Origins and Evolution of Language
Week 5: vocal learning and grammar learning

Kenny Smith

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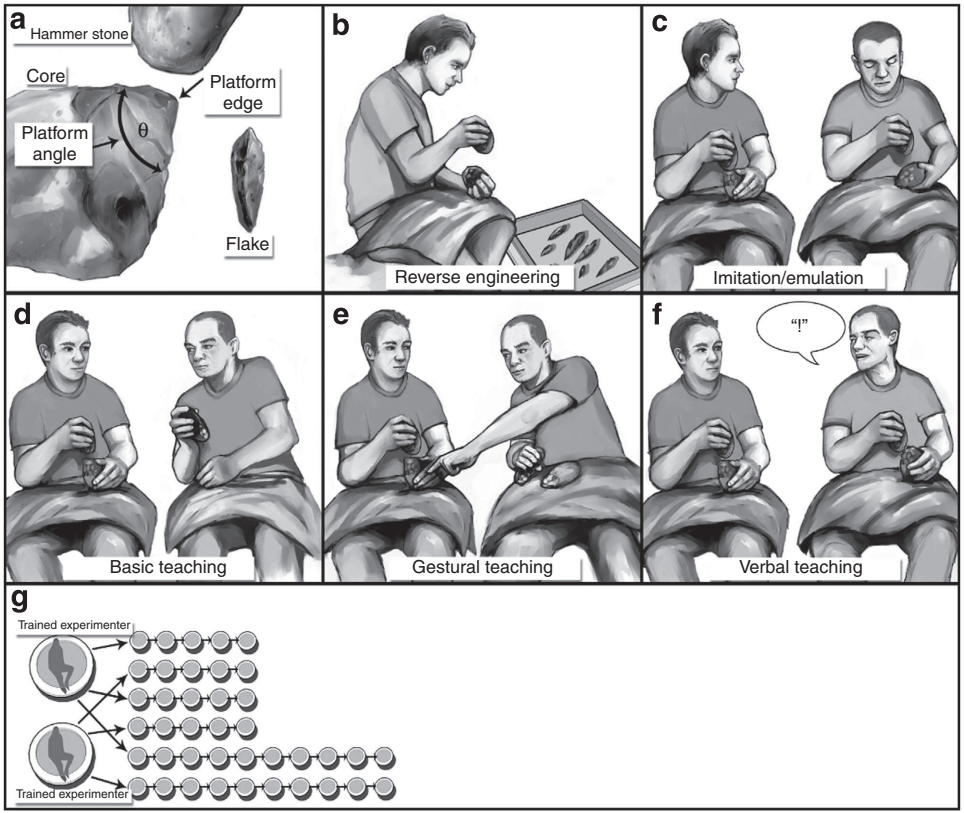
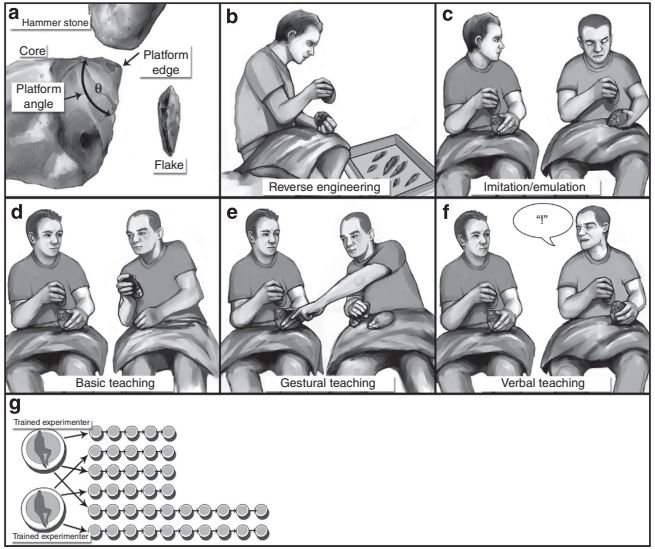
Plan for today

- Finishing off on technology and language
  - Technology, cumulative culture, and language
- Evolution of vocal apparatus for speech: quick summary of Fitch chapter 8
  - Descended larynx, thoracic vertebral canal, air sacs
- Evolution of neural apparatus for speech: quick summary of Fitch chapter 9
  - Complex vocal imitation
- Comparative psychology of grammar learning
  - Are humans special in our grammar learning abilities?

Is imitation enough to preserve stone tool technology?



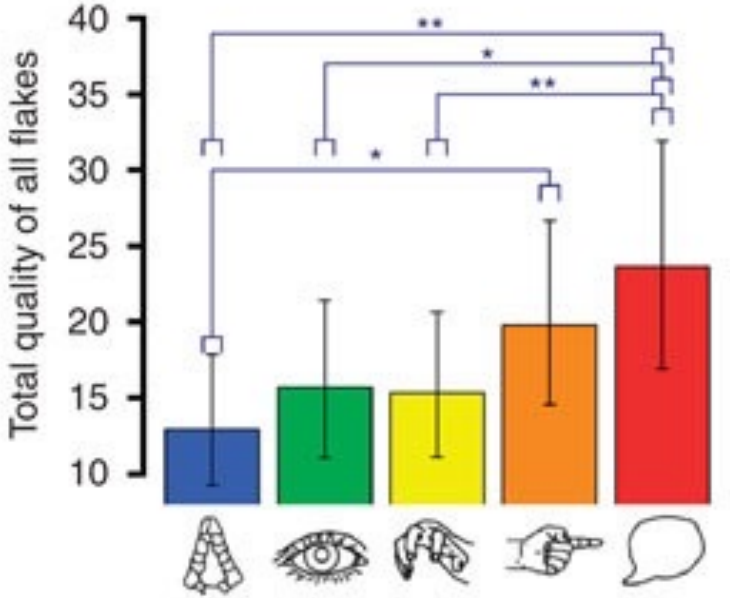


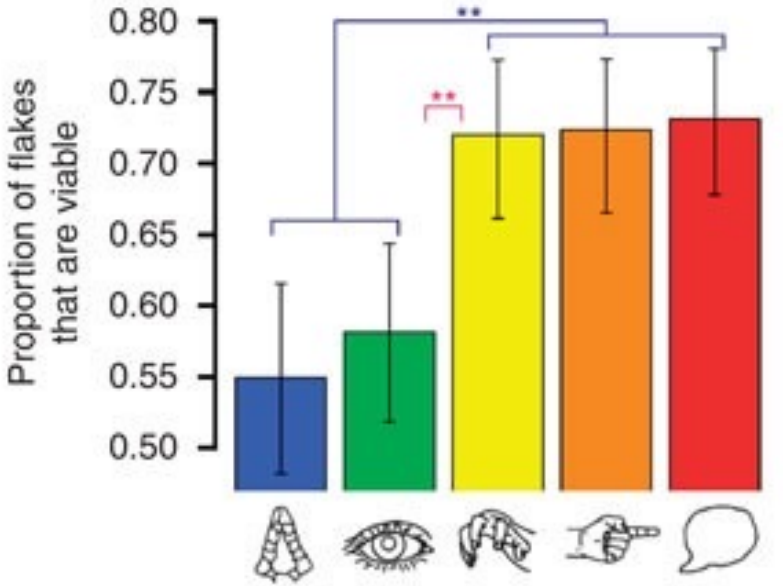
How do you think it's going to turn out?

http://app-ca.tophat.com/e/285083

A: Language will beat all these other mechanisms.
B: More sophisticated teaching is better, but in a smooth, gradual way.
C: Any kind of teaching is better than none, language isn't special.
D: I don't care too much what the results are here, this experiment isn't capturing what I think is important.

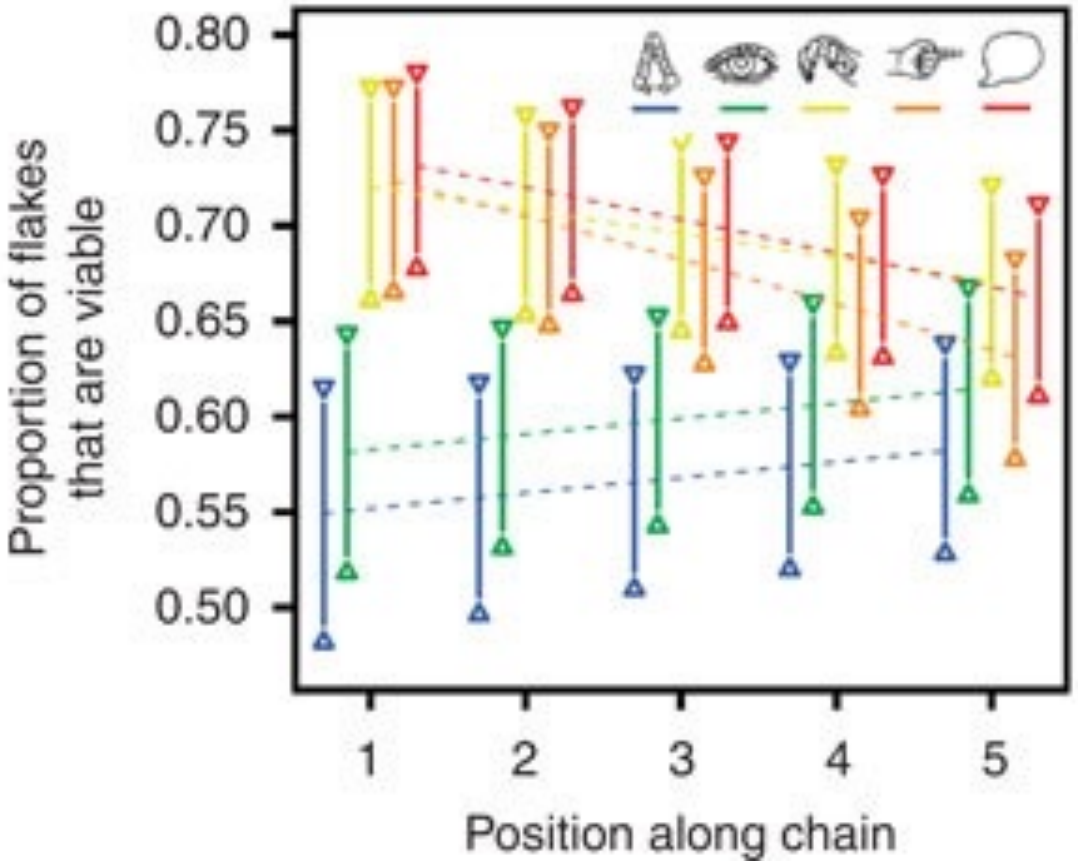
Does language-based teaching make you better at the task?





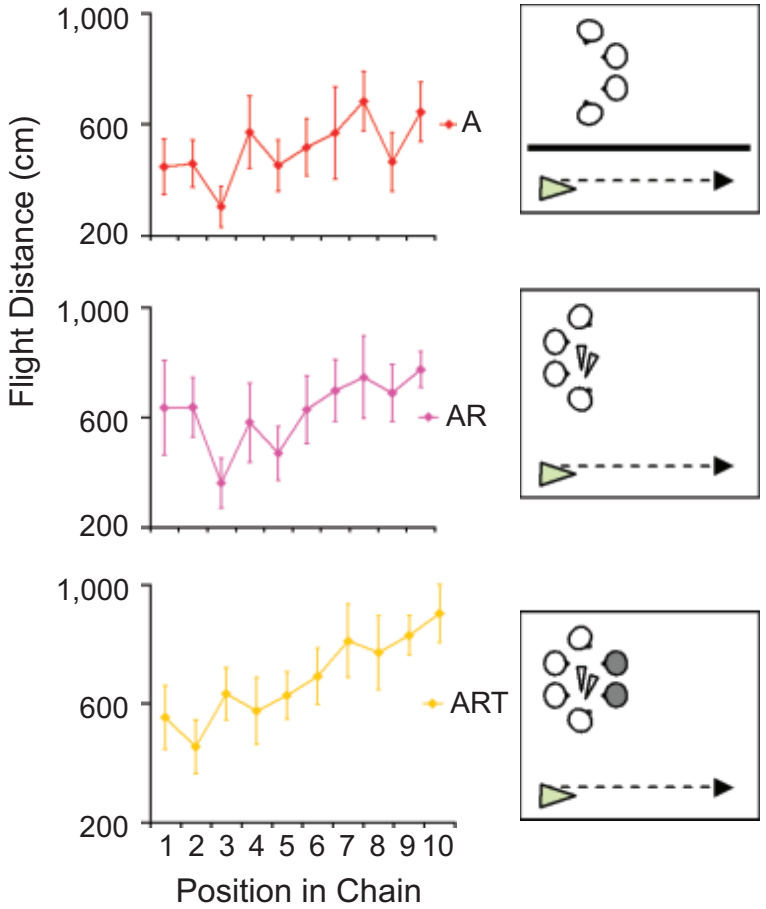
Morgan, T. J. H., et al., (2015). Experimental evidence for the co-evolution of hominin tool-making teaching and language. *Nature Communications, 6,* 6029.

Is imitation enough to preserve stone tool technology?



Morgan, T. J. H., et al., (2015). Experimental evidence for the co-evolution of hominin tool-making teaching and language. *Nature Communications, 6,* 6029.

Although: no benefit for teaching in a paper plane task



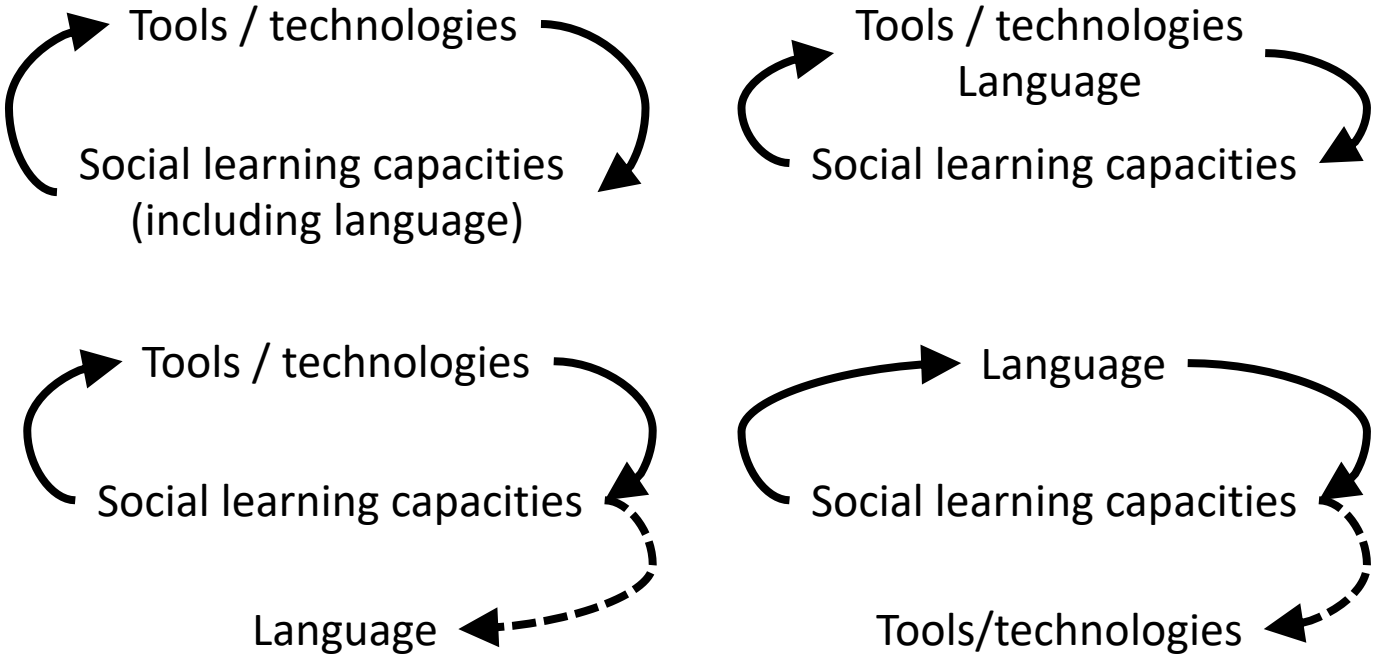
Caldwell, C. A., and Millen, A. E. (2009). Social learning mechanisms and cumulative cultural evolution: Is imitation necessary? *Psychological Science, 20,* 1478-1483.

Co-evolution of technology, teaching and language (?)

"our data imply that Oldowan tool making would have created a continuous selective gradient leading from observational learning to much more complex verbal teaching. This process need not have taken place entirely within the Oldowan, but was probably already underway during the Oldowan and likely continued well after, as Oldowan tools continued to be made for hundreds of thousands of years beyond the Oldowan time period. **Furthermore, assuming that the transmission of more complex technologies also benefits from more complex means of communication, later technologies would have reinforced the gene-culture co-evolutionary dynamic.** Such a process could have lasted for millions of years (and may be ongoing), with more complex communication allowing the stable and rapid transmission of increasingly complex technologies, which in turn generate selection for even more complex communication and cognition, and so forth. Although this places little necessary constraint on when teaching and language may have evolved, our central contribution is to provide evidence that Oldowan tools, produced by hominins since at least 2.5 mya, were involved in this dynamic." (Morgan et al., 2015)

Morgan, T. J. H., et al., (2015). Experimental evidence for the co-evolution of hominin tool-making teaching and language. *Nature Communications, 6,* 6029.

Co-evolution of technology, social learning, and language: some scenarios



Summary of last week

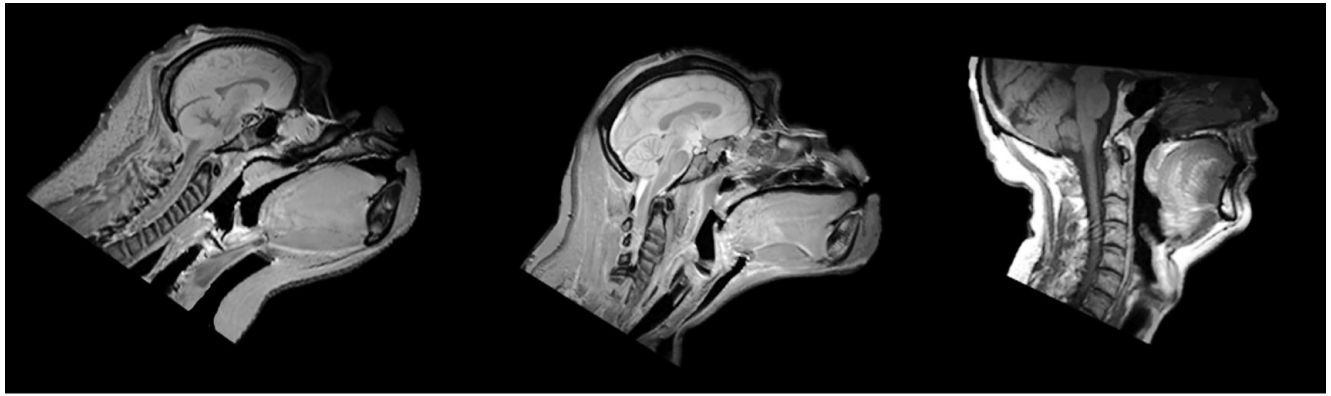
- Human evolution
  - Bushy, not linear
  - Rapid evolution of brain size
  - Evolution of technology, The Great Leap Forward
- Social learning, tool use, and language
  - High-fidelity social learning required to sustain tool use
  - Drove the evolution of language?
  - Drove selection for social learning in general (reappropriated for language)?

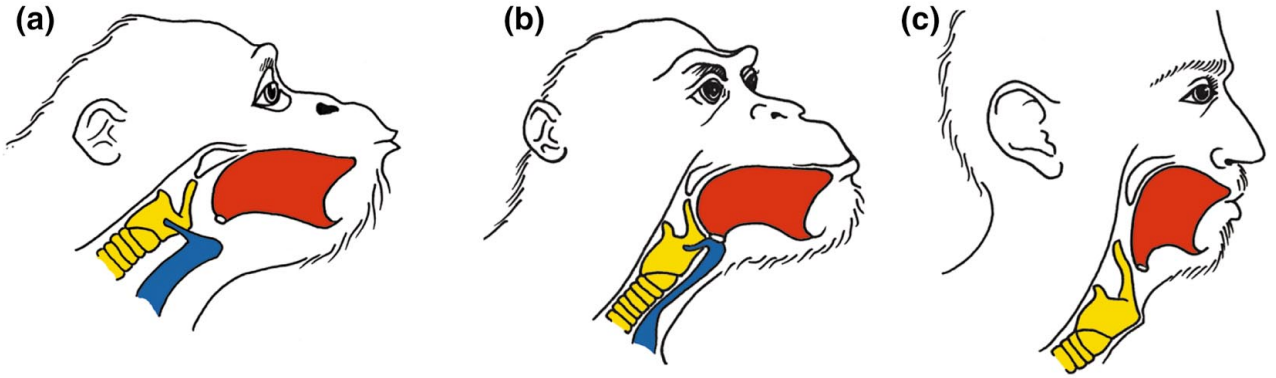
Evolution of speech: the vocal apparatus (Fitch chapter 8)

The human articulators at work

http://www.youtube.com/watch?v=0-aEN2xHBCc

The descended larynx and the two-chamber vocal tract

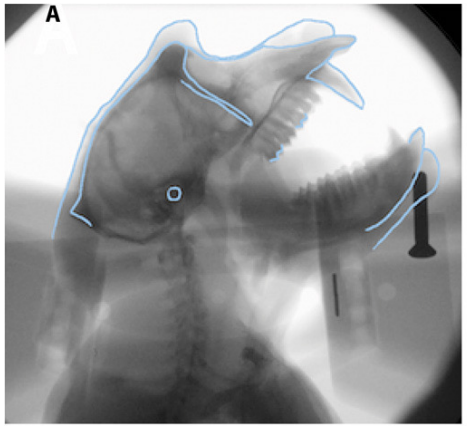


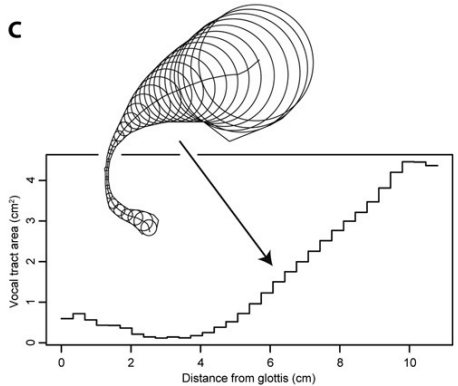


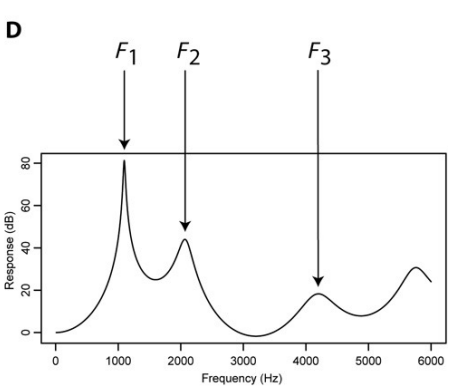
Fitch, W. T. (2000). The evolution of speech: a comparative review. *Trends in Cognitive Sciences, 4*, 258-267.

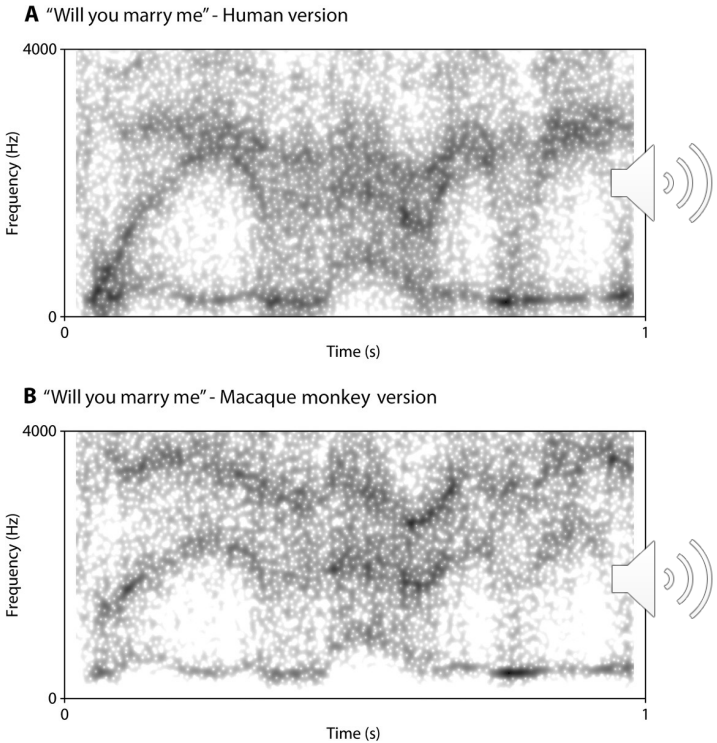
Fitch, W.T. and D. Reby, The descended larynx is not uniquely human. *Proceedings of the Royal Society B, 268,* 1669-1675

And a monkey vocal tract is probably good enough







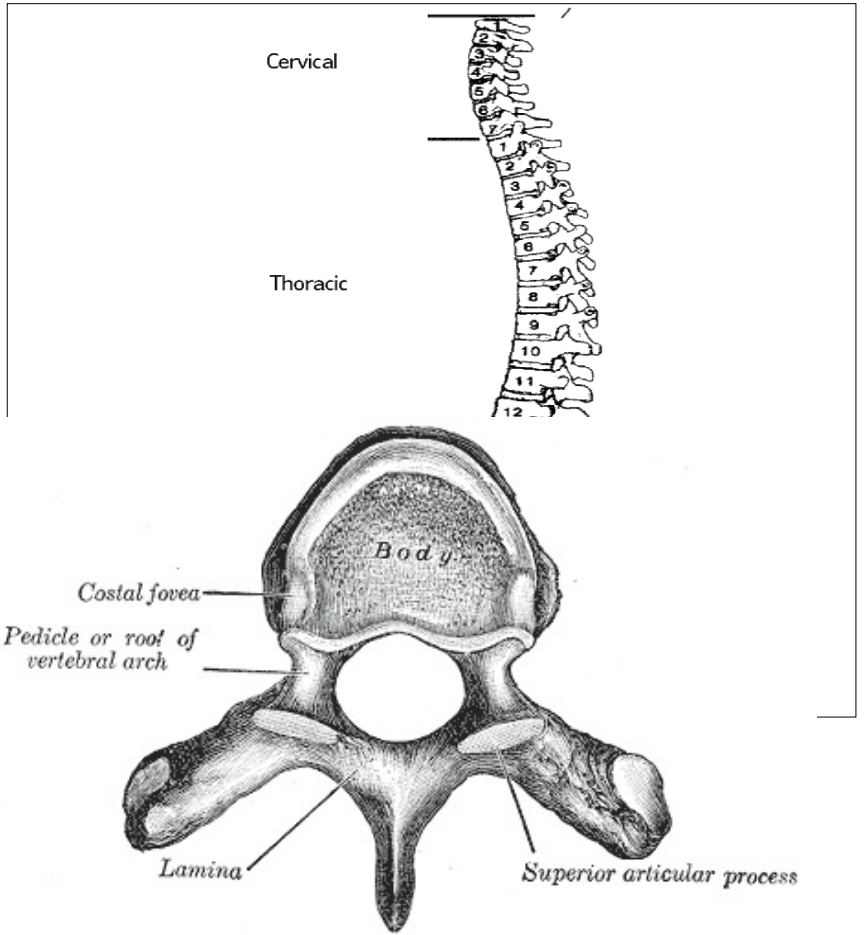


Fitch, W. T., De Boer, B., Mathur, N., & Ghazanfar, A. A. (2016). Monkey vocal tracts are speech-ready. *Science Advances, 2*, e1600723.

Breathing control

"[M]odern humans and Neanderthals have an expanded thoracic vertebral canal compared with australopithecines and *Homo ergaster,* who had canals of the same relative size as extant nonhuman primates. … [T]here was an increase in thoracic innervation during human evolution. Possible explanations for this increase include postural control for bipedalism, increased difficulty of parturition, respiration for endurance running, an aquatic phase, and choking avoidance. These can all be ruled out, either because of their evolutionary timing, or because they are insufficiently demanding neurologically. The remaining possible functional cause is increased control of breathing for speech."

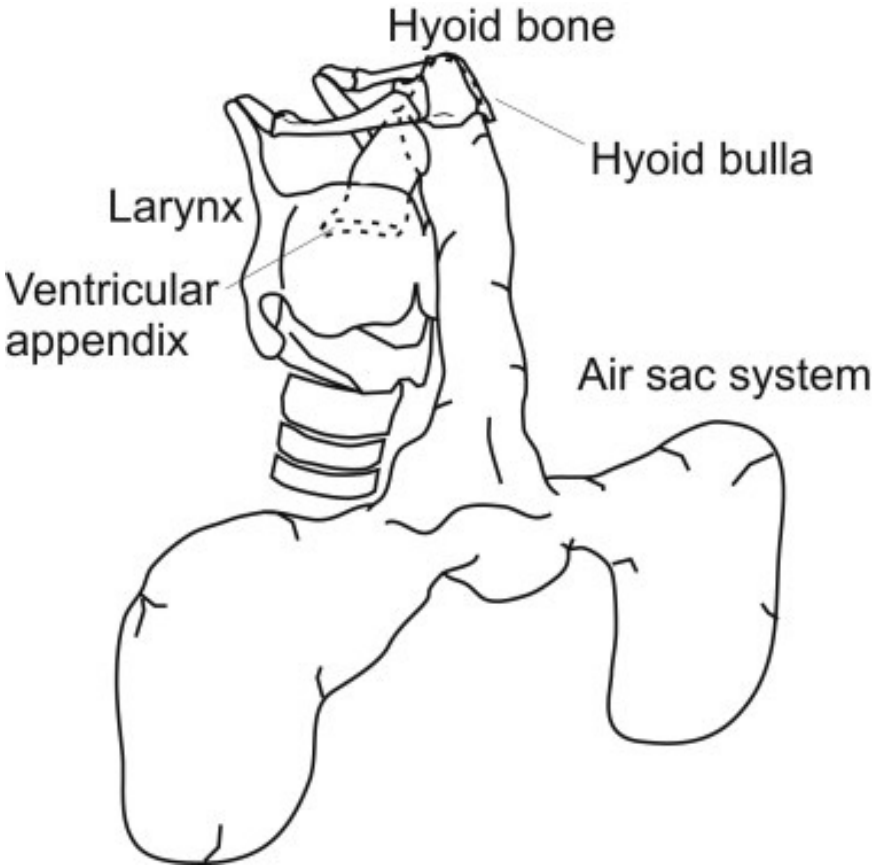
- Date: 1.6M to 100k years ago

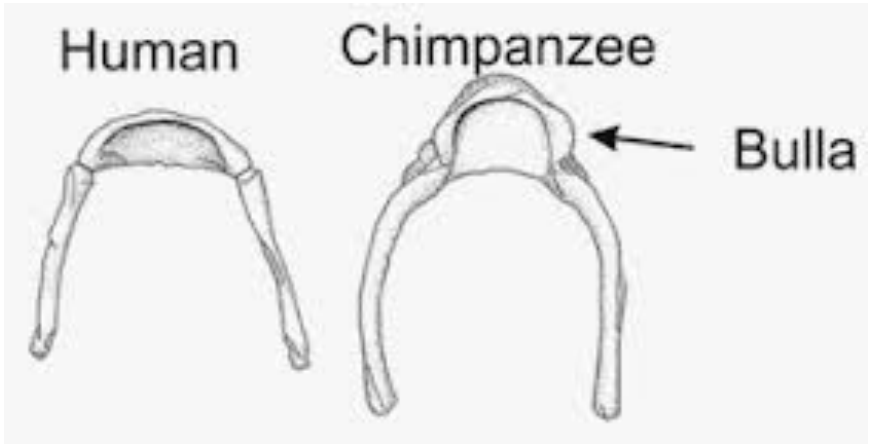


MacLarnon, A. & Hewitt, G. (1999). The evolution of human speech: the role of enhanced breathing control. *American Journal of Physical Anthropology*, *109,* 341–363.


Air sacs

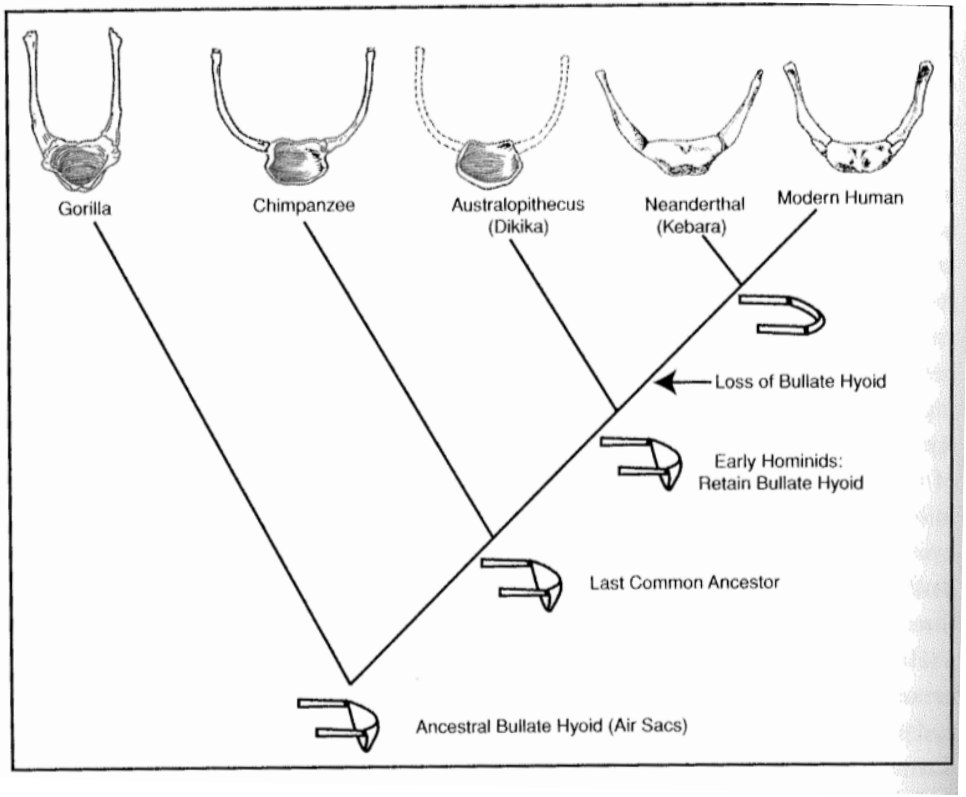
Air sacs



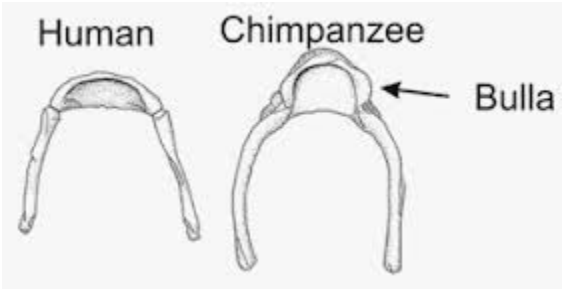


De Boer, B. (2012). Loss of air sacs improved hominin speech abilities. *Journal of Human Evolution*, *62,* 1–6.

Air sac evolution



Fitch 2010, p. 334



Cause of the loss of air sacs?

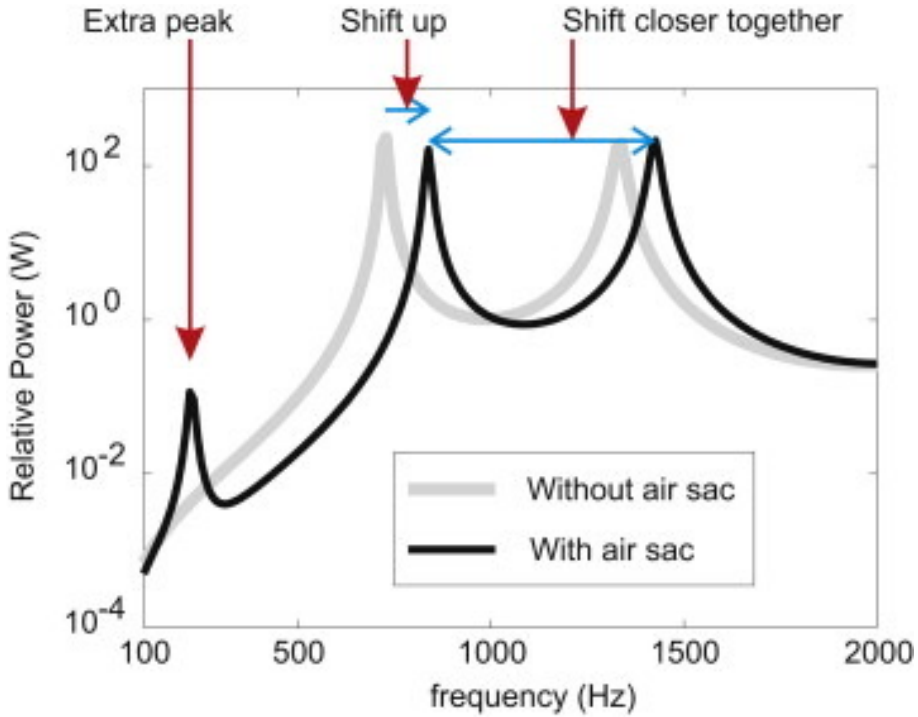
- Descended larynx as an alternative mechanism for size exageration?
- Pressure for reliable production of distinctive signals?

The acoustic effects of air sacs

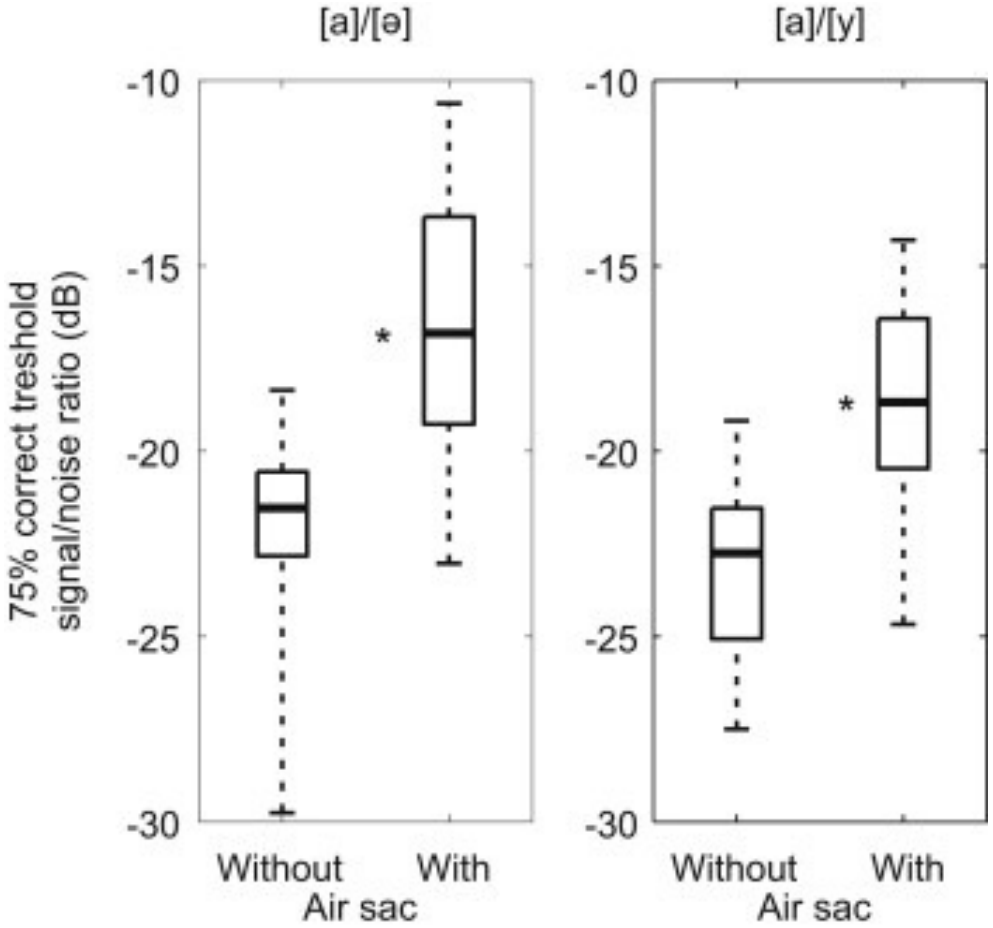
You sound bigger

Sound travels better in dense forests

But potential loss of distinctiveness?



De Boer, B. (2012). Loss of air sacs improved hominin speech abilities. *Journal of Human Evolution*, *62,* 1–6.



De Boer, B. (2012). Loss of air sacs improved hominin speech abilities. *Journal of Human Evolution*, *62,* 1–6.

Evolution of speech: vocal learning (Fitch chapter 9)

Complex vocal imitation

http://www.youtube.com/watch?v=0-aEN2xHBCc

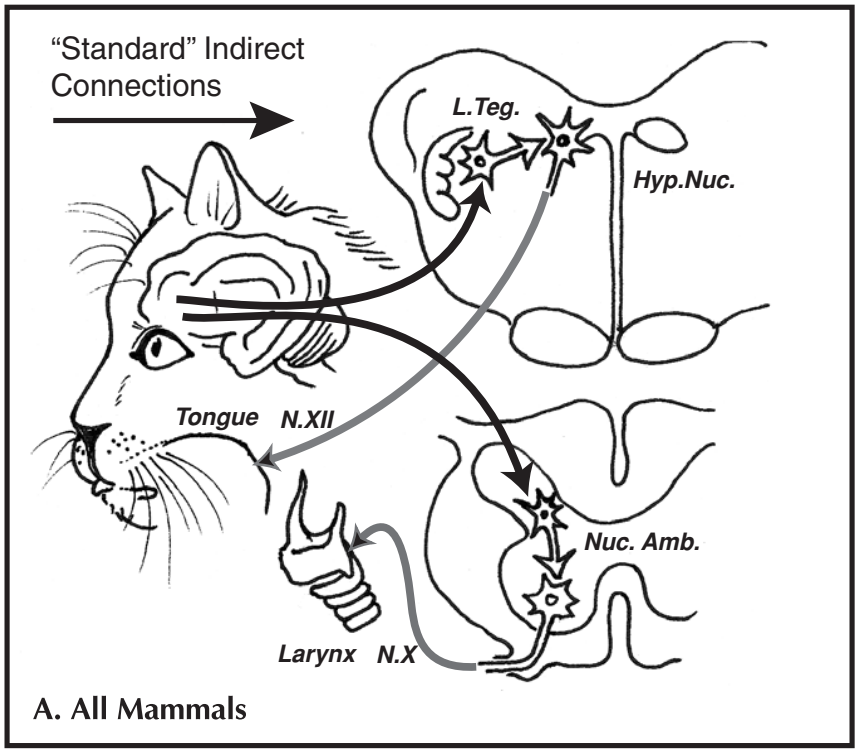
Complex vocal imitation in non-humans

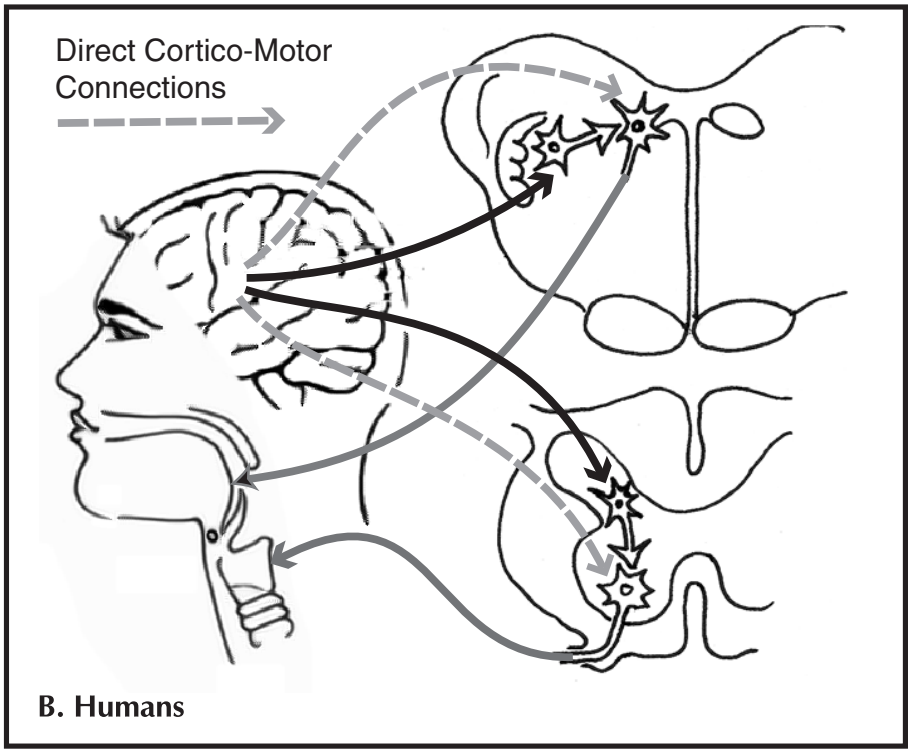
https://www.youtube.com/watch?v=VjE0Kdfos4Y

Ridgwaye, S., Carder, D., Jeffries, M., & Todd, M. (2012). Spontaneous human speech mimicry by a cetacean. *Current Biology, 22,* R860-R861.

Rawls, K, Fiorelli, P, & Gish, S. (1985). Vocalizations and vocal mimicry in captive harbor seals, *Phoca vitulina. Canadian Journal of Zoology, 63,* 1050-1056.

The neural basis of vocal learning in humans





FOXP2: a gene involved in speech and language

Phenotype: verbal dyspraxia, non-verbal deficits in fine motor control

Spotted from KE family pedigree

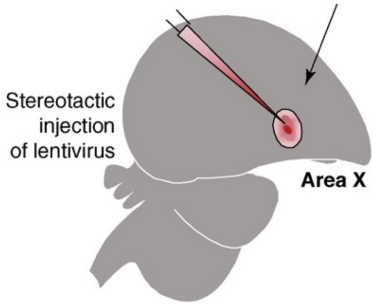
FOXP2 regulates expression of ≈ 400 other genes, some of which must be involved in language function

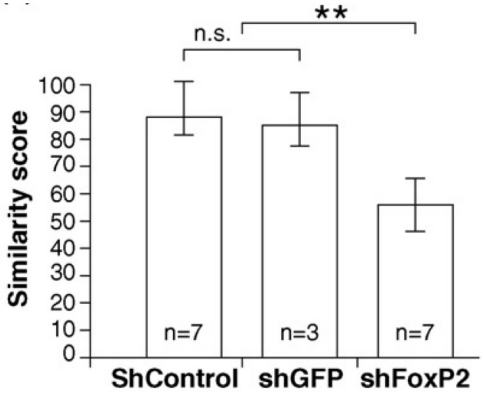
https://www.youtube.com/watch?v=Fg2rLOkoL9Q

Role of FOXP2 in other species

Heterozygote mice with KE-type mutated FOXP2 show delayed motor skill learning

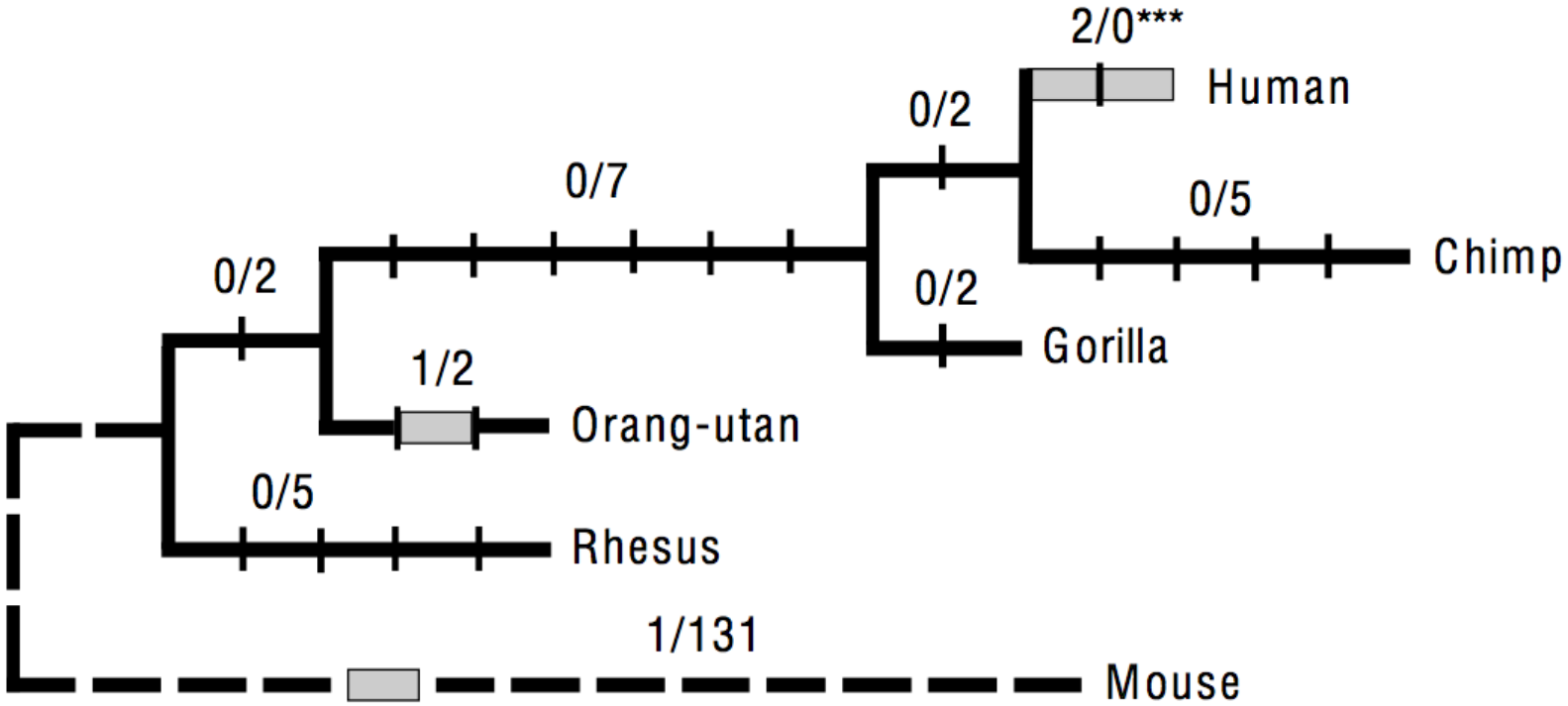
Zebra finches with selective knock-down of FOXP2 show impaired song learning





Fisher, S. E, & Scharff, C. (2009). FOXP2 as a molecular window into speech and language. *Trends in Genetics, 25,* 166-177.

Evolution of FOXP2



Enard, W., et al. (2002). Molecular evolution of FOXP2, a gene involved in speech and language. *Nature, 418*, 869-872.

Functions of vocal learning?

Complexity?

- Create elaborate repertoire: complexity as an end in itself

Index of group membership?

- *Password* hypothesis
- Dialects and accents, and early learning

Pair / group bonding?

- Duetting birds
- Functions of music?

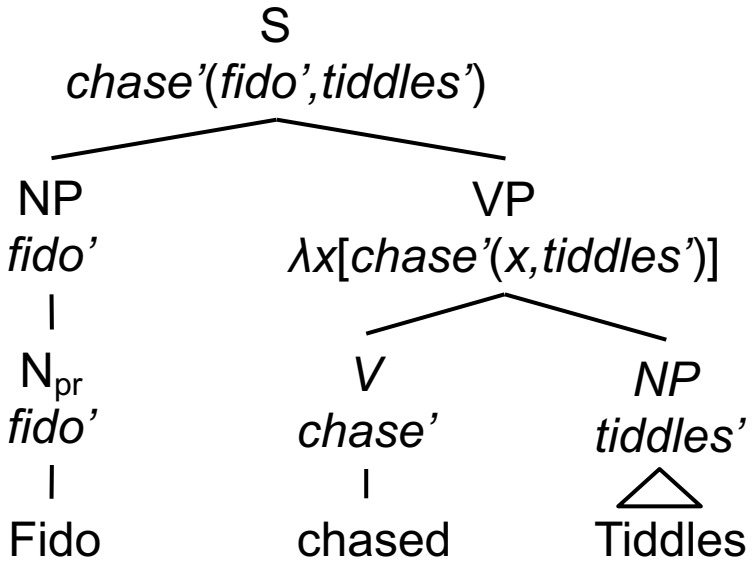
Fitch, W. T. (2000). The evolution of speech: a comparative review. *Trends in Cognitive Sciences, 4*, 258-267.

Grammar learning in non-humans

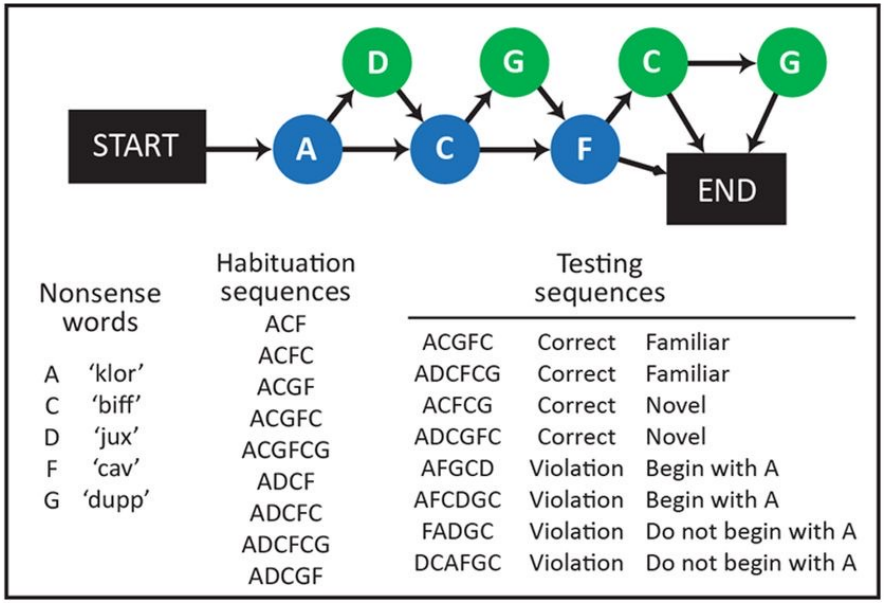
Reminder: Language's communicative power comes from its **structure**

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 $\lambda x\,[\lambda y\,[(chase'(x,y)]]$



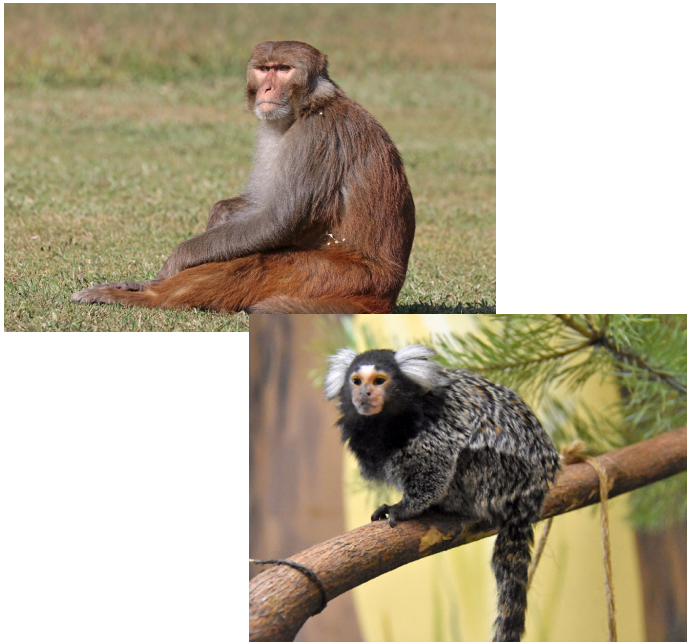
Artificial Grammar Learning in non-humans



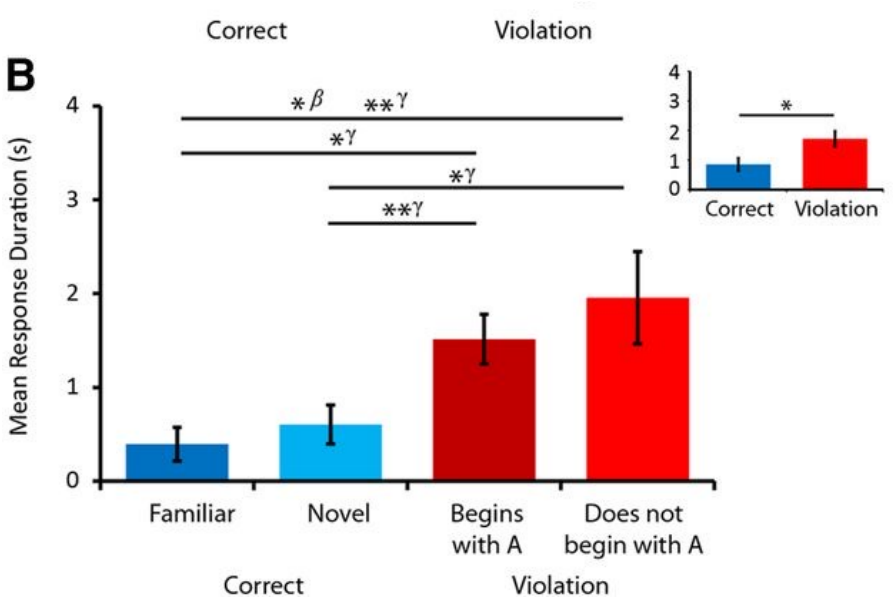
Nonsense words	
A	'klor'
C	'biff'
D	'jux'
F	'cav'
G	'dupp'

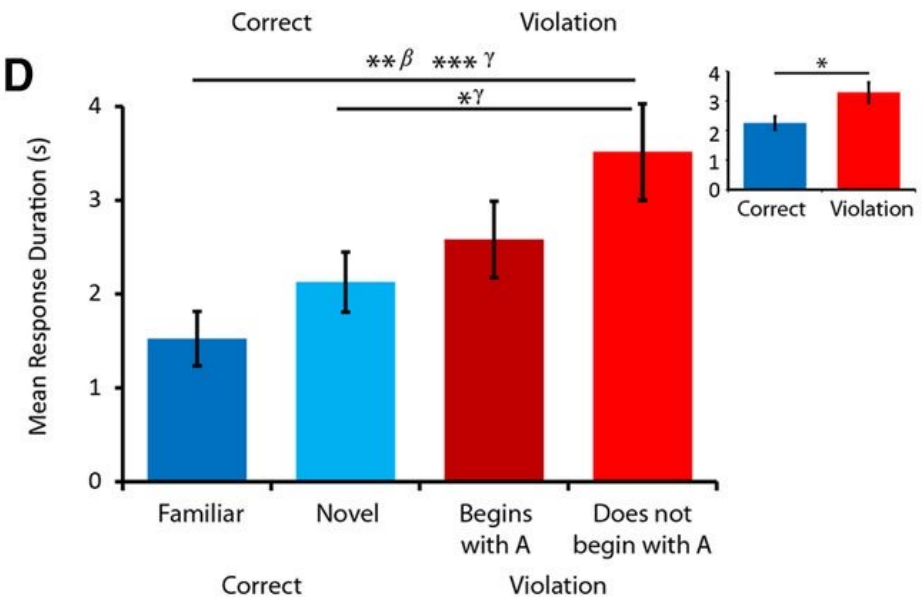
Habituation sequences
ACF
ACFC
ACGF
ACGFC
ACGFCG
ADCF
ADCFC
ADCFCG
ADCGF

Testing sequences		
ACGFC	Correct	Familiar
ADCFCG	Correct	Familiar
ACFCG	Correct	Novel
ADCGFC	Correct	Novel
AFGCD	Violation	Begin with A
AFCDGC	Violation	Begin with A
FADGC	Violation	Do not begin with A
DCAFGC	Violation	Do not begin with A



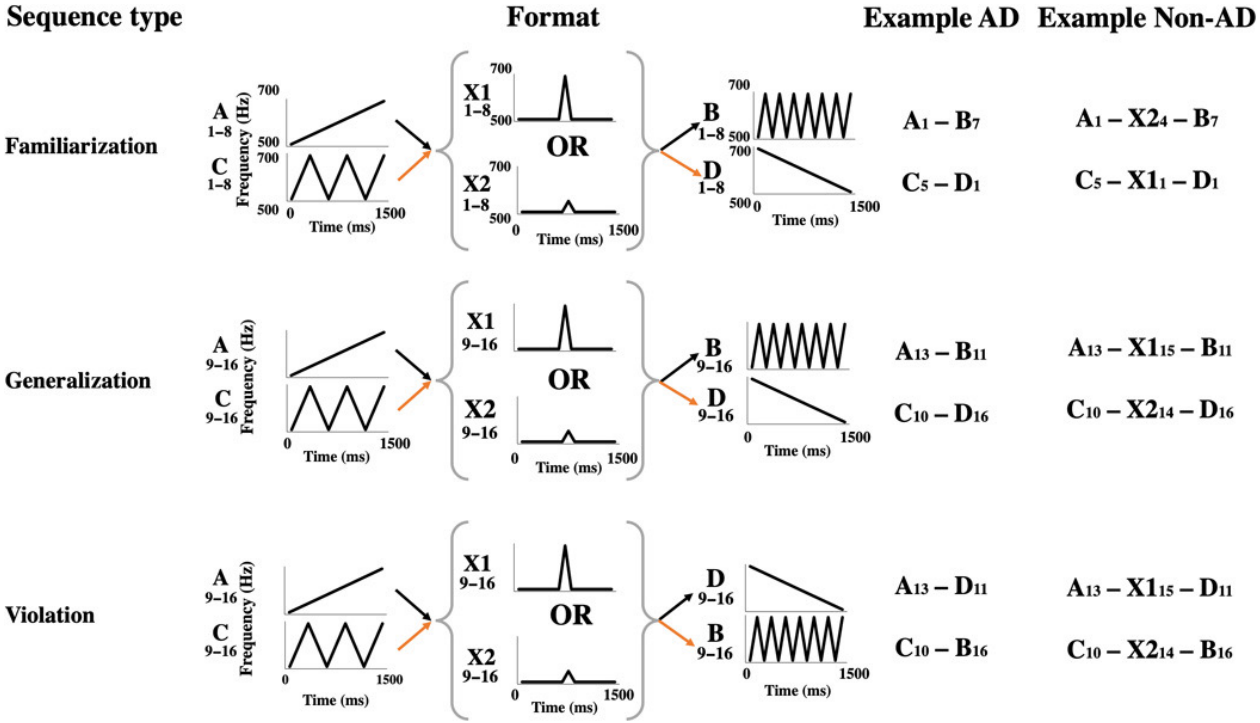
Wilson, B., Slater, H., Kikuchi, Y., Milne, A., Marslen-Wilson, W., Smith, K., & Petkov, C. (2013). Auditory artificial grammar learning in macaque and marmoset monkeys. *Journal of Neuroscience, 33,* 18825-18835.
For review see e.g. Petkov, C. I., & Ten Cate, C. (2020). Structured Sequence Learning: Animal Abilities, Cognitive Operations, and Language Evolution. *Topics in Cognitive Science, 12,* 828– 842.



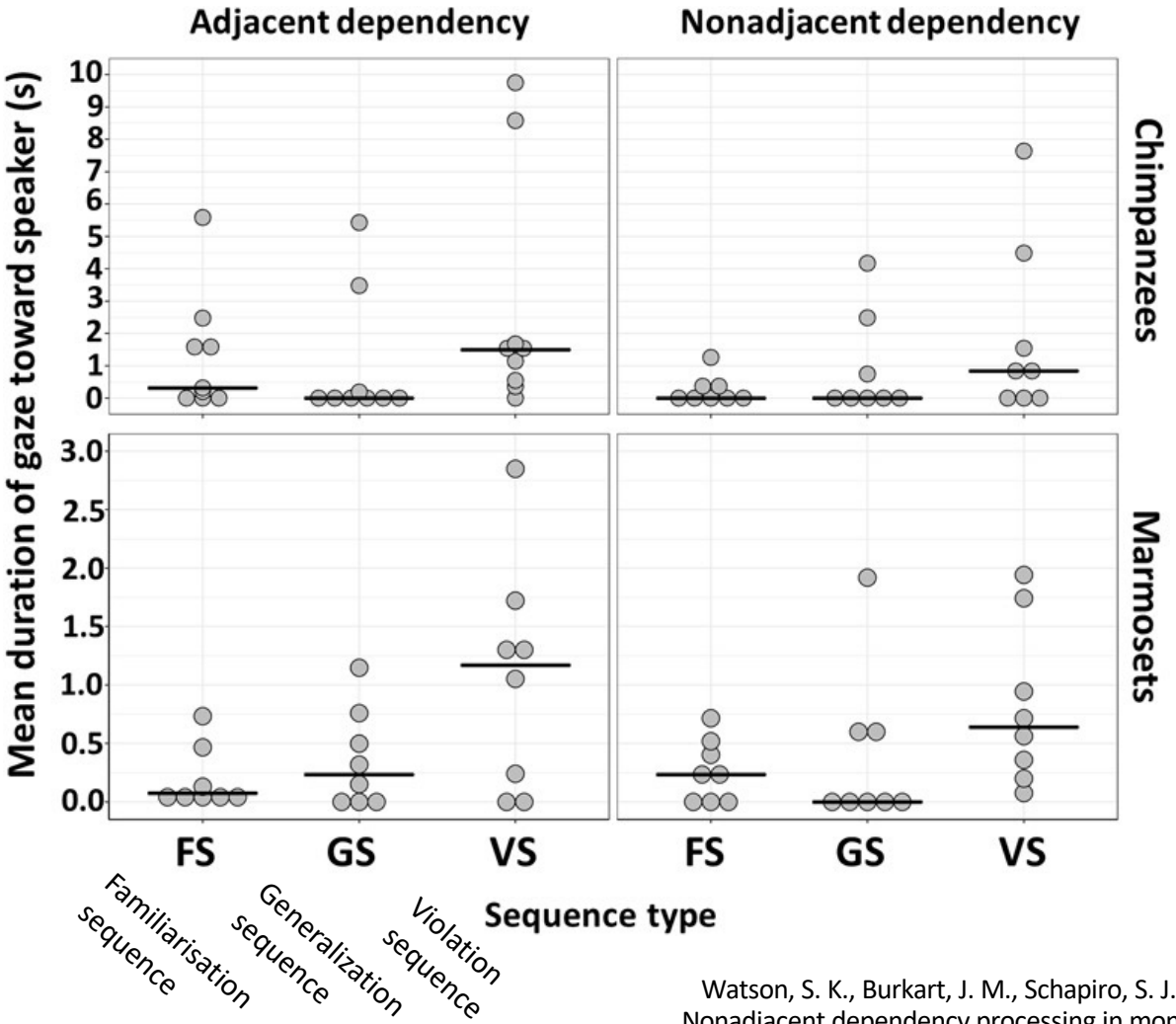


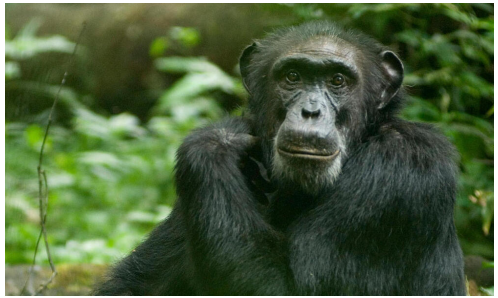
Wilson, B., Slater, H., Kikuchi, Y., Milne, A., Marslen-Wilson, W., Smith, K., & Petkov, C. (2013). Auditory artificial grammar learning in macaque and marmoset monkeys. *Journal of Neuroscience, 33,* 18825-18835.

Non-adjacent dependency learning



Watson, S. K., Burkart, J. M., Schapiro, S. J., Lambeth, S. P., Mueller, J. L., & Townsend, S. W. (2020). Nonadjacent dependency processing in monkeys, apes, and humans. *Science Advances, 6,* eabb0725.





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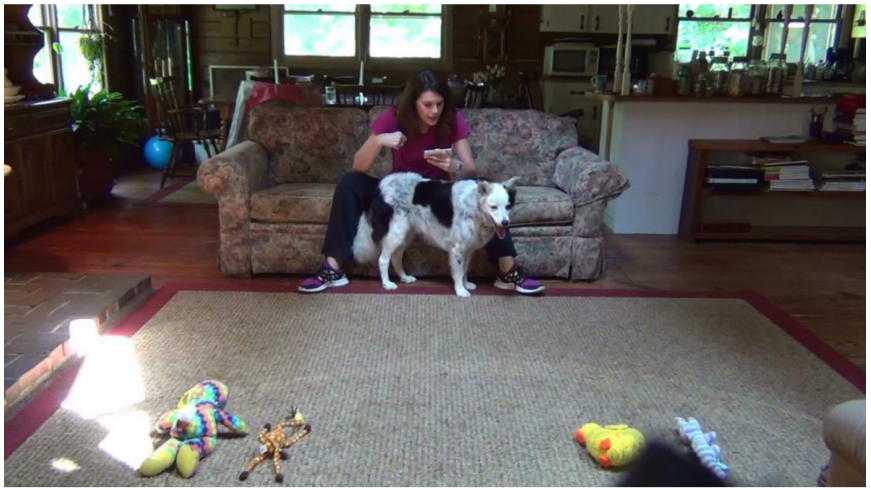
How about learning of **meaningful** sequences?

“ball fetch”
“stick point”

Ramos, D., & Ades, C. (2012). Two-item sentence comprehension by a dog (Canis familiaris). *PLoS ONE, 7,* e29689.



“to sugar take decoy”
“to decoy take sugar”

Pilley, J. W. (2013). Border collie comprehends sentences containing a prepositional object, verb, and direct object. *Learning and Motivation, 44,* 229-240.

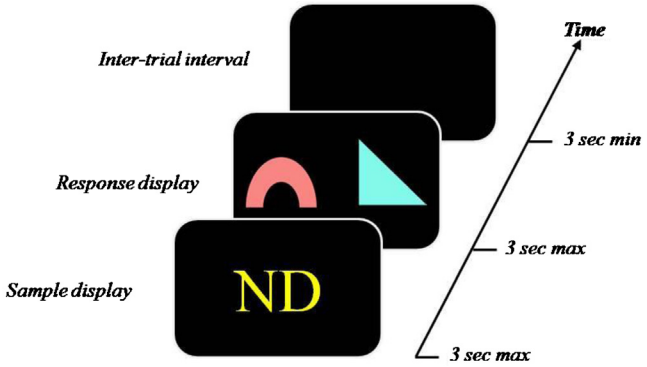
Savage-Rumbaugh, E. S., Murphy, J., Sevcik, R., Brakke, K., Williams, S., Rumbaugh, D., & Bates, E. (1993). Language comprehension in ape and child. *Monographs of the Society for Research in Child Development, 58*, 1–252.

Perhaps a deficit for **hierarchy**?

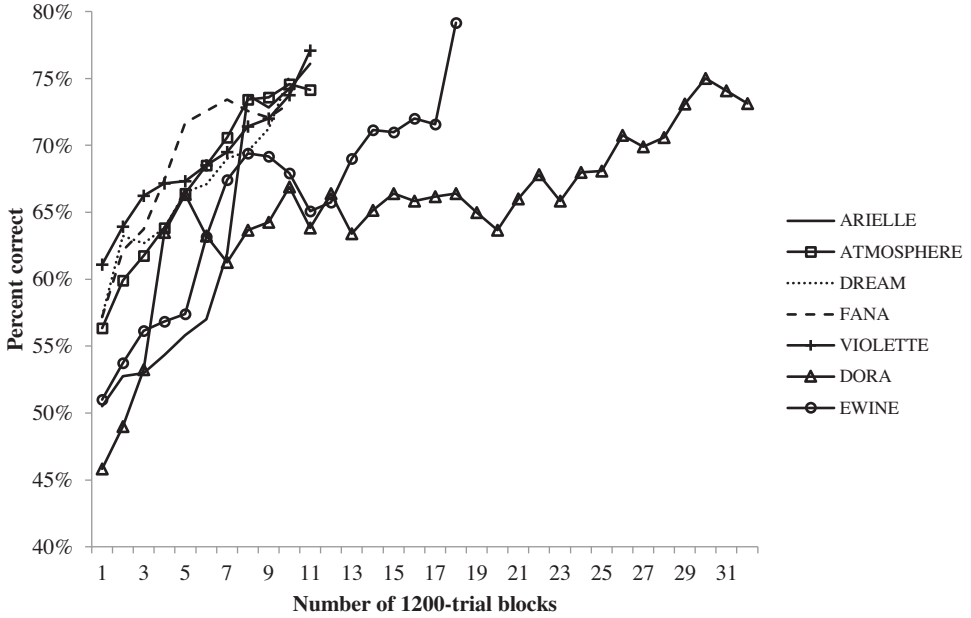
- Could just be ‘semantic soup’ plus smart interpretation?
  - *Cut the onions with your knife*
  - *Put the pine needles in the refrigerator*
- But he can handle reversible events (cf. also Chaser)
  - *Put the tomato in the oil*
  - *Put some oil in the tomato* [Kanzi pours oil in a bowl with the tomato]
- But no strong evidence for **hierarchy**
  - *Give the water and the doggie to Rose*. [Gives dog only]
  - *Give the lighter and the shoe to Rose*. [Gives lighter only]
  - *Give me the milk and the lighter* [Responds correctly]

Truswell, R. (2017). Dendrophobia in bonobo comprehension of spoken English. *Mind and Language, 32,* 395-415.

Puzzling failures in (most) baboons



6 letters (3 for shapes, 3 for colours)
3 shapes, 3 colours



Medam, T., & Fagot, J. (2016). Behavioral assessment of combinatorial semantics in baboons (Papio papio). Behavior Processes, 123, 54-62.

Summary on grammar learning

Artificial Grammar Learning suggests abilities to learn sequence constraints are present in other animals (including other primates)

- Grammars tested to date are quite simple
- Interpretation can be contentious

Language-trained animals can interpret complex expressions

- But larger-N lab studies surprisingly scarce, and these tasks seem to be hard

Humans are not unique in our ability to process meaningful sequences

- **But we may be uniquely proficient**

Next up

- Debate tutorial (Friday groups only)
  - Spoken or gestural origins?
- Essay 1 (2nd March)
- Next lecture (6th March): the evolution of social cognition
  - Sharing, theory of mind, intentionality