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?”

FOXP2: a gene involved in speech and language

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

Spotted from KE family pedigree

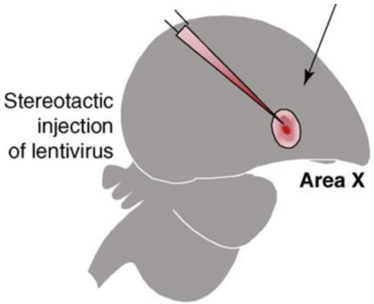
FOXP2 regulates expression of ≈ 400 other genes, some of which must be involved in language function

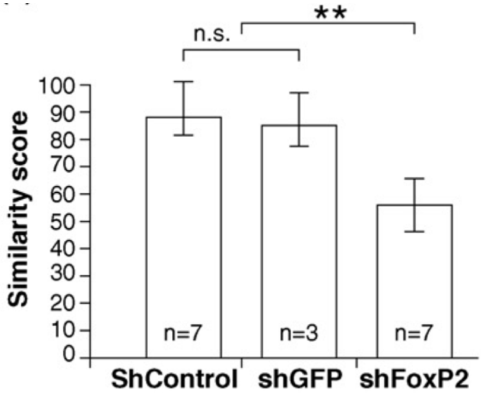
https://www.youtube.com/watch?v=Fg2rLOkoL9Q

Role of FOXP2 in other species

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

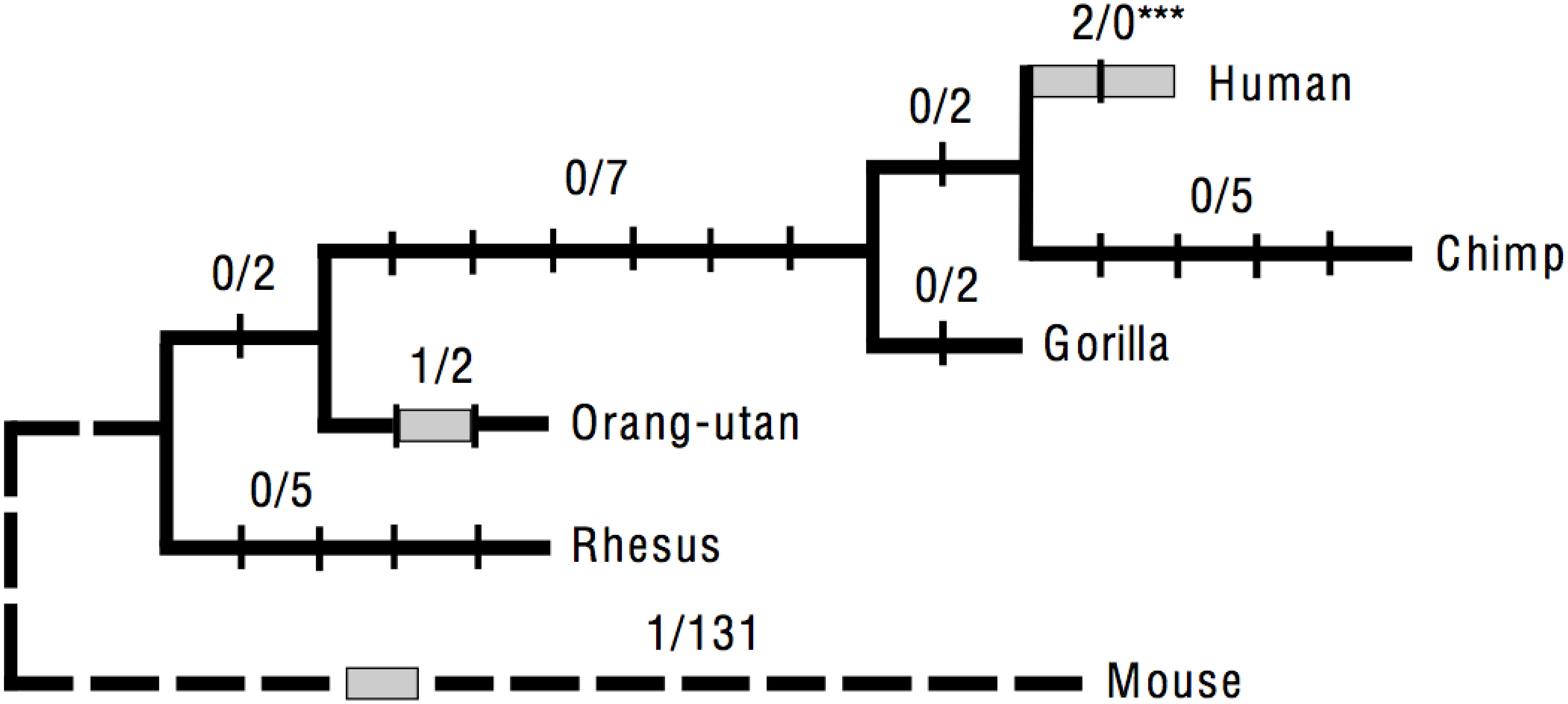
Zebra finches with selective knock-down of FOXP2 show impaired song learning





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.

“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. …”

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

"… 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. …"

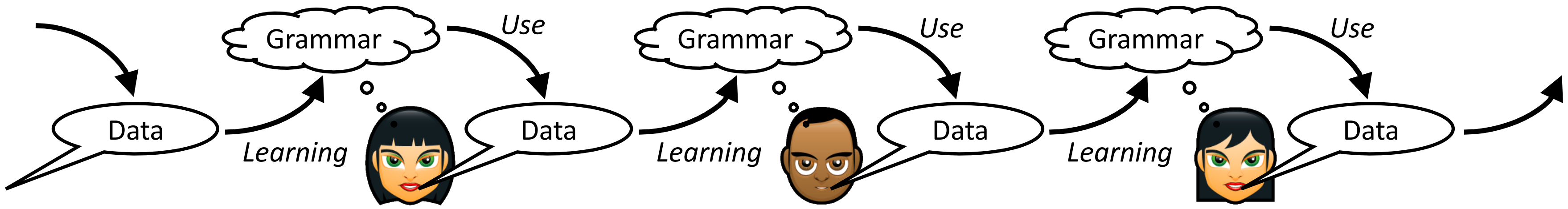
Krause, J., et al. (2007). The Derived FOXP2 Variant of Modern Humans Was Shared with Neandertals. *Current Biology, 17,* 1908-1912

"… 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)

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

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?


Data
Learning
Grammar
Use
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Learning
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Learning
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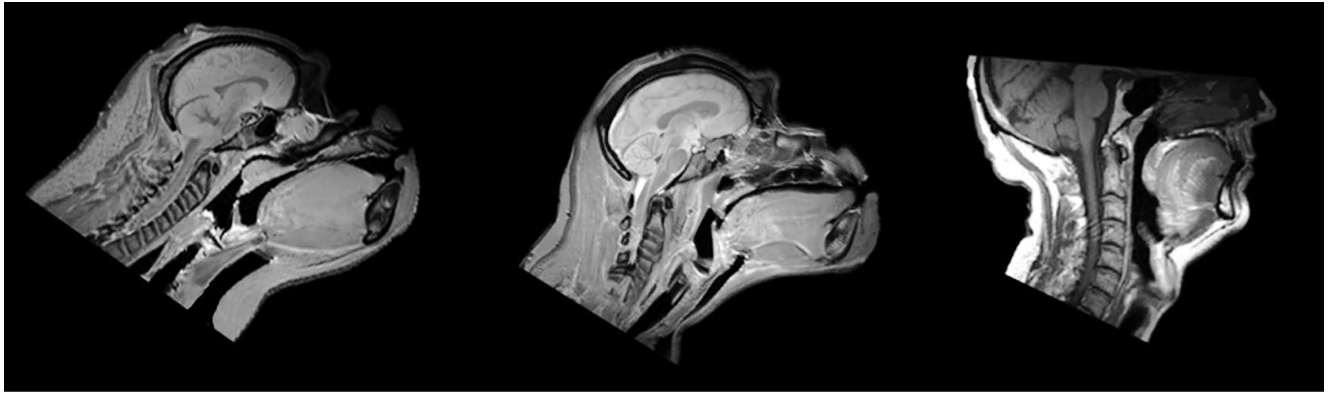
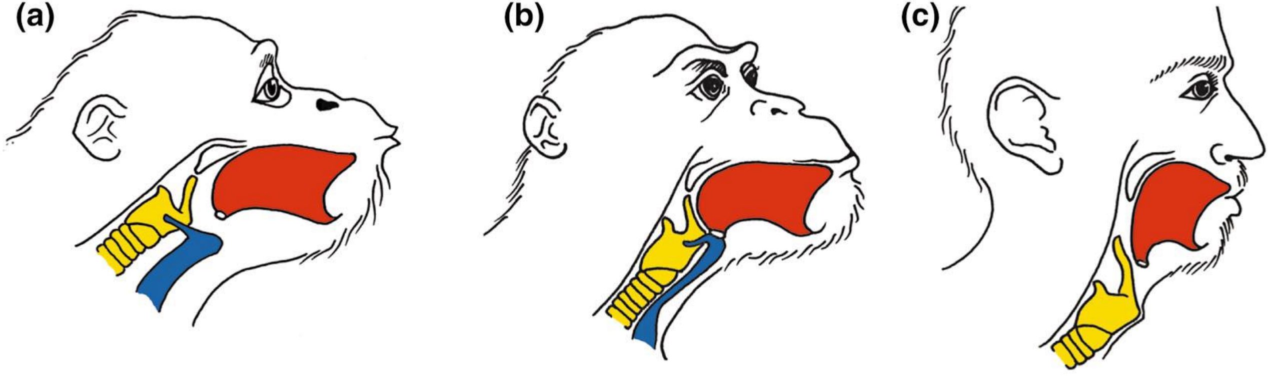
Evolution of speech: the vocal apparatus

The human articulators at work

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

The descended larynx and the two-chamber vocal tract

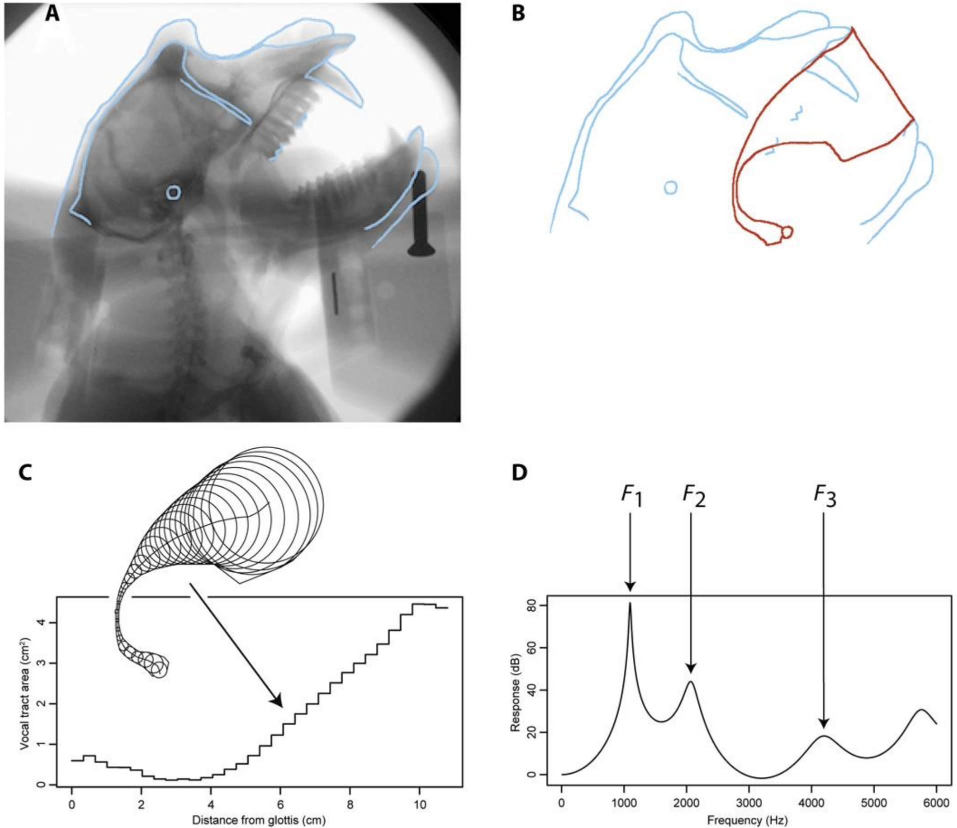


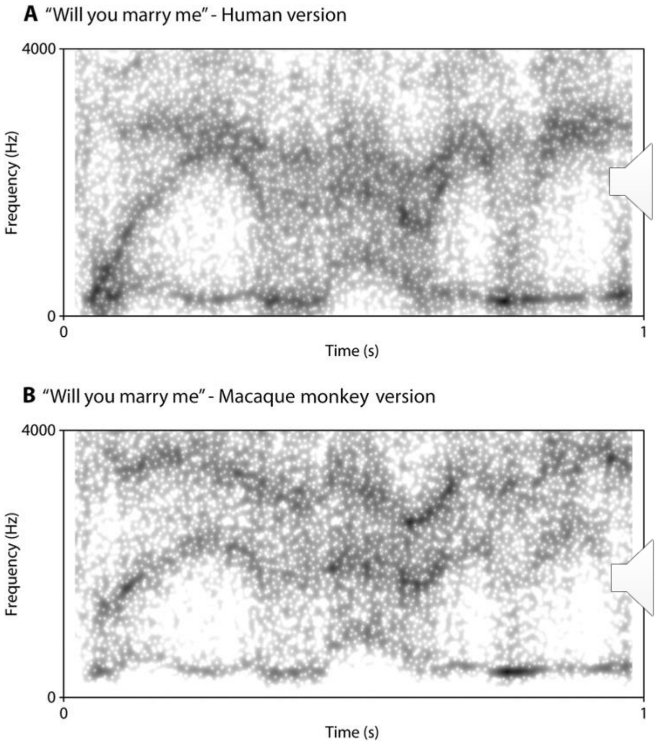


Fitch, W. T. (2000). The evolution of speech: a comparative review. *Trends in Cognitive Sciences*, *4*, 258-267.

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



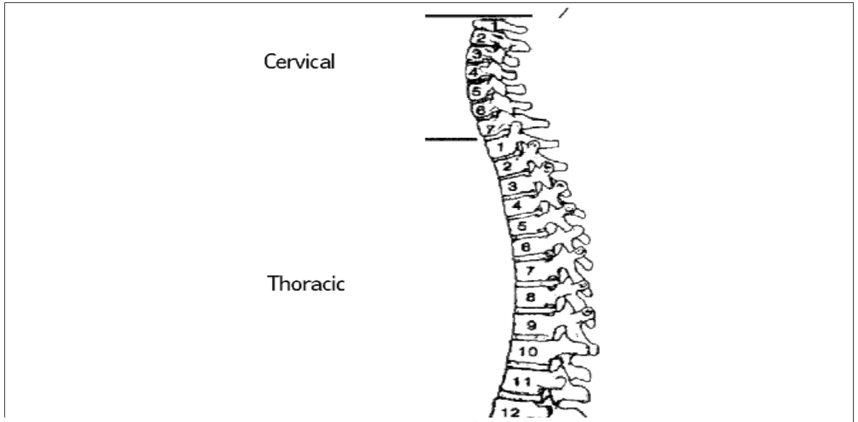


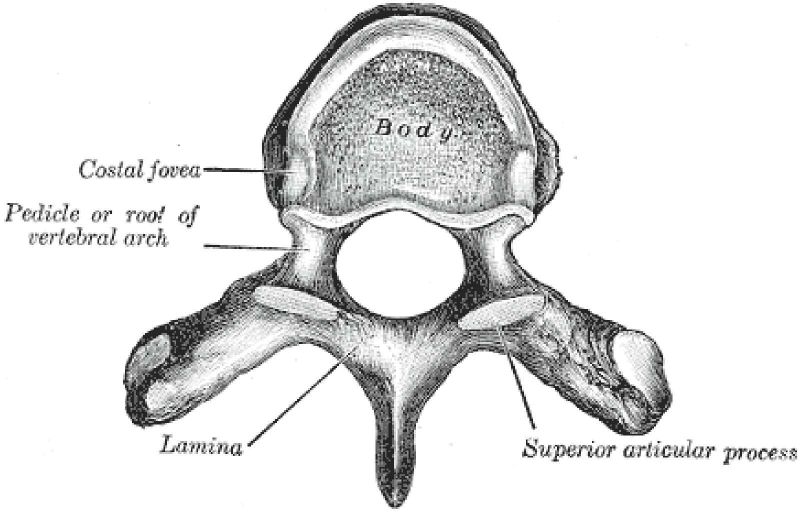
Fitch, W. T., De Boer, B., Mathur, N., & Ghazanfar, A. A. (2016). Monkey vocal tracts are speech-ready. *Science Advances, 2*, e1600723.

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

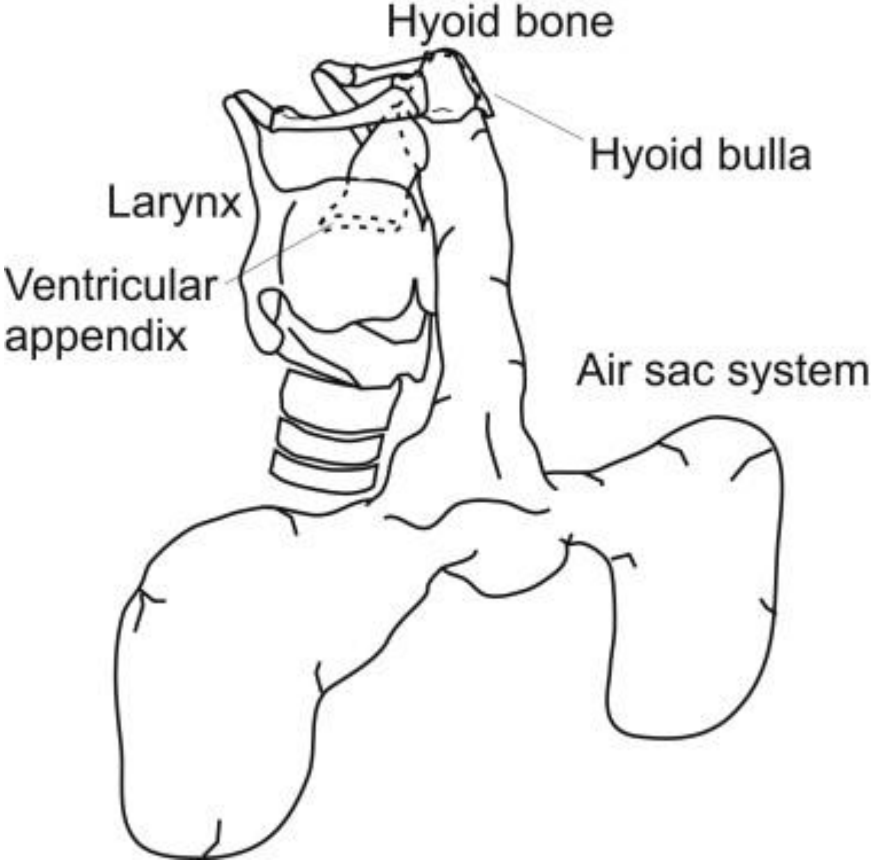


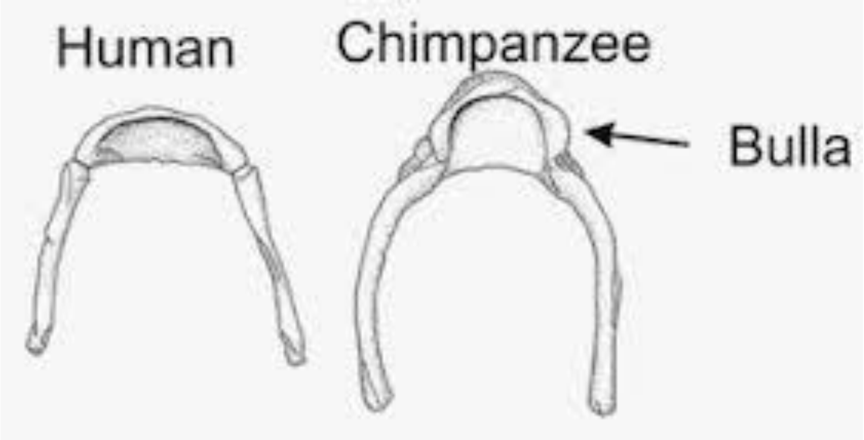


MacLarnon, A. & Hewitt, G. (1999). The evolution of human speech: the role of enhanced breathing control. *American Journal of Physical Anthropology*, *109,* 341–363.

Air sacs

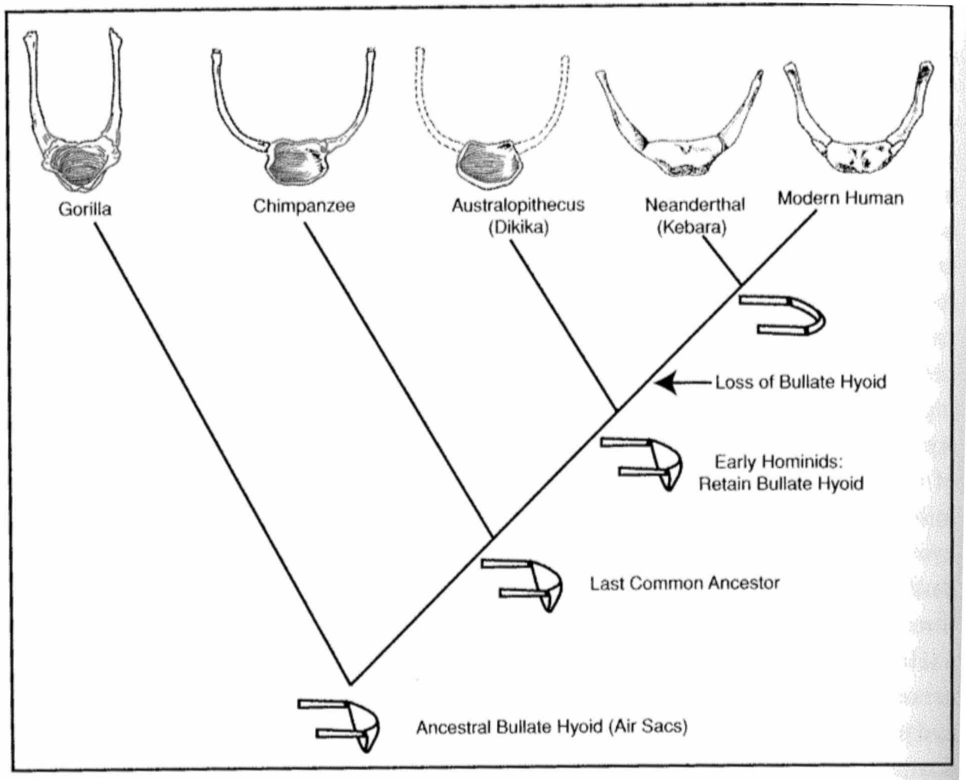
Air sacs



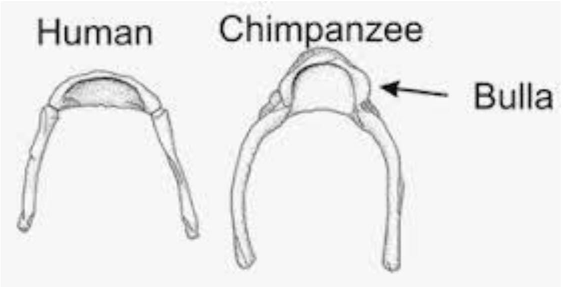


De Boer, B. (2012). Loss of air sacs improved hominin speech abilities. *Journal of Human Evolution*, *62,* 1–6.

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

Complex vocal imitation

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.

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

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 $\quad VP'(NP')$

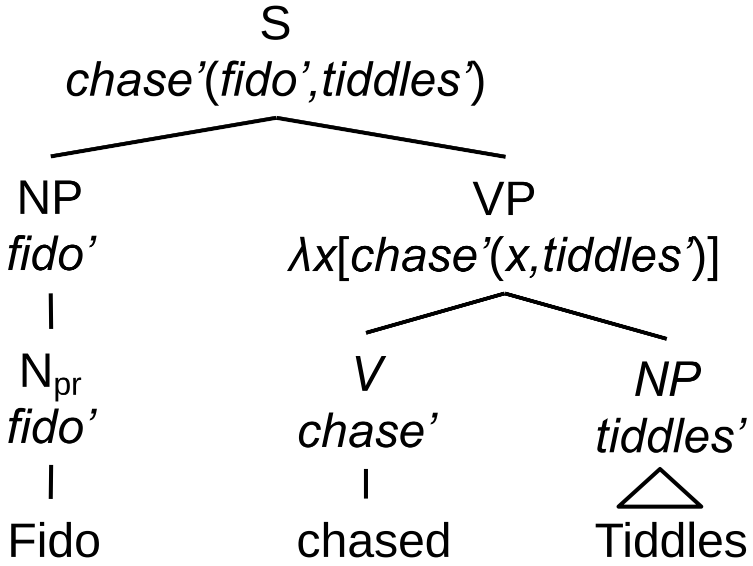
NP → N_{pr} $\quad N'_{pr}$

N_{pr} → Fido $\quad$ *fido'*

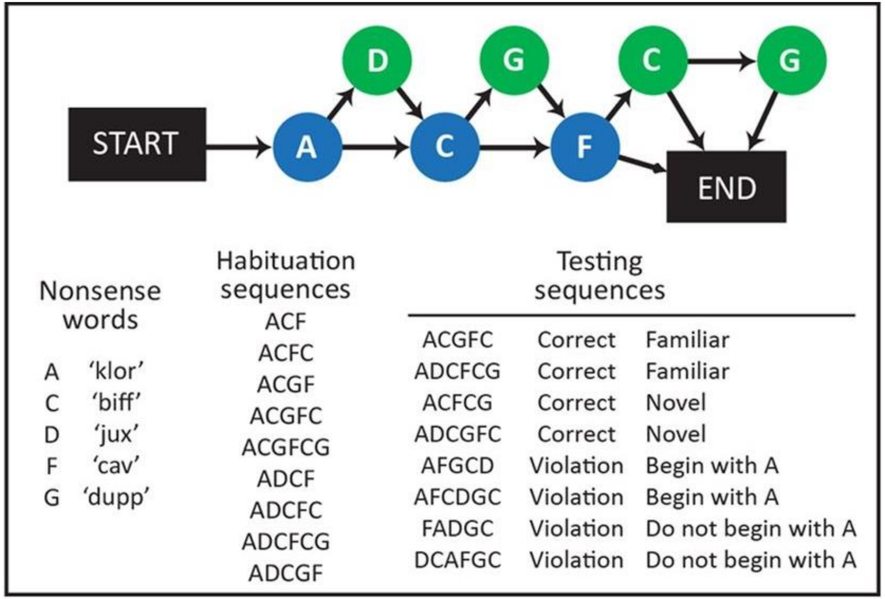
N_{pr} → Tiddles $\quad$ *tiddles'*

VP → V NP $\quad V'(NP')$

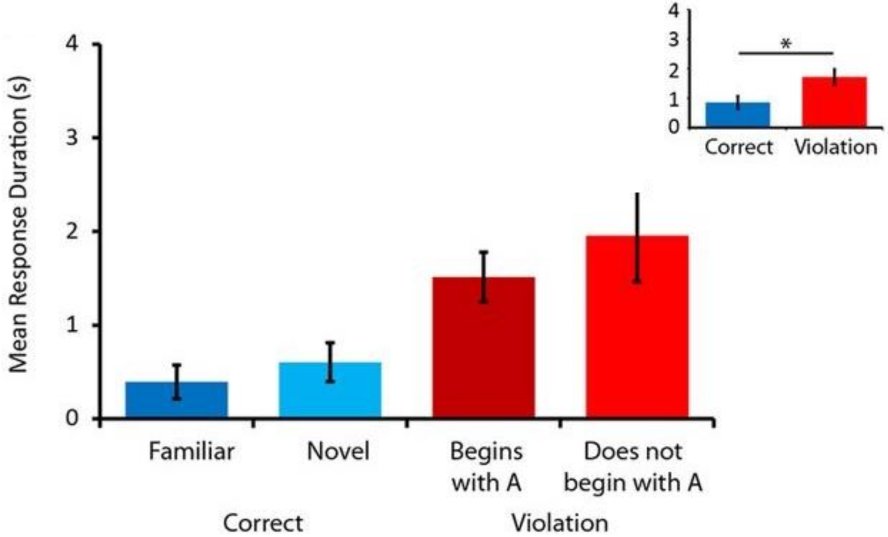
V → chased $\quad \lambda x\ [\lambda y\ [(chase'(x,y))]]$

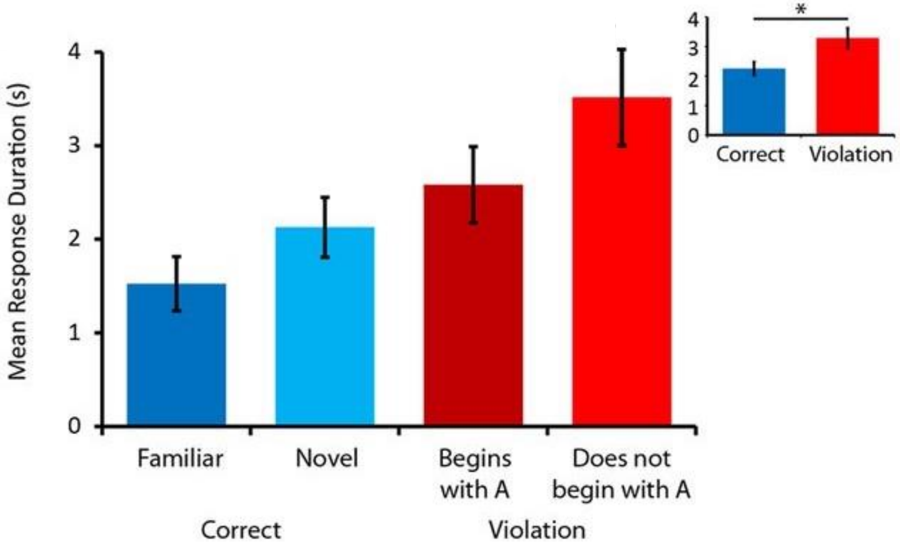


Artificial Grammar Learning in non-humans



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.





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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

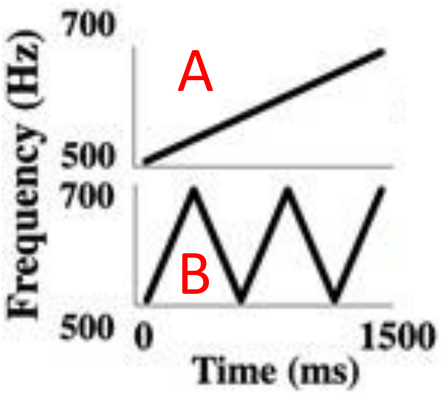
pel wadim jic?

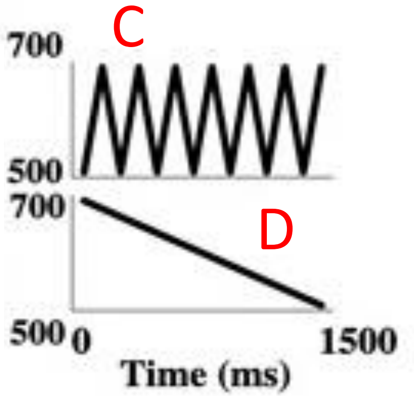
vot wadim jic

vot wadim rud?

Gomez, R. (2002). Variability and detection of invariant structure. *Psychological Science, 13,* 431-436.

Non-adjacent dependency learning



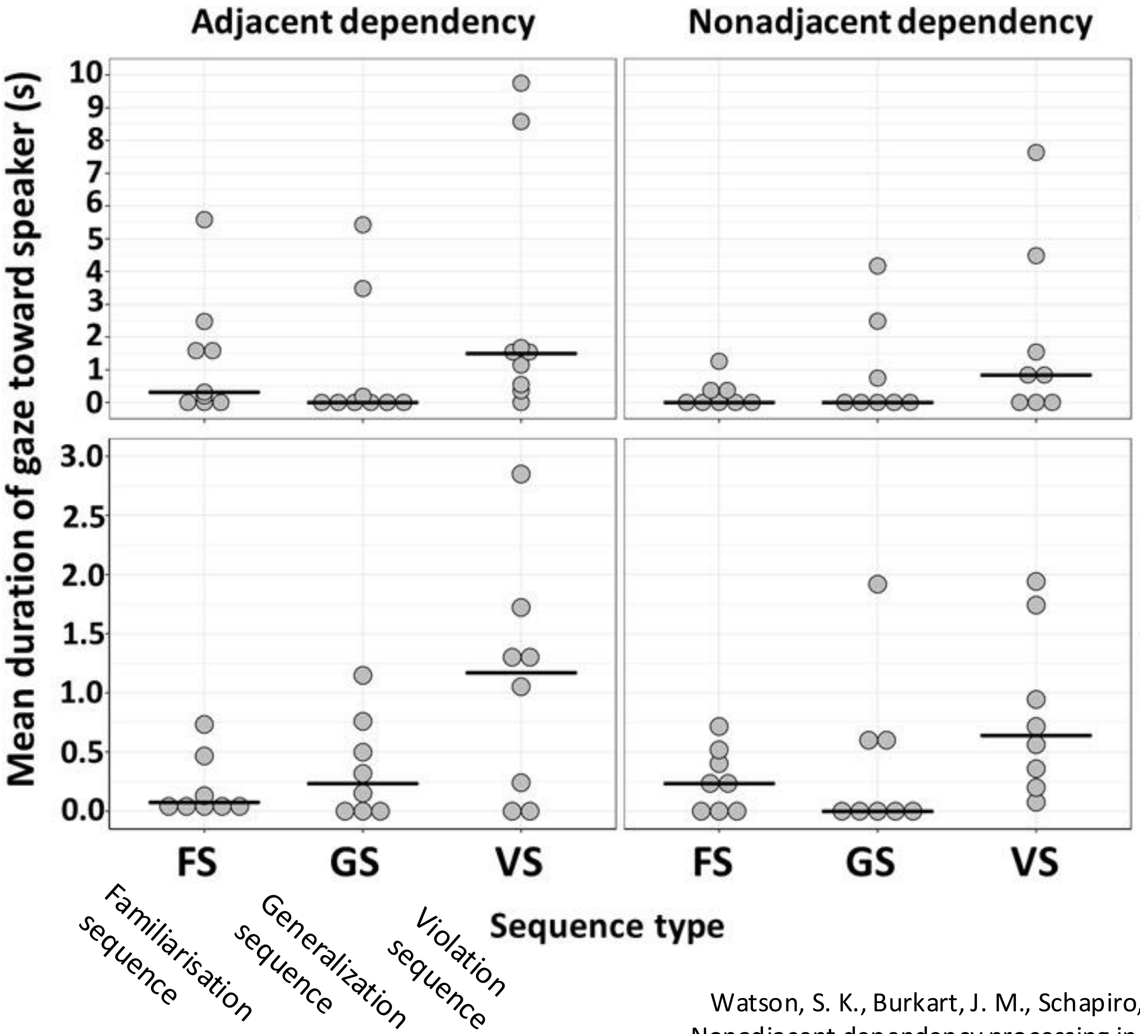


Watson, S. K., Burkart, J. M., Schapiro, S. J., Lambeth, S. P., Mueller, J. L., & Townsend, S. W. (2020). Nonadjacent dependency processing in monkeys, apes, and humans. *Science Advances, 6,* eabb0725.

Non-adjacent dependency learning

Sequence type	Example AD	Example Non-AD
Familiarization	$A_1 - B_7$	$A_1 - X2_4 - B_7$
	$C_5 - D_1$	$C_5 - X1_1 - D_1$
Generalization	$A_{13} - B_{11}$	$A_{13} - X1_{15} - B_{11}$
	$C_{10} - D_{16}$	$C_{10} - X2_{14} - D_{16}$
Violation	$A_{13} - D_{11}$	$A_{13} - X1_{15} - D_{11}$
	$C_{10} - B_{16}$	$C_{10} - X2_{14} - B_{16}$

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.



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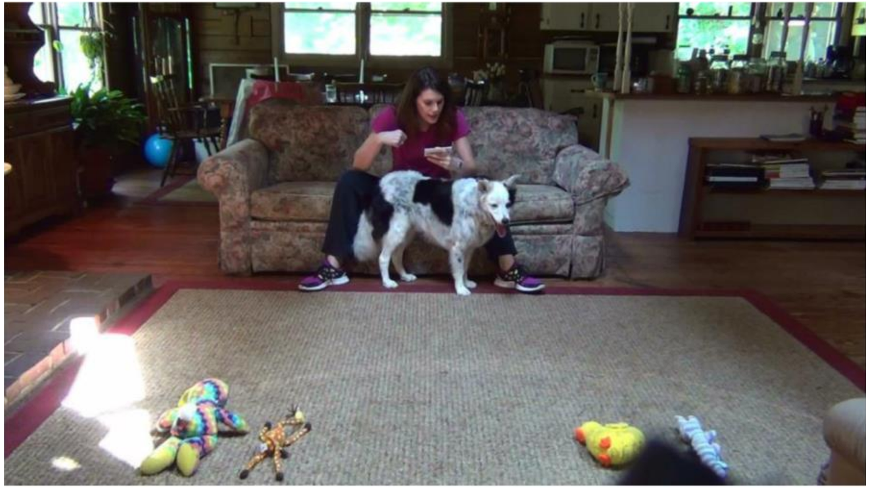
How about learning of **meaningful** sequences?

"ball fetch"
"stick point"

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



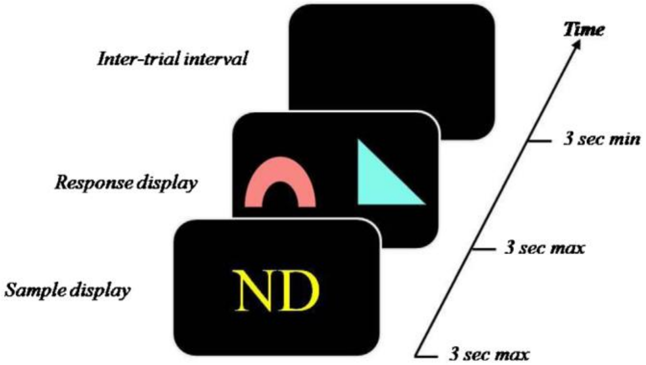
"to sugar take decoy"
"to decoy take sugar"

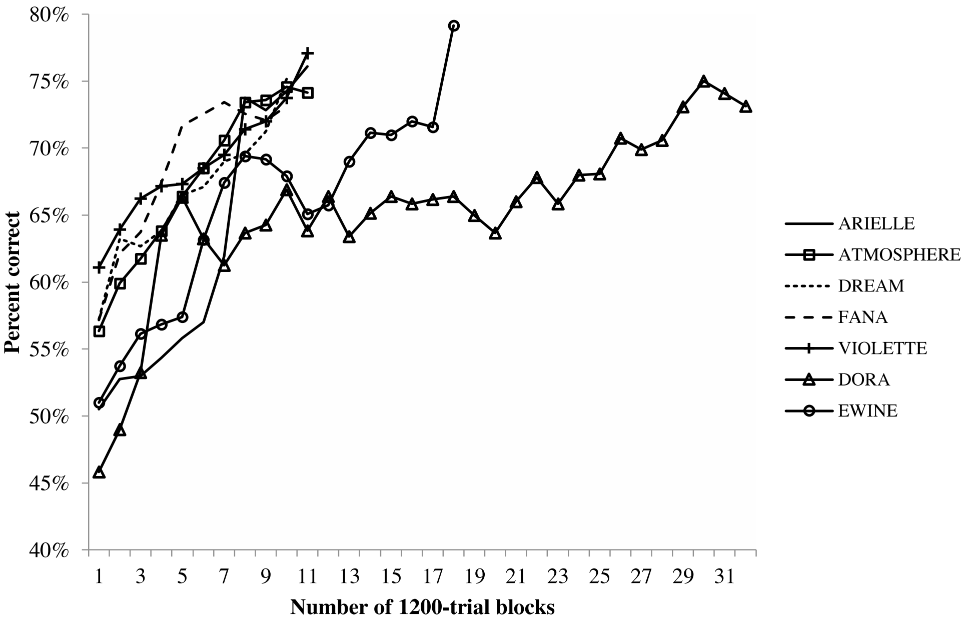
Pilley, J. W. (2013). Border collie comprehends sentences containing a prepositional object, verb, and direct object. *Learning and Motivation, 44,* 229-240.

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.

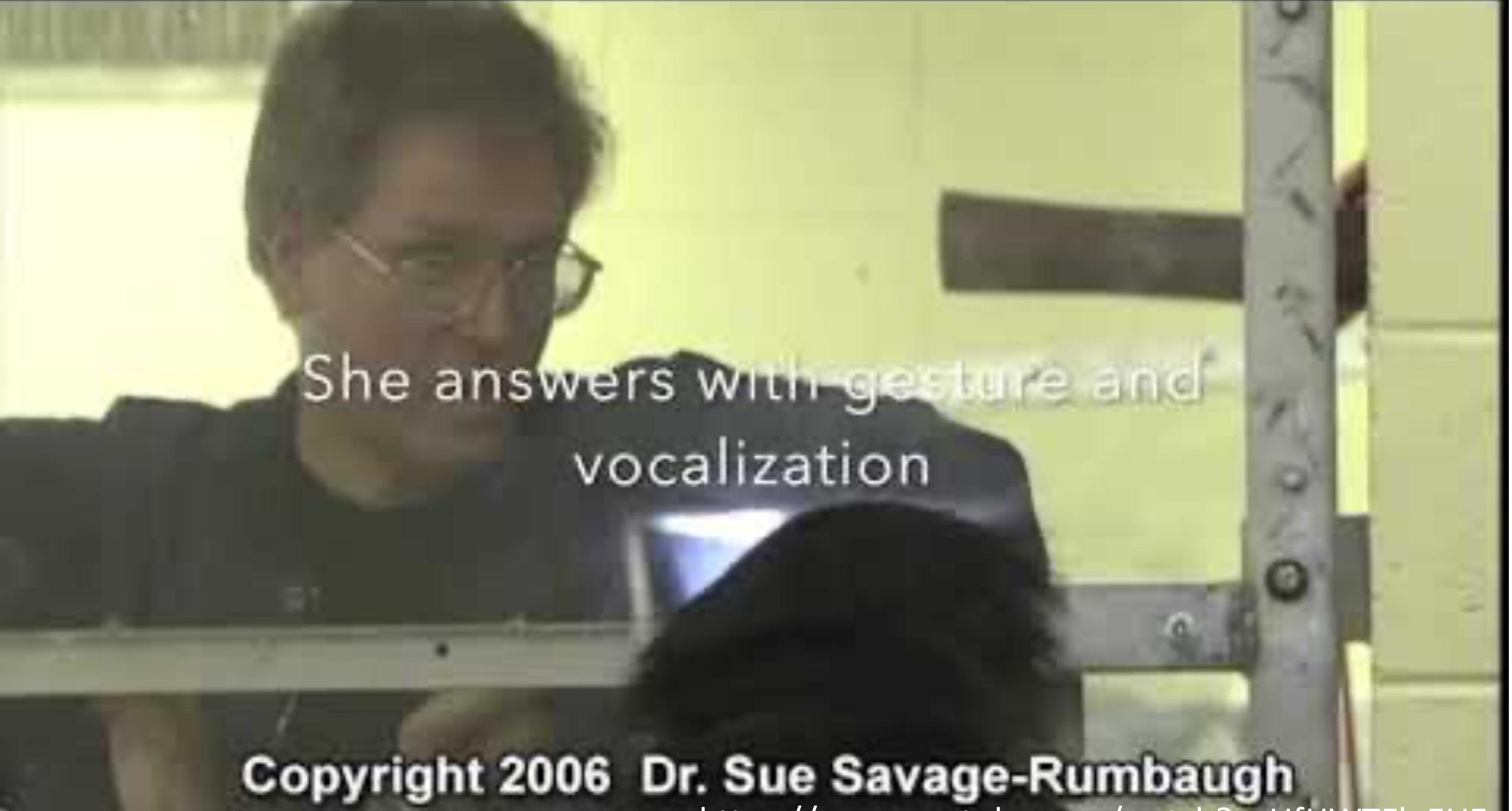
Puzzling failures in (most) baboons





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.



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


FluentPet

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