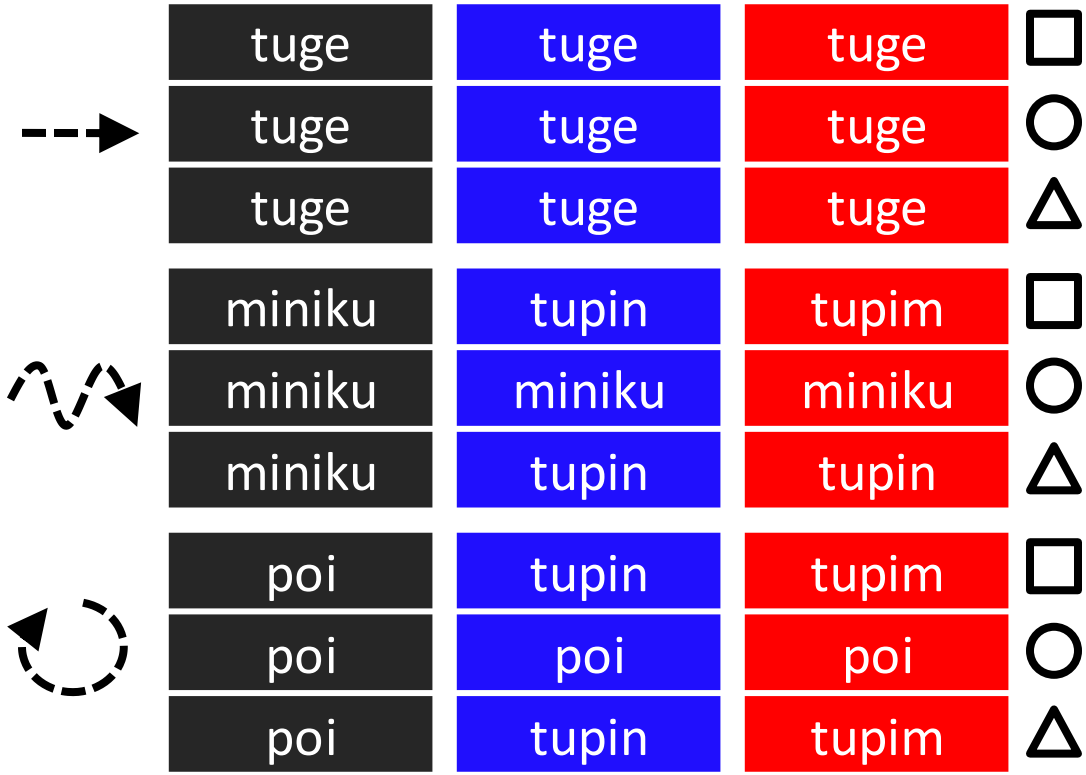
Generation 4 language from chain 4



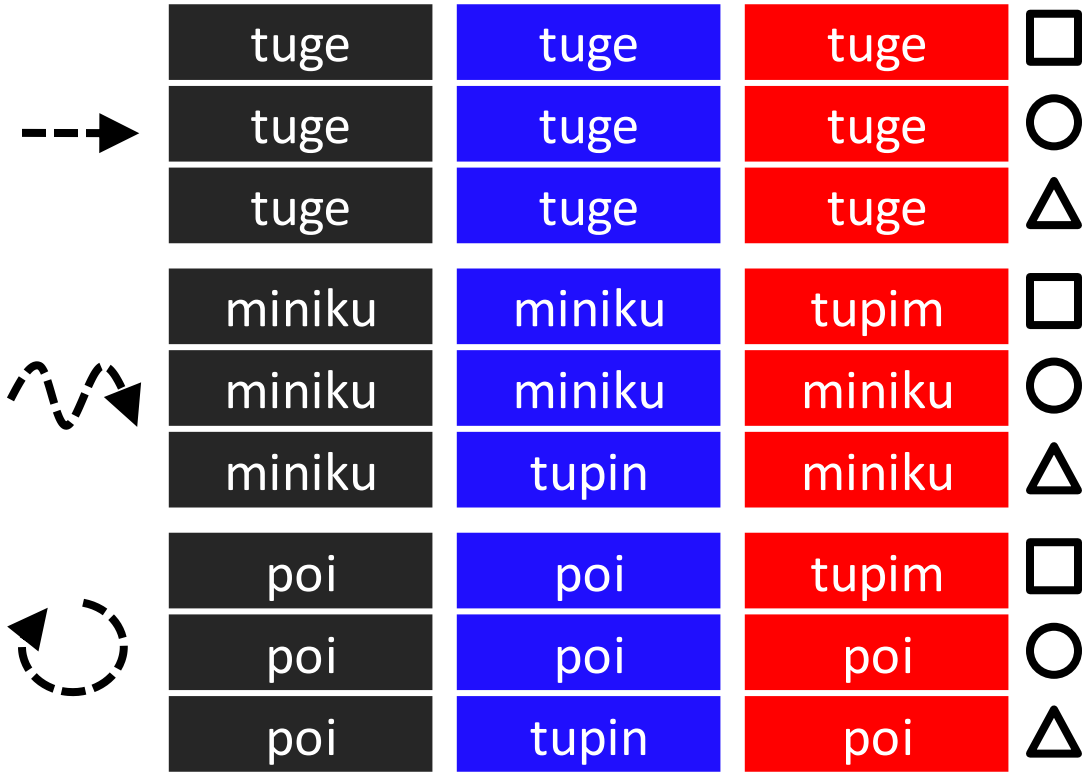
Generation 5 language from chain 4



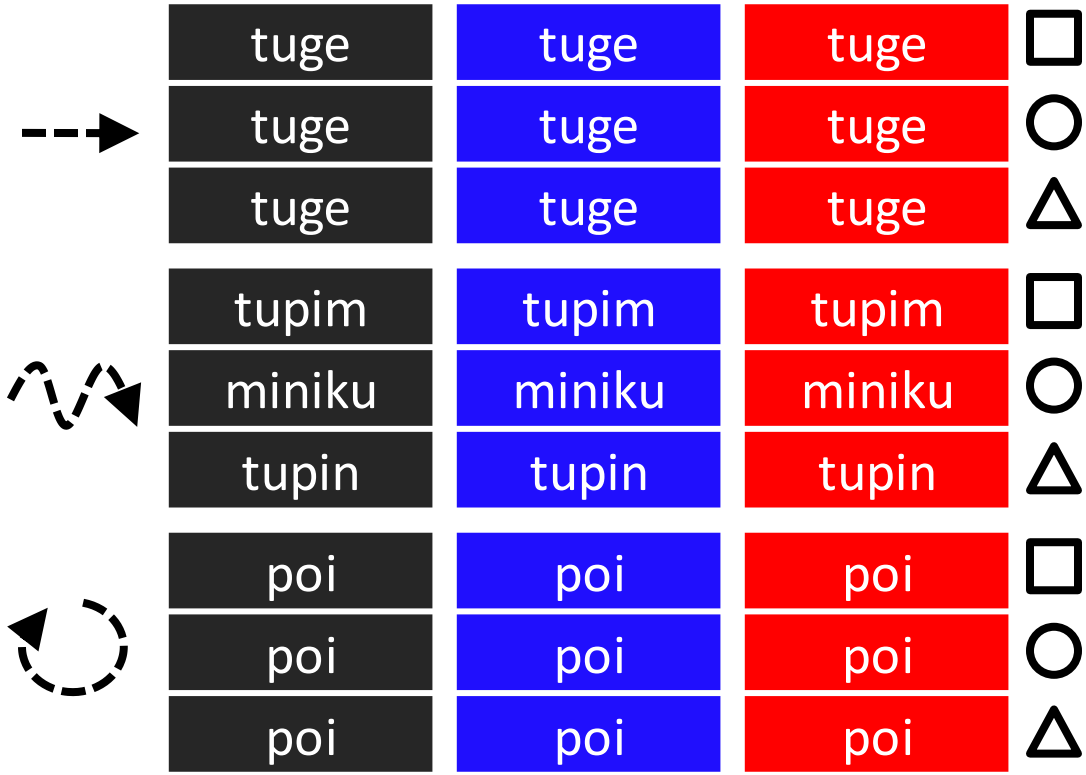
Generation 6 language from chain 4



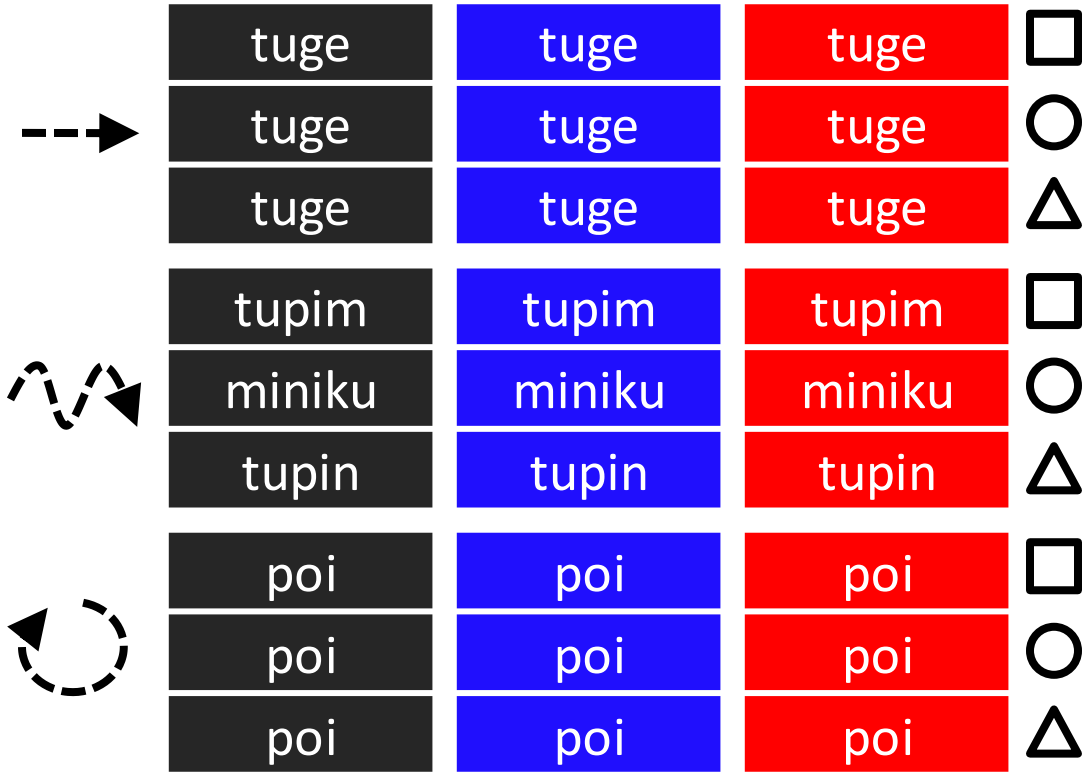
Generation 7 language from chain 4



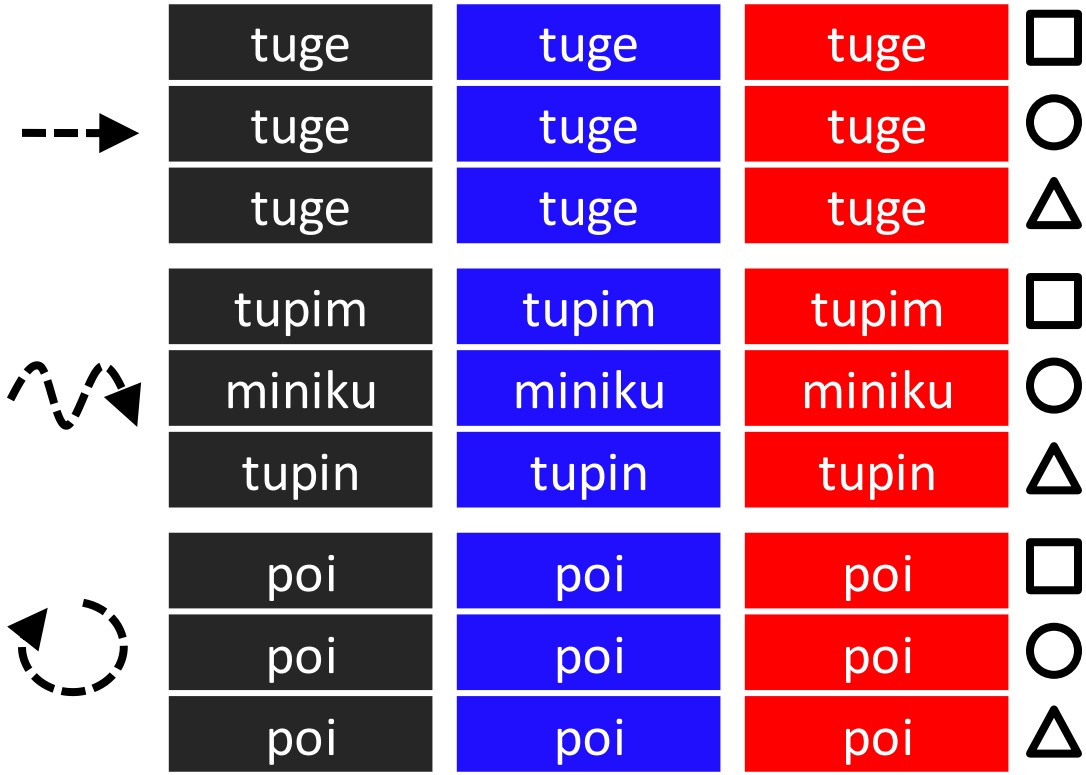
Generation 8 language from chain 4



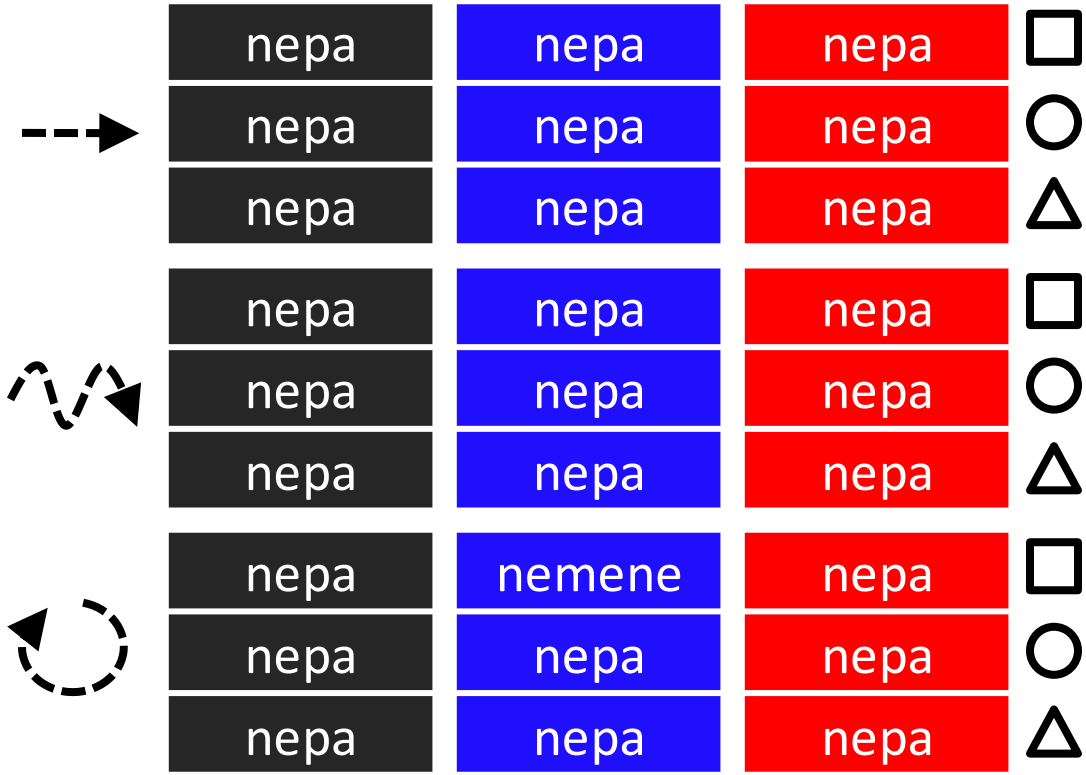
Generation 9 language from chain 4



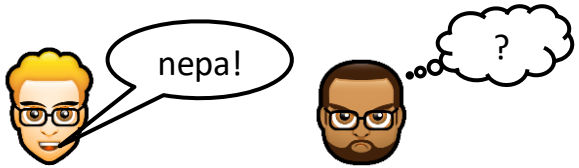
Generation 10 language from chain 4



Final language from chain 1 (!)



The languages become **degenerate**



Learnability and degeneracy

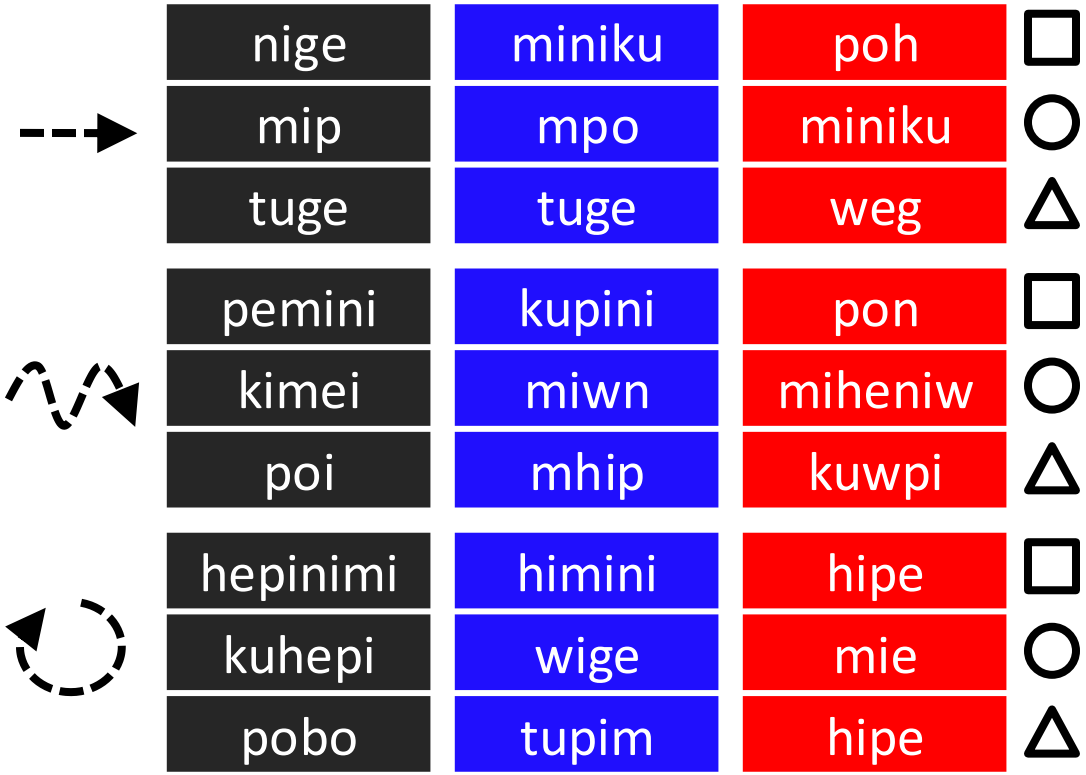
Learners prefer simpler languages

The only pressure in Kirby, Cornish & Smith (2008) Experiment 1 is **learnability**

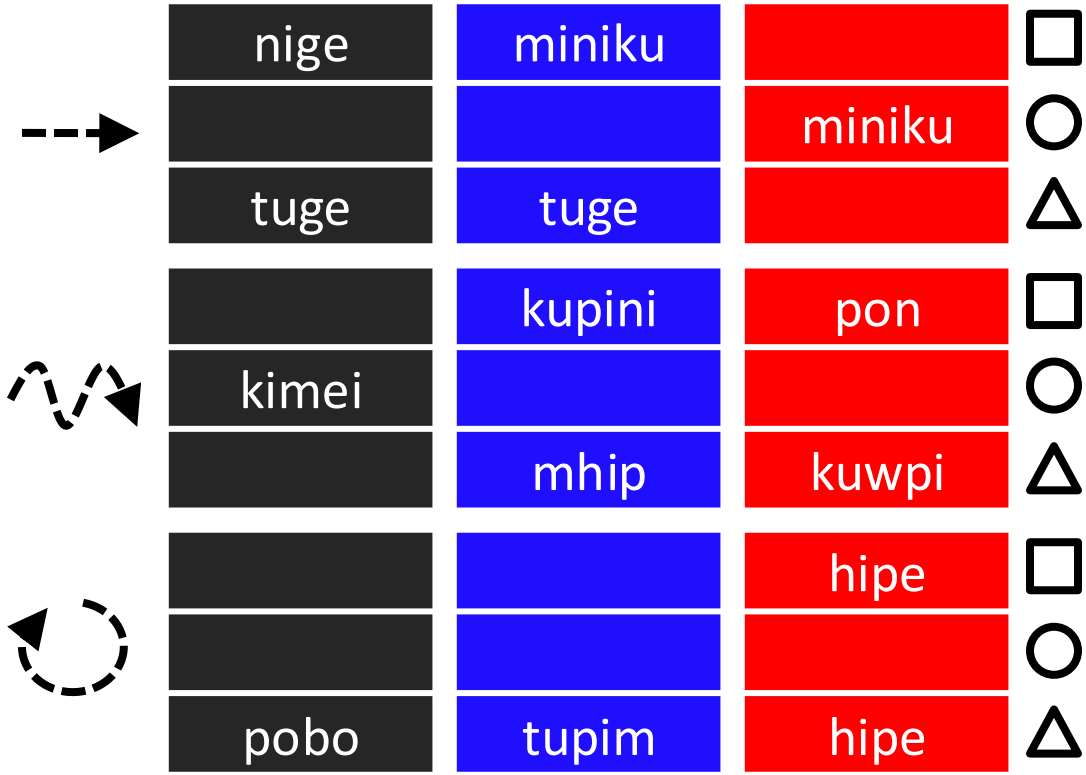
- The languages don't need to be **expressive**
- They get very simple

Can we add in a pressure for expressivity?

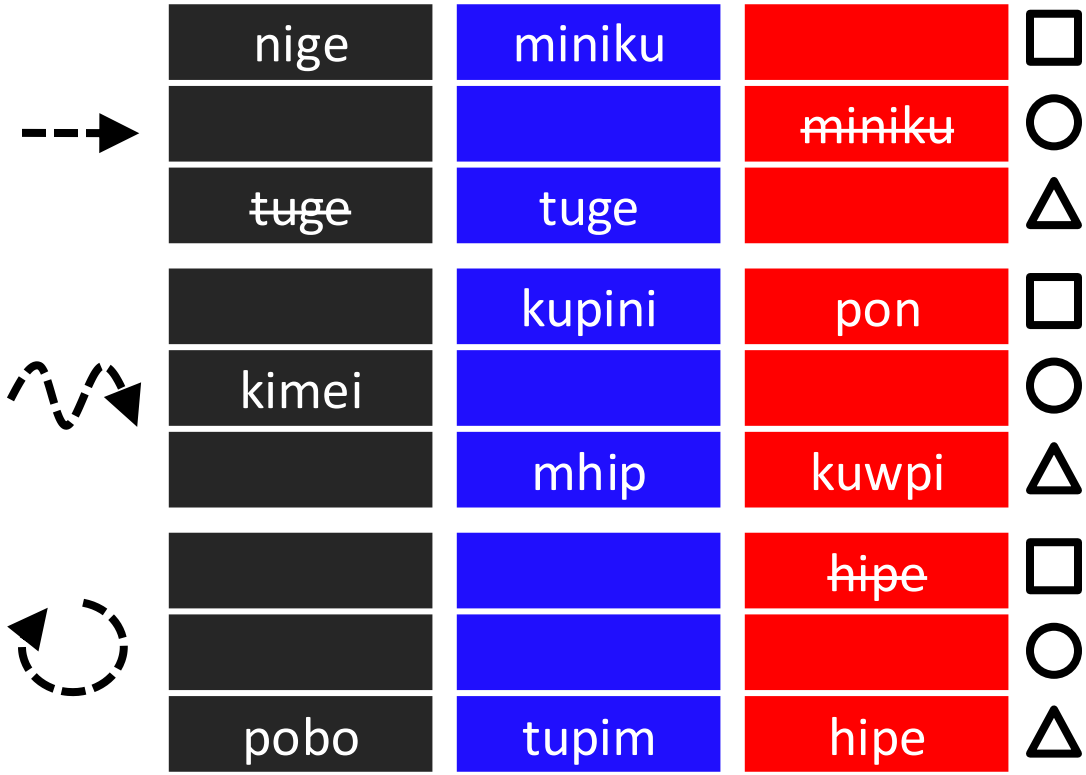
Experiment 2: adding a proxy for use/expressivity (to be improved!)



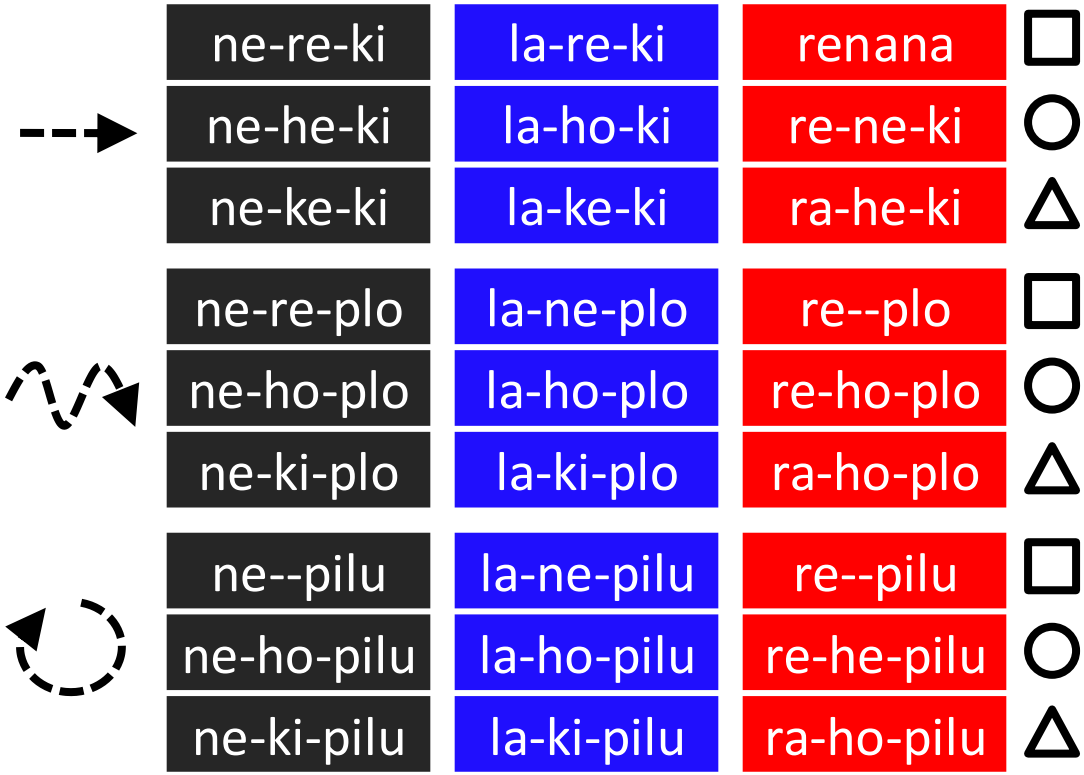
Experiment 2: adding a proxy for use/expressivity (to be improved!)



Experiment 2: adding a proxy for use/expressivity (to be improved!)



Generation 9 language from chain 5 (with homonymy filter)



Your questions from the pre-lecture quiz

“I understand that participants generalize from the SEEN to the UNSEEN set, but I'm not sure about what "poverty of the stimulus" means. Could you please explain what this concept refers to in real language learning?”

“Could you further explain the poverty of the stimulus in language learning?

A question from the pre-lecture quiz

“In the second experiment, when you removed all the shapes that had been given the same 'string', **did you remove them by putting them in the unseen category**, generating a random string for them, or something else?”

A question from the pre-lecture quiz

“For the second experiment, how is filtering out instances where one string is assigned to multiple meanings analogous to a pressure to be expressive? The participants don't see any strings with underspecified meanings, but how does that become a pressure for the participants to maintain the status quo of producing no strings that correspond to multiple meanings?”

A question from the pre-lecture quiz

“In the discussion, one of the defences for why the results dont [only!] reflect the participants native language is that it wouldnt explain the morphological concatenation in experiment 2. I don't quite understand this, as natural languages exhibit compositional structure with morphemes, and they were restricted to one word, so couldn't use other types of compositional structure. Given the restrictions, the emergent structure seems to reflect natural language structure. (But I agree that the results don't reflect their native language, just unclear about this defence!)”

A question from the pre-lecture quiz

“can I check what underspecification means especially in the context of experiment 2?”

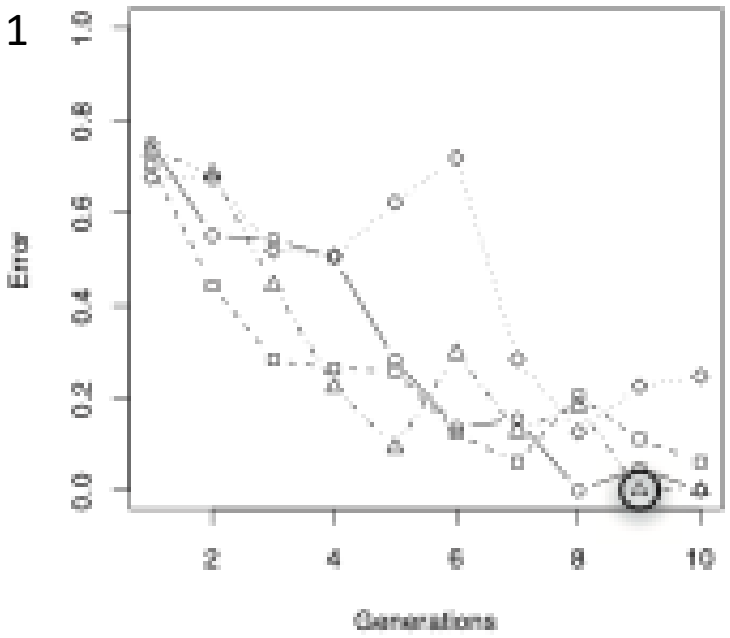
A question from the pre-lecture quiz

“What is faithful transmission?”

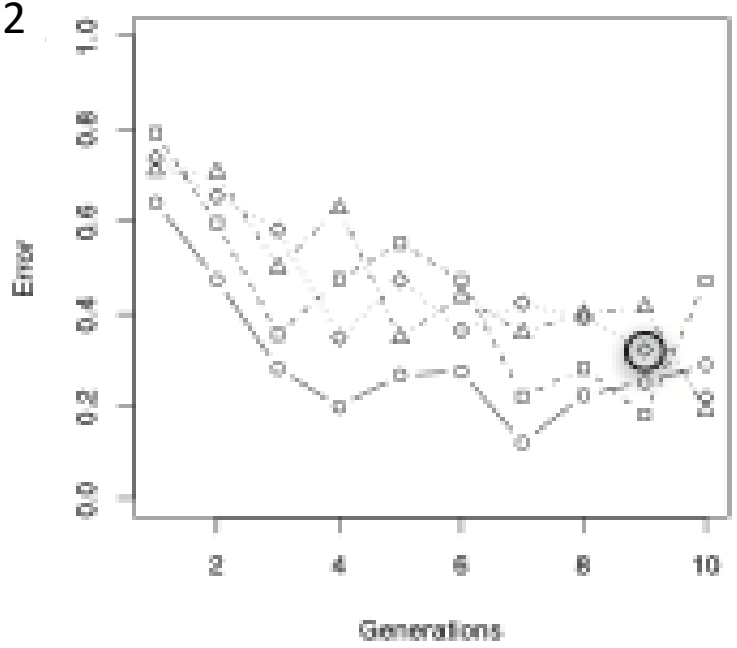
“How do you know that all of the participants were acting faithfully? You say experiment 1 often resulted in one string being used for all meanings - how do you know someone didn't get bored halfway through their set and just sabotage the experiment? They weren't aware that their answers would be used to test the next participant.”

(fairly) gradual

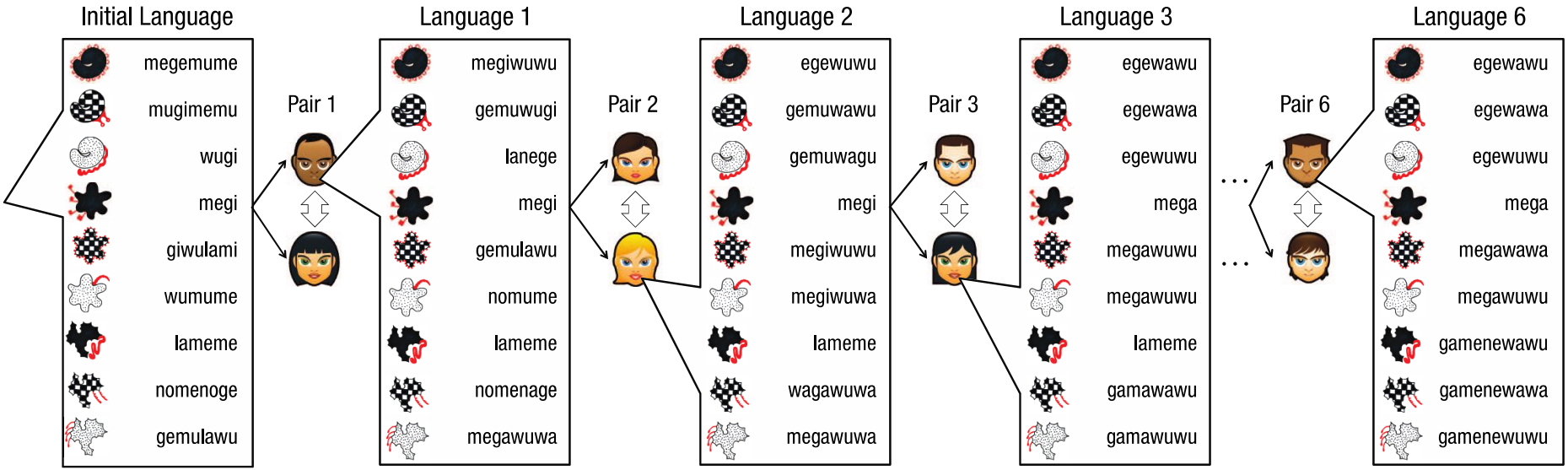
Exp 1



Exp 2

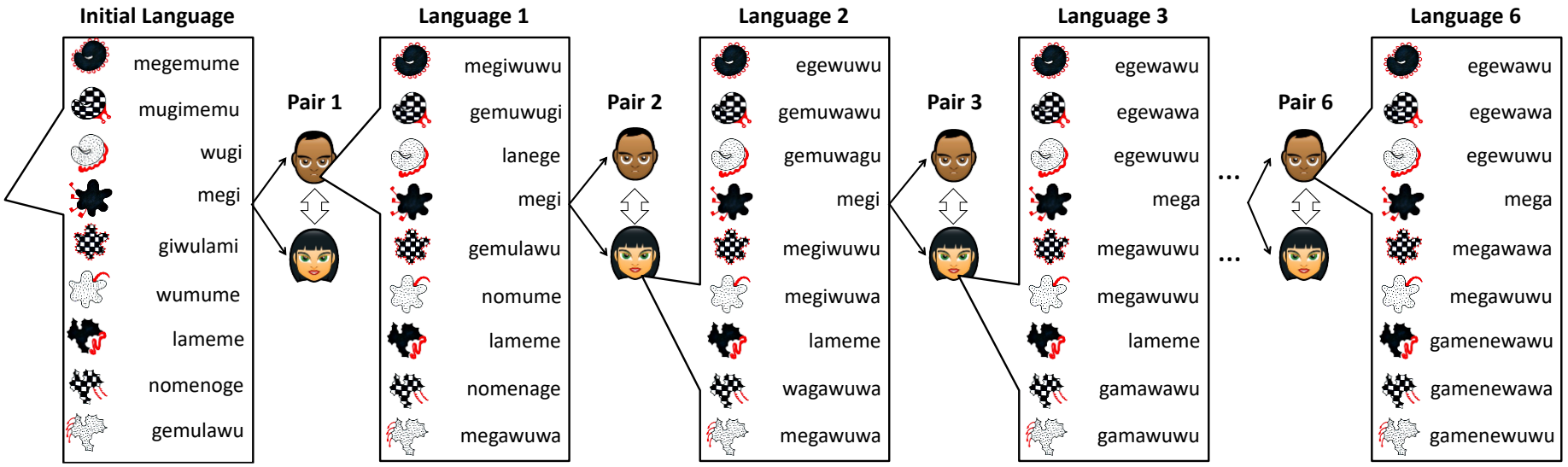


Kirby, Tamariz, Cornish & Smith (2015): Adding communication



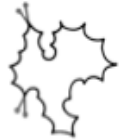
Kirby, S., Tamariz, M., Cornish, H., & Smith, K. (2015). Compression and Communication in the Cultural Evolution of Linguistic Structure. *Cognition, 141*, 87-102.

Kirby, Tamariz, Cornish & Smith (2015): Adding communication, removing learning

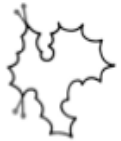


Kirby, S., Tamariz, M., Cornish, H., & Smith, K. (2015). Compression and Communication in the Cultural Evolution of Linguistic Structure. *Cognition, 141*, 87-102.

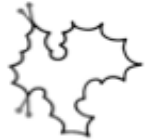
An initial language

 megemume	 megi	 lameme
 mugimemu	 giwulami	 nomenoge
 wugi	 wumume	 gemulawu
 lamege	 wulamugi	 megiwuwa

A final language from a chain

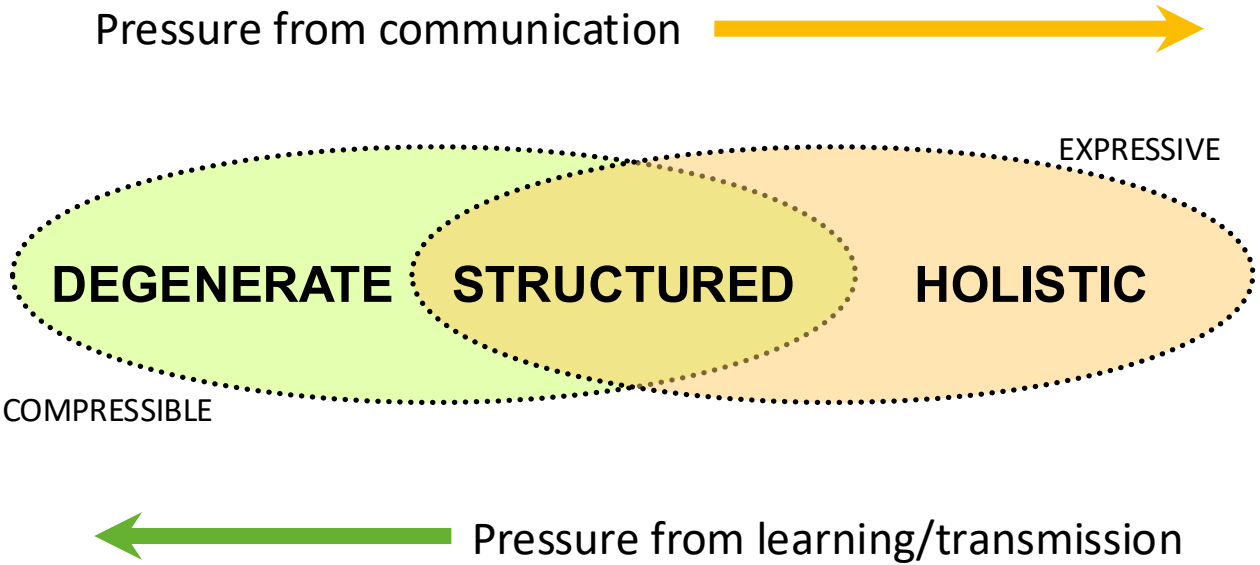
 egewawu	 mega	 gamenewawu
 egewawa	 megawawa	 gamenewawa
 egewuwu	 megawuwu	 gamenewuwu
 ege	 wulagi	 gamane

A final **holistic** language from a dyad

 manunumoko	 moko	 konu
 wekihumanunu	 mokowekihu	 lawa
 makihu	 mahiku	 wekihulawa
 manunumonu	 nomu	 wekihu

Learnability + expressivity = **structure**

Structure as a trade-off between compressibility and expressivity that plays out over cultural transmission



What about the beautiful adaptive fit between the structure of our thoughts and the structure of language?

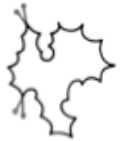
Reminder from week 2
Pinker & Bloom (1990)





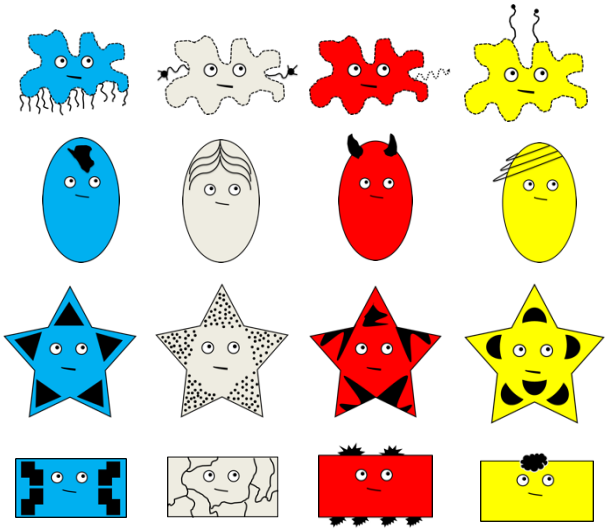
"All we have argued is that human language, like other specialized biological systems, evolved by natural selection. Our conclusion is based on two facts that we would think would be entirely uncontroversial: Language shows signs of complex design for the communication of propositional structures, and the only explanation for the origin of organs with complex design is the process of natural selection." (p. 726)

Pinker, S., & Bloom, P. (1990). Natural language and natural selection. *Behavioural and Brain Sciences, 13,* 707-784.

 egewawu	 mega	 gamenewawu
 egewawa	 megawawa	 gamenewawa
 egewuwu	 megawuwu	 gamenewuwu
 ege	 wulagi	 gamane

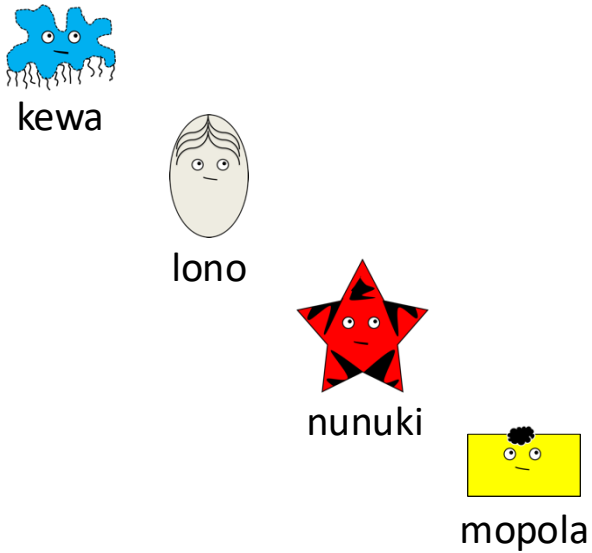
The structure of the communicative task affects the kinds of structures that emerge

E.g. Winters, J., Kirby, S., & Smith, K. (2018). Contextual predictability shapes signal autonomy. *Cognition, 176,* 15-30.



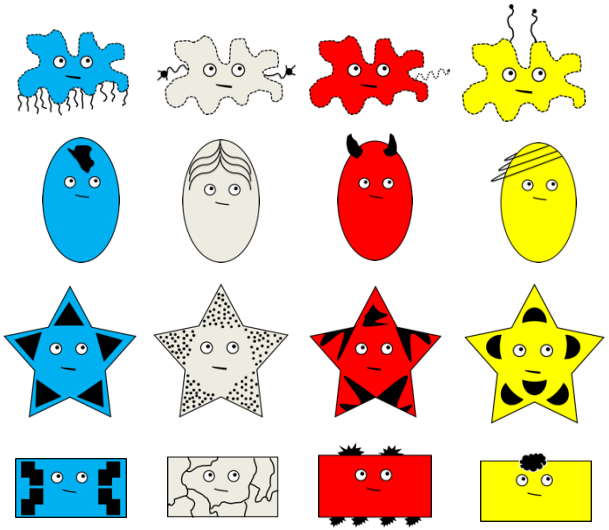
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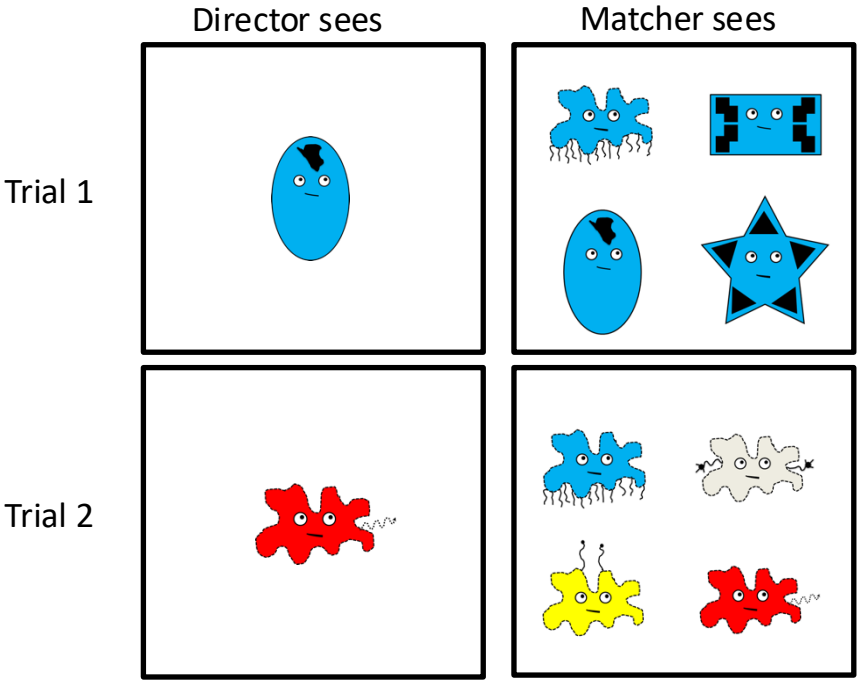
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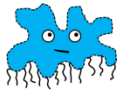


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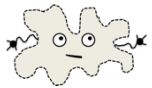
E.g. Winters, J., Kirby, S., & Smith, K. (2018). Contextual predictability shapes signal autonomy. *Cognition, 176,* 15-30.




Director sees
Matcher sees
Trial 1
Trial 2
...



mege-ha



mege-hi



mege-hu



megi-lo



waka-ha



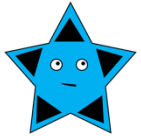
waka-hi



waka-hu



waki-lo



goko-ha



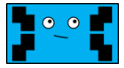
goko-hi



goko-hu



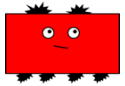
goki-lo



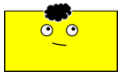
kuki-ha



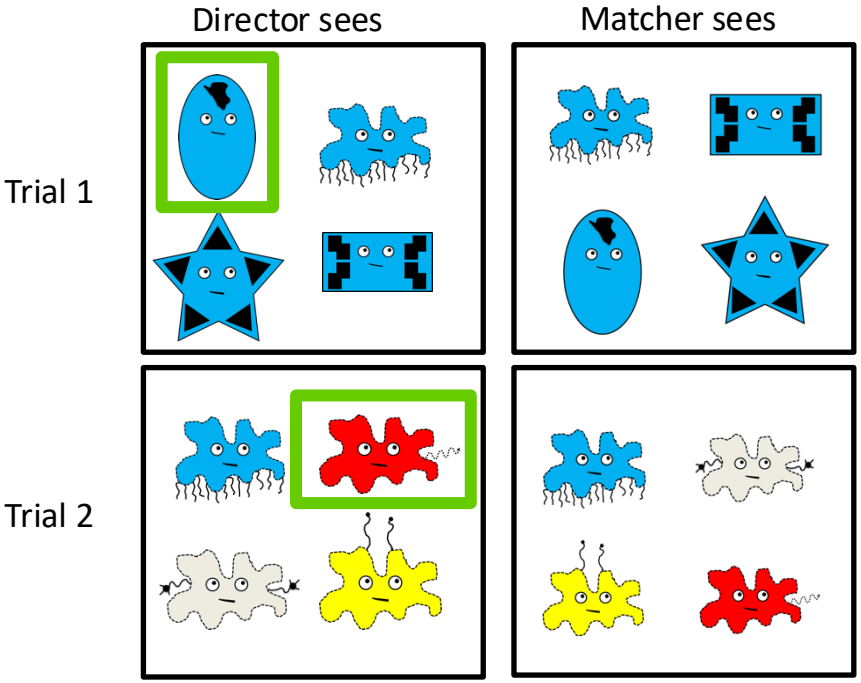
kuko-hi



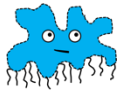
kuko-hu

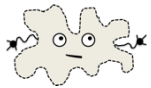


kuki-lo


Director sees
Matcher sees
Trial 1
Trial 2
...

On shape-relevant trials …


kewu


kewu


kewu

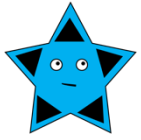

kewu


nunuki

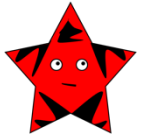

nunuki


nunuki

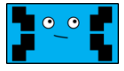

nunuki


lono

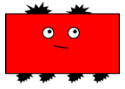

lono

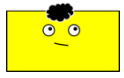

lono


lono


mopola

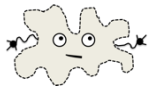

mopola


mopola


mopola

On colour-relevant trials…


kewu mopola


kewu nunuki


kewu lono

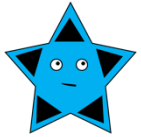

kewu kewu


nunuki mopola


nunuki


nunuki lono

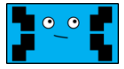

nunuki kewu


lono mopola

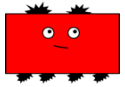

lono nunuki

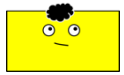

lono

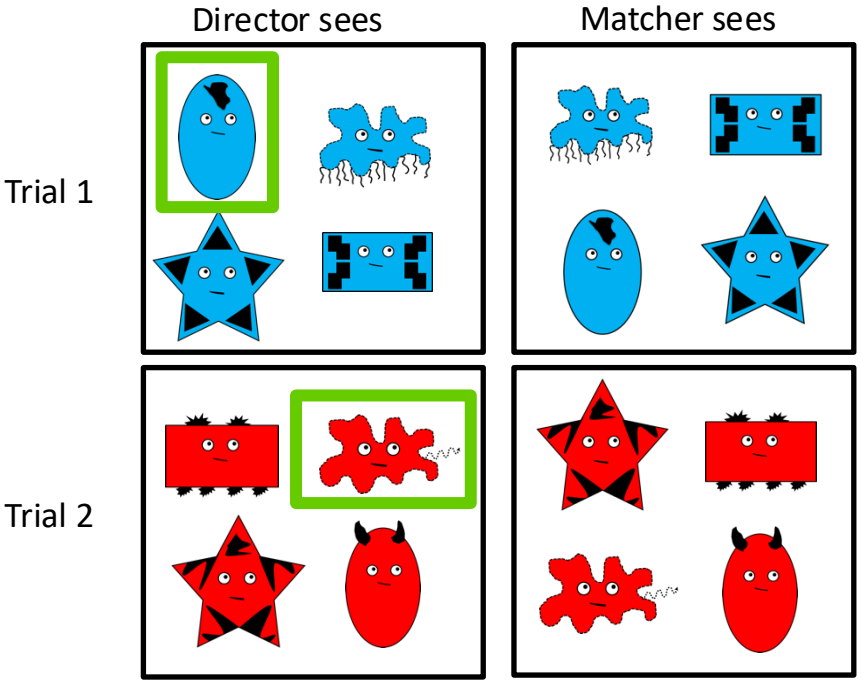

lono kewu


mopola mopola


mopola nunuki

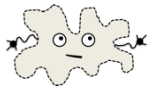

mopola lono


mopola kewu


Director sees
Matcher sees
Trial 1
Trial 2
...



hagolo



hagolo



hagolo



hagolo



nuhumi



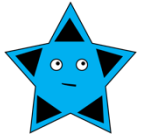
nuhumi



nuhumi



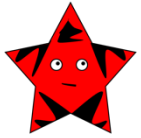
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winigo



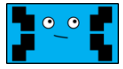
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winigo



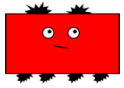
winigo



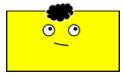
kamu



kamu



kamu



kamu

A question from the pre-lecture quiz

“Could you explain what generalisation pressure means (Smith 2022 reading) and whether it counteracts or works alongside pressures of simplicity and expressivity?

Reminder from week 2
Pinker & Bloom (1990)





"All we have argued is that human language, like other specialized biological systems, evolved by natural selection. Our conclusion is based on two facts that we would think would be entirely uncontroversial: Language shows signs of complex design for the communication of propositional structures, and the only explanation for the origin of organs with complex design is the process of natural selection." (p. 726)

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Example: duality of patterning

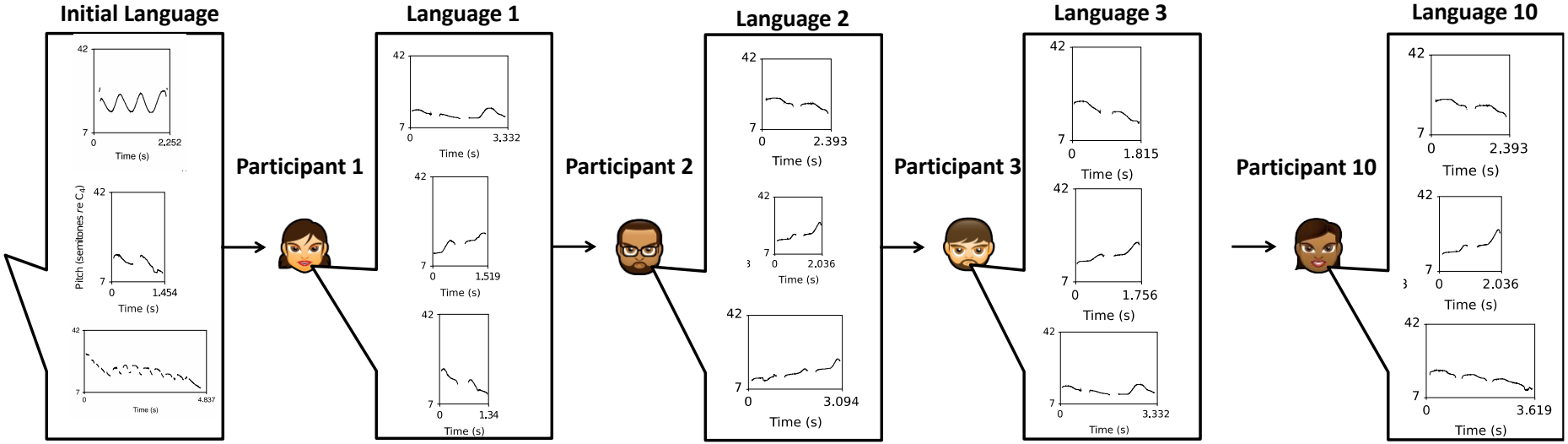
Language's communicative power comes from its **structure**

Duality of patterning: meaning-bearing units composed of (re)combinations of meaningless differentiating units

Word	**Meaning**
log	*"Noun; an unhewn portion of a felled tree"*
dog	*"Noun; A domesticated carnivorous mammal"*
dig	*"Verb; To work in making holes or turning the ground"*
dim	*"Adjective; Faintly luminous"*

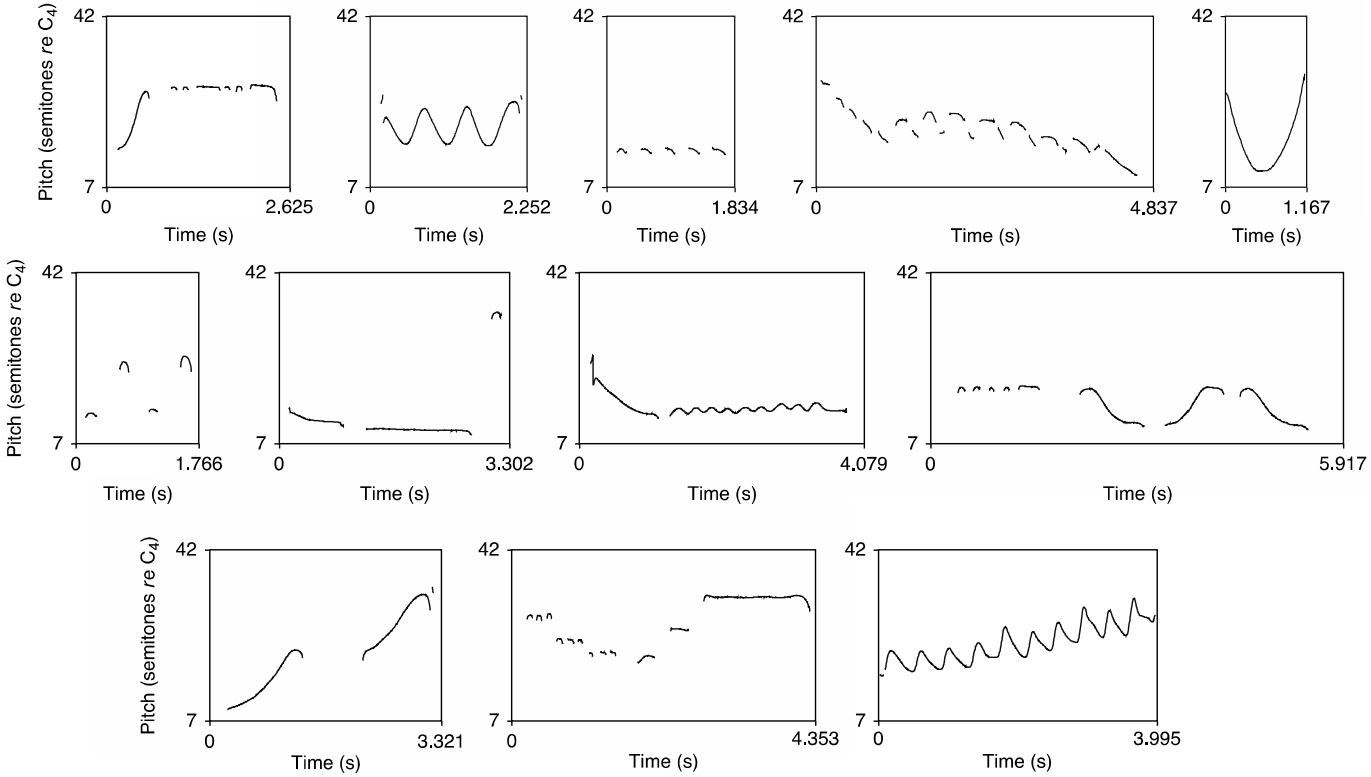
Iterated Learning of Whistles



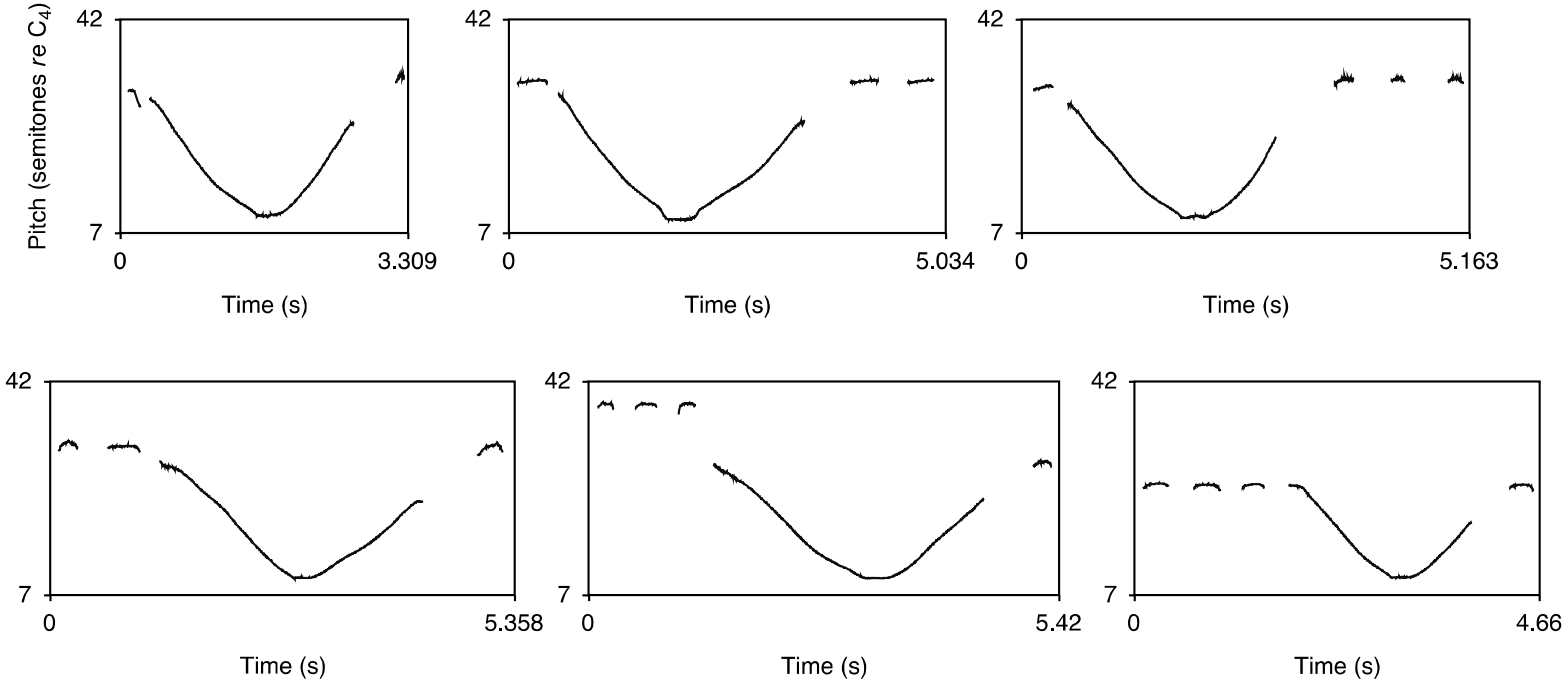


Verhoef, T., Kirby, S., & de Boer, B. (2014). Emergence of combinatorial structure and economy through iterated learning with continuous acoustic signals. *Journal of Phonetics, 43,* 57-68.

The initial whistle set



(Part of) A generation 10 whistle set



Cultural evolution of language: a summary

A uniformitarian approach

- We should attempt to explain the (hidden) past in terms of processes we can see operating in the present
- How far can we get in appealing only to the same processes we see shaping language in the present?

Language change

- (analogy-based) learning and (ostensive-inferential) use are important mechanisms

Language evolution

- Same processes can explain origins of symbols, compositionality, and duality of patterning
- At least in populations capable of the right kind of learning and use

Next up

- Tutorial
  - Do natural languages in different communities (transmitted under different constraints, with different communitive needs) show different adaptations to those different niches?
  - Illustrated with a fun game/experiment (probably)
- Next week
  - Sign language emergence as a window into language origins