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Author

Yoo, Hannah

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WIRED FOR WORDS: THE SCIENCE OF LANGUAGE DEVELOPMENT

BY: HANNAH YOO



Hearing a child confidently proclaim “I goed” instead of “I went” reveals what many linguists and cognitive scientists have described as one of the most unique attributes of the human species and the brain: the ability to acquire, use, and adapt language throughout time. Language has been described as a central characteristic of the human species due to its complexity, generativity, and necessity for abstract thought and social frameworks.¹ Even young children often apply internal grammatical rules when they speak, but where did these rules come from? How are these rules for language learned, and how is language itself acquired? More pressingly, are humans the only species with this instinct?

UNDERSTANDING WHAT LANGUAGE IS

Despite the importance of language in human life, there is ongoing debate about how the word itself should be defined, as different academic disciplines emphasize different aspects of language. The complex

sphere of “language” includes research from the fields of linguistics, biology, and psychology, making it difficult to assign just one description. Most linguists and scientists agree that language is first and foremost a system of conventional symbols that humans use to communicate and express themselves. Notably, humans use language as members of certain social groups or cultures and within specific contexts, which distinguishes human language from other species’ forms of communication.²

Across the world, humans employ language intentionally and unintentionally between generations or regions within a country. Adaptations and specific linguistic features such as slang words, dialects, and the languages themselves all help to establish social groups, thus providing people with ways to shape their identities. Regional slang and dialects often emerge from shared local history and cultural experiences, enhancing familiarity and identity with places and people. A meaningful illustration of this is with African American Vernacular English, which contains dis-

tinctive grammatical structures such as the use of “be” with verbs (as in “She be working”), or the absence of copula, words such as “is” and “became” that connect a subject and its complement in a sentence (as in “he real friendly”). These features carry rich cultural and historical significance, functioning not only as linguistic tools but also as markers of community, continuity, and solidarity. In this way, vernacular features and other linguistic aspects work as subtle but powerful elements of social interaction between humans.

Underlying this rich framework of identity and social workings, however, is a fixed structure consisting of established rules and components that provide the foundation for the evolution of language. To better examine how this system works, linguists and scientists typically divide language into a hierarchy of five interconnected domains: phonology, morphology, syntax, semantics, and pragmatics. Phonology involves identifying and utilizing different phonemes, bits of sound that are perceptually distinct from each other—essentially the smallest

units of speech—when listening. Morphology involves understanding the meaning of morphemes, the smallest meaningful units of a language that are the building blocks of words and using them aloud. Syntax refers to the set of rules for sentence structures. Semantics concerns the meanings of words and expressions. Finally, pragmatics focuses on how context like social rules or real-world situations influence the meaning and interpretation of words. Each of these domains plays a crucial role in how we produce, comprehend, and adapt language from the smallest units of sound to ongoing conversations.

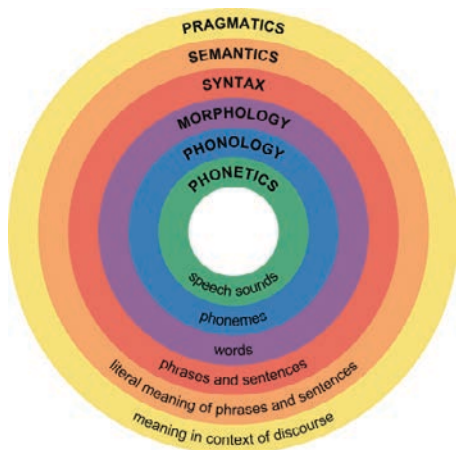


Figure 1: The major levels of linguistic structure, increasing outwards in complexity.

Although it may be tempting to condense the definition of spoken language into a mere collection of sounds strung together to become words, one must consider the aspects of language left out in these domains; for instance, how knowledge acquired over time aids interpretation, perception, and even how individual humans form memories differently.

THE EVOLUTION OF LANGUAGE

As of now, it is impossible to identify exactly when linguistic capacity—the ability to speak and express thoughts—emerged in humans. However, if predicated on the assumption that early modern humans utilized some form of rudimentary communication such as drawn symbols and accompanying physical gestures, fossil and genomic data suggest that human language as we know it emerged 150,000 to 200,000 years ago.³ Other analyses suggest that linguistic potential may have been present in *Homo sapiens* at the latest by 135,000 years

ago.⁴ As with the problem of assigning a fixed, specific definition to “language,” it is difficult to arrive at a concrete conclusion due to the criteria and methods that different researchers use. Even so, these numbers provide a general idea of when linguistic capacity must have first emerged.

Throughout its evolution to today, the human linguistic ability has remained distinct from that of other species due to a few unique features. Most notably, human language is compositional, meaning that it utilizes specific grammar rules and employs subjects, verbs, objects, and verb tenses to concoct unlimited sentences—a trait that allows humans to generate ideas and express their thoughts.³ On the other hand, the languages of other species generally utilize either straightforward symbolic communication through gestures and actions or a less sophisticated version of vocalized communication that lacks the characteristic of compositionality at the same creative level as the human species.

But why did evolution select for sophisticated language in humans? A well-established theory maintains that spoken language was essentially an evolution of the language of gestures, body language, and facial expressions—a more efficient way of communicating.⁵ A more recent theory takes a retroactive approach, searching for evidence of a surge in cognitive capacity and processing that enabled more complex thought and consequently the need to express these thoughts to others. In this view, the development of vocalized language, changes in neurological structure, and vocal anatomy were essentially a cycle of co-evolution and reinforcement.⁶ Although there is no clear answer, these perspectives all highlight the complex interplay of cognitive, social, and anatomical pressures and growth.

THE GENETICS BEHIND LANGUAGE

Historically, the capability of spoken language has been associated with the *FOXP2* gene, which is linked to speech and language disorders. However, recent research and studies discovered that this gene is not exclusive to humans, with the gene and its relevant mutations appearing in hominid species like Neanderthals—as well as non-hominid species such as bats, dogs, and wolves, meaning that *FOXP2* cannot be the sole source of human-specific linguistic

ability. Instead, researchers have now also linked human language acquisition and development to a specific single gene variant of *NOVA1*, a protein in the brain that has been linked to the development of cognitive function as well as neurological conditions and disorders. Unlike *FOXP2*, *NOVA1* is a variant that has been found only in humans and no other species as of yet.⁷ Specifically, *NOVA1* has been linked to spoken language and vocalizations. Although the gene does not exist solely for this purpose and might supplement other cognitive or language functions, it is most likely associated with the production of language. In 2025, researchers Yoko Tajima and Cesar Vargas inserted the human variant of *NOVA1* into mice and discovered that this completely

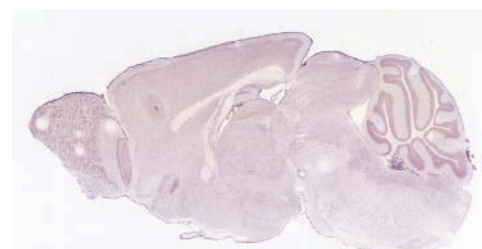


Figure 2: Side view of a mouse brain. The mouse brain shares many anatomical similarities with the human brain, such as the cerebellum, brainstem, and general organization, allowing mice to be important models for studying human neural development and cognition.

changed the way the mice communicated and “spoke” to each other.⁸ Baby mice called to their mothers differently, and male

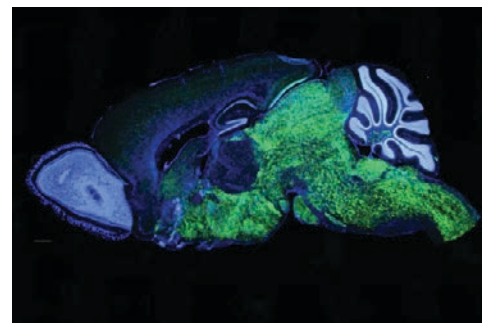


Figure 3. Cells producing the *NOVA1* protein (green) in the brain of a mouse. A specific variant of this protein is unique to humans and researchers suggest it is linked to spoken language development.

mice looking to attract females utilized altered vocalizations. Upon further examination of syllables and sounds that the mice used, Tajima and Vargas found that the hu-

man-variant mice produced different vocal sequences and syllables compared to the wild-type mice. These incredible findings suggested that the human-specific NOVA1 likely contributes to the development and utilization of spoken language.

FACTORS THAT INFLUENCE LANGUAGE ACQUISITION

Despite its basis in the human genome, language is not only innate. Its emergence in humans as well as the changes it experiences over time are shaped by major factors, identified by researchers Ilia Markov et al., as being socio-demographic factors and the very relevant technological advances of today.⁹

One prevalent example of such social selective pressures involves the effect of population size. Languages spoken by larger groups are more likely to utilize lexical strategies, meaning that grammatical information is expressed through additional words (for example, saying “I will go” as opposed to “I go-ed”), in place of inflectional morphology (how words retain their meaning but change grammatical form to add information to a word, such as plurality). Because of the size of these groups, languages then function primarily as tools of communication. On the other hand, languages with smaller numbers of speakers are not as relied on; this also explains why smaller populations have higher rates of vocabulary loss as opposed to larger groups of language speakers, which often experience vocabulary gain.⁹

In the twenty-first century, language development is influenced by technological adaptations. One of the most major changes in modern history is the speed of communication. The increased prevalence of instant messaging and fast communication prompted a surge in shortened words or rapidly redefined words, such as “info” from “information” and “TMI” from “too much information.” Some such shortenings became so prevalent, they emerged in more formal, corporate contexts as well as colloquial language, such as “legit” from “legitimate” and ASAP for “as soon as possible.” These shortenings in turn force the brain to “process an unending stream of linguistic input and respond to it immediately... called... the ‘Now-or-Never bottleneck,’ which describes the immediacy with which the brain must compress and recode lin-

guistic input,” according to psychology and behavioral sciences professors Morten H. Christiansen and Nick Chater.¹⁰ This shift towards rapid communication has fascinating implications for long-term language acquisition. The demand for the brain to immediately and quickly process information combined with frequent switching between conversations and speaking styles may train the brain to monitor many channels of input simultaneously—but for increasingly shorter durations of time. Thus, while there may be a cultivation of responsiveness, there is also the potential for reduced attention spans. Such aspects of modern language acquisition reveal a complex balance between new forms of communication, comprehension, and social interaction as influenced by technology. They indicate how language, from its written form to its spoken, informal, formal, and vernacular forms continues to change in unique ways.

CONCLUDING THOUGHTS: THE FUTURE OF LANGUAGE

The evolution and use of language is deeply rooted in the past. At the same time, language ultimately stands as a dynamic and living facet of humanity established in biology yet constantly changing along with the volatile social and technological world. From reflecting the distinctive quirks and characteristics of different generations to allowing people to associate themselves with specific social groups, language and its study remain a fascinating and essential part of the human world. Even with new forms of communication, language will continue to evolve as an enduring mirror of human cognition, culture, and creativity.

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REFERENCES

1. Pinker, S. (1994). *The Language Instinct: How the Mind Creates Language*. William Morrow and Company.
2. Robins, R. H. (2025, September 23). *Language | Definition, Types, Charac-*

teristics, Development, & Facts. *Britannica*. <https://www.britannica.com/topic/language>

3. Pagel M. (2017). Q&A: What is human language, when did it evolve and why should we care?. *BMC biology*, 15(1), 64. <https://doi.org/10.1186/s12915-017-0405-3>
4. Miyagawa S, DeSalle R, Nóbrega VA, Nitschke R, Okumura M and Tattersall I (2025) Linguistic capacity was present in the Homo sapiens population 135 thousand years ago. *Front. Psychol.* 16:1503900. doi: 10.3389/fpsyg.2025.1503900
5. Handwerk, B. (2019, December 11). Human ancestors may have evolved the physical ability to speak more than 25 million years ago. *Smithsonian Magazine*. <https://www.smithsonianmag.com/science-nature/human-ancestors-may-have-evolved-physical-ability-speak-more-25-million-years-ago-180973759/>
6. De Boer, B. (2016). Evolution of speech and evolution of language. *Psychonomic Bulletin & Review*, 24(1), 158—162. <https://doi.org/10.3758/s13423-016-1130-6>
7. Fenz, K., Darnell, R.B., & Jarvis, E.D. (2025, February 18). Researchers identify a gene potentially linked to the evolution of spoken language. *The Rockefeller University*. <https://www.rockefeller.edu/news/37275-researchers-identify-a-gene-potentially-linked-to-the-evolution-of-spoken-language/>
8. Tajima, Y., Vargas, C.D.M., Ito, K. et al. A humanized NOVA1 splicing factor alters mouse vocal communications. *Nat Commun* 16, 1542 (2025). <https://doi.org/10.1038/s41467-025-56579-2>
9. Markov, I., Kharitonova, K., & Grigorenko, E. L. (2023). Language: Its Origin and Ongoing Evolution. *Journal of Intelligence*, 11(4), 61. <https://doi.org/10.3390/jintelligence11040061>
10. Christiansen, M. H., & Chater, N. (2016). *Creating Language: Integrating Evolution, Acquisition, and Processing*. In *The MIT Press eBooks*. <https://doi.org/10.7551/mitpress/10406.001.0001>

IMAGE REFERENCES

1. Banner: Qi, Z. (n.d.). Illustration of language processing, language learning, language intervention. *The Language*

Acquisition and Brain Lab. University of Delaware. Retrieved from <https://sites.udel.edu/q-lab/>.

2. Figure 1: File:MajorlevelsofLinguistic-structure.png - Wikimedia Commons. (2010, January 3). <https://commons.wikimedia.org/wiki/File:Majorlevelsoflinguisticstructure.png>
3. Figure 2: File:C11orf16 mouse brain.png - Wikimedia Commons. (2018, May 2). https://commons.wikimedia.org/wiki/File:C11orf16_mouse_brain.png
4. Figure 3: Margherita, B. (2025). Cells producing the NOVA1 protein are shown in green in the brain of a mouse. Retrieved from <https://www.smithsonianmag.com/smart-news/scientists-identify-a-gene-linked-to-spoken-language-and-it-makes-lab-mice-squeak-differently-180986083/>.