

Provable Failure of Language Models in Learning Majority Boolean Logic via Gradient Descent

Bo Chen^{*} Zhenmei Shi[†] Zhao Song[‡] Jiahao Zhang[§]

Abstract

Recent advancements in Transformer-based architectures have led to impressive breakthroughs in natural language processing tasks, with models such as GPT-4, Claude, and Gemini demonstrating human-level reasoning abilities. However, despite their high performance, concerns remain about the inherent limitations of these models, especially when it comes to learning basic logical functions. While complexity-theoretic analyses indicate that Transformers can represent simple logic functions (e.g., AND, OR, and majority gates) by its nature of belonging to the TC^0 class, these results assume ideal parameter settings and do not account for the constraints imposed by gradient descent-based training methods. In this work, we investigate whether Transformers can truly learn simple **majority** functions when trained using gradient-based methods. We focus on a simplified variant of the Transformer architecture and consider both $n = \text{poly}(d)$ and $n = \exp(\Omega(d))$ number of training samples, where each sample is a d -size binary string paired with the output of a basic majority function. Our analysis demonstrates that even after $\text{poly}(d)$ gradient queries, the generalization error of the Transformer model still remains substantially large, growing exponentially with d . This work highlights fundamental optimization challenges in training Transformers for the simplest logical reasoning tasks and provides new insights into their theoretical limitations.

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Descent Of Language

Sverker Johansson



Descent Of Language:

The Origin of Language Merritt Ruhlen, 1994 But more than simply describing his and his colleagues theories Dr Ruhlen invites you to share in the joys of discovery He arms you with the linguist s basic tool kit and lets you work through the evidence for yourself and draw your own conclusions You ll classify languages and language families trace language family trees and even reconstruct some of the basic vocabulary used by our most distant ancestors

The History and Origin of Language A.S. Diamond, 2023-12-30 First Published in 1959 The history and origin of language deals with one of the most important and most fascinating subject matter of all human historical problems that of the origin and development of language It is the first attempt to solve it not by a priori methods but by marshalling and analyzing the whole of the evidence It is a work of great originality by a scholar who has written other well known sociological works and the treatment is that of the sociologist Dr Diamond writes for the intelligent layman as well as the linguist He first seeks the true nature of language and its true function and structure in modern society and traces the paths along which language has developed and changed in its known history both in the forms of its words and in their meanings examining for this purpose many languages of civilized and primitive peoples These paths he then pursues backwards with the aid of data from human physiology the language of children and observations of animal behaviour and shows how all these paths converge to one beginning and deduces how language originated both the form of its first words and their meanings He finally shows relics of these earliest words and meanings in languages which still survive The arguments are cumulative and many sided and the case made is convincing This is a must read for scholars and researchers of linguistics

Origins of Language Sverker Johansson, 2005-02-17 Sverker Johansson has written an unusual book on language origins with its emphasis on empirical evidence rather than theory building This is a book for the student or researcher who prefers solid data and well supported conclusions over speculative scenarios Much that has been written on the origins of language is characterized by hypothesizing largely unconstrained by evidence But empirical data do exist and the purpose of this book is to integrate and review the available evidence from all relevant disciplines not only linguistics but also e g neurology primatology paleoanthropology and evolutionary biology The evidence is then used to constrain the multitude of scenarios for language origins demonstrating that many popular hypotheses are untenable Among the issues covered 1 Human evolutionary history 2 Anatomical prerequisites for language 3 Animal communication and ape language 4 Mind and language 5 The role of gesture 6 Innateness 7 Selective advantage of language 8 Proto language

The Descent of Language Rod Mengham, 1993 In this book poet and critic Rod Mengham takes a look at the origins ends and development of languages in the histories of societies and the lives of individuals In ranging from the details of brain functions to tracking the spread of Indo European the largest family of languages in the world Mengham reveals how these processes have become complicated by successive waves of technological advance by writing by movable type and printing by the telephone by

computer networks This book argues that it is through language that human beings define themselves and their world He analyses the way that cultures are organised around language from literary classics to advertising slogans and reflects on the rise of dictionaries translations and universal language schemes Above all it uncovers the fundamental role that language plays in the process of social change and demonstrates how it can be used equally as a force for conservatism or for radical innovation in the formation of nationality and family gender and class It also presents the fruits of the latest research in linguistics history psychology and neurology to a non specialist audience

Inquiries Into the Origin of Language James H. Stam,1976

Language: Its Nature, Development and Origin Otto Jespersen,2022-05-28 In *Language Its Nature Development and Origin* Otto Jespersen explores the intricate tapestry of language considering its biological psychological and social dimensions Through a rigorous linguistic framework Jespersen employs a descriptive and analytical style that deftly combines historical linguistics with contemporary insights revealing the evolution of language as a dynamic and living system He delves into concepts such as phonetics syntax and semantics while situating linguistic development within broader cultural and historical contexts making it an essential text for understanding the complexities of human communication Otto Jespersen a prominent Danish linguist and a pioneering figure in the field of English grammar draws on his extensive academic background to craft this seminal work His experiences in the rapidly evolving landscape of European languages during the late 19th and early 20th centuries likely informed his inquiry into language origins and classifications Jespersen s ability to synthesize various linguistic theories showcases his commitment to the scientific study of language making him a respected authority in the field This book is highly recommended for scholars students and language enthusiasts alike offering profound insights into the essence of language itself Jespersen s thoughtful analysis invites readers to reflect on their own linguistic experiences while providing a comprehensive foundation for further exploration in the spheres of linguistics and semiotics In this enriched edition we have carefully created added value for your reading experience A succinct Introduction situates the work s timeless appeal and themes The Synopsis outlines the central plot highlighting key developments without spoiling critical twists A detailed Historical Context immerses you in the era s events and influences that shaped the writing A thorough Analysis dissects symbols motifs and character arcs to unearth underlying meanings Reflection questions prompt you to engage personally with the work s messages connecting them to modern life Hand picked Memorable Quotes shine a spotlight on moments of literary brilliance Interactive footnotes clarify unusual references historical allusions and archaic phrases for an effortless more informed read

On the Origin of Language John H. Moran,Alexander Gode,1986-03-15 Additionally Rousseau s essay is an important text for semiotics and modern critical theory as it plays a very important role in Jacques Derrida s book *Of Grammatology* Rousseau supplements his discussion of the origin of languages with theories about the origins of music melody and harmony and the relationship of languages to government

On the Origin of Language Wilhelm Heinrich Immanuel Bleek,1869 *The Origin and Diversification of*

Language Morris Swadesh, 2017-09-04 Morris Swadesh one of this century's foremost scientific investigators of language dedicated much of his life to the study of the origin and evolution of language This volume left nearly completed at his death and edited posthumously by Joel F Sherzer is his last major study of this difficult subject Swadesh discusses the simple qualities of human speech also present in animal language and establishes distinctively human techniques of expression by comparing the common features that are found in modern and ancient languages He treats the diversification of language not only by isolating root words in different languages but also by dealing with sound systems with forms of composition and with sentence structure In so doing he demonstrates the evidence for the expansion of all language from a single central area Swadesh supports his hypothesis by exhibits that conveniently present the evidence in tabular form Further clarity is provided by the use of a suggestive practical phonetic system intelligible to the student as well as to the professional The book also contains an Appendix in which the distinguished ethnographer of language Dell Hymes gives a valuable account of the prewar linguistic tradition within which Swadesh did some of his most important work

The Origins of Complex Language Andrew Carstairs-McCarthy, 1999 This book proposes a new theory of the origins of human language ability and presents an original account of the early evolution of language It explains why humans are the only language using animals challenges the assumption that language is a consequence of intelligence and offers a new perspective on human uniqueness The author draws on evidence from archaeology linguistics cognitive science and evolutionary biology Making no assumptions about the reader's prior knowledge he first provides an introductory but critical survey of all sources of evidence for language evolution He then considers what language itself reveals about its own and human origins and evolution He shows that certain central aspects of language do not unexpectedly reflect what they are used for are maladapted for their function He considers why this should be and argues that these odd aspects of language reveal important clues about its evolutionary origin *The Origins of Complex Language* fulfils the promise of its title In doing so it turns upside down conventional theories about the relation between cognition and expression truth and reference and the co evolution of mind and body Original in conception brilliantly executed stylishly written this book will attract a wide range of readers interested in the evolution and origins of language

The Nature and Origin of Language Denis Bouchard, 2013-09-26 This book looks at how the human brain got the capacity for language and how language then evolved Its four parts are concerned with different views on the emergence of language with what language is how it evolved in the human brain and finally how this process led to the properties of language Part I considers the main approaches to the subject and how far language evolved culturally or genetically Part II argues that language is a system of signs and considers how these elements first came together in the brain Part III examines the evidence for brain mechanisms to allow the formation of signs Part IV shows how the book's explanation of language origins and evolution is not only consistent with the complex properties of languages but provides the basis for a theory of syntax that offers insights into the learnability of

language and to the nature of constructions that have defied decades of linguistic analysis including including subject verb inversion in questions existential constructions and long distance dependencies Denis Bouchard s outstandingly original account will interest linguists of all persuasions as well as cognitive scientists and others interested in the evolution of language *The Origins and Prehistory of Language* Géza Révész,1956 *Theory of Morals and Origin of Language* ,1871

The Origin of Language George Albert Wells,1987 *On the Origin of Language* Hensleigh Wedgwood,2023-07-18 This book presents a historical and etymological investigation into the origin of language Using examples from multiple languages and drawing upon research from famous thinkers in the field of linguistics Wedgwood traces the development of languages from their earliest forms A must read for anyone interested in the origins of human communication This work has been selected by scholars as being culturally important and is part of the knowledge base of civilization as we know it This work is in the public domain in the United States of America and possibly other nations Within the United States you may freely copy and distribute this work as no entity individual or corporate has a copyright on the body of the work Scholars believe and we concur that this work is important enough to be preserved reproduced and made generally available to the public We appreciate your support of the preservation process and thank you for being an important part of keeping this knowledge alive and relevant *Original Sanskrit Texts on the Origin and History of the People of India, Their Religion and Institutions* ,1874 *The Origins and Development of the English Language* Thomas Pyles,1971 **An Essay on the Origin of Language** Frederic W. Farrar,2022-07-19 Reprint of the original first published in 1860 **Origins of Language** James R. Hurford,2014-03-06 *Origins of Language A Slim Guide* offers a concise and accessible overview of what is known about the evolution of the human capacity for language Non human animals communicate in simple ways they may be able to form simple concepts to feel some limited empathy for others to cooperate to some extent and to engage in mind reading Human language however is characterized by its ability to efficiently express a wide range of subtle and complex meanings After the first simple beginnings human language underwent an explosion of complexity leading to the very complicated systems of grammar and pronunciation found in modern languages Jim Hurford looks at the very varied aspects of this evolution covering human prehistory the relation between instinct and learning biology and culture trust altruism and cooperation animal thought human and non human vocal anatomy the meanings and forms of the first words and the growth of complex systems of grammar and pronunciation Written by an internationally recognized expert in the field it draws on a number of disciplines besides linguistics including philosophy neuroscience genetics and animal behaviour and will appeal to a wide range of readers interested in language origins and evolution

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Table of Contents Descent Of Language

1. Understanding the eBook Descent Of Language
 - The Rise of Digital Reading Descent Of Language
 - Advantages of eBooks Over Traditional Books
2. Identifying Descent Of Language
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Descent Of Language
 - User-Friendly Interface
4. Exploring eBook Recommendations from Descent Of Language
 - Personalized Recommendations
 - Descent Of Language User Reviews and Ratings
 - Descent Of Language and Bestseller Lists
5. Accessing Descent Of Language Free and Paid eBooks

- Descent Of Language Public Domain eBooks
 - Descent Of Language eBook Subscription Services
 - Descent Of Language Budget-Friendly Options
6. Navigating Descent Of Language eBook Formats
 - ePub, PDF, MOBI, and More
 - Descent Of Language Compatibility with Devices
 - Descent Of Language Enhanced eBook Features
 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Descent Of Language
 - Highlighting and Note-Taking Descent Of Language
 - Interactive Elements Descent Of Language
 8. Staying Engaged with Descent Of Language
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Descent Of Language
 9. Balancing eBooks and Physical Books Descent Of Language
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Descent Of Language
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Descent Of Language
 - Setting Reading Goals Descent Of Language
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Descent Of Language
 - Fact-Checking eBook Content of Descent Of Language
 - Distinguishing Credible Sources
 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development

- Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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