



Modern Human Origins

Adaptive and Non-Adaptive Theories of Language Evolution

Christian Bentz

07 January 2019, Lecture 8, Bentz



Readings for Lecture 8

Bentz, Christian. 2018. *Adaptive languages: An information-theoretic account of linguistic diversity*. Berlin: De Gruyter Mouton. p. 9-24.

Berwick, Robert C. Angela D. Friederici, Noam Chomsky, and Johan J. Bolhuis. 2013. Evolution, brain, and the nature of language. *Trends in Cognitive Sciences* 17 (2): 89-98.

Jäger, Gerhard, and James Rogers. 2012. Formal language theory: refining the Chomsky hierarchy. *Philosophical Transactions of the Royal Society* 367: 1956-1970.

Course websites

<https://moodle02.zdv.uni-tuebingen.de/course/view.php?id=1932>

http://www.christianbentz.de/teaching_humanOrigins2018.html



Introduction

Language evolution: the hardest problem in science?

Christiansen & Kirby (2003)



Fundamental problem:

“Language leaves no direct imprint in the fossil record.”

Bolhuis et al. (2014)

Theories of language evolution are often (inevitably?) more speculative than theories of human evolution based on archaeological and palaeoanthropological evidence.

Société de Linguistique de Paris

ART. 2. - La Société n'admet aucune communication concernant, soit **l'origine du langage** soit la création d'une langue universelle.

Société de Linguistique de Paris. Statuts de 1866.

Language leaves no
direct imprint in
the fossil record...

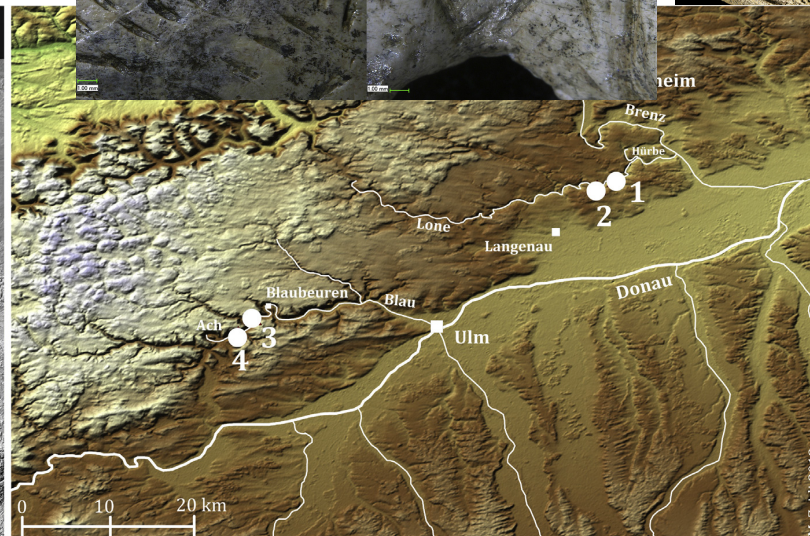
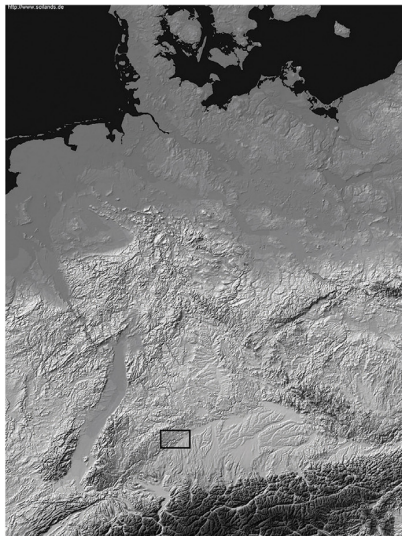
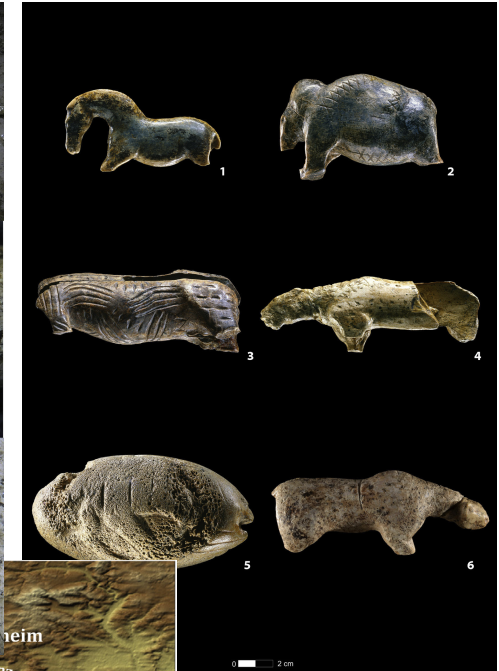
or

... does it?



There is an abundance of abstract signs in the Upper Palaeolithic (ca. 40 000 to 10 000 years ago) of Europe.

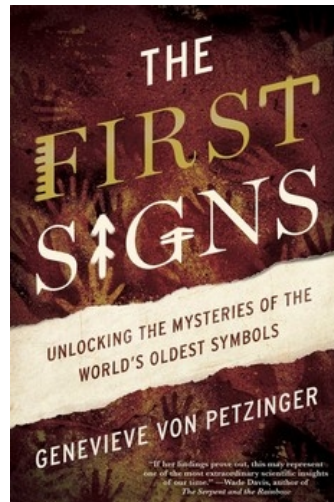
Example:
Finds of art objects in the Swabian Jura



Dutkiewicz,
Wolf & Conard
(2017)

There is an abundance of abstract signs in the Upper Palaeolithic (ca. 40 000 to 10 000 years ago) of Europe.

Example:
Abstracts signs in cave art

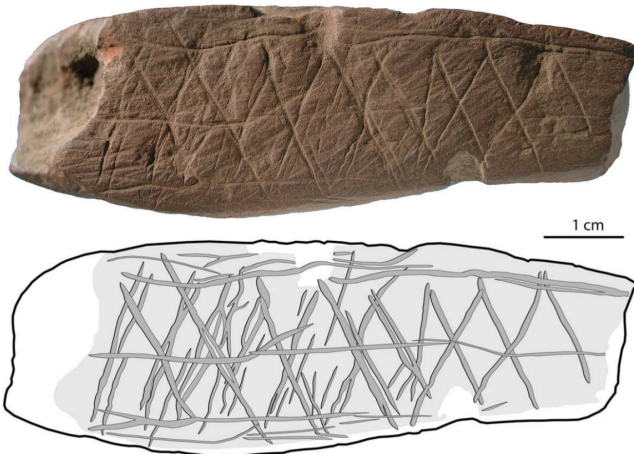


“The Inscription”
Cueva de la Pasiega,
Spain (ca. 18000 BC)



How do we get from...

engravings



Blombos Cave (South Africa) ca. 70 000 BCE



writing



Sumerian Cuneiform (Mesopotamia) ca. 3000 BCE

?

Animal communication



Human language

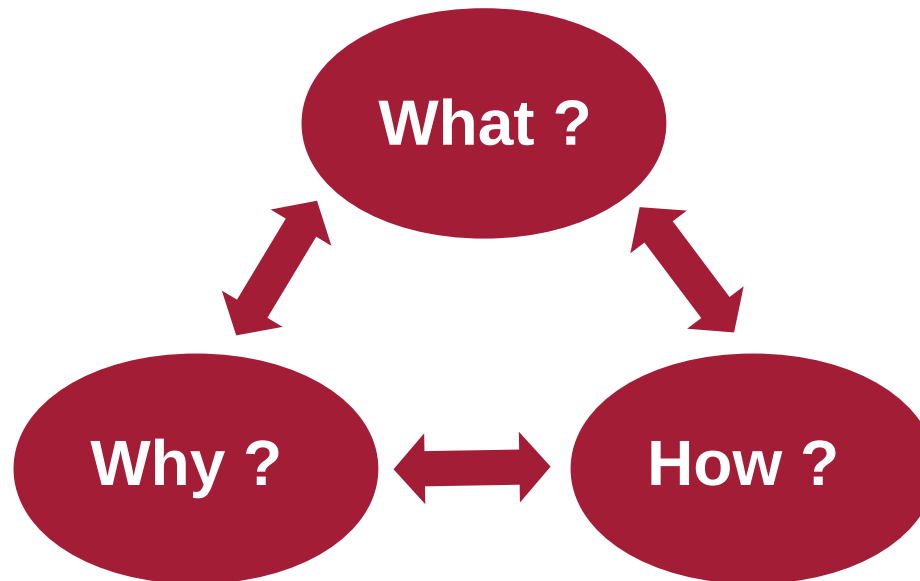


?



Three **interdependent** questions:

- 1) **What** evolved, i.e. what is “language” in the first place?
- 2) **Why** did it evolve, i.e. did it have particular function(s)?
- 3) **How** did it evolve, e.g. suddenly via mutation, gradual, etc.?





Question 1: **What is language?**

- I-language and E-language
- discrete infinity

Question 1: What is „language“?

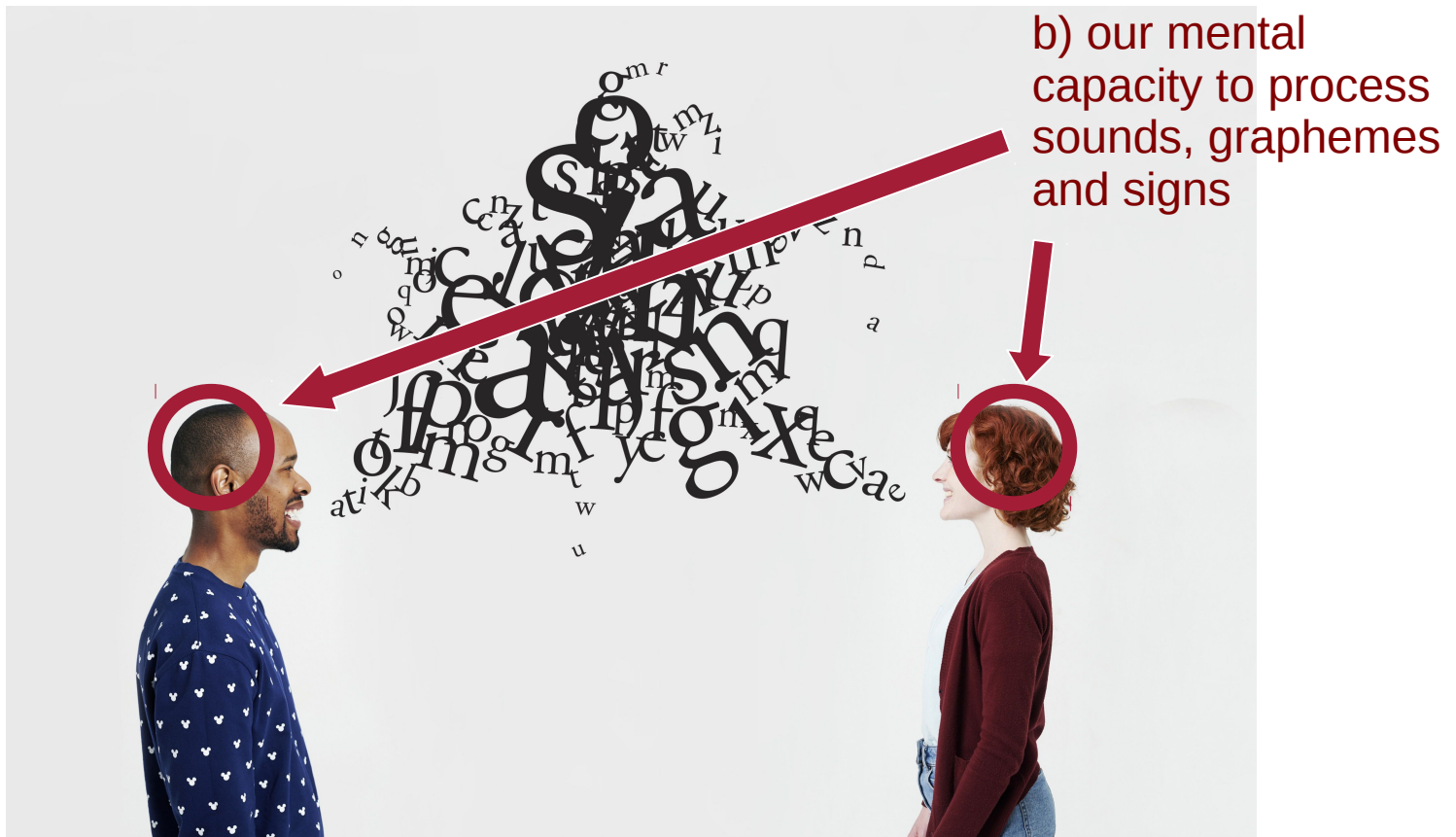


Question 1: What is „language“?

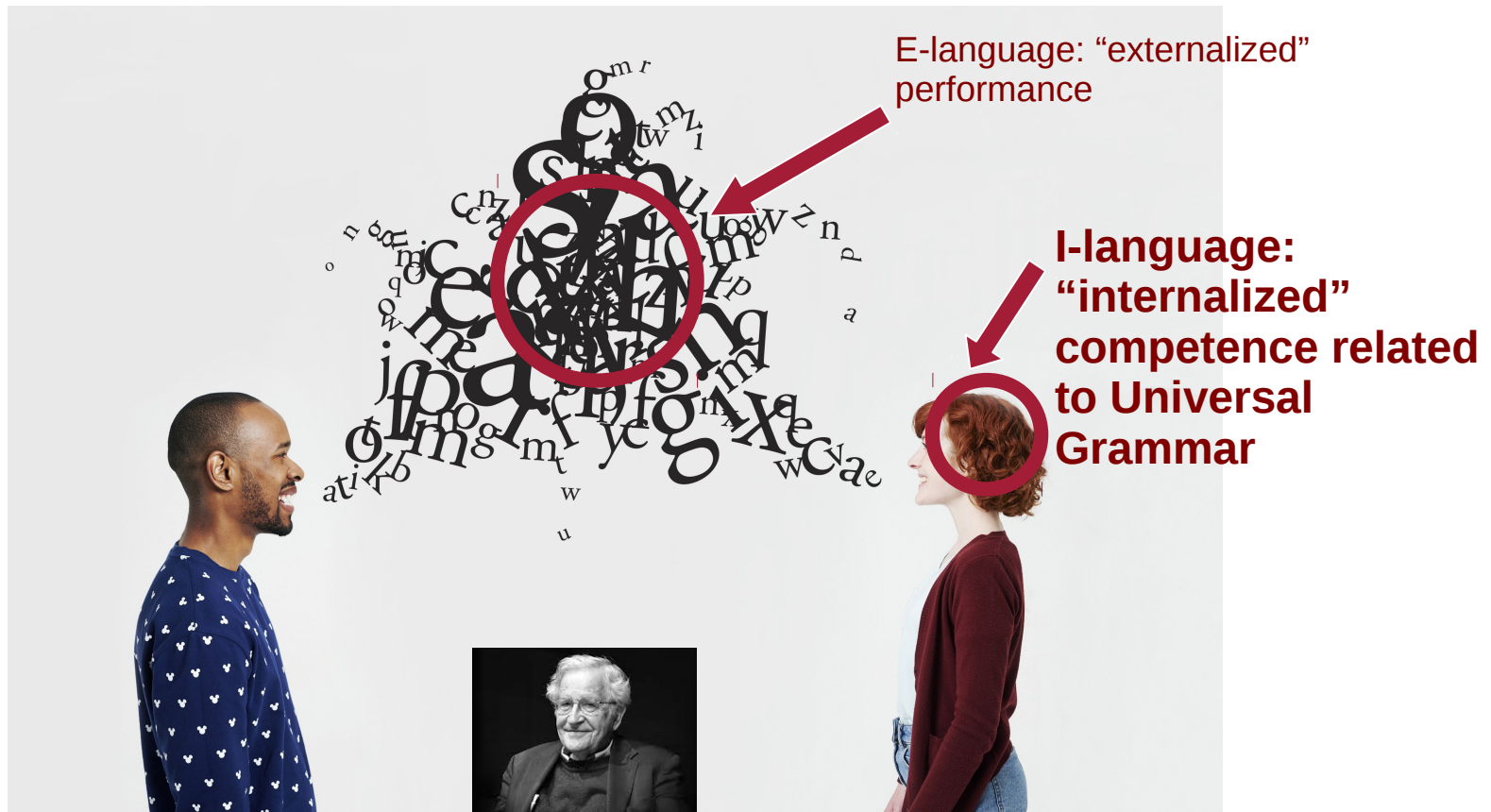


a) The sounds,
graphemes and signs
we see and hear

Question 1: What is „language“?



Answer by generative syntacticians:



Chomsky (1965). Aspects of the theory of syntax.

Chomsky (1986). Knowledge of language: it's nature, origin and use.

Question 1: What is Universal Grammar?



simplest speculation about the evolution of language. Within some small group from which we are all descended, a rewiring of the brain took place in some individual, call him *Prometheus*, yielding the operation of unbounded Merge, applying to concepts with intricate (and little understood) properties.

Chomsky (2005). Some simple evo devo theses: how true might they be for language?



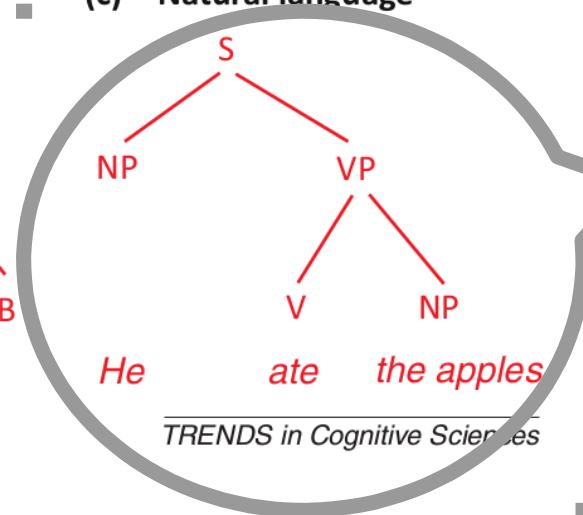
(a) $(AB)^n$ Sequence



(b) A^nB^n Sequence



(c) Natural language



[...] the unified nature of human language arises from a shared, species-specific computational ability. This ability has identifiable correlates in the brain and has remained fixed since the origin of language approximately 100 thousand years ago.

Berwick et al. (2013). Evolution, brain, and the nature of language.

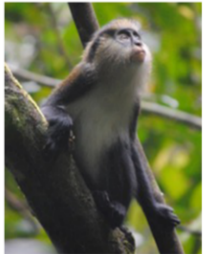
Fundamental problem:

What can we infer from production (E-language) regarding the language capacity (I-language)?

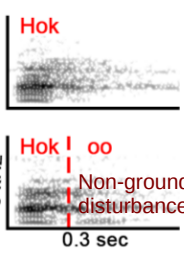


Is there a **decision algorithm** that would tell us from empirical data whether “language” is present?

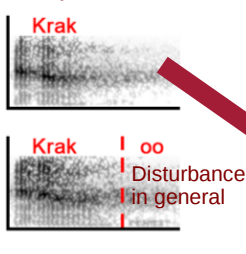
Campbell's monkeys



Eagle!



Leopard!



no

የሃዋርያት፡እምነት።

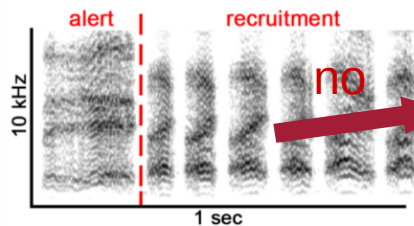
እኔ፡መሬትንና፡ሰማይን፡በፈጠረውና፡ምንም፡በማይላነው፡
እምላክ፡አብና፡እንዲሁም፡በመንፈስ፡ቅዱስ፡ተረጋገጠ፡
ከድንግል፡ማርያም፡በተወለደው፡በእንጤናዊው፡ጳላሙስ፡
ስር፡በተሰቃየው፡በተሰቀለው፡በሞተው፡በተቀበረው፡
ወደሃዋንም፡ወርዶ፡በሶስተኛ፡ቀኑ፡ከመታን፡መካል፡ተነስቶ፡
ወደ፡ሰማይ፡ባረገው፡ምንም፡ከማይላነው፡አብ፡እምላክ፡ቀኛ፡
ጎን፡በተቀመጠው፡ከዘሊያ፡ተነስቶ፡መታንንና፡ሀዋንን፡
ለመፍረድ፡በማመጣው፡በአንድ፡ልጁ፡በጌታችን፡በእያሱስ፡
ክርስቶስ፡እምናለሁ።እኔ፡በመንፈስቅዱስ፡በቅድስት፡
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yes

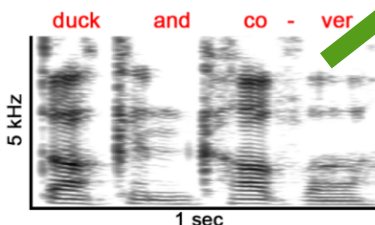
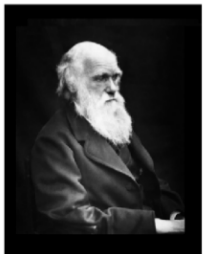


no

Pied babblers

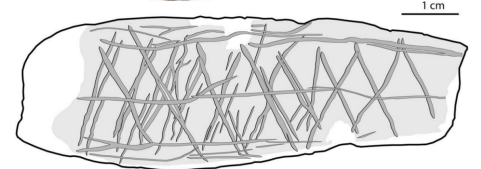


no



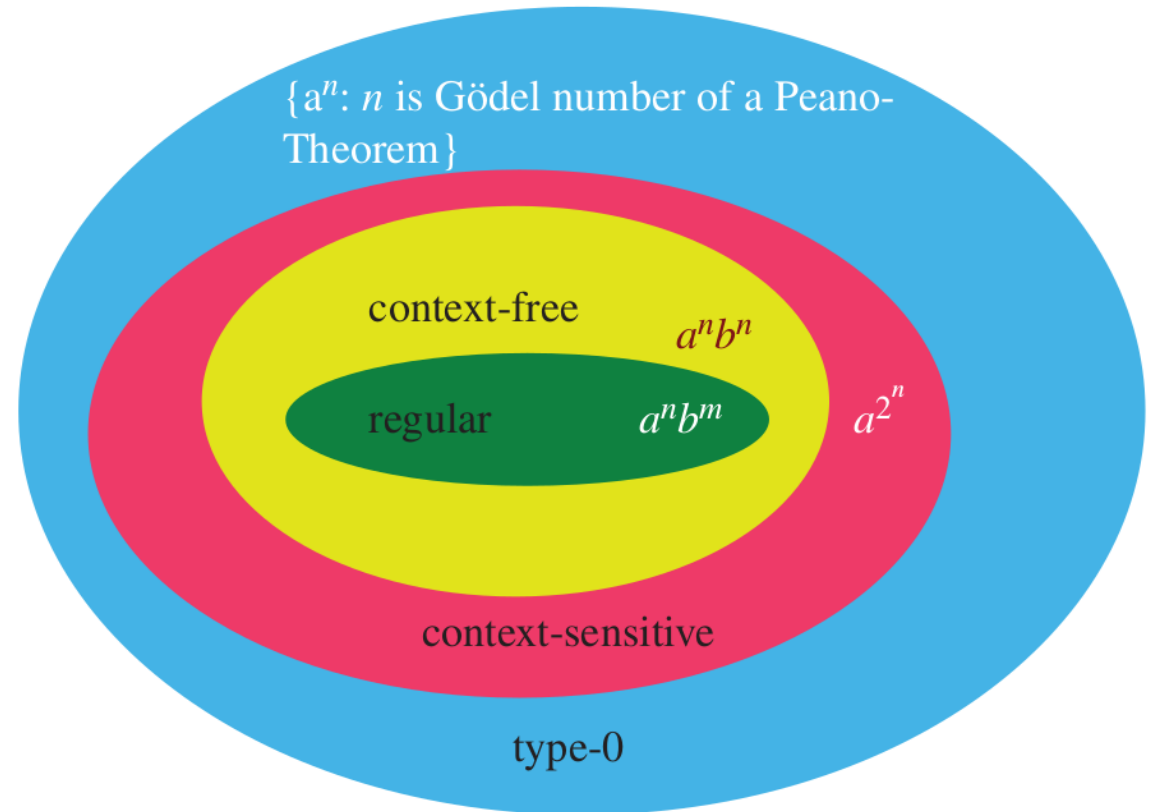
yes

yes



Townsend et al. (2018). Compositionality in animals and humans.

Formal language theory: The Chomsky hierarchy



Jäger & Rogers (2012). Formal language theory: refining the Chomsky hierarchy.
Chomsky (1956). Three models for the description of language.

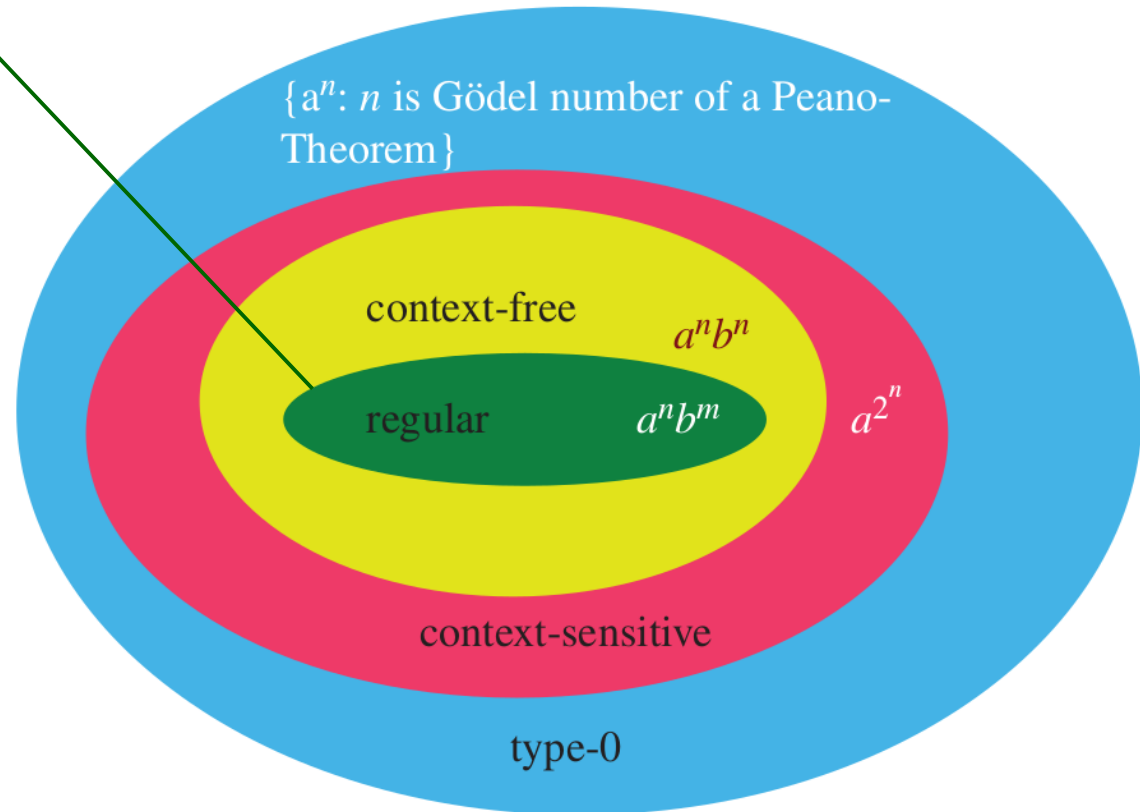
Regular language generated by a **finite state automaton**, aka **Markov process**

Example of a regular grammar
to generate strings of the type $a^n b^m$:

rule 1: $A \rightarrow aA$
rule 2: $A \rightarrow aB$
rule 3: $B \rightarrow bB$
rule 4: $B \rightarrow b$

Generating an example string:

apply rule 1: aA
apply rule 1: aaA
apply rule 2: aaB
apply rule 3: $aaabB$
apply rule 4: $aaabb$



Jäger & Rogers (2012). Formal language theory: refining the Chomsky hierarchy.
Chomsky (1956). Three models for the description of language.

Context-free (non-regular) language generated by a **push down stack**

Example of a context-free grammar
to generate strings of the type $a^n b^n$:

rule 1: $S \rightarrow aSb$

rule 2: $S \rightarrow \epsilon$ (empty string)

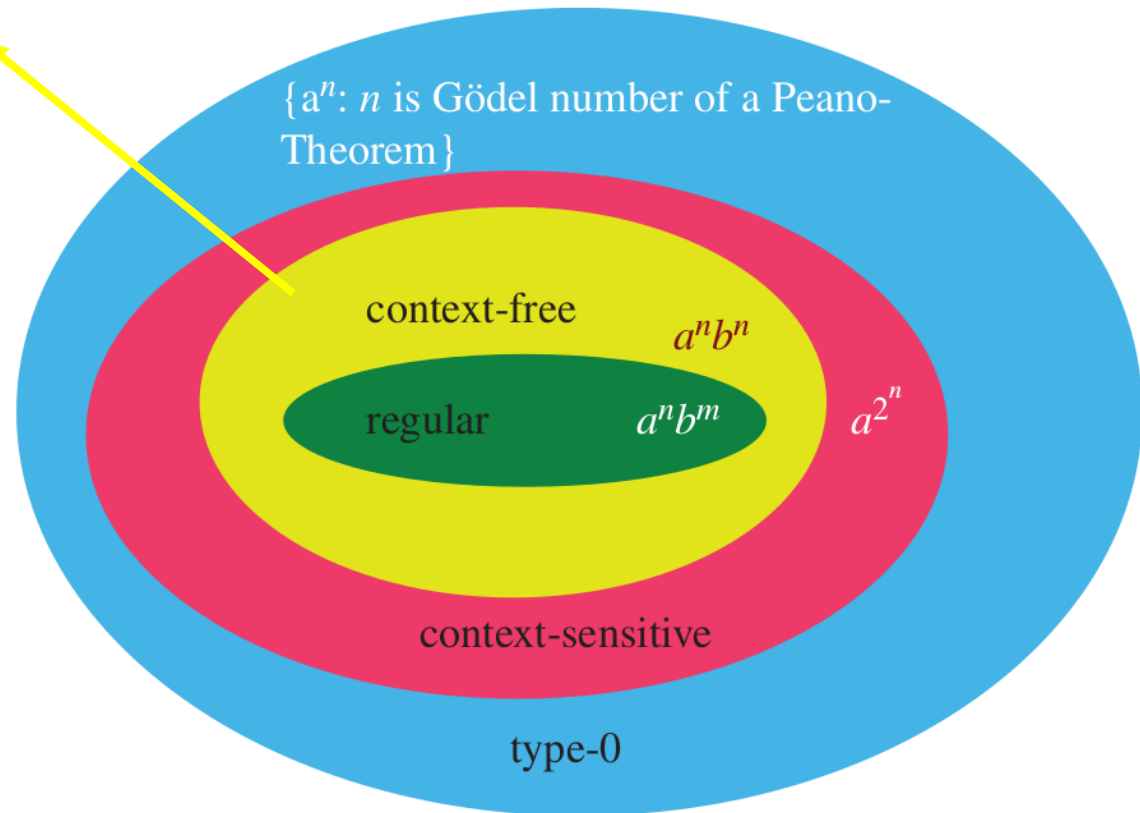
Generating an example string:

apply rule 1: aSb

apply rule 1: $aaSbb$

apply rule 1: $aaaSbbb$

apply rule 2: $aaabbb$



Jäger & Rogers (2012). Formal language theory: refining the Chomsky hierarchy.
Chomsky (1956). Three models for the description of language.



“English is not a finite-state language, and we are forced to reject the theory of language under discussion [i.e. language as a Markov process] ...”

Chomsky (1956). Three models for the description of language.

Neither did John claim that he neither smokes while [...] nor snores, nor did anybody believe it.

aabb

more generally:

aⁿbⁿ

Jäger & Rogers (2012). Formal language theory: refining the Chomsky hierarchy.



Is there a **decision algorithm** that would tell us from empirical data whether “language” is present?

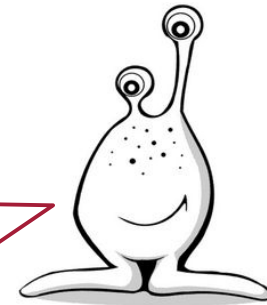
abb, aabbb, aaaabbbb, aaab,
aab, aab, aabbb, abb, ab,
aaaaaaabbbb, abbbbbbbbbbb,
aabbbb, aaabbbb, abbbb,
aaaaaaaaaaaaabbbb, aaab,
abbbb, aaaaabbbb, aaabb,
abb



ab, aabb, aaaabbbb, ab,
aabb, ab, aaabbb, aabb, ab,
aaaabbbb, ab, aabb,
aaabbb, ab, aaaaabbbb,
ab, ab, aaaabbbb,
aaaaaaaaaabbbbbbbbbbbb,
ab, aabb, aaaaabbbb



aab, abb, aaaabbbb, ab,
aaabb, abb, aabbb, aaabb,
abb, aabbbb, abb, abb,
aaabbb, ab, aabbbb, abb,
aab, aaaabb, aaaaabbbb,
abbbb, aabb, aaaab





Is there a **decision algorithm** that would tell us from empirical data whether “language” is present?

Some caveats:

- a finite-state automaton (regular grammar) **can** in fact create $a^n b^n$ sequences (either coincidentally or by implementing a simple counter)
- the argument that language is not a finite-state automaton is based on the assumption of **potentially infinite dependencies** (n). However, empirical data are always finite
- in natural languages, there can be **intervening symbols** as in the example above (*neither ... neither ... nor ... nor*)
- in natural languages, the structural property of $a^n b^n$ does not necessarily refer to “**surface**” **properties** of the string (e.g. sequences of characters of phonemes), but higher order structures such as NP (noun phrase) or VP (verb phrase)



Question 2: **Why** did language evolve?

- Communication
- Thinking
- No function (?)



Question 2: Why did it evolve?

- **Vocal communication**

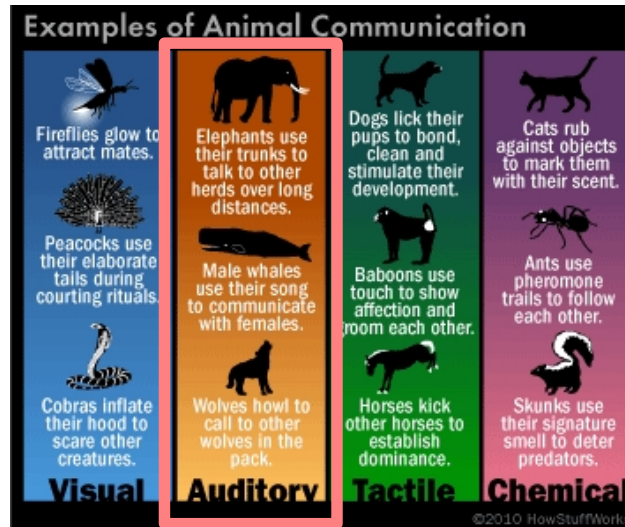
- Gestural communication

- Social bonding (grooming)

- Gossiping

- Thinking

- No function (?)



Christiansen & Kirby (2003)
Chapter 14 by Philip Lieberman
Chapter 2 by Steven Pinker

Question 2: Why did it evolve?

- Vocal communication

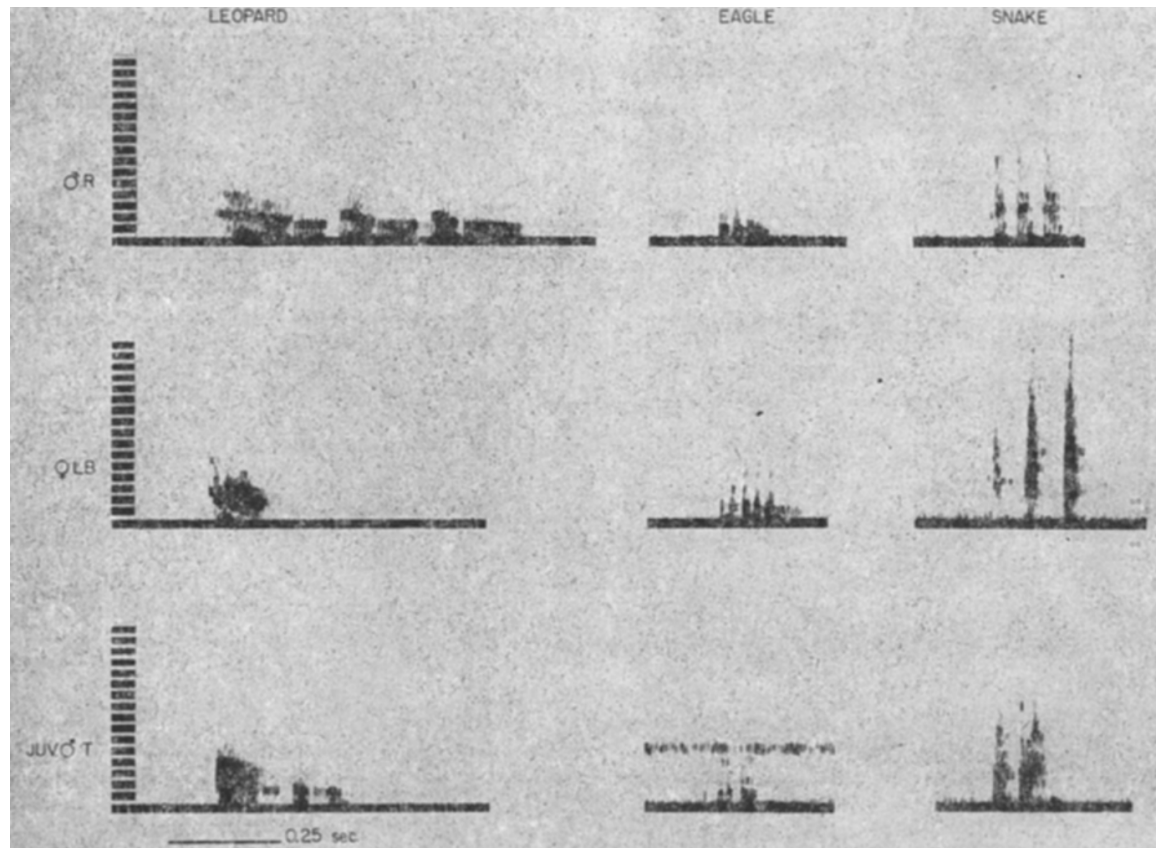
- Gestural communication

- Social bonding (grooming)

- Gossiping



Spectrograms of alarm calls in Vervet monkeys



Seyfarth et al. (1980). Vervet monkey alarm calls: semantic communication in a free-ranging primate.

Question 2: Why did it evolve?

- Vocal communication

- Gestural communication

- Social bonding (grooming)

- Gossiping

- Thinking

- No function (?)

Alarm calls, e.g. in Vervet monkeys

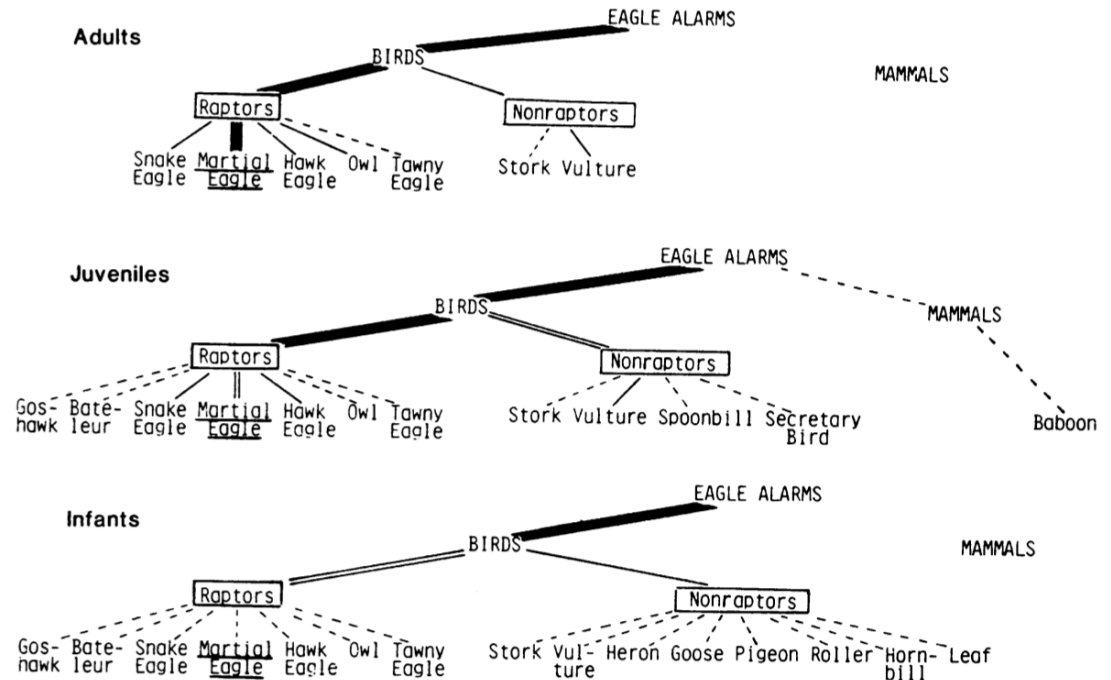


Fig. 1. Eagle alarms given by adult, juvenile, and infant monkeys to different species or objects. Broken line, 1 to 5 alarms; single line, 6 to 10 alarms; double line, 11 to 15 alarms; solid line, more than 15 alarms. Data on 149 alarms were collected over 14 months from 31 adults, 16 juveniles, and 17 infants.

Seyfarth et al. (1980). Monkey responses to three different alarm calls: evidence of predator classification and semantic communication.



<https://www.youtube.com/watch?v=q8ZG8Dpc8mM>

Question 2: Why did it evolve?

- Vocal communication
- **Gestural communication**
- Social bonding (grooming)
- Gossiping
- Deception
- Thinking
- No function (?)



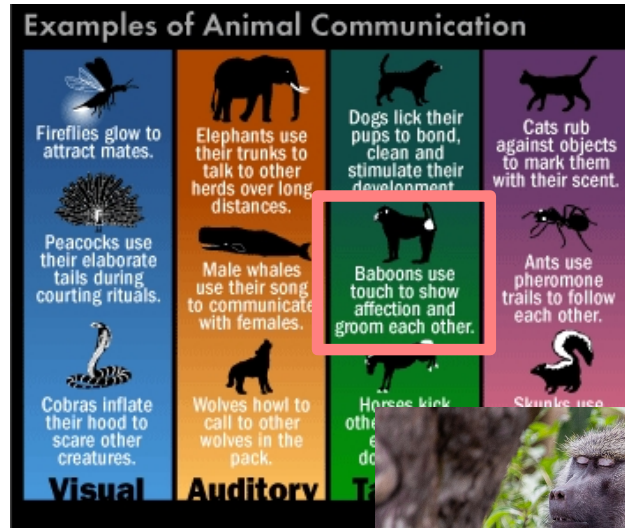
Christiansen & Kirby (2003)
Chapter 10 by Michael A. Arbib
Chapter 11 by Michael C. Corballis



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

Question 2: Why did it evolve?

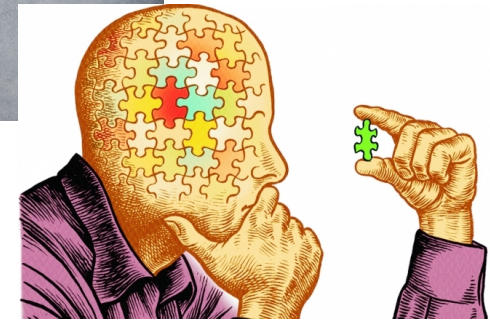
- Vocal communication
- Gestural communication
- **Social bonding (grooming)**
- Gossiping
- Thinking
- No function (?)



Christiansen & Kirby (2003)
Chapter 12 by Robin Dunbar

Question 2: Why did it evolve?

- Vocal communication
- Gestural communication
- Social bonding (grooming)
- Gossiping
- **Thinking**
- No function (?)



... language is not properly regarded as a system of communication. It is a system for expressing thought, something quite different. It can of course be used for communication, as can anything people do—manner of walking or style of clothes or hair, for example. But in any useful sense of the term, communication is not the function of language, and may even be of no unique significance for understanding the functions and nature of language (Chomsky, 2000b, p. 75).

Cited in Pinker & Jackendoff 2005, p. 223

Question 2: Why did it evolve?

- Vocal communication
- Gestural communication
- Social bonding (grooming)
- Gossiping
- Thinking

- No function (?)



Definite Articles

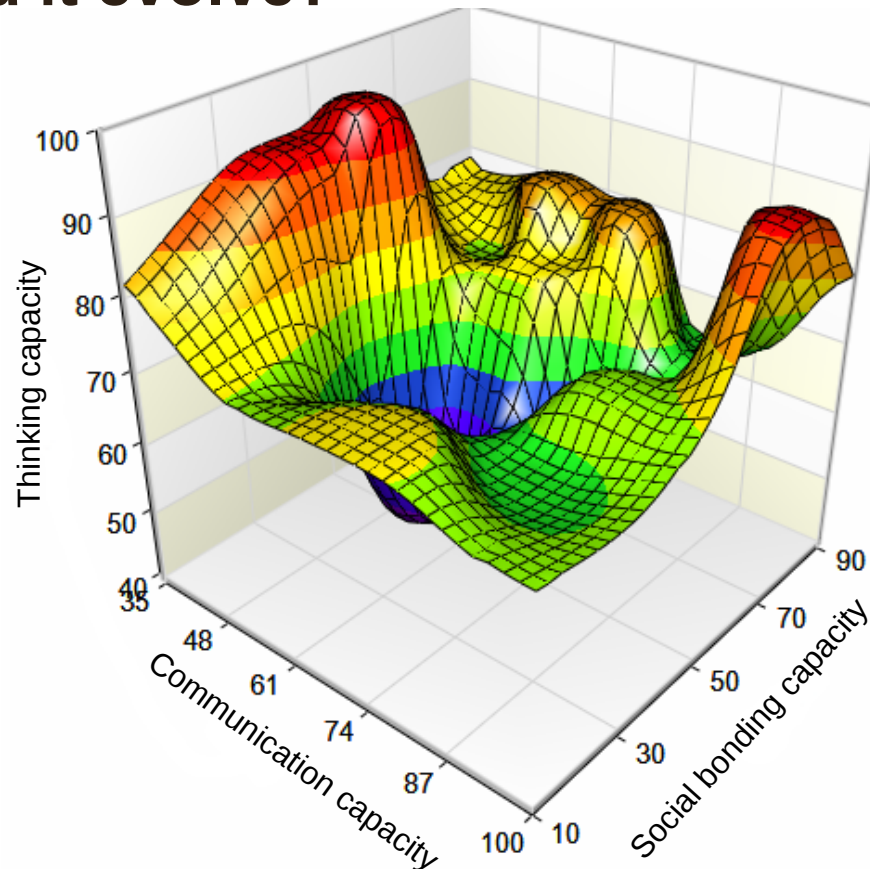
	M	N	F	P
N	er	as	ie	ie
A	en	as	ie	ie
D	em	em	er	en
G	es	es	er	er

Language design as such appears to be in many respects “**dysfunctional**,” yielding properties that are not well adapted to the function language is called upon to perform. ... What we seem to discover are some intriguing and unexpected features of language design ... [which are] unusual among biological systems of the natural world (Chomsky, 1995, p. 162).

Cited in Pinker & Jackendoff 2005, p. 223

Question 2: Why did it evolve?

- Vocal communication
- Gestural communication
- Social bonding (grooming)
- Gossiping
- Thinking
- No function (?)



Does there have to be an either/or answer? Or is it possible that language is located in a multidimensional design space with trade-offs between different functions?



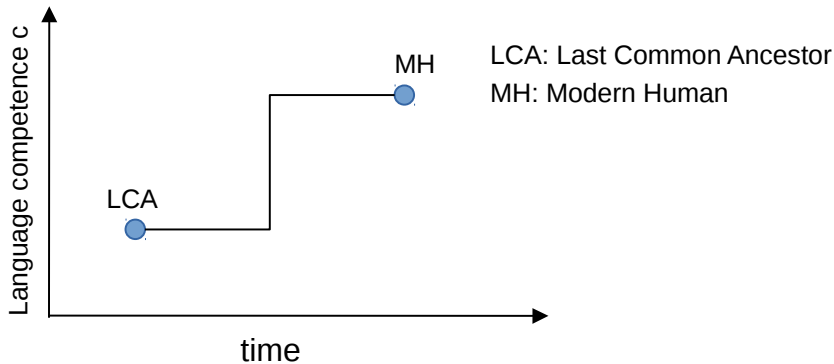
Question 3:

How did language evolve?

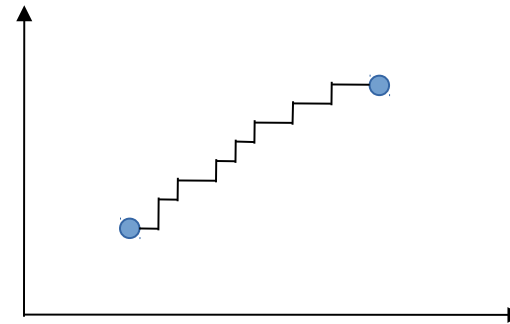
- The Saltational Account
- The Gradual Account
- The Co-Evolution Account

Question 2: How did language evolve?

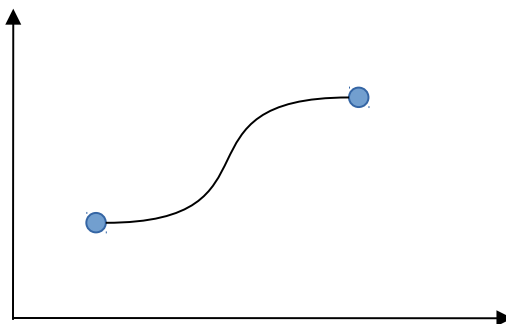
Sudden big jump (saltation)



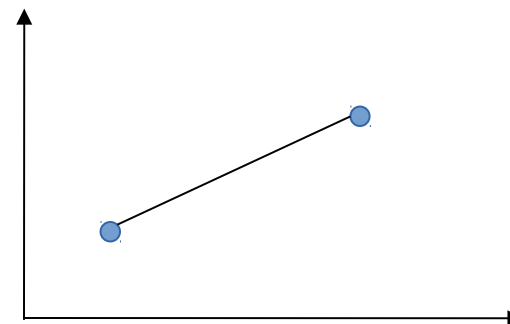
Small jumps (gradual, stepwise)



Continuous change with sudden spurts (variable rate)

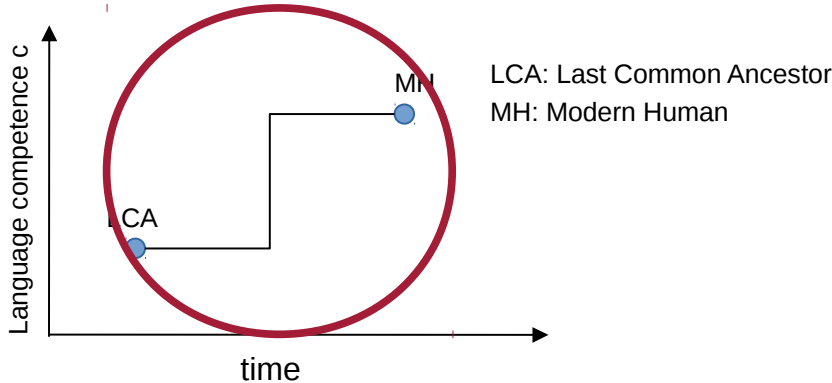


Continuous change (constant rate)

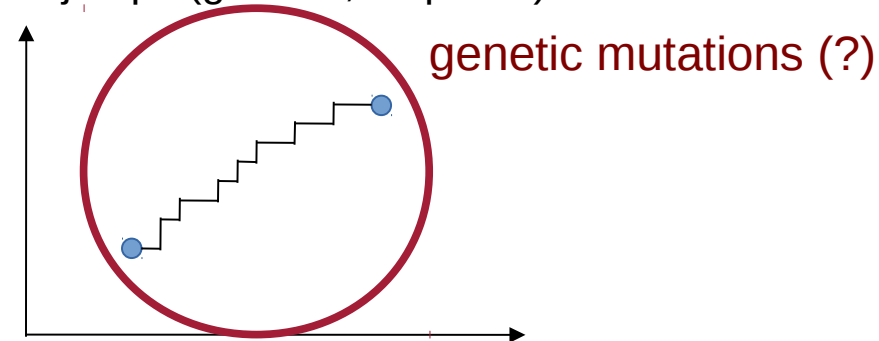


Question 2: How did language evolve?

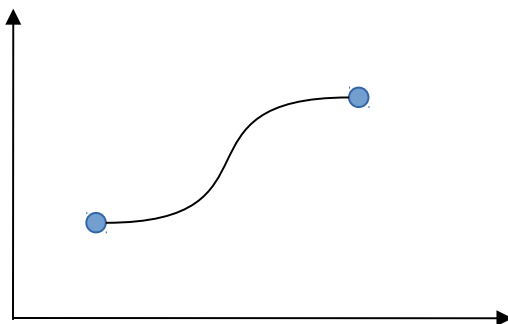
Sudden big jump (saltation)



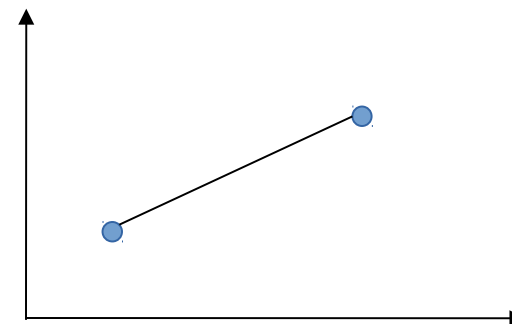
Small jumps (gradual, stepwise)



Continuous change with sudden spurts (variable rate)

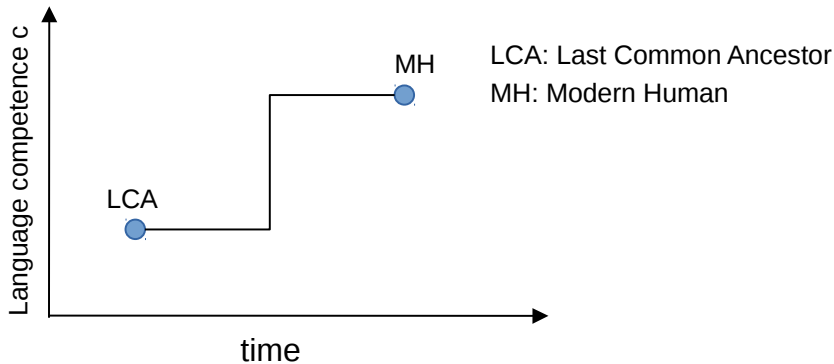


Continuous change (constant rate)

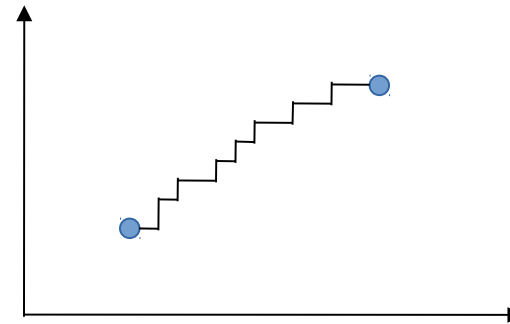


Question 2: How did language evolve?

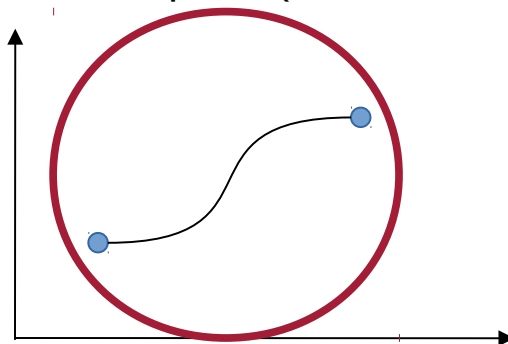
Sudden big jump (saltation)



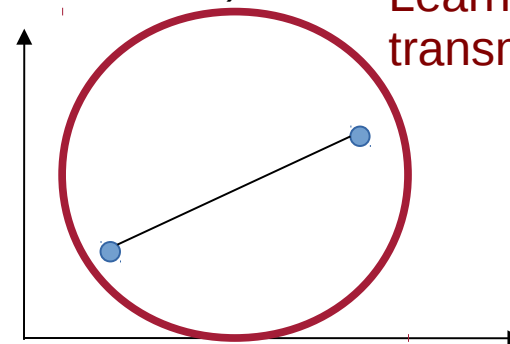
Small jumps (gradual, stepwise)



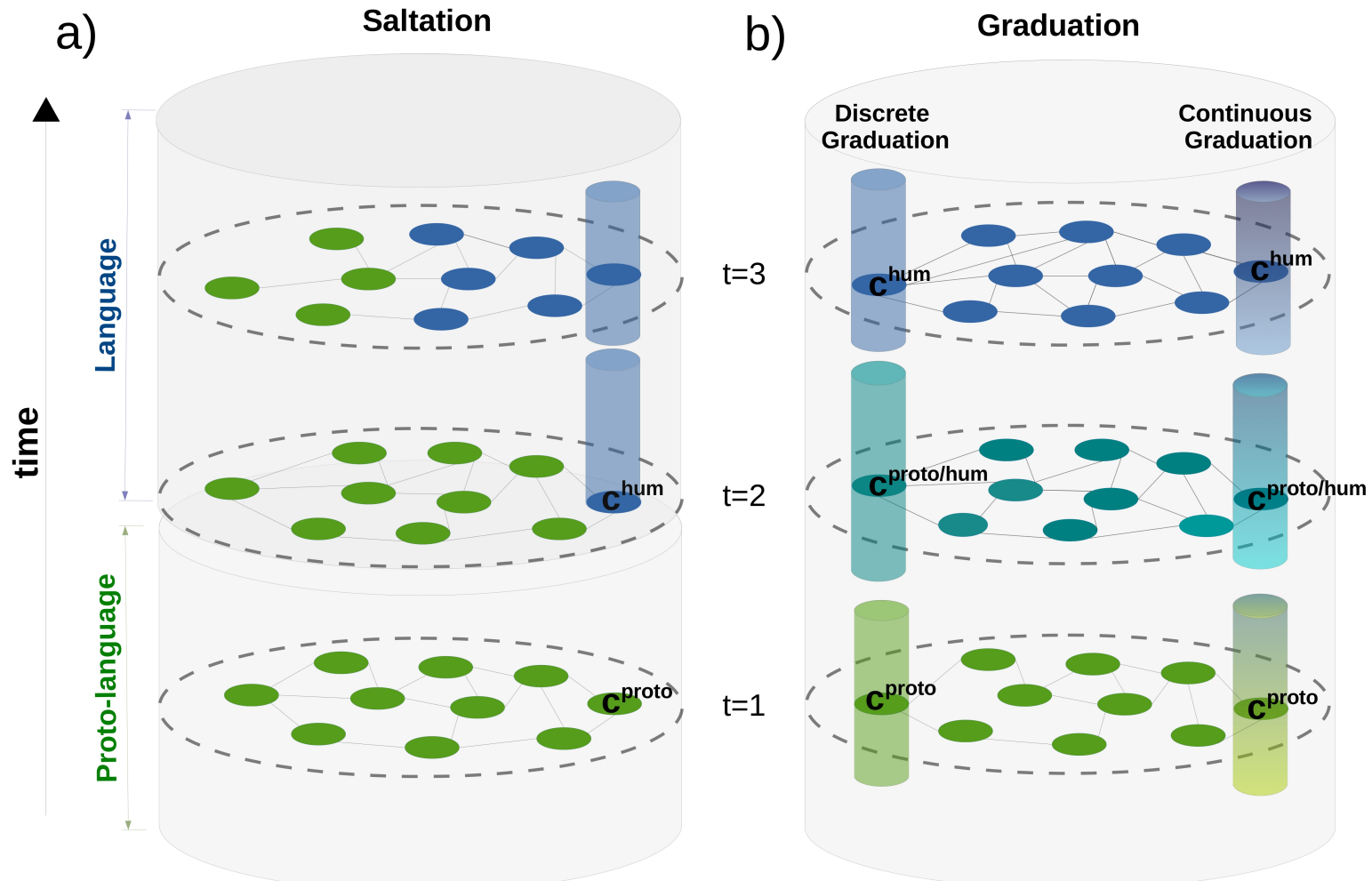
Continuous change with sudden spurts (variable rate)



Continuous change (constant rate)



Learning and cultural transmission (?)



Bentz (2018) Adaptive languages: An information-theoretic account of linguistic diversity.



The Saltational Account

- What is language?

A human specific cognitive ability to process “infinite discreteness”, i.e. recursion (called operation Merge within the Minimalist Program)

- Why did it evolve?

Potentially independent of communication, e.g. for number cognition and/or navigation

- How did it evolve?

Most likely via a sudden mutation (saltation), not necessarily with any adaptive advantage



REVIEW: NEUROSCIENCE

The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?

Marc D. Hauser,^{1*} Noam Chomsky,² W. Tecumseh Fitch¹

Review

Cell
PRESS

Feature Review

Evolution, brain, and the nature of language

Robert C. Berwick¹, Angela D. Friederici², Noam Chomsky³, and Johan J. Bolhuis⁴

OPEN ACCESS Freely available online

PLOS BIOLOGY

Essay

How Could Language Have Evolved?

Johan J. Bolhuis^{1,2*}, Ian Tattersall³, Noam Chomsky⁴, Robert C. Berwick⁵

¹ Cognitive Neurobiology and Helmholtz Institute, Departments of Psychology and Biology, Utrecht University, Utrecht, The Netherlands, ² Department of Zoology and Sidney Sussex College, University of Cambridge, Cambridge, United Kingdom, ³ Division of Anthropology, American Museum of Natural History, New York, New York, United States of America, ⁴ Department of Linguistics and Philosophy, MIT, Cambridge, Massachusetts, United States of America, ⁵ Department of Electrical Engineering & Computer Science and Brain and Cognitive Sciences, MIT, Cambridge, Massachusetts, United States of America

Hauser, Chomsky & Fitch (2002).

Berwick, Friederici, Chomsky, & Bolhuis (2013).

Bolhuis, Tattersall, Chomsky & Berwick (2014).

The Saltational Account

- What is language?

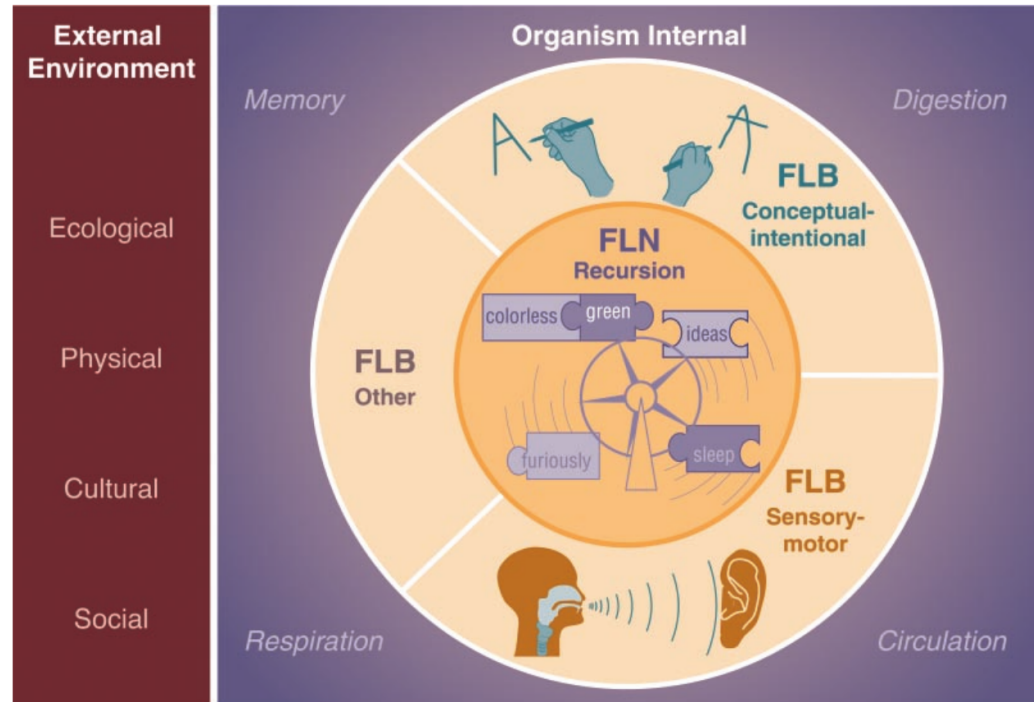
A human specific cognitive ability to process “infinite discreteness”, i.e. recursion (called operation Merge within the Minimalist Program)

- Why did it evolve?

Potentially independent of communication, e.g. for number cognition and/or navigation

- How did it evolve?

Most likely via a sudden mutation (saltation), not necessarily with any adaptive advantage



FLB: Faculty of Language in a **B**road sense, i.e. not human and/or language specific

FLN: Faculty of Language in a **N**arrow sense, i.e. human *and* language specific

Hauser, Chomsky & Fitch (2002).



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The easy way to discrete infinity:

Domain-general example of “tail” recursion:

$(ab)^n$, where n is potentially infinite;
ab, abab, ababab, etc.

Language example: Coordination

$\begin{array}{c} a \quad b \\ \diagdown \quad \diagup \\ \text{Paul swims} \end{array}$

$\begin{array}{c} a \quad b \\ \diagdown \quad \diagup \\ \text{Paul swims} \end{array} \text{ and } \begin{array}{c} a \quad b \\ \diagdown \quad \diagup \\ \text{Mary runs} \end{array}$

$\begin{array}{c} a \quad b \\ \diagdown \quad \diagup \\ \text{Paul swims} \end{array} \text{ and } \begin{array}{c} a \quad b \\ \diagdown \quad \diagup \\ \text{Mary runs} \end{array} \text{ and } \begin{array}{c} a \quad b \\ \diagdown \quad \diagup \\ \text{Isa jumps} \end{array}$

etc.



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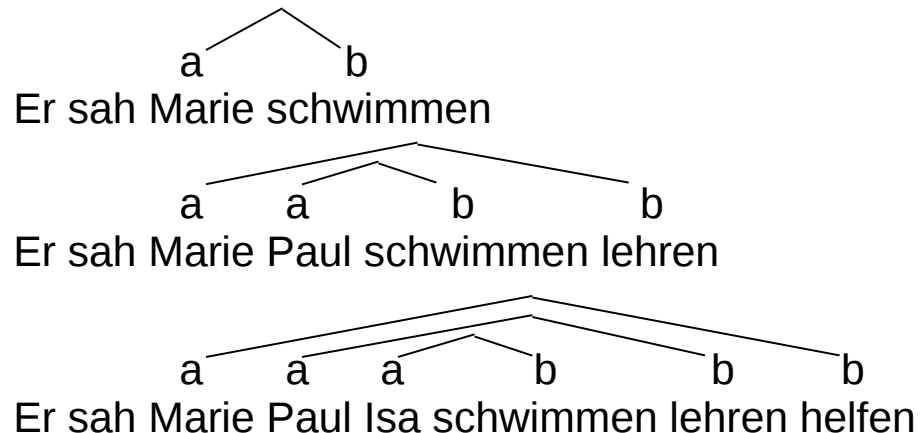
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The difficult way to discrete infinity:

Domain-general example of “true” recursion:

$a^n b^n$, where n is potentially infinite;
ab, aabb, aaabbb, etc.

Language example:



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RESEARCH ARTICLE

A Corpus Investigation of Syntactic Embedding in Pirahã

Richard Futrell^{1*}, Laura Stearns¹, Daniel L. Everett², Steven T. Piantadosi³, Edward Gibson¹

¹ Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA, United States of America, ² Dean of Arts and Sciences, Bentley University, Waltham, MA, United States of America, ³ Department of Brain and Cognitive Sciences, University of Rochester, Rochester, NY, United States of America



Language without recursion?

“Our analysis has failed to find strong support for syntactically embedded structures in Pirahã. We emphasize that any conclusions that can be drawn from this corpus evidence must be highly tentative, due to the difficulty of working with a language whose speakers are so difficult to access, as well as the computational challenges of characterizing linguistic complexity.”

Futrell, Stearns, Everett, Piantadosi & Gibson (2016).



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“The quality of language that makes it unique does not seem to be so much its role in communicating directives for action” or other common features of animal communication, Jacob continued, but rather “its role in symbolizing, in evoking cognitive images,” in “molding” our notion of reality and yielding our capacity for thought and planning,” [...]

Jacob (1982) cited in:
Chomsky (2005). Three factors in language design.

“A complex train of thought can be no more carried out without the use of words, whether spoken or silent, than a long calculation without the use of figures or algebra”

Charles Darwin cited in:
Bolhuis et al. (2014)



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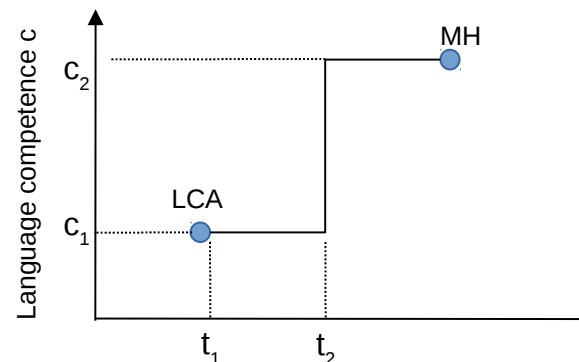
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“The simplest account of the “Great Leap Forward” in the evolution of humans would be that the brain was rewired, perhaps by some slight mutation, to provide the operation Merge, at once laying a core part of the basis for what is found at that dramatic “moment” of human evolution” [...]

Chomsky (2005). Three factors in language design.

Sudden big jump (saltation)



In Bolhuis et al. (2014) the point in time t is speculated to be around 200 000 to 80 000 years ago based on the appearance of modern *Homo sapiens* and the earliest symbolic finds in Blombos cave (South Africa)

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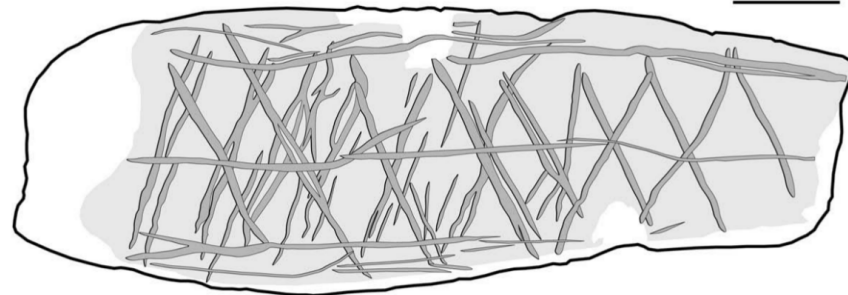
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Think about it...



Does this represent “discrete infinity”, “tail recursion”, or “true recursion”?



The Gradual Account

- What is language?

A toolbox of different cognitive abilities specific to humans and language (FLN)

- Why did it evolve?

Most likely as an adaptation for more explicit communication of complex propositions

- How did it evolve?

Gradually via several mutations and selection (here called discrete graduation)

BEHAVIORAL AND BRAIN SCIENCES (1990) 13, 707–784
Printed in the United States of America

Natural language and natural selection

Steven Pinker^a and Paul Bloom^b

^aDepartment of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139 and ^bDepartment of Psychology, University of Arizona, Tucson, AZ 85721

Electronic mail: ^asteve@psyche.mit.edu and ^bbloom@rvax.ccit.arizona.edu

Pinker & Bloom (1990)
Pinker & Jackendoff (2005)



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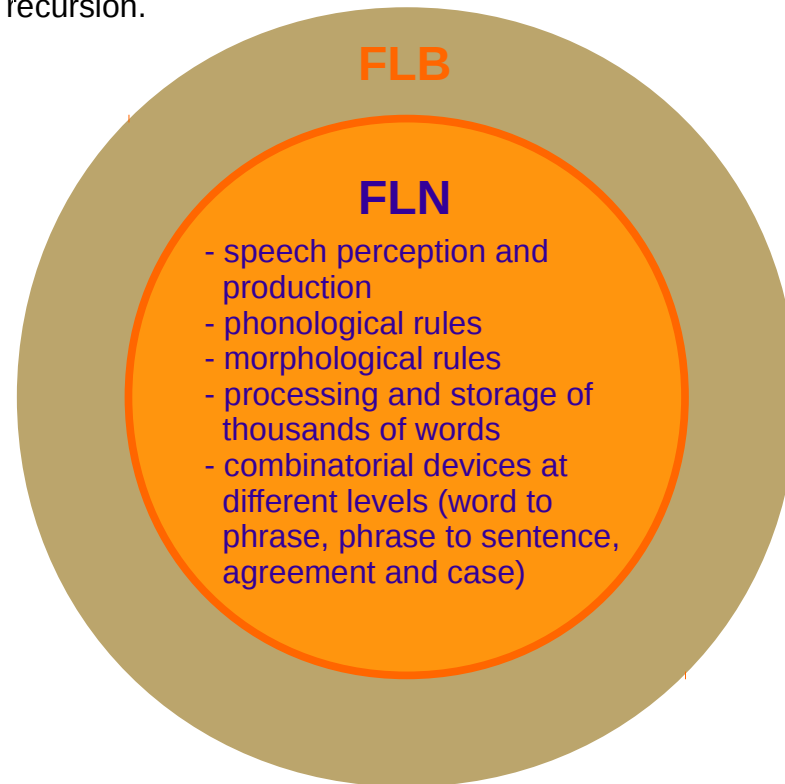
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“Language” is mainly the FLN – in agreement with Hauser, Chomsky and Fitch (2002). However, the FLN is much richer, i.e. contains many more human and language specific properties, not just some form of recursion.



Pinker & Jackendoff (2005)

The Gradual Account

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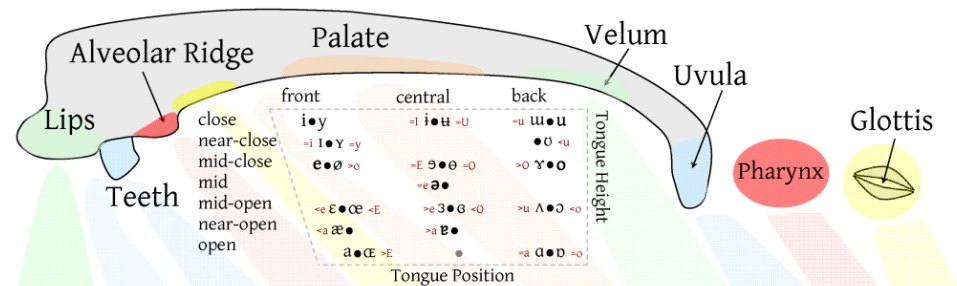
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Example: Speech perception and production



CONSONANTS	Bilabial	Labiodental	Dental	Alveolar	Post-alveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p	b	t̪ t͡ʃ t̬ t̚	d d̪ d͡ʒ d̬ d̚	t	ɖ	c	k	q		ʔ
Nasal	m	ɱ >m	n n̪ n͡ɟ n̬ n̚			ɳ >n	ɲ >n	ŋ >n	ɴ =N		
Trill				r					ʀ =R		
Flap				ɾ >r		ɽ <r					
Fricative	f =f β =b	v	θ =t ð =d	s z	ʃ =s ʒ =z	ʂ =s ʐ =z	ç =c ʝ =j	x	χ =x ʁ =R	ħ >h ʕ <ʔ	h ḥ -h
Lateral Fric.				ɬ =l ɮ =l							
Lateral Appr.				ɭ		ɻ <l		ɭ =L			
Approximant	ɹ =w w*	ʋ =v		j =r		ɻ =R	j	ɯ =w w*			
Vowel (above)							e ə o u				
Implosive	ɓ >b			ɗ >d			ɟ =j	ɡ =g	ɠ =G		
Click	ǀ =p		ǃ ??		ǁ						

Lateral flap: ɬ >L. Other symbols: ʰ pʰ ʳ nʳ p̣ p̣|| ṭ ṭ< ẹ ẹ|| ṃ ṃ& ṭ ṭ&#s



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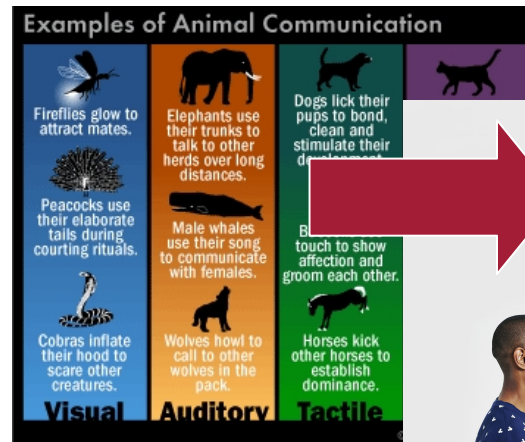
As an adaptation for more explicit communication of complex propositions

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“Moreover the design of language – a mapping between meaning and sound – is precisely what one would expect in a system that **evolved for the communication of propositions**. We cannot convey recipes, hunting techniques, gossip, or reciprocal promises by “manner of walking or style of clothes or hair,” because these forms of behavior lack grammatical devices that allow propositions to be encoded in a recoverable way in details of the behavior.”

Pinker and Jackendoff (2005), p. 224.



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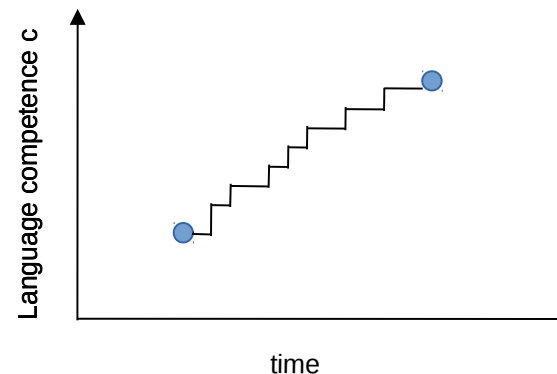
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“[...] the language faculty evolved gradually in response to the adaptive value of more precise and efficient communication [...]. Gradual emergence implies that later stages had to build on earlier ones in the contingent fashion characteristic of natural selection [...]”

Pinker and Jackendoff (2005), p. 223.

Small jumps



Pinker & Jackendoff use the terms “piecemeal” and “gradually”, this could probably also be called “stepwise”. Strictly speaking this is still different from a continuous evolution, as it involves discrete mutations that might be selected for.



The Co-Evolution Account

- What is language?

The empirical sounds, graphemes and signs produced and used by a speaker, hearer, or signer population

- Why did it evolve?

As a communicative and social tool (similar to the gradual account)

- How did it evolve?

In a continuous co-evolution of the human brain and the empirical usage data

BEHAVIORAL AND BRAIN SCIENCES (2008) 31, 489–558
Printed in the United States of America
doi:10.1017/S0140525X08004998

Language as shaped by the brain

Morten H. Christiansen

Department of Psychology, Cornell University, Ithaca, NY 14853, and Santa Fe Institute, Santa Fe, NM 87501
christiansen@cornell.edu
<http://www.psych.cornell.edu/people/Faculty/mhc27.html>

Nick Chater

Division of Psychology and Language Sciences, University College London, London, WC1E 6BT, United Kingdom
n.chater@ucl.ac.uk
<http://www.ucl.ac.uk/psychlangsci/people/nick.htm>

Language Is a Complex Adaptive System: Position Paper

The “Five Graces Group”

Clay Beckner

University of New Mexico

Nick C. Ellis

University of Michigan

Richard Blythe

University of Edinburgh

John Holland

Santa Fe Institute; University of Michigan

Joan Bybee

University of New Mexico

Jinyun Ke

University of Michigan

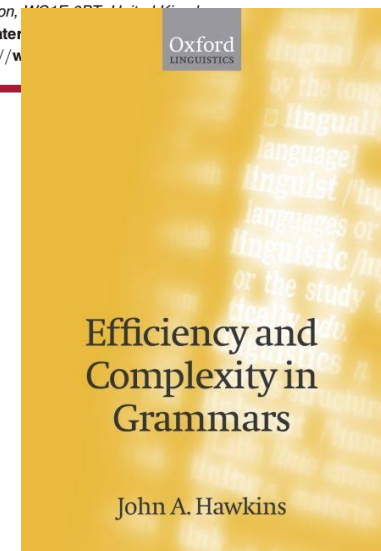
Morten H. Christiansen

Cornell University

Diane Larsen-Freeman

University of Michigan

Christiansen & Kirby (2003). Chapter 15.
Hawkins (2004)
Christiansen & Chater (2008)
Beckner et al. (2009)



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We propose [...] to invert the perspective on language evolution, shifting the focus from the evolution of *language users* to the evolution of *languages*.

[...] linguistic adaptation allows for the evolution of increasingly expressive languages that can nonetheless still be learned and processed by domain-general mechanisms.

Christiansen & Chater (2008), p. 497



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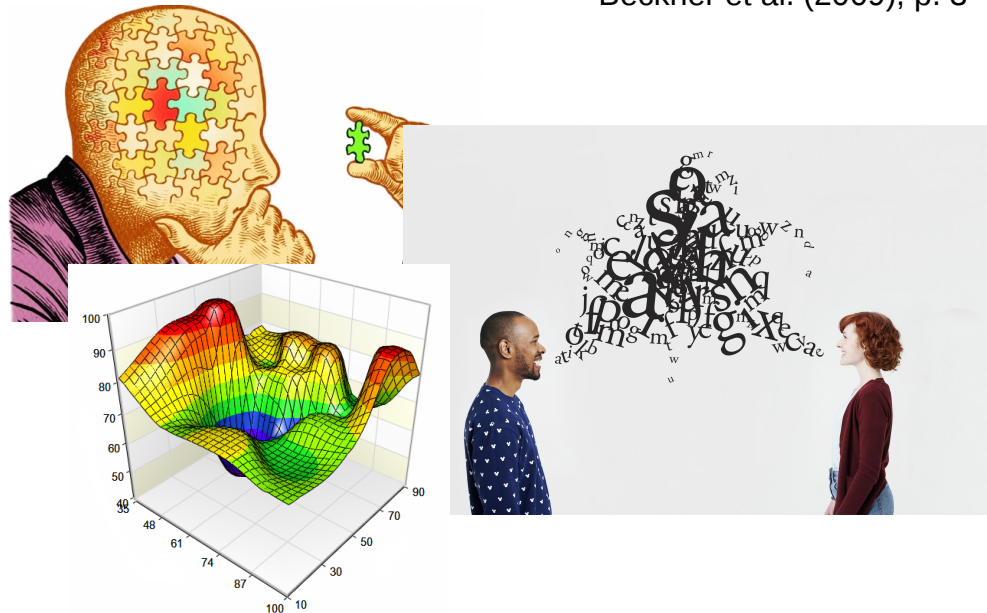
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Language is used for **human social interaction**, and so its origins and capacities are dependent on its role in our social life [...]

To understand how language has evolved in the human lineage [...] we need to look at the combined effect of many **interacting constraints**, including the structure of thought processes, perceptual and motor biases, cognitive limitations, and socio-pragmatic factors.

Beckner et al. (2009), p. 3



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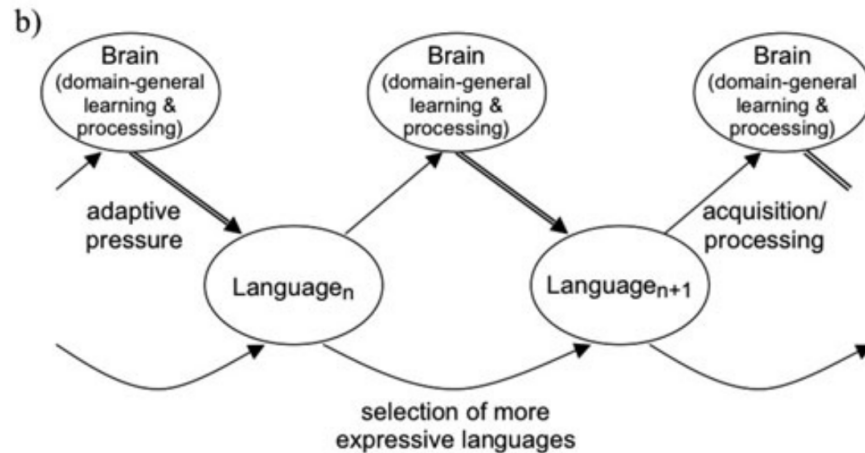
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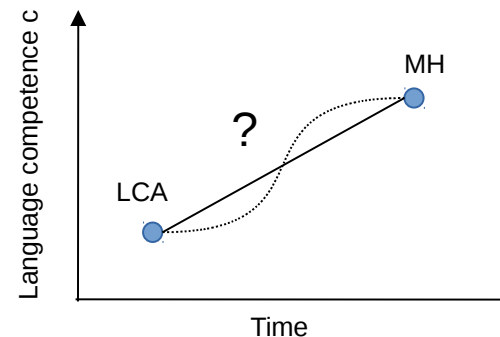
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Christiansen & Chater (2008)

Continuous change with or without sudden spurts





Summary: Models of Language Evolution

Is language more like growing a wing or more like learning to play chess?



Saltational Account



Gradual Account



Co-evolution Account





Contact:

DFG Center for Advanced Studies

“Words, Bones, Genes, Tools”

Rümelinstraße 23

72070 Tübingen · Germany

Phone: +49 7071 29-76548

monika.doll@ifu.uni-tuebingen.de