Kognitionspsychologie: Session 6
Language

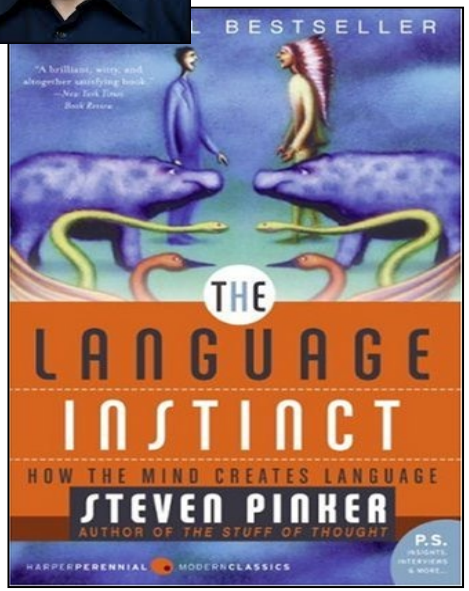
Rui Mata, HS2025

Version: November 11, 2025

Learning Objectives

- Discuss whether language should be seen as instinct vs. cultural artifact; be aware of historical changes in psychology's theorising about language
- Discuss the **adaptive significance** of language in the past and today
- Learn how **comparative approaches** to language acquisition and linguistic performance suggest a role for evolution in the origins of language
- Learn about **developmental patterns** (sensitive/critical periods) in the acquisition of language and how this provides support for the role of biological preparedness for language acquisition
- Learn about modern **neural and computational model**(s) of language, including its some of its different components and associated breakdown patterns (aphasia)

Language: Instinct vs. cultural artifact



1994

“Language is not a cultural artifact that we learn the way we learn to tell time or how the federal government works. Instead, it is a distinct piece of the biological makeup of our brains. Language is a complex, specialized skill, which develops in the child spontaneously, without conscious effort or formal instruction, is deployed without awareness of its underlying logic, is qualitatively the same in every individual, and is distinct from more general abilities to process information or behave intelligently. For these reasons some cognitive scientists have described language as a psychological faculty, a mental organ, a neural system, and a computational module. But I prefer the admittedly quaint term "instinct." It conveys the idea that people know how to talk in more or less the sense that spiders know how to spin webs. Web-spinning was not invented by some unsung spider genius and does not depend on having had the right education or on having an aptitude for architecture or the construction trades. Rather, spiders spin spider webs because they have spider brains, which give them the urge to spin and the competence to succeed.” (p. 18)

Language: Instinct vs. cultural artifact

It became clear(er) across the last decades that human languages are cultural products ruled by cultural transmission and not (just) biological universals…

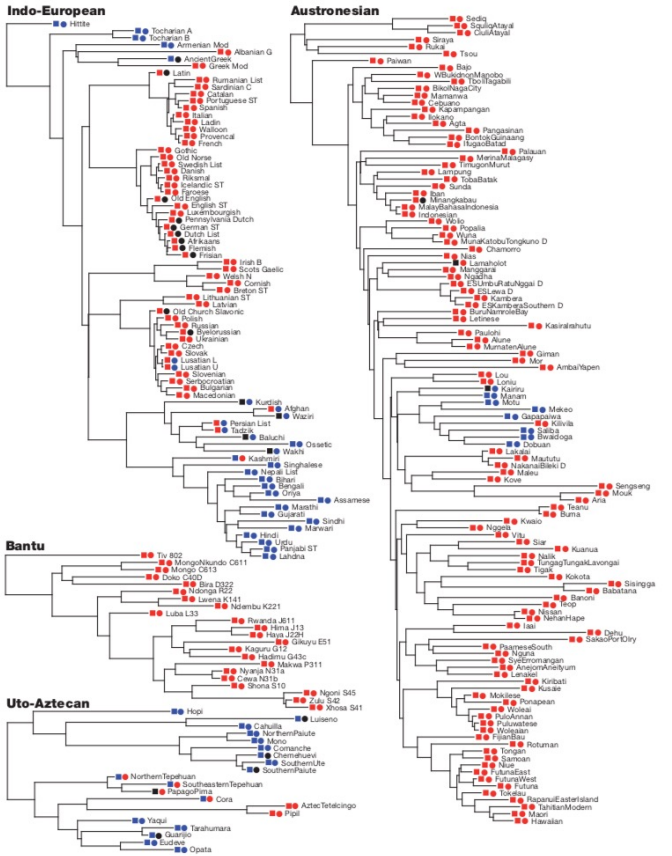


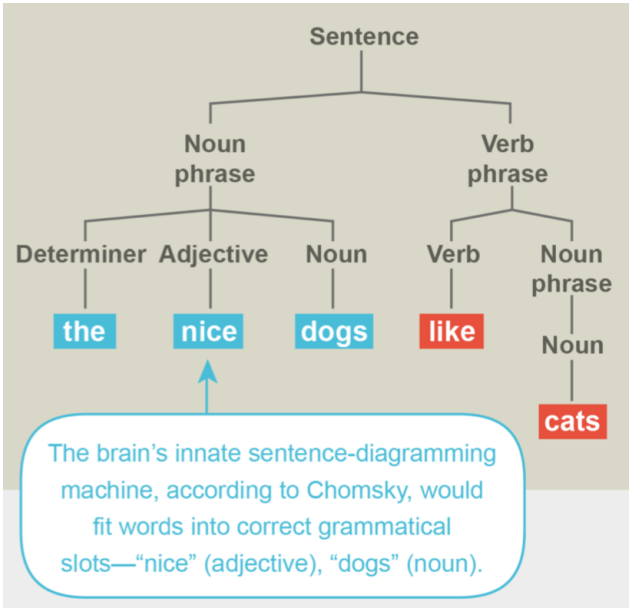
Figure 1 | **Two word-order features plotted onto maximum clade credibility trees of the four language families.** Squares represent order of adposition and noun; circles represent order of verb and object. The tree sample underlying this tree is generated from lexical data[16,22]. Blue–blue indicates postposition, object–verb. Red-red indicates preposition, verb–object. Red-blue indicates preposition, object–verb. Blue-red indicates postposition, verb–object. Black indicates polymorphic states.

"Generative linguists following Chomsky have claimed that linguistic diversity must be constrained by innate parameters that are set as a child learns a language. In contrast, other linguists following Greenberg have claimed that there are statistical tendencies for co-occurrence of traits reflecting universal systems biases, rather than absolute constraints or parametric variation. Here we use computational phylogenetic methods to address the nature of constraints on linguistic diversity in an evolutionary framework. First, contrary to the generative account of parameter setting, we show that the evolution of only a few word-order features of languages are strongly correlated. Second, contrary to the Greenbergian generalizations, **we show that most observed functional dependencies between traits are lineage-specific rather than universal tendencies**. These findings support the view that—at least with respect to word order—cultural evolution is the primary factor that determines linguistic structure, with the current state of a linguistic system shaping and constraining future states."

Dunn, M., Greenhill, S. J., Levinson, S. C., & Gray, R. D. (2011). Evolved structure of language shows lineage-specific trends in word-order universals. Nature, 473(7345), 79–82. http://doi.org/10.1038/nature09923

Psychology of Language: From UG to Usage-based learning

Chomsky's Universal Grammar (UG)



UG assumes children are equipped with a grammatical template, that is, a set of rules that work on and transform phrases

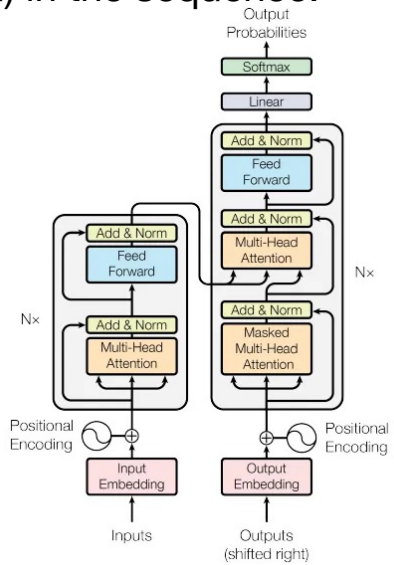
Usage-based learning (UbL)

UbL assumes a number of "instincts" (e.g., theory of mind, general learning mechanisms for categorization, analogical thinking) that allow children to learn patterns of usage that lead to grammatical regularities

Ibbotson, P., & Tomasello (2016). What"s universal grammar? Evidence rebuts Chomsky's theory of language learning. *Scientific American*.

Does ChatGPT refute Chomsky's claims about language?

ChatGPT relies on transformers (a type of neural network with many layers that track how units relate to each other in sequences). It's mainly trained through token prediction, for example, the model sees part of a sentence and learns by trying to guess the next word (or piece of a word) in the sequence.



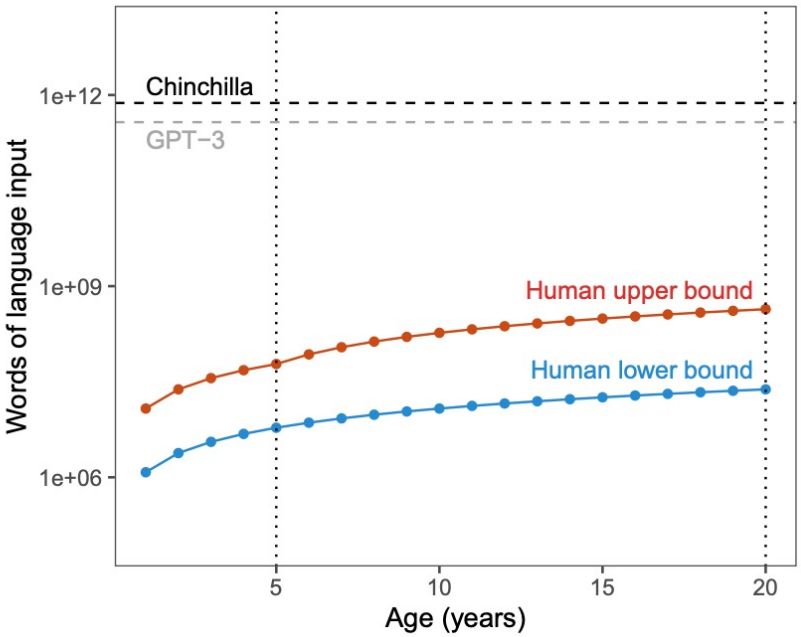
Explain how large language models undermine Chomsky's main claims about linguistics.
Noam Chomsky is a prominent linguist and philosopher who has made significant contributions to the field of linguistics and language theory. He has put forward the idea that language is an innate, biologically determined ability that is unique to humans, and that all humans possess a universal grammar, or a set of innate linguistic rules that allow us to understand and produce language. However, the development of large language models like GPT-3 has challenged some of Chomsky's main claims about linguistics and the nature of language. First, the fact that language models can be trained on large amounts of text data and can generate human-like language without any explicit instruction on grammar or syntax suggests that language may not be as biologically determined as Chomsky has claimed. Instead, **it suggests that language may be learned and developed through exposure to language and interactions with others**. (…).

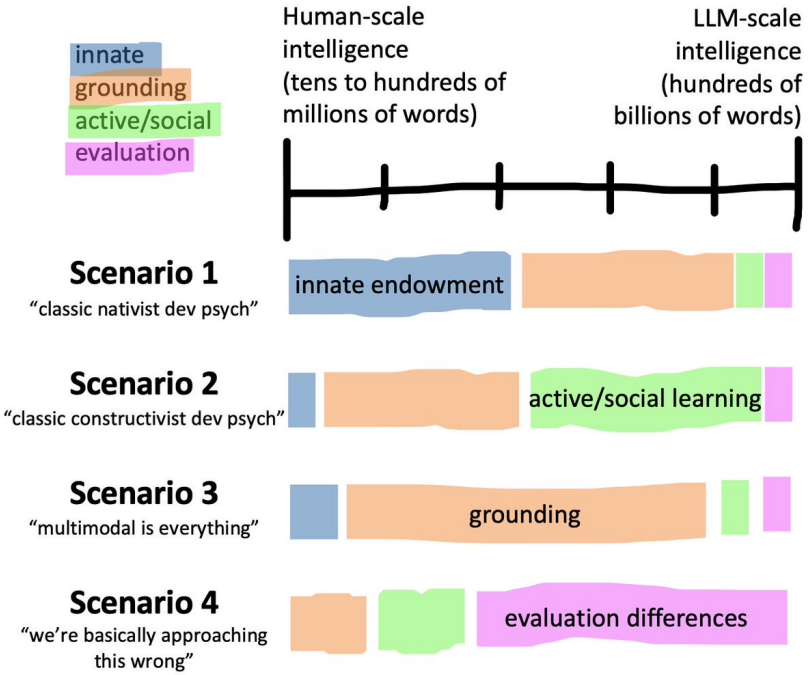
generated with ChatGPT

Piantadosi, S. T. (2023). Modern language models refute Chomsky's approach to language. https://lingbuzz.net/lingbuzz/007180

Hussain, Z., Binz, M., Mata, R. & Wulff, D (2024). A tutorial on open-source large language models for behavioral science. Behav Res 56, 8214–8237. https://doi.org/10.3758/s13428-024-02455-8

Does ChatGPT refute Chomsky's claims about language?





Frank (2023) lists different hypotheses…
Innate Endowment: Humans are born with foundational knowledge that aids quick language learning;
Grounding: unlike LLMs that rely solely on text, humans learn language through sensory experiences and physical interaction
Active/Social Learning: Human language learning is interactive and adapted to social context, LLMs learn from static data;
Evaluation Differences: Humans and LLMs are assessed differently, possibly skewing performance comparisons.

Frank, M. C. (2023). Bridging the data gap between children and large language models. Trends in Cognitive Sciences, S1364661323002036. https://doi.org/10.1016/j.tics.2023.08.007

Language

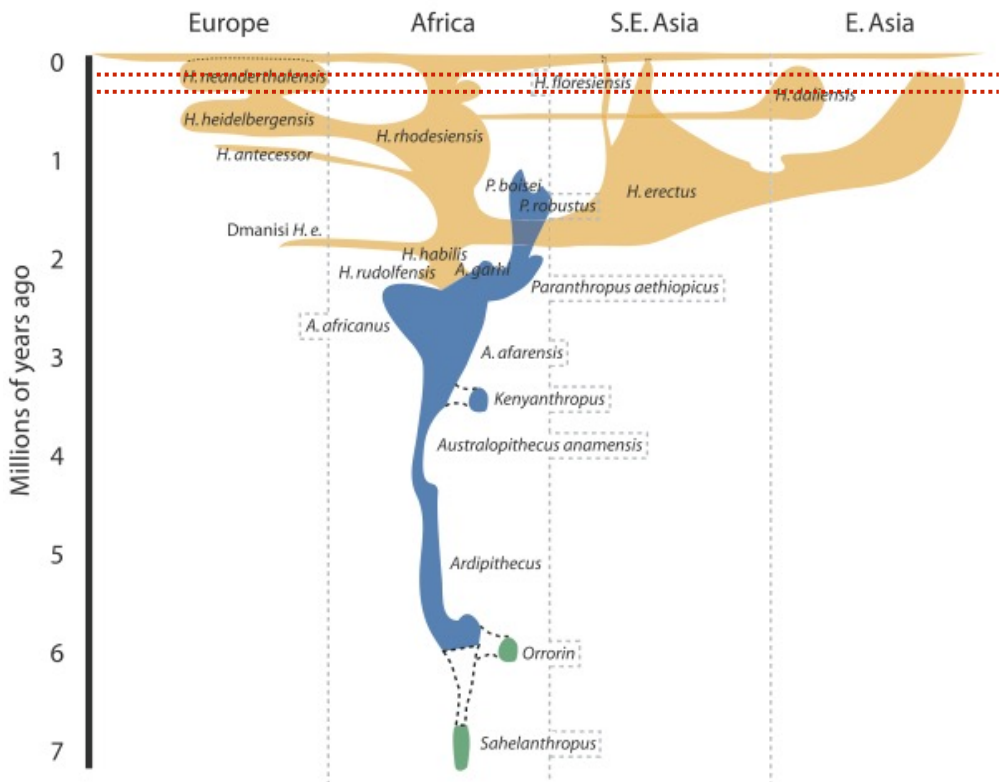
Ontogeny

Mechanism

Phylogeny

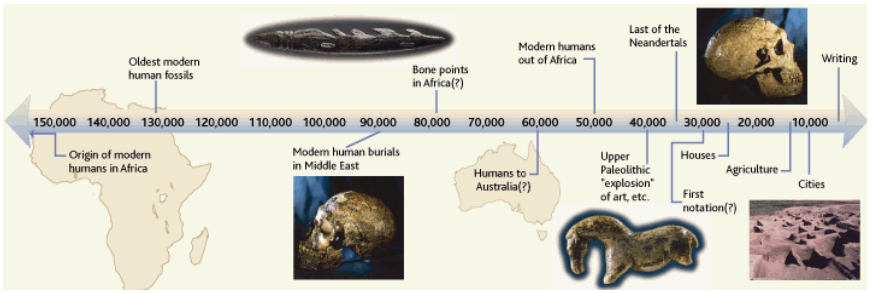
Adaptive Significance

Adaptive significance of language: Natural selection



~5,000 years: writing
~50,000 to 100,000 years: appearance of modern human bodies (vocal tract) and behavior (symbolic behavior)
~200,000 years: early Homo sapiens

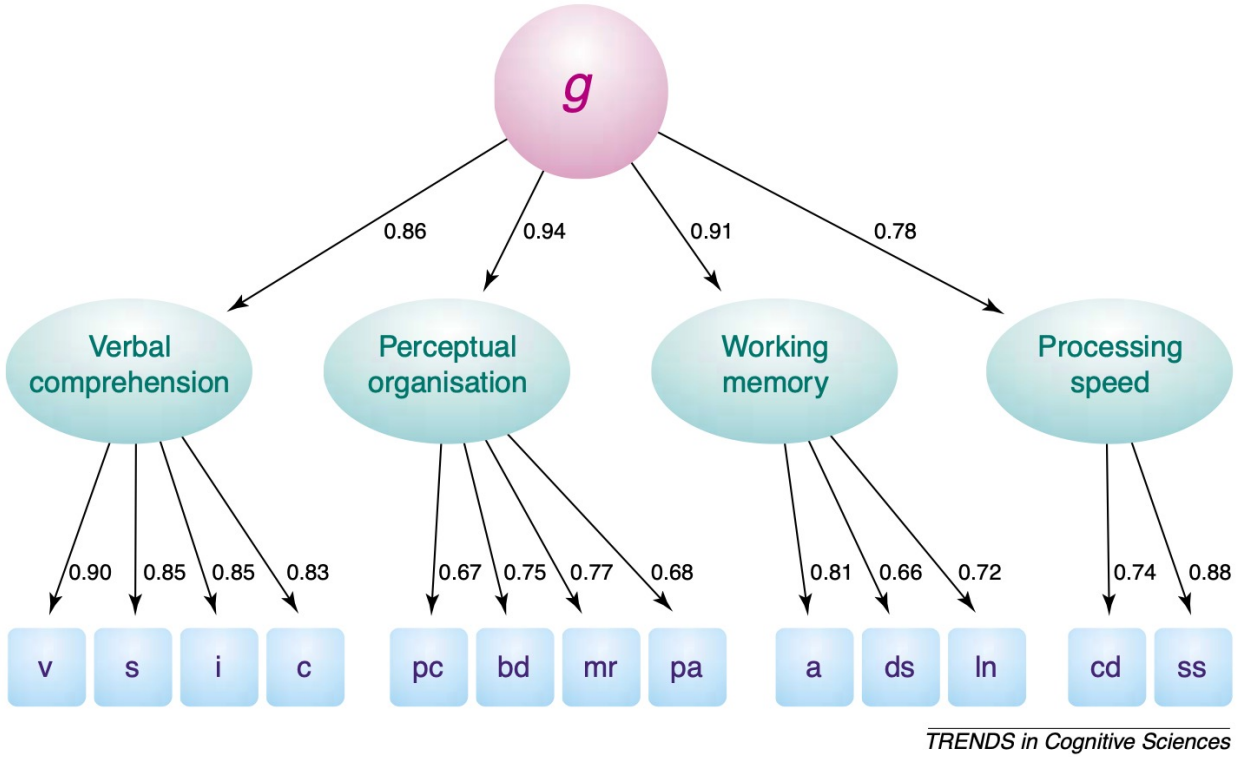
Out-of-Africa-Theory



"It was only in our reconstruction of the most recent fossil specimens—the modern humans postdating 50,000 years— that we identified an anatomy that could have accommodated a fully modern, equally proportioned vocal tract. Interestingly, the date of these specimens coincides with the appearance of the Upper Paleolithic tool kit, (…) associated with a florescence in modern human cognitive capacities."

Lieberman, P., & McCarthy, R.C (2007). Tracking the evolution of language and speech: Comparing vocal tracts to identify speech capabilities. ***Expedition Magazine, 49***, 15-20

Adaptive significance of language



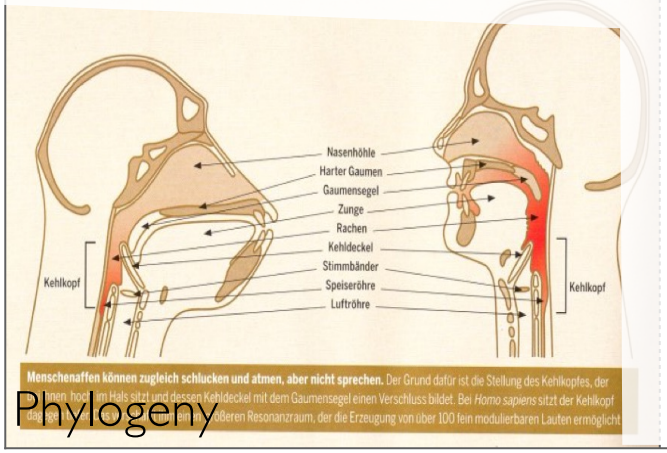
Verbal comprehension is strongly related to intellectual function (g) and other important life outcomes (e.g., academic achivement, occupational attainment)

Deary, I.J. (2001). Human intelligence differences: A recent history. *Trends in Cognitive Sciences, 5*, 127–130.

Language

Ontogeny

Mechanism



Adaptive Significance

Human language is different from animal communication

Characteristics that distinguish human language from animal communication?

- Spatial and temporal displacement (but compare to bees' ability to express direction and distance)

- Use of arbitrary symbols (but compare to dogs' ability to map human words to objects)

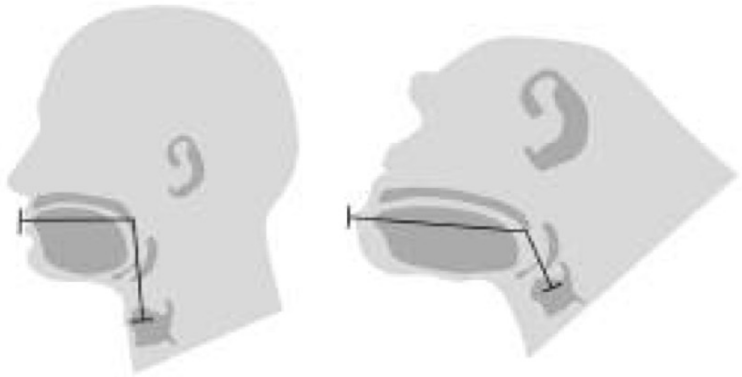
- Productivity and recursion (but compare to non-human primates' ability to understand sentences and sign-language)

Productivity
a general term in linguistics for the limitless ability to use language to say new things,also known as ***open-endedness*** or ***creativity***.

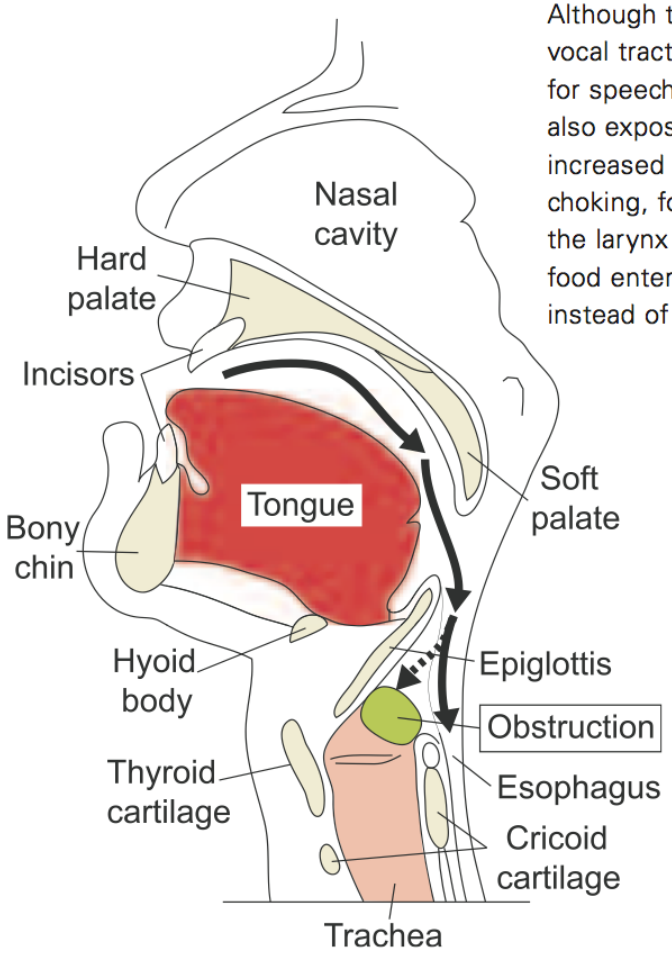
Recursion
the process of repeating items in a self-similar way. The application of recursion in language refers to the repeated use of the syntactic units in such a way that a potentially infinite chain of words can be produced.

Human language is different from animal communication

Anatomical adaptations: Vocal tract



L-shaped vocal tract (supralaryngeal vocal tract)



Although the adult human vocal tract is advantageous for speech production, it also exposes us to an increased risk of death by choking, for example, when the larynx gets blocked by food entering the trachea instead of the esophagus.

Lieberman, P., & McCarthy, R.C (2007). Tracking the evolution of language and speech: Comparing vocal tracts to identify speech capabilities. ***Expedition Magazine, 49***, 15-20

Human language is different from animal communication

Cognitive adaptations: Theory of Mind? Categorization? Recursion?

Kanzi (bonobo)

Washoe (chimpanzee)

"(…) Laura-Ann Petitto, one of the leading researchers of primate communication and early language acquisition, observes that a chimpanzee uses the label for 'apple' to refer to 'the action of eating apples, the location where apples are kept, events and locations of objects other than apples that happened to be stored with an apple (the knife used to cut it), and so on and so forth – all simultaneously, and without apparent recognition of the relevant differences or the advantages of being able to distinguish among them"

Berwick, R. C., Friederici, A. D., Chomsky, N., & Bolhuis, J. J. (2013). Evolution, brain, and the nature of language. Trends in Cognitive Sciences, 17(2), 91–100.

TED
Ideas worth spreading

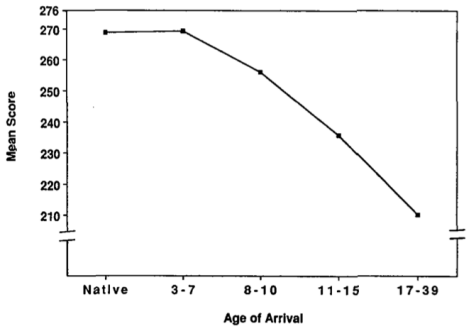
http://www.ted.com/talks/susan_savage_rumbaugh_on_apes_that_write

Gardner, R.A. & Gardner, B.T. (1969). Teaching sign language to a chimpanzee, ***Science 165***, 664-672.

Savage-Rumbaugh, S., & Lewin, R., (1994). ***Kanzi: The Ape at the Brink of the Human Mind***. Wiley.

Language

Ontogeny



Mechanism

Phylogeny

Menschenaffen können zugleich schlucken und atmen, aber nicht sprechen. Der Grund dafür ist die Stellung des Kehlkopfes, der

Adaptive Significance

Language shows a typical developmental pattern

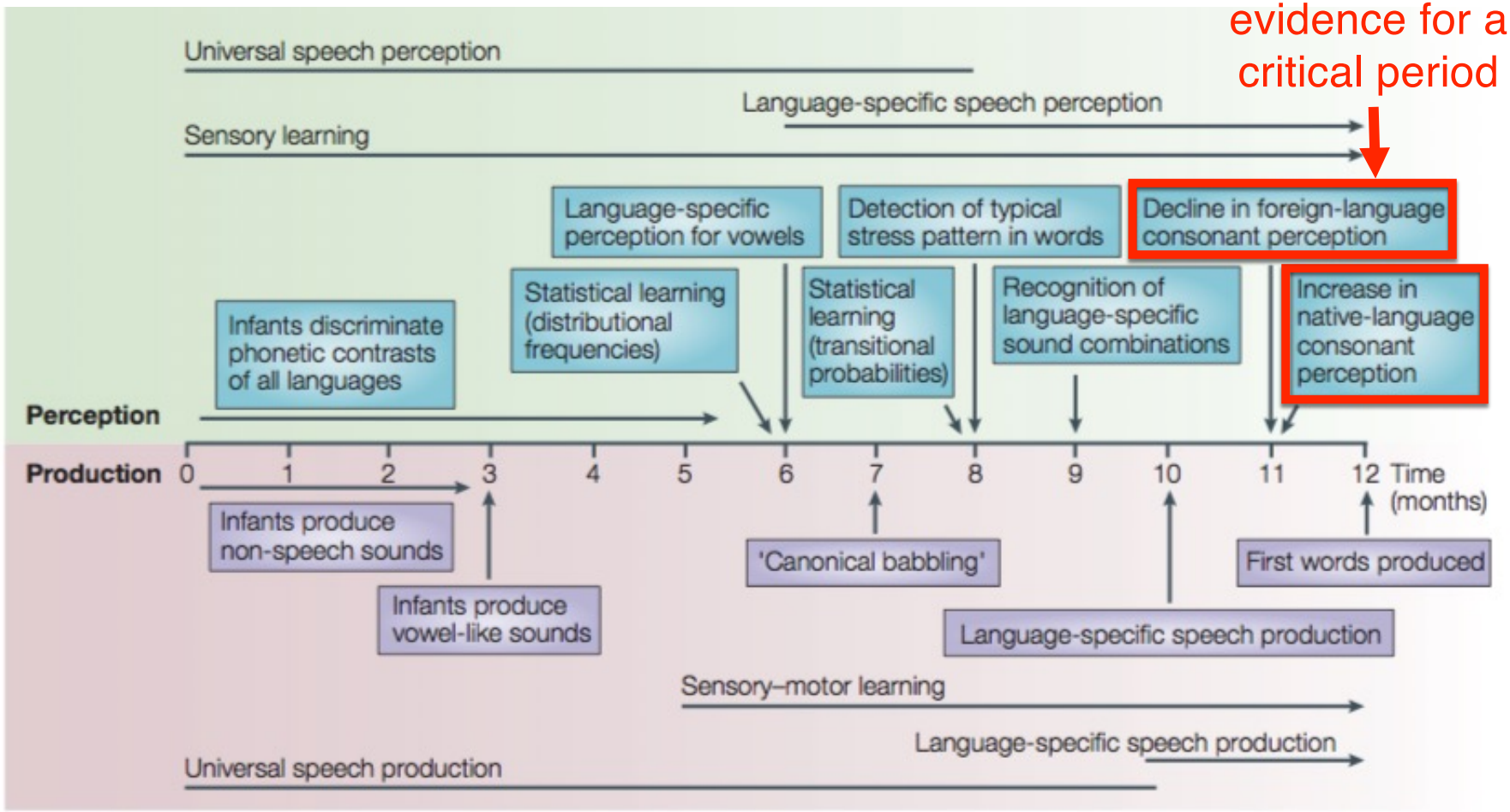
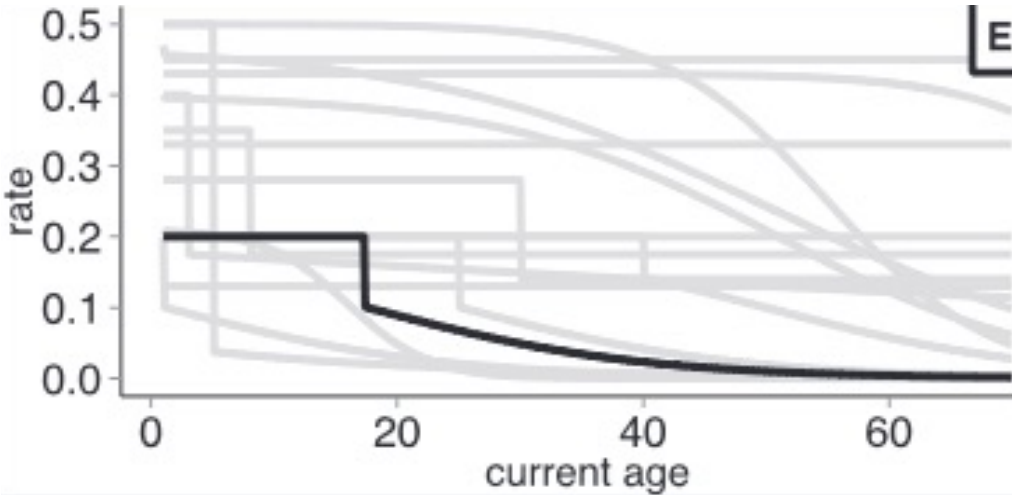


Figure 1 | **The universal language timeline of speech-perception and speech-production development.** This figure shows the changes that occur in speech perception and production in typically developing human infants during their first year of life.

TED Ideas worth spreading https://www.youtube.com/watch?v=G2XBIkHW954

Kuhl, P. K. (2004). Early language acquisition: Cracking the speech code. *Nature Reviews Neuroscience, 5*, 831-843.

Language shows a typical developmental pattern



Language learning rate as function of age (in black) estimated by Hartshorne et al. (2018), with examples of alternative hypotheses for how learning rate changes with age (in grey).

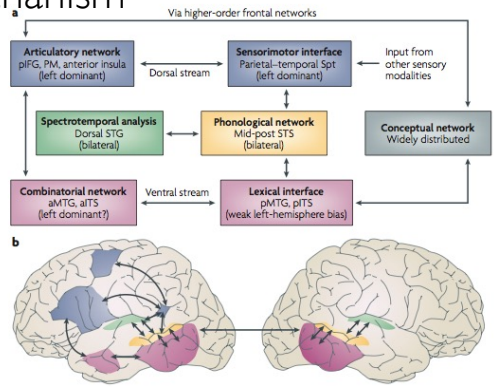
"Children learn language more easily than adults, though when and why this ability declines have been obscure (…). We address both limitations with a dataset of unprecedented size (669,498 native and non-native English speakers) and a computational model that estimates the trajectory of underlying learning ability by disentangling current age, age at first exposure, and years of experience. This allows us to provide the first direct estimate of how grammar-learning ability changes with age, finding that it is preserved almost to the crux of adulthood (17.4 years old) and then declines steadily. This finding held not only for "difficult" syntactic phenomena but also for "easy" syntactic phenomena that are normally mastered early in acquisition. **The results support the existence of a sharply-defined critical period for language acquisition**, but the age of offset is much later than previously speculated."

Hartshorne, J. K., Tenenbaum, J. B., & Pinker, S. (2018). A critical period for second language acquisition: Evidence from 2/3 million English speakers. ***Cognition***, ***177***, 263–277. http://doi.org/10.1016/j.cognition.2018.04.007

Language

Ontogeny

Mechanism



Phylogeny

Menschenaffen können zugleich schlucken und atmen, aber nicht sprechen. Der Grund dafür ist die Stellung des Kehlkopfes, der

Adaptive Significance

Human language has a typical neural architecture

Pierre Paul Broca
(1824-1880)

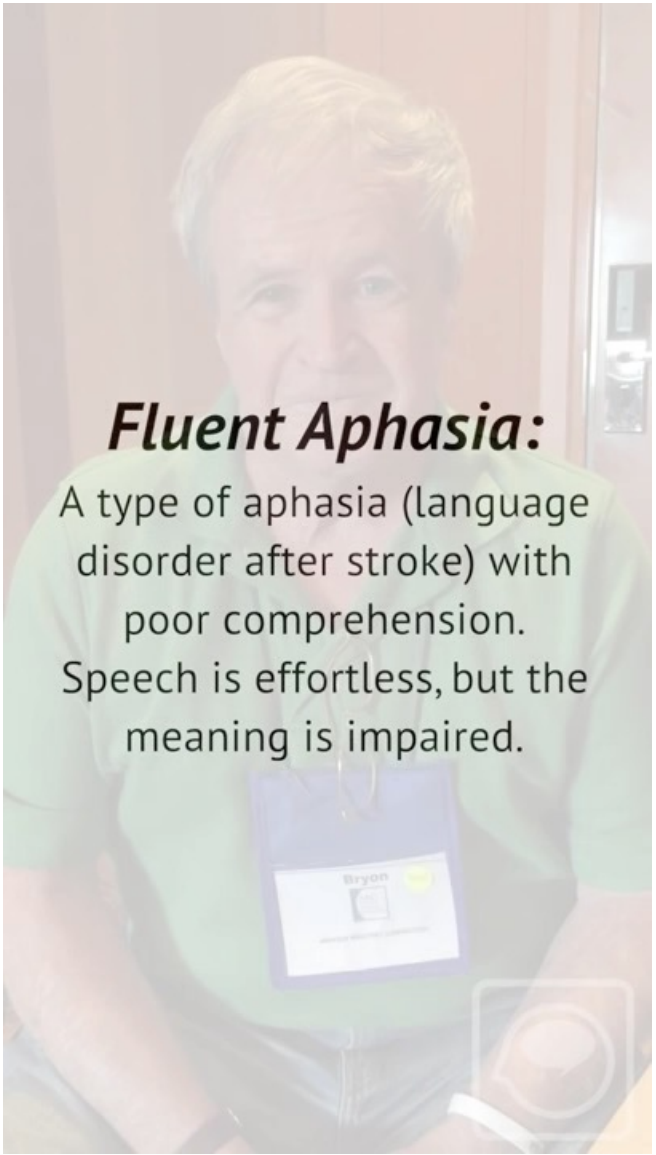
Broca's aphasia (expressive or non-fluent aphasia) is characterised by the loss of the ability to **produce** language (spoken or written) associated with a lesion in the inferior frontal gyrus (IFG)

Karl Wernicke
(1848-1905)

Wernicke's aphasia (receptive, fluent, or sensory aphasia) is characterised by the loss of ability to **understand** (or produce coherent) language in its spoken or written form, associated with a lesion in the superior temporal gyrus (STG).

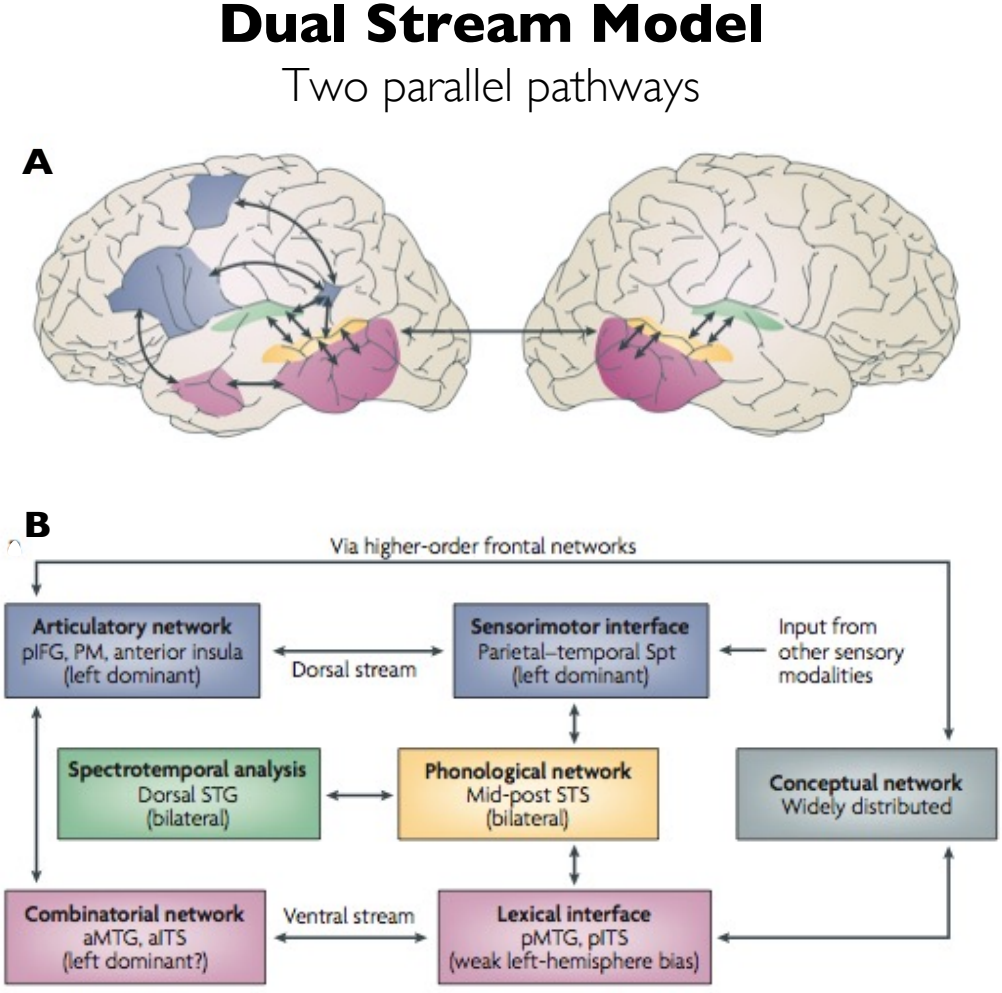
Aphasia
inability to comprehend or produce language because of damage to specific brain regions. The major causes are a cerebral vascular accident (stroke), or head trauma, but aphasia can also be the result of tumors, infections, or neurodegenerative diseases that lead to brain damage. There are a number of different types of aphasia (Broca's and Wernicke's being only two of the most common)

https://www.youtube.com/watch?v=IP8hkopObvs



https://www.youtube.com/watch?v=3oef68YabD0&list=PLmFhYIpKmLyj79aWnzsCYxVJI_5E2iZI1

Human language has a typical neural architecture



A | Approximate anatomical locations of the dual-stream model. Regions shaded blue represent the dorsal stream, which is strongly left dominant. The posterior region of the dorsal stream corresponds to an area in the Sylvian fissure at the parieto-temporal boundary (area Spt), which is proposed to be a sensorimotor interface, whereas the more anterior locations in the frontal lobe, probably involving Broca's region and a more dorsal premotor site, correspond to portions of the articulatory network. aITS = anterior inferior temporal sulcus; aMTG = anterior middle temporal gyrus; pIFG = posterior inferior frontal gyrus; PM = premotor cortex.

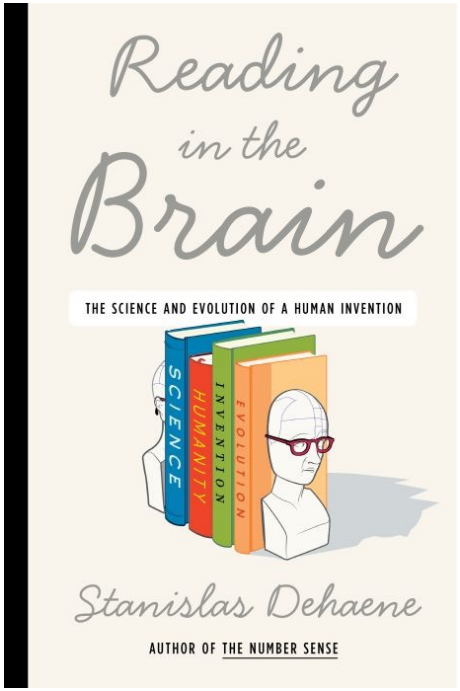
B | Schematic diagram of the dual-stream model. The earliest stage of cortical speech processing involves spectrotemporal analysis carried out in auditory cortices bilaterally in the supratemporal gyrus (STG). Phonological-level processing and representation involves the middle to posterior portions of the superior temporal sulcus (STS) bilaterally, with weak left-hemisphere bias. Subsequently, the system diverges into two broad streams, a **dorsal pathway** (blue) that maps sensory or phonological representations onto articulatory motor representations, and a **ventral pathway** (pink) that maps sensory or phonological representations onto lexical conceptual representations.

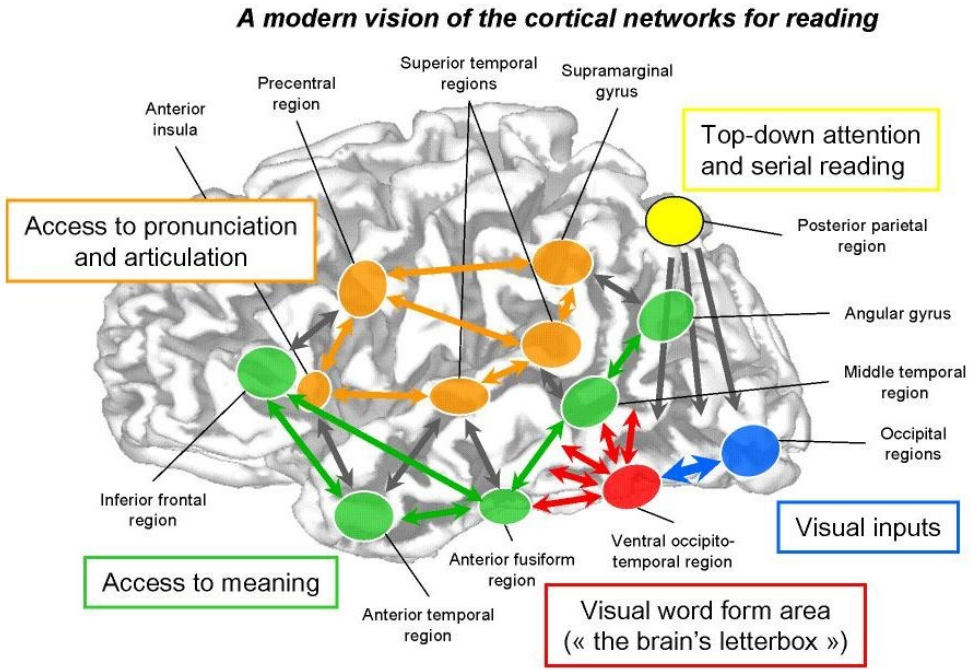
Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews Neuroscience, 8*(5), 393–402. doi:10.1038/nrn2113

Human language has a typical neural architecture

If oral language is an instinct (or the product of a number of instincts), what about reading and writing that are not a spontaneous, universal ability?

Stanislas Dehaene's "neuronal recycling" hypothesis proposes that cultural inventions, such as reading (and writing), co-opt existing brain circuits that evolved for other purposes, like, in the case of reading, visual object recognition and top-down attention.





Summary

- **What is language?** Language as instinct & cultural artefact; pendulum swinging between nativism and associationism in psychology: verbal learning -> UG -> usage-based learning
- **Adaptive Significance**: evolutionary theories typically emphasise language's benefits regarding communication (e.g., acquisition and passing on knowledge) that explain the evolution of language as the result of natural selection; presently, linguistic ability is associated with many life outcomes (academic or occupational attainment).
- **Comparative approaches:** comparative work suggests human-specific anatomical adaptations (L-shaped vocal tract) as well as cognitive adaptations, but the nature of the latter is yet undefined (e.g., recursion; analogical reasoning; theory of mind); and there is debate concerning whether these adaptations emerged for language specifically (for example, recursion could be important for coordination of motor sequences -> tool making)
- **Development:** evidence for sensitive periods indicates an important interaction between biological preparedness and environmental exposure; possibly distinct sensitive/critical periods for different abilities (consonant perception, syntax, prosody)
- **Neural and computational models of language:** modern theories of language comprehension and production involve several components and their interaction (not just Broca and Wernicke's areas, albeit these are central components); dual stream model emphasises the parallel workings of ventral and dorsal streams of language processing