

Origins and Evolution of Language

Week 5: vocal learning and grammar learning

Kenny Smith

kenny.smith@ed.ac.uk

Questions from the pre-reading quiz

“Theoretically, if our technology and knowledge advance to the level which allows us to clone, or rather grow an individual from the genetic material found in the bones of extinct Homo species and earlier Homo sapiens, it might be possible to research their brain functions including linguistic capabilities. Since it would raise a lot of ethical questions, do you think it would be possible instead to recreate virtual versions of some of our ancestors and other Hominins from the genetic data and would it help us learn more about the brain?”

Are there any studies that focus on sequencing ancient genomes and comparing them to those of modern humans to find if there are specific genes that are responsible for speech potential, language comprehension, etc. that were present in early hominins?”

RESEARCH ARTICLE



Reintroduction of the archaic variant of *NOVA1* in cortical organoids alters neurodevelopment

CLEBER A. TRUJILLO , EDWARD S. RICE , NATHAN K. SCHAEFER , ISAAC A. CHAIM , [...], AND ALYSSON R. MUOTRI 

+22 authors

[Authors Info](#)

[& Affiliations](#)

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 \approx
400 other genes, some of which
must be involved in language
function



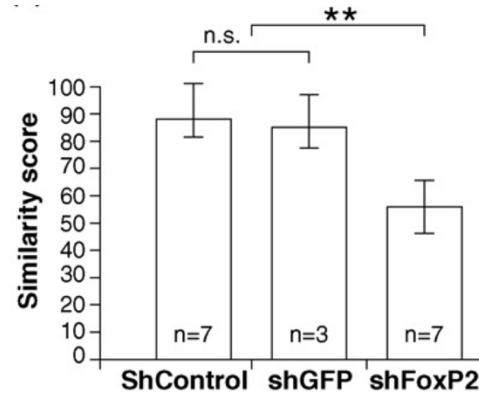
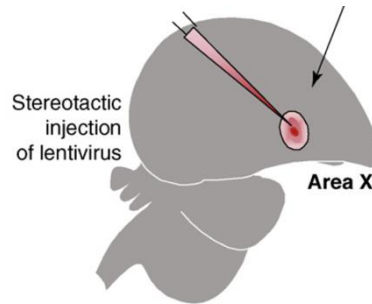
<https://www.youtube.com/watch?v=Fg2rLOkoL9Q>

Role of FOXP2 in other species

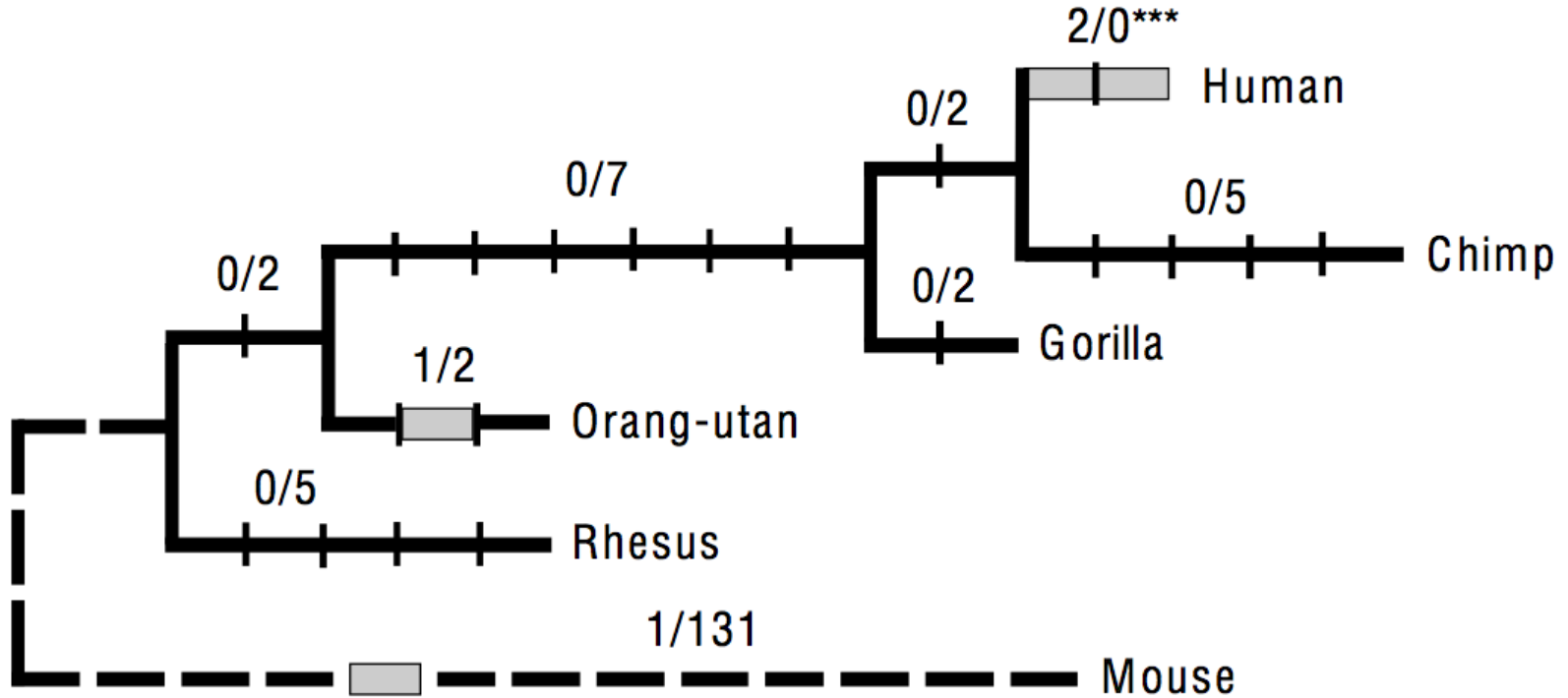
Heterozygote mice with KE-type mutated FOXP2 show delayed motor skill learning



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



Evolution of FOXP2



“In conclusion, the current results show that the Neandertals carried a FOXP2 protein that was identical to that of present-day humans in the only two positions that differ between human and chimpanzee. ...”

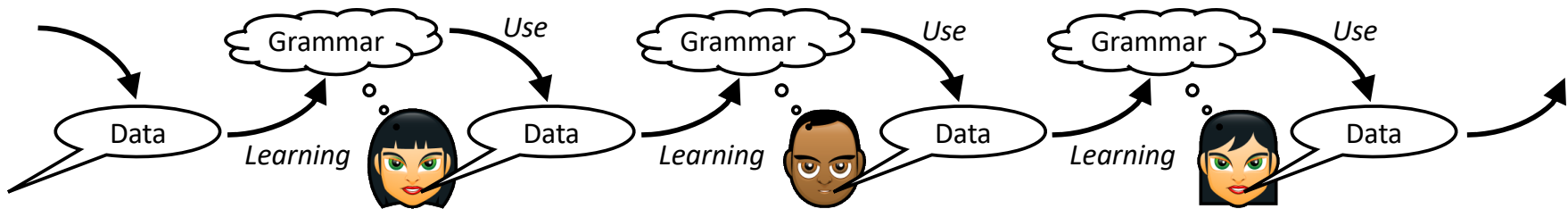
“... this establishes that these changes were present in the common ancestor of modern humans and Neandertals. The date of the emergence of these genetic changes therefore must be older than that estimated with only extant human diversity data, thus demonstrating the utility of direct evidence from Neandertal DNA sequences for understanding recent modern human evolution. ...”

Krause, J., et al. (2007). The Derived FOXP2 Variant of Modern Humans Was Shared with Neandertals. *Current Biology*, 17, 1908-1912

“... Whatever function the two amino acid substitutions might have for human language ability, it was present not only in modern humans but also in late Neandertals. Ongoing in vivo and in vitro experiments should help to delineate these functions.” (Krause et al., 2007, p.1911)

Plan for today

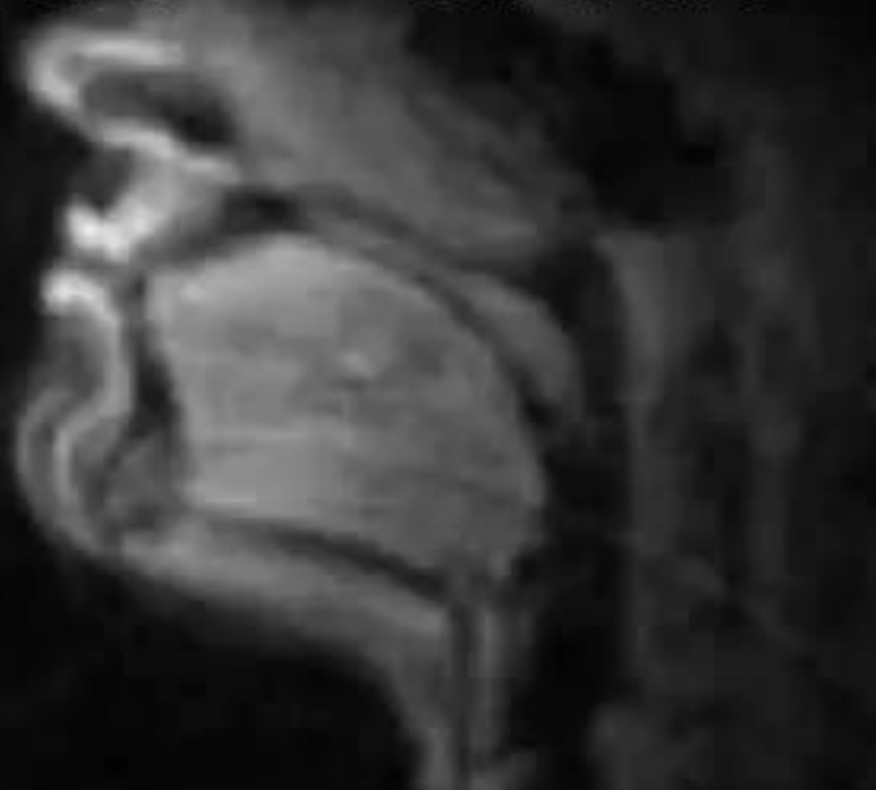
- A quick look at the vocal apparatus for speech
 - Descended larynx, thoracic vertebral canal, air sacs
- Comparative psychology of language learning
 - Complex vocal imitation
 - Grammar learning
 - Are humans special in our language learning abilities?



Evolution of speech: the vocal apparatus

USC

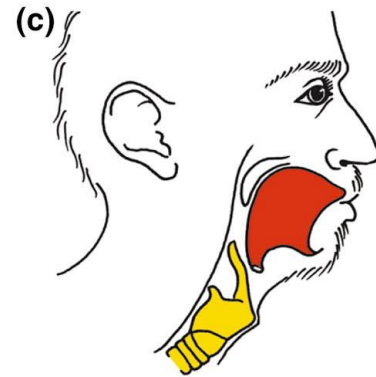
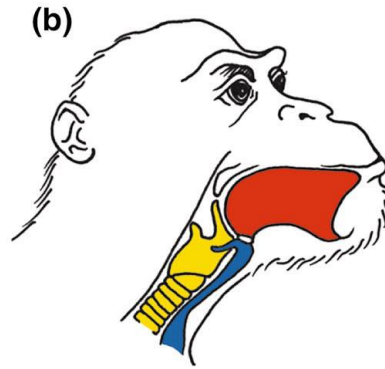
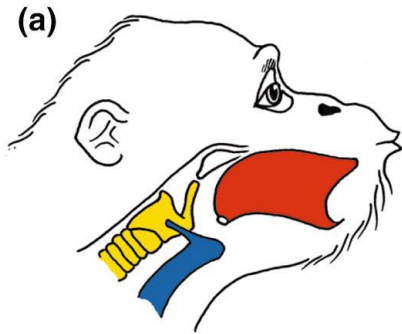
SPAN



The human articulators at work

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

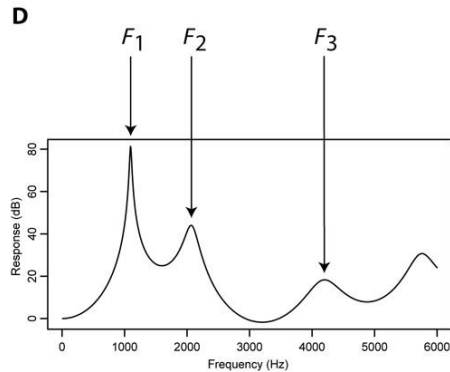
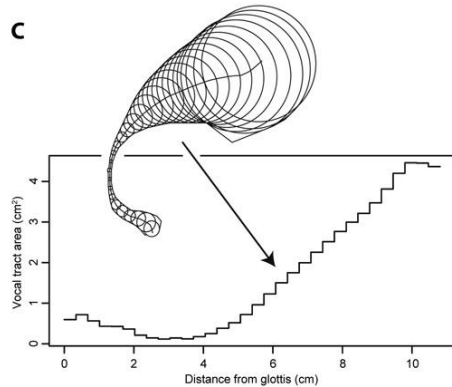
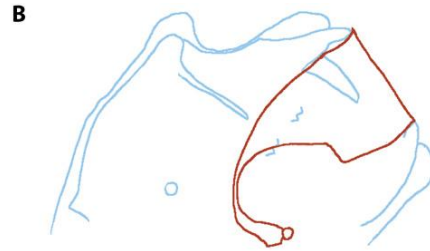
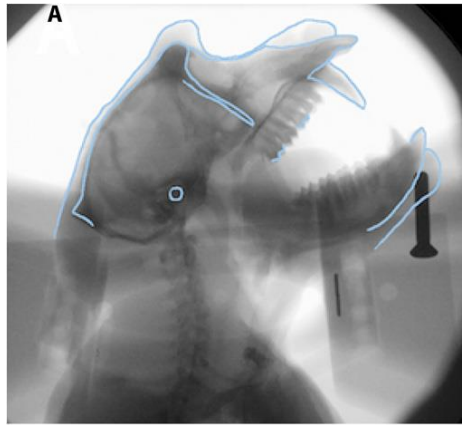
The descended larynx and the two-chamber vocal tract



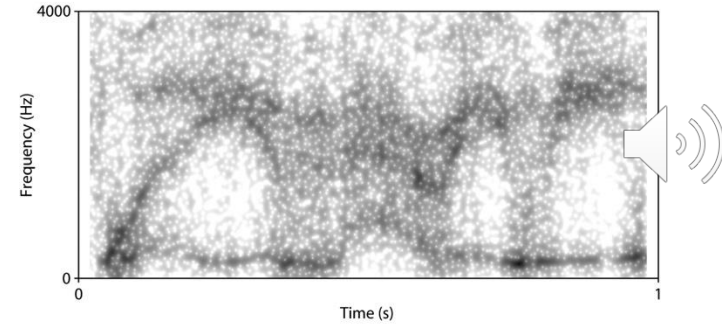


Fitch, W.T. and D. Reby, The descended larynx is not uniquely human.
Proceedings of the Royal Society B, 268, 1669-1675

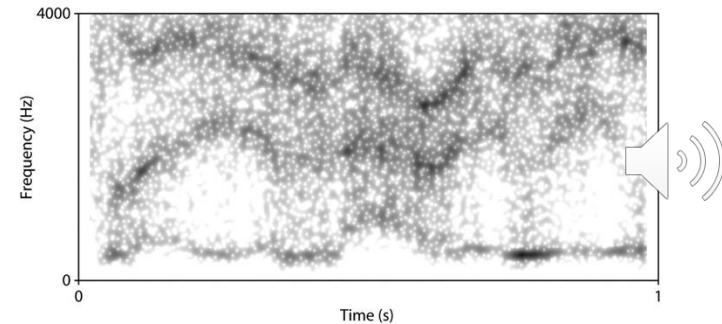
And a monkey vocal tract is probably good enough



A "Will you marry me" - Human version



B "Will you marry me" - Macaque monkey version

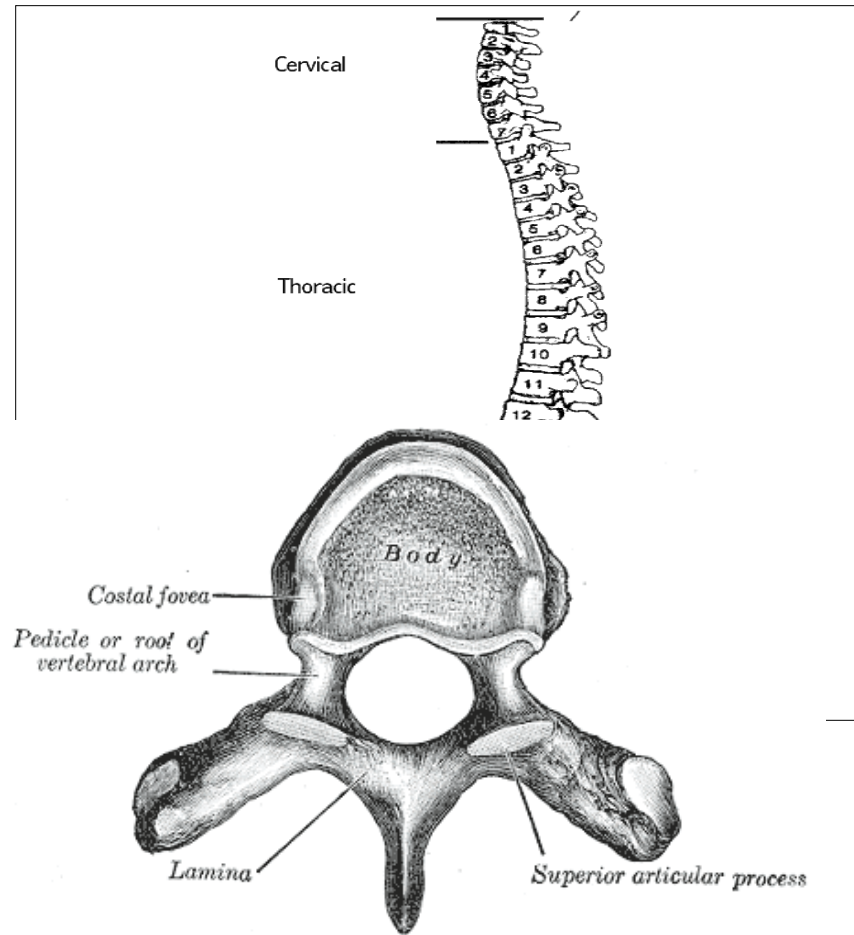


Fitch, W. T., De Boer, B., Mathur, N., & Ghazanfar, A. A. (2016).
Monkey vocal tracts are speech-ready. *Science Advances*, 2, e1600723.

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.”

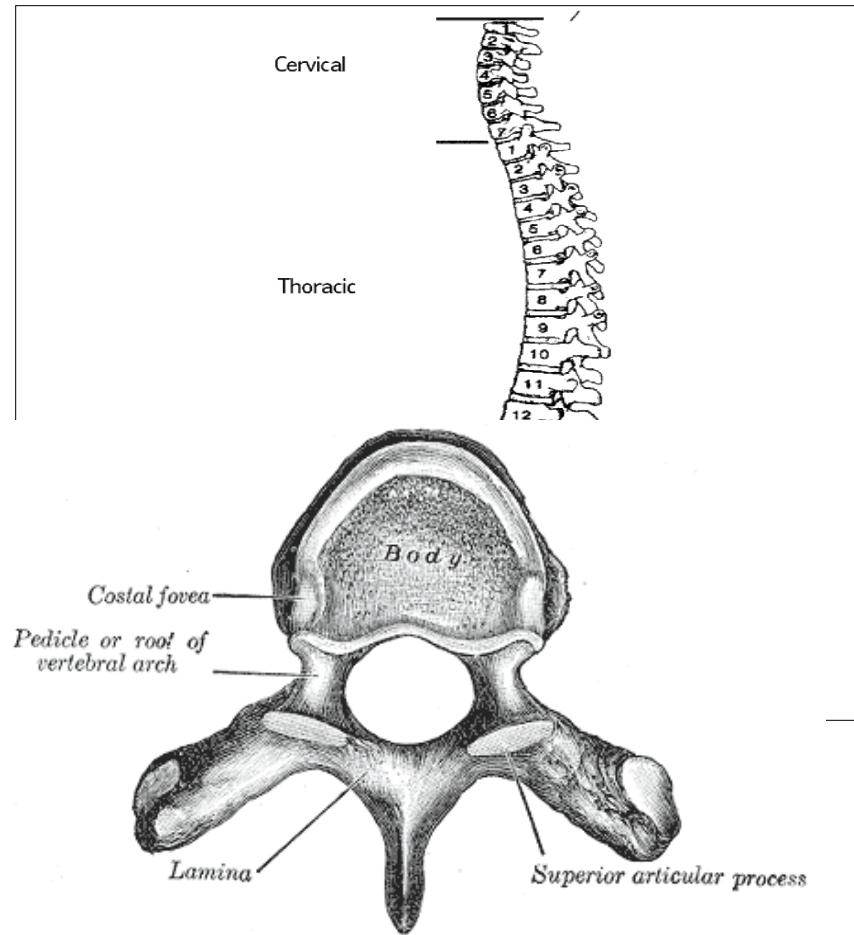
- Date: 1.6M to 100k years ago



Breathing control

“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

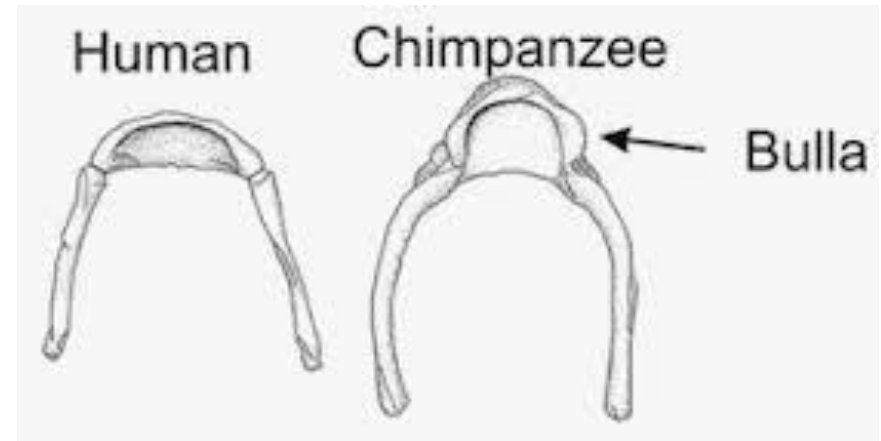
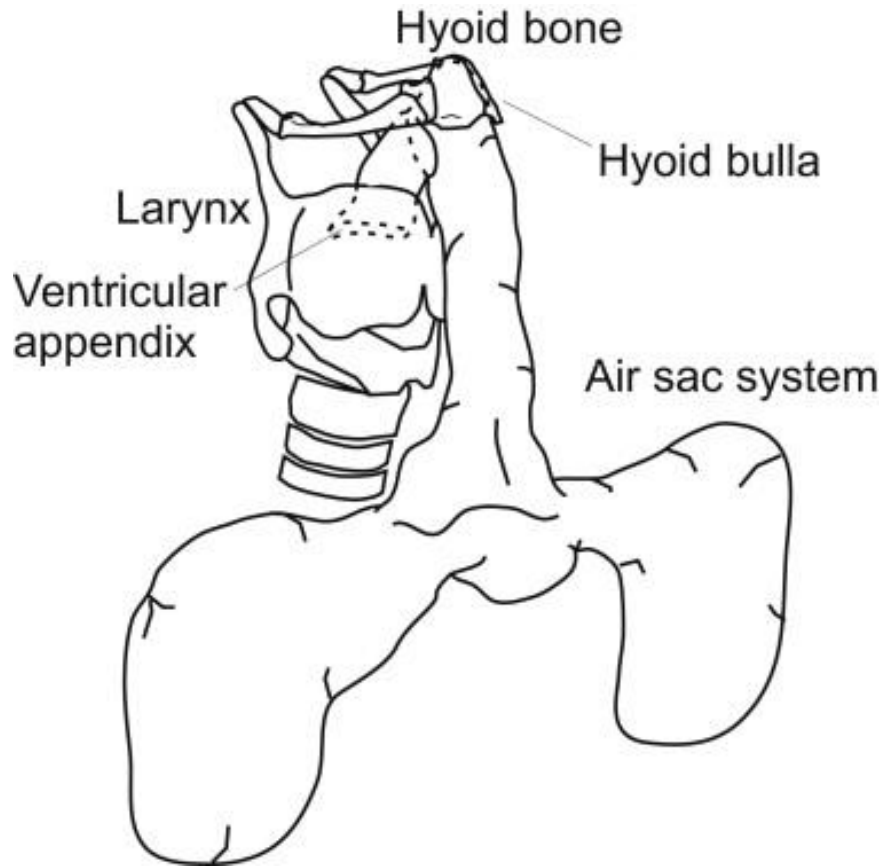


MacLarnon, A. & Hewitt, G. (1999). The evolution of human speech: the role of enhanced breathing control. *American Journal of Physical Anthropology*, 109, 341–363.

Air sacs

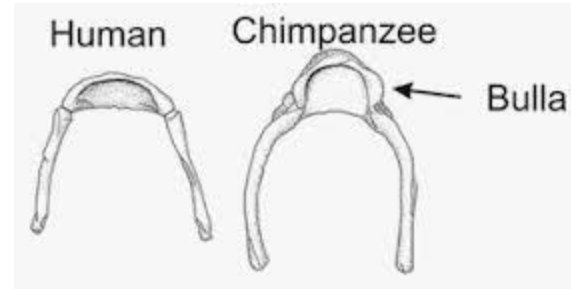
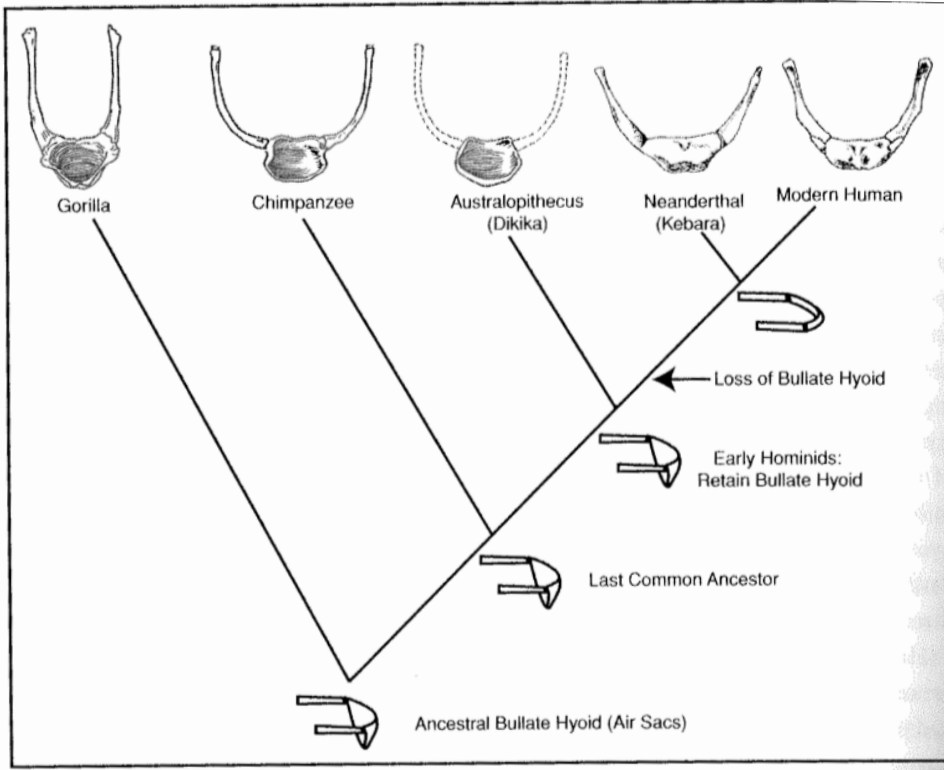


Air sacs



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

Air sac evolution



Date: 3.3M to 500k years ago

Cause of the loss of air sacs?

- Descended larynx as an alternative mechanism for size exaggeration?
- Pressure for reliable production of distinctive signals? See De Boer, B. (2012). Loss of air sacs improved hominin speech abilities. *Journal of Human Evolution*, 62, 1–6.

Complex vocal imitation

USC

SPAN



Complex vocal imitation

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

Complex vocal imitation in non-humans



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

Ridgway, 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.



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?

Grammar learning

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

$S \rightarrow NP VP \quad VP'(NP')$

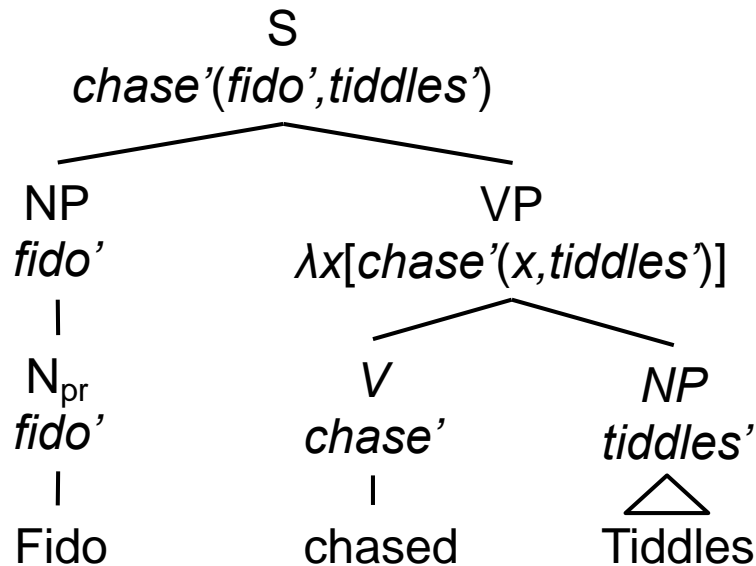
$NP \rightarrow N_{pr} \quad N'_{pr}$

$N_{pr} \rightarrow Fido \quad fido'$

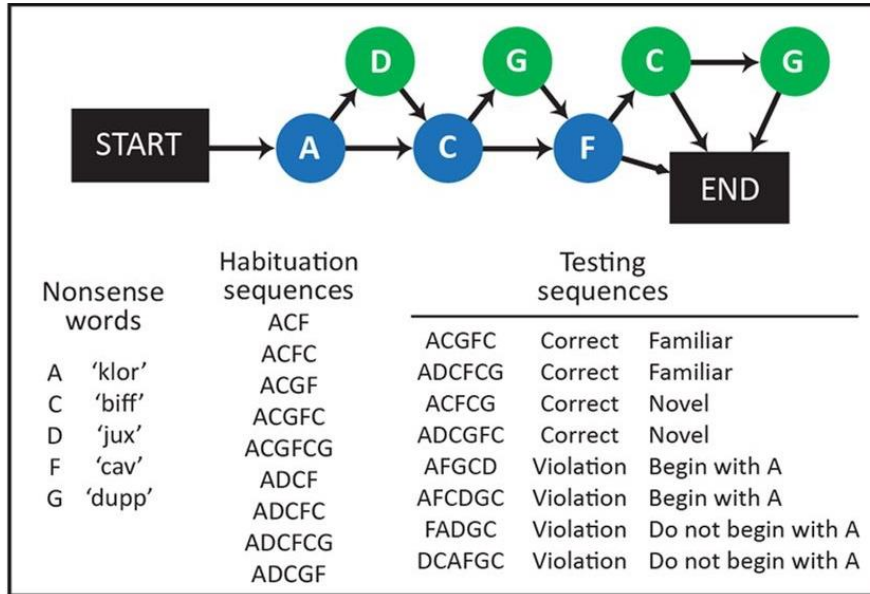
$N_{pr} \rightarrow Tiddles \quad tiddles'$

$VP \rightarrow V NP \quad V'(NP')$

$V \rightarrow chased \quad \lambda x [\lambda y [(chase'(x,y))]]$

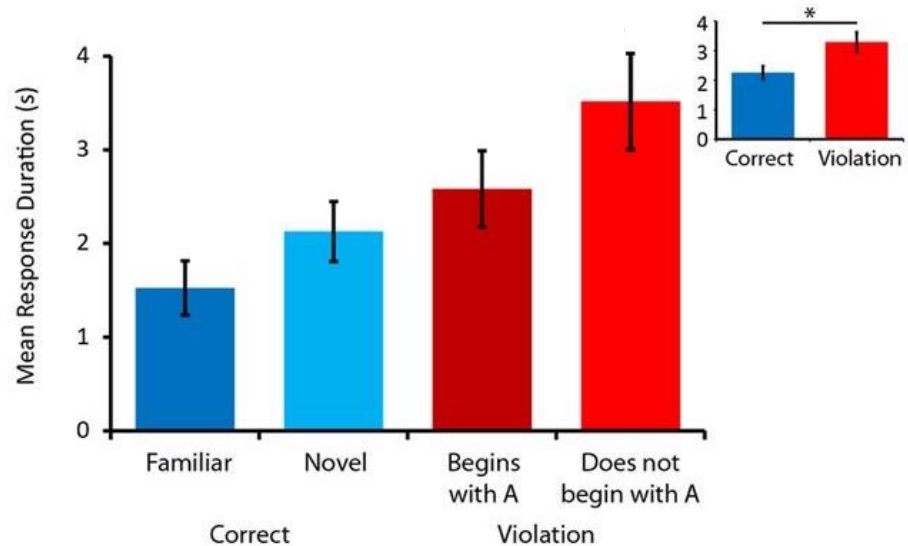
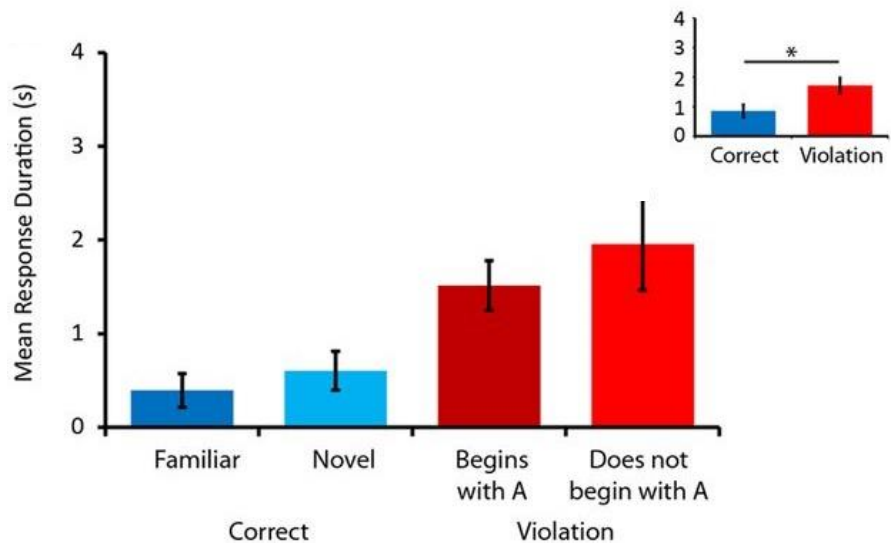


Artificial Grammar Learning in non-humans



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.

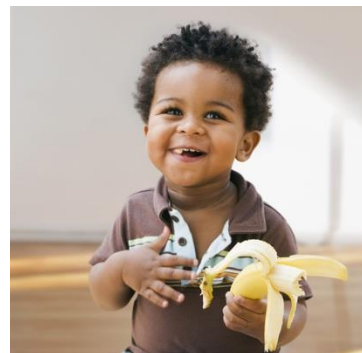


Wilson, B., Slater, H., Kikuchi, Y., Milne, A., Marslen-Wilson, W., Smith, K., & Petkov, C. (2013). Auditory artificial grammar learning in macaque and marmoset monkeys. *Journal of Neuroscience*, 33, 18825-18835.

Non-adjacent dependency learning

Training

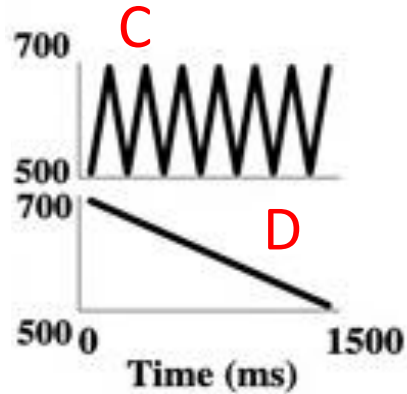
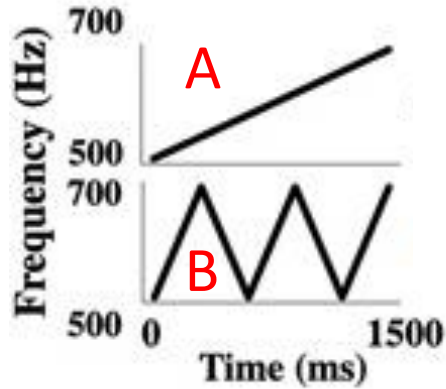
pel wadim rud... vot kicey jic... pel feenam rud...
vot wadim jic... vot puser jic... pel puser rud...
vot kicey jic... vot skiger jic... pel kicey rud ...



Test

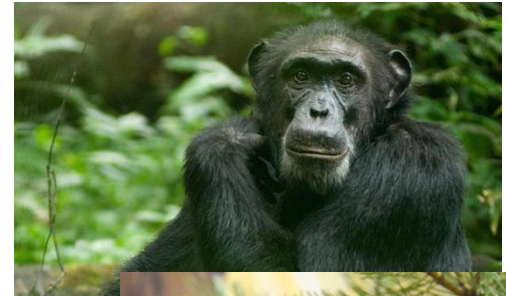
pel wadim rud
pel wadim jic?
vot wadim jic
vot wadim rud?

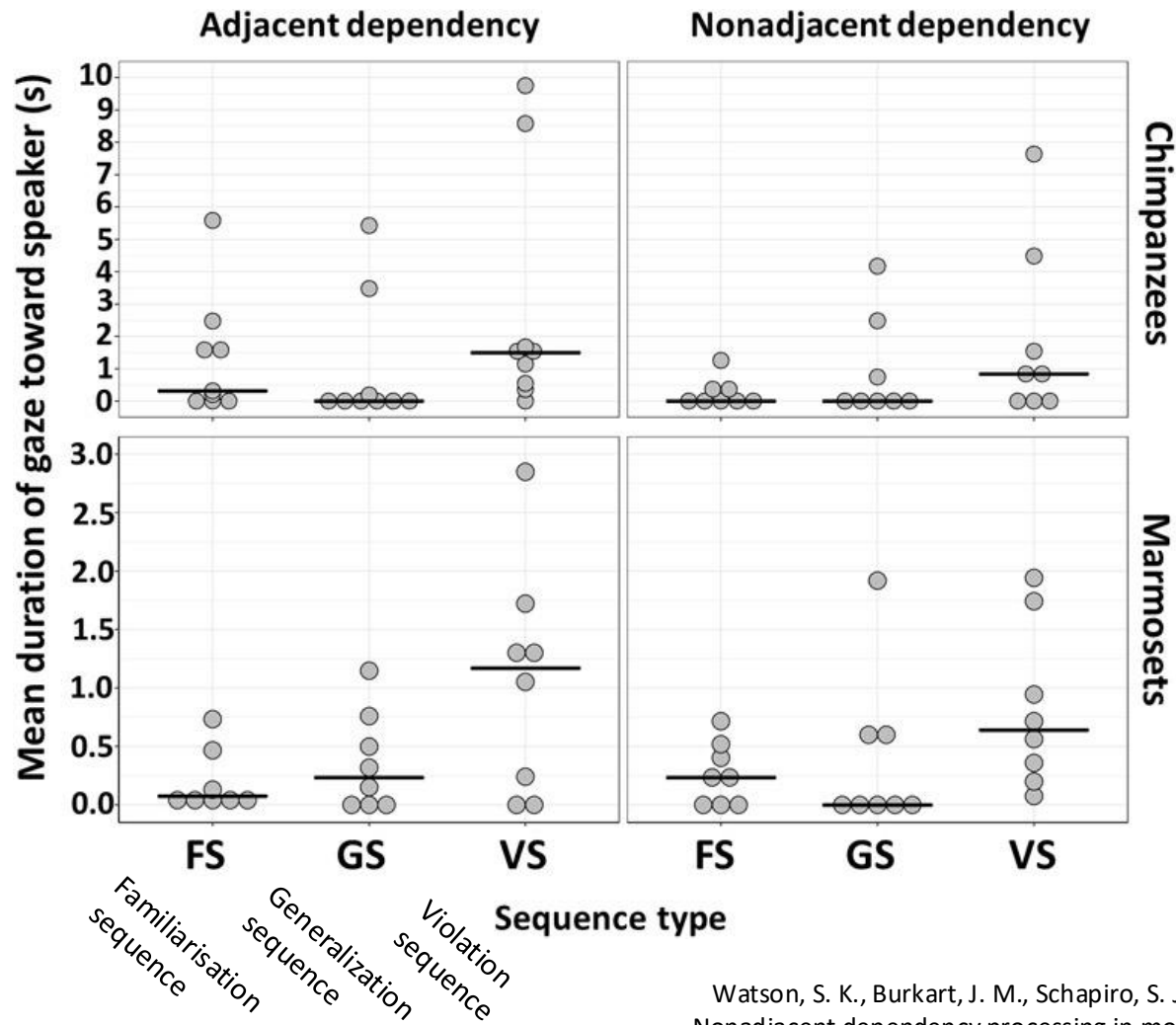
Non-adjacent dependency learning



Non-adjacent dependency learning

Sequence type	Example AD	Example Non-AD
Familiarization	$A_1 - B_7$	$A_1 - X_{24} - B_7$
	$C_5 - D_1$	$C_5 - X_{11} - D_1$
Generalization	$A_{13} - B_{11}$	$A_{13} - X_{115} - B_{11}$
	$C_{10} - D_{16}$	$C_{10} - X_{214} - D_{16}$
Violation	$A_{13} - D_{11}$	$A_{13} - X_{115} - D_{11}$
	$C_{10} - B_{16}$	$C_{10} - X_{214} - B_{16}$





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.

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.



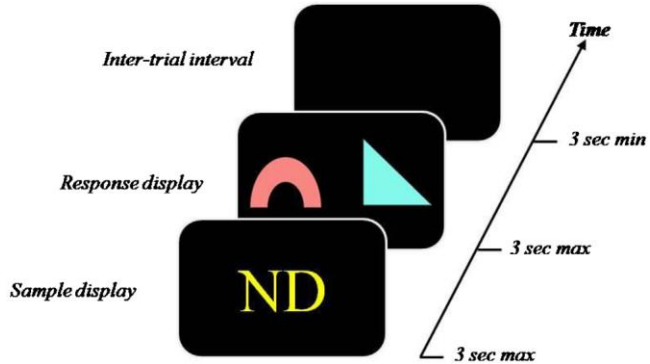
“to sugar take decoy”
“to decoy take sugar”

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

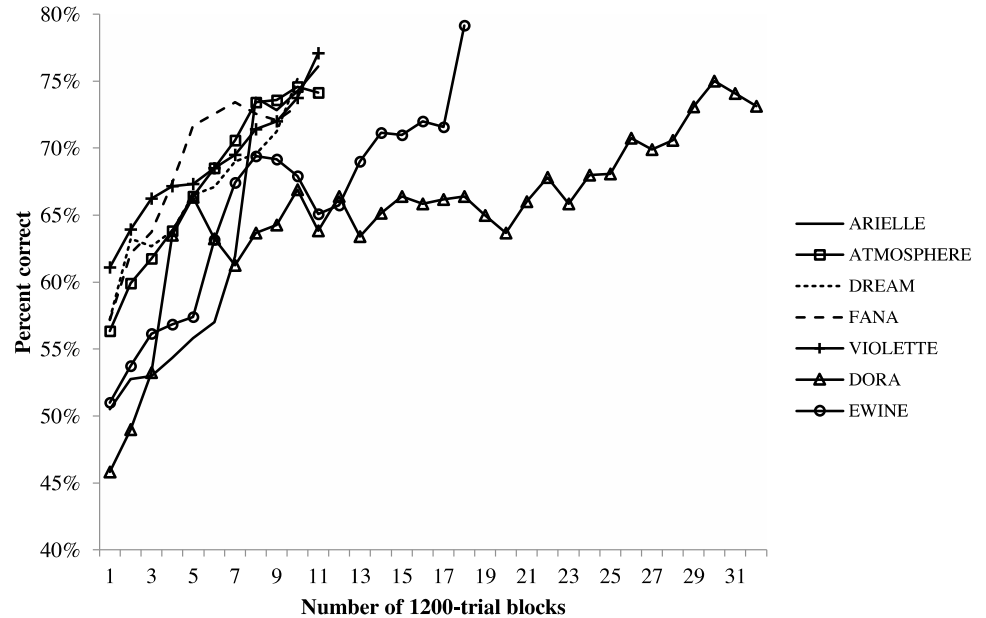
<https://youtu.be/2Dhc2zePJFE>

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.

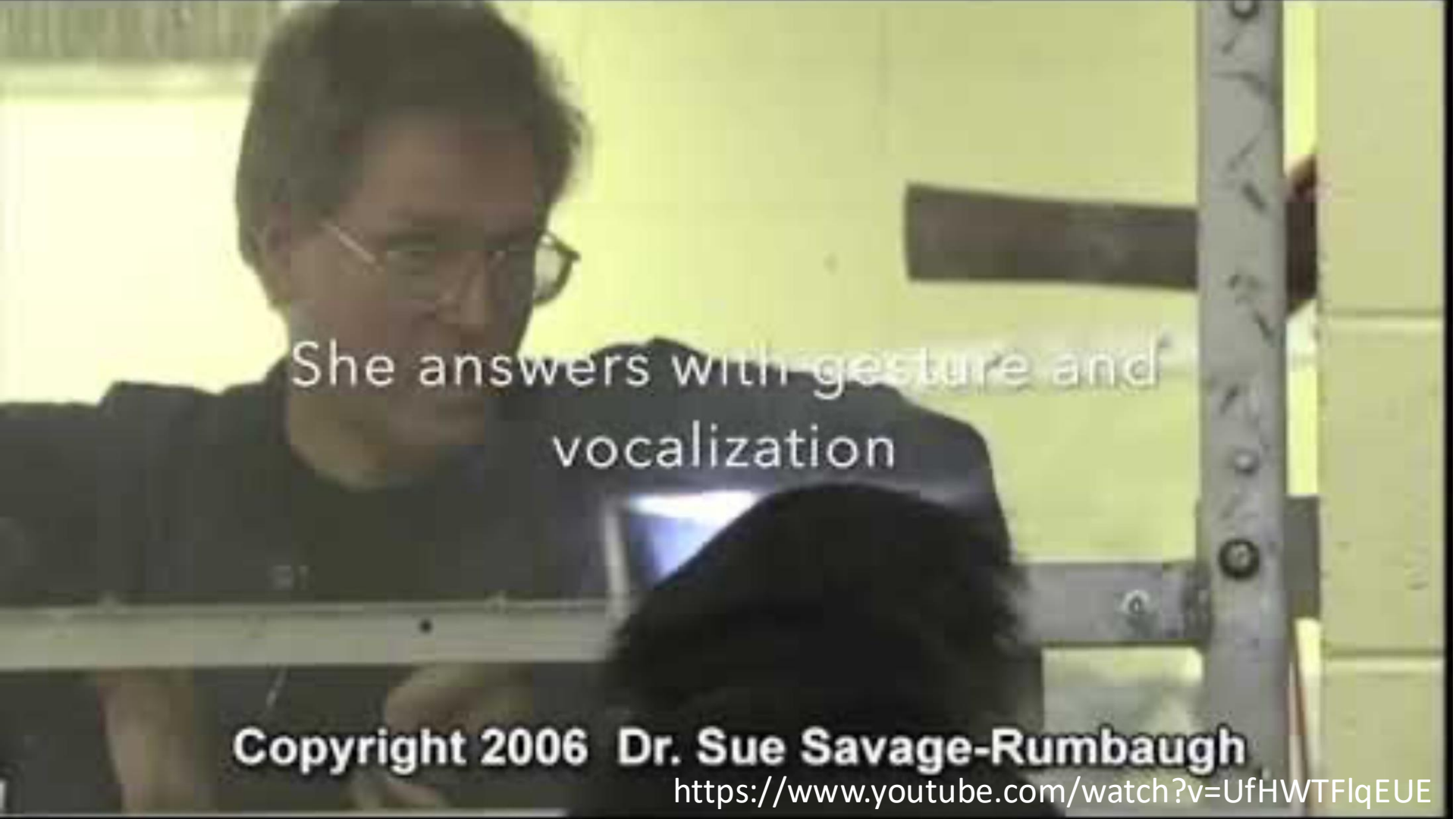
Puzzling failures in (most) baboons



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.

A man with glasses is looking at a laptop screen. The background is a laboratory or office setting with a white wall and a metal frame. The text "She answers with gesture and vocalization" is overlaid on the image.

She answers with gesture and
vocalization

Copyright 2006 Dr. Sue Savage-Rumbaugh

<https://www.youtube.com/watch?v=UfHWTFlqEUE>





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 (i.e. multi-part) 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

- Tutorial: song culture in zebra finches
- (Also week 6 tutorial: dendrophobia in a language-trained ape)
- Next lecture: the evolution of social cognition
 - Sharing, theory of mind, intentionality