

## Counterfactual Reasoning and Cognitive Sciences: A Bibliometric Analysis

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### Abstract

This bibliometric analysis follows the PRISMA criteria to systematically find and combine existing literature that connects counterfactual thinking to cognitive science. The Scopus database identified 1253 articles, out of which 256 were pertinent. The analysis demonstrates a substantial increase in academic publications in cognitive science related to counterfactual thinking since 1990, suggesting a heightened scholarly commitment and interest in this interdisciplinary field. The study emphasizes the global significance and impact of research endeavors investigating this subject. In addition, the growing corpus of literature recognizes counterfactual thinking as a critical component of cognitive processes. The review calls for more research into and inclusion of counterfactual thinking in cognitive science studies. It stresses the need for collaborations between different fields and new ways of doing things in order to fully understand the complex connection between cognitive processes and counterfactual thinking.

**Keywords:** Counterfactual Reasoning, Cognitive Sciences, Thinking, Cognition, Bibliometric Analysis.

### Introduction

The second half of the twentieth century saw significant changes that laid the foundation for the development of a new framework in scientific thinking, known as the cognitive revolution. We are now studying and analyzing the mind to gain a better understanding of its functioning. This shift from philosophical contemplation to objective scientific exploration involves the integration of various fields of knowledge, including psychology, linguistics, neuroscience, artificial intelligence, and others.

Over the years, various academic fields have examined the notion of the counterfactual, and its scope has broadened as interdisciplinary research has become more interconnected. In his

seminal paper, "The Problem of the Counterfactual," philosopher Nelson Goodman emphasizes the importance of counterfactual thinking and highlights the potential pitfalls associated with its application. (Goodman, 1947) asserts that "the analysis of counterfactual conditionals is no fussy little grammatical exercise. Indeed, if we lack the means for interpreting counterfactual conditionals, we can hardly claim to have any adequate philosophy of science". Goodman asserts that science heavily depends on counterfactual reasoning, as counterfactual structures are prevalent in language.

Counterfactual thinking is a common occurrence in daily life and has been studied by philosophers and psychologists who are interested in the process of counterfactual reasoning (e.g., Byrne & Tasso, 1999; Lewis, 1973; Stalnaker, 1968). Counterfactual ideas refer to mental representations of alternate possibilities for prior events, acts, or situations. The expression "what could have been" encapsulates these thoughts, extending beyond the hypothetical scenario to the actual one. Counterfactuals, at their core, pertain to alternate possibilities for how things could have occurred. For instance, we can consider what is factually accurate, what is not factually accurate but could have been, and what actions should be taken, specifically those that were not taken but could have been. Dancygier & Sweetser (2005) assert that conditionality, or the use of conditional thinking, holds significant importance in human cognition. Philosophers have always emphasized conditional formulations as expressions of human logical reasoning. Psychologists, philosophers, and researchers of human reasoning should find the distinctive and compelling cognitive patterns exhibited in conditions to be of interest. Conditionality is a significant issue not just in philosophy but also in the field of linguistics. The concept of conditionality elicits linguistic analysis in the areas of grammar, semantics, and cognitive methods.

The main aim of this bibliometric analysis is to explore the potential synergies between counterfactual reasoning and cognitive sciences, which is a relatively understudied field of scientific inquiry. We need to better integrate these areas, recognizing that counterfactual reasoning, a crucial function in our everyday lives, happens in the subconscious mind under the influence of cognitive processes. Our objective is to analyze the chosen publications in order to discover and resolve any existing gaps in the current knowledge regarding the connection between cognitive sciences and counterfactual reasoning. The purpose of this bibliometric evaluation was to investigate the following research questions:

**Research Questions:**

1. What is the distribution of Counterfactual reasoning in publications on cognitive from 1990 to 2023?
2. Which nations have the most impact on Counterfactual reasoning in publications on cognitive sciences from 1990 to 2023?
3. Which educational institutions have made the most notable contributions to the study of Counterfactual reasoning in publications on cognitive sciences from 1990 to 2023?
4. Which Authors have produced the most substantial contributions to the field of Counterfactual reasoning in publications on cognitive sciences from 1990 to 2023?
5. Over the last decade, what have been the most prominent research terms concerning Counterfactual reasoning in publications on cognitive sciences from 1990 to 2023?

## Methods

This section will cover the methodologies employed in this paper. Furthermore, this investigation employed the PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) as its primary framework. The methodical and transparent synthesis of the research findings ensured the identification, assessment, and reporting of all relevant studies with a high degree of accuracy and consistency.

### **Identification:**

Scopus, which has been prominently chosen as the main source for this research, is a highly extensive and comprehensive database that contains a wide range of papers from many fields of study. It grants access to a diverse range of studies and enables effortless navigation through a wealth of data. This review took place on 6<sup>th</sup> may, 2024. This review aimed to investigate the relationship between counterfactual reasoning and cognitive sciences.

Three main keywords were used for instance, counterfactual, reasoning and cognitive, and the query used for this is TITLE-ABS-KEY (counterfactual, reasoning, AND cognitive). This search has been conducted for the last thirty-three years, as this query was used AND AND PUBYEAR > 1989 AND PUBYEAR < 2024. A set of inclusion and exclusion criteria were used on this review. Table 1 shows the inclusion and exclusion criteria.

Table 1

#### *Inclusion and Exclusion Criteria*

Inclusion criteria	exclusion criteria
counterfactual, reasoning and cognitive	Any other keywords.
Articles from 1989 to 2023	Any research before 1990 was excluded, and any research in 2024.
Only articles in English language	Any other languages
Only articles	Conference papers, books, thesis
Arts social science, psychology and neurology	Any other field.

### **Screening**

The initial search resulted 1,253 documents in the Scopus database. After applying the set of inclusion and exclusion criteria this review included only 256 documents, whereas 997 were excluded from the search.

### **Eligibility**

Only articles in the field of arts, social science psychology and neurology were included in this search, following the query AND ( LIMIT-TO ( SUBJAREA , "SOCI" ) OR LIMIT-TO ( SUBJAREA , "PSYC" ) OR LIMIT-TO ( SUBJAREA , "NEUR" ) OR LIMIT-TO ( SUBJAREA , "ARTS" ) ) Moreover, only articles were included AND ( LIMIT-TO ( DOCTYPE , "ar" ) ). A set of "exact keywords" were used to provide more precise results as follow, "Counterfactual Reasoning, Counterfactuals, Thinking, Cognition, Causal Reasoning, Counterfactual Thinking, Computational Linguistics, Cognitive Development, Probability, Semantics, Conditional Reasoning, Causal Inference, Psychology, Cognitive Systems, Possible Worlds, Knowledge Representation, Reasoning Ability, Neuropsychological Tests, Linguistics, Counterfactual Conditionals, Conditional Logic, Human" as follow; AND ( LIMIT-TO ( EXACTKEYWORD , "Counterfactual Reasoning" ) OR LIMIT-TO ( EXACTKEYWORD , "Counterfactuals" ) OR LIMIT-

TO ( EXACTKEYWORD , "Thinking" ) OR LIMIT-TO ( EXACTKEYWORD , "Cognition" ) OR LIMIT-TO ( EXACTKEYWORD , "Causal Reasoning" ) OR LIMIT-TO ( EXACTKEYWORD , "Counterfactual Thinking" ) OR LIMIT-TO ( EXACTKEYWORD , "Computational Linguistics" ) OR LIMIT-TO ( EXACTKEYWORD , "Cognitive Development" ) OR LIMIT-TO ( EXACTKEYWORD , "Probability" ) OR LIMIT-TO ( EXACTKEYWORD , "Semantics" ) OR LIMIT-TO ( EXACTKEYWORD , "Conditional Reasoning" ) OR LIMIT-TO ( EXACTKEYWORD , "Causal Inference" ) OR LIMIT-TO ( EXACTKEYWORD , "Psychology" ) OR LIMIT-TO ( EXACTKEYWORD , "Cognitive Systems" ) OR LIMIT-TO ( EXACTKEYWORD , "Possible Worlds" ) OR LIMIT-TO ( EXACTKEYWORD , "Knowledge Representation" ) OR LIMIT-TO ( EXACTKEYWORD , "Reasoning Ability" ) OR LIMIT-TO ( EXACTKEYWORD , "Neuropsychological Tests" ) OR LIMIT-TO ( EXACTKEYWORD , "Linguistics" ) OR LIMIT-TO ( EXACTKEYWORD , "Counterfactual Conditionals" ) OR LIMIT-TO ( EXACTKEYWORD , "Conditional Logic" ) OR LIMIT-TO ( EXACTKEYWORD , "Human" ) ). Lastly, only articles in English language were included as follow; AND ( LIMIT-TO ( LANGUAGE , "English" ) ).

### ***Inclusion and Reporting***

The results of this bibliometric analysis are presented in adherence to the PRISMA framework, as shown in Figure 1 below (Moher et al., 2009). The next part will begin by answering the research questions that were presented, presenting the results in a systematic and transparent manner.

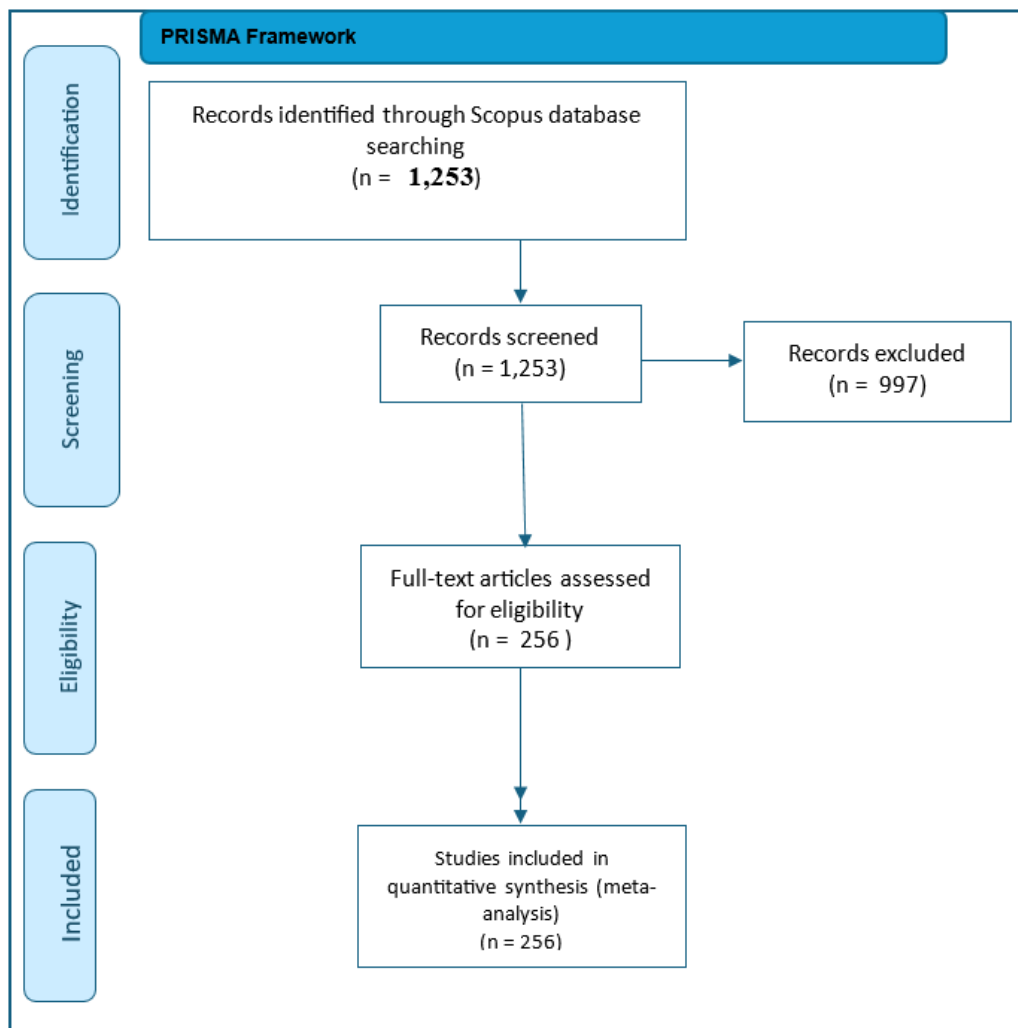


Figure 1: PRISMA Framework

## Results

This section presents the findings of a bibliometric study examining the relationship between counterfactual thinking and cognitive sciences. Our study spans a period of 30 years of research and provides significant insights into various facets of this constantly changing field. The information encompasses significant subject areas, publishing trends, influential journals and countries, key academic institutions, prolific authors, and primary research keywords. Hence, the objective of this study is to demonstrate the evolution of counterfactual reasoning research, pinpoint the key drivers of academic research in this field, and provide a comprehensive overview of the worldwide endeavors to comprehend the impact of counterfactual reasoning on cognitive sciences.

### *The Distribution According to Years.*

This section will address the study question: "What is the distribution of Counterfactual reasoning in publications on cognitive from 1990 to 2023?" The analysis of papers on counterfactual reasoning in cognitive sciences from 1990 to 2023 provides insight into the field's changing research trends. During this time, we observe a notable increase in research interest, which suggests a rising acknowledgement of the importance of counterfactual reasoning in comprehending cognitive processes as shown in Figure 2. The consistent rise,

especially noticeable since the early 2000s, indicates a significant change in emphasis or approach, leading to a greater investigation of the subject. With the increasing number of publications indicating a greater interest in counterfactual thinking, it is clear that this field of study has significant implications for our knowledge of human cognition.

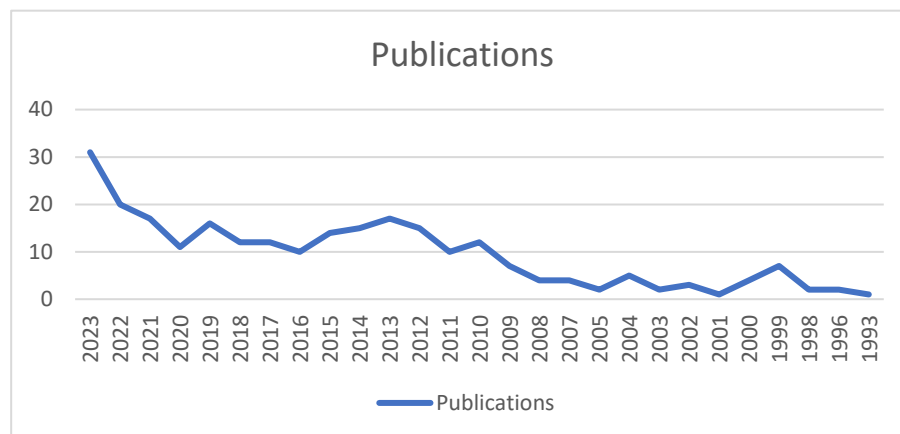


Figure 2: publications by years

As Figure 2 presents the data. The publication distribution on counterfactual reasoning in cognitive sciences from 1990 to 2023 follows an intriguing pattern. During this time period, there is a noticeable pattern of growing interest in the subject, marked by variations in the number of publications from year to year. The increase in publications from the early 2000s onwards, specifically in the field of counterfactual reasoning within the cognitive sciences community, is particularly remarkable and indicates a growing importance and focus on this topic. Peak publication numbers, such as the highest reported in 2023 with 31 articles, indicate periods of heightened study activity and involvement with the issue. Improvements in research methodology, technological breakthroughs, and changes in theoretical paradigms have sparked a renewed curiosity in investigating counterfactual reasoning, leading to the increase in growth.

Furthermore, the subject's multidisciplinary nature is evident in the dispersion of publications over different years, underscoring its convergence with disciplines such as psychology, neurology, philosophy, and artificial intelligence. New research trends, funding availability, and notable articles or researchers may have driven the observed changes in publication numbers. Essentially, the distribution of articles over time reveals a dynamic and dynamic field of study on counterfactual reasoning within the cognitive sciences. The field experiences periods of development, stability, and collaboration between various disciplines.

### ***The Most Significant Countries***

In order to examine the second study inquiry, which nations have the most impact on counterfactuals in the field of cognitive sciences research? Publications are distributed by country. An examination of the influence of various countries on publications related to counterfactual reasoning in cognitive sciences between 1990 and 2023 reveals a complex and ever-changing worldwide research environment, as seen in Figure 3.

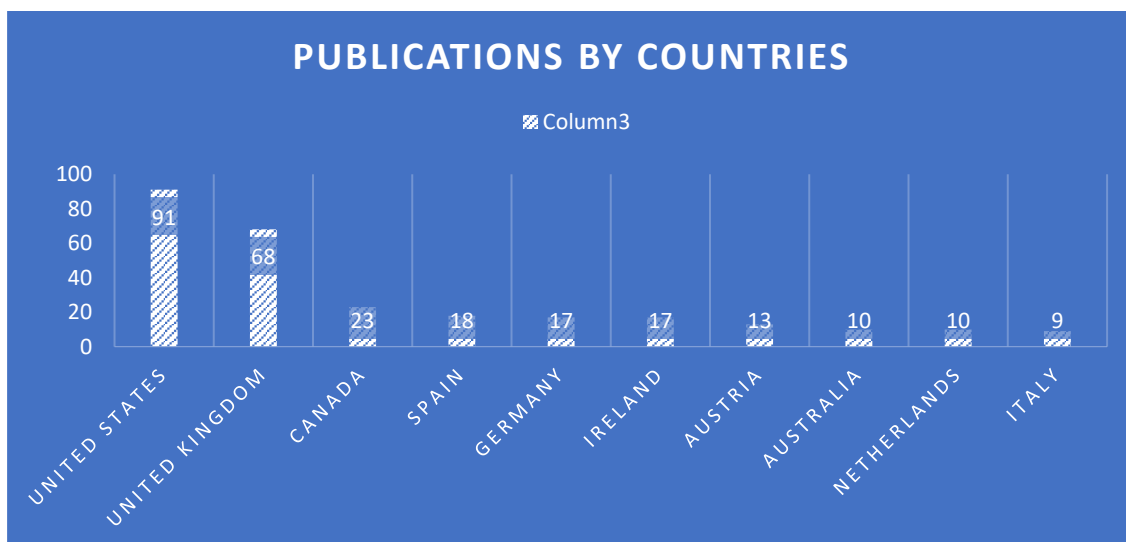


Figure 3: Publications by Countries

This review examines the contributions of different nations to counterfactual thinking in the cognitive sciences, focusing on the global scale of research efforts. The United States dominates the field with 91 articles, thanks to its strong scientific infrastructure, significant research expenditures, and a culture that fosters academic brilliance and innovation. The UK follows closely with 68 articles, demonstrating its significant impact and enduring legacy in cognitive science research. The UK's interdisciplinary research methodology, combining knowledge from psychology, philosophy, neuroscience, and artificial intelligence, enhances our understanding of cognitive processes. Canada, with 23 publications, is a significant contender due to its commitment to collaboration, innovation, and diversity.

Spain, Germany, Ireland, and Austria each contribute to the worldwide research environment with 17 to 13 publications, adding more diversity. The rise of research centers in countries like Australia, the Netherlands, and Italy indicates the growing global interest in cognitive science research and the growing significance of interdisciplinary cooperation in advancing our understanding of complex cognitive phenomena.

The analysis highlights the interdependence of research endeavors across national boundaries and continents, emphasizing the importance of global cooperation, interdisciplinary methods, and different perspectives for better understanding counterfactual reasoning and other complex cognitive phenomena. In the future, it will be crucial to promote international collaboration, adopt interdisciplinary techniques, and acknowledge the importance of multiple views to make progress in understanding counterfactual reasoning and other intricate cognitive phenomena.

### ***The Most Significant Educational Institutions***

The data provided addresses the third research question: "Which educational institutions have made significant contributions to the study of Counterfactual reasoning in publications on cognitive sciences between 1990 and 2023?" Highlights multiple such establishments. As indicated in Table 2.

Table 2

*Top 10 Educational Institutions In (Counterfactual reasoning and cognitive sciences)*

#	Educational institutions	TP	Most cited publications	Time cited
1	Trinity College Dublin	17	Counterfactual thought	284
2	Universität Salzburg	11	Counterfactual reasoning: From childhood to adulthood	99
3	University of Birmingham	11	<i>Relating developments in children's counterfactual thinking and executive functions</i>	76
4	Harvard University	8	<i>Normality and actual causal strength</i>	84
5	University College London	8	<i>Do we do?</i>	161
6	Stanford University	7	<i>Normality and actual causal strength</i>	84
7	Universidad Nacional de Educacion a Distancia	7	Inferences from semifactual 'even if' conditionals	30
8	Yale University	6	Causal superseding	101
9	University of Toronto	6	<i>Mature counterfactual reasoning in 4- and 5-year-olds</i>	49
10	Universidad de Granada	6	<i>Inferences from semifactual 'even if' conditionals</i>	30

TP= Total publications

The study of counterfactual thinking in the cognitive sciences has been significantly influenced by the contributions of various educational institutions. Trinity College Dublin, Universität Salzburg, and Harvard University have made significant contributions to the field through their innovative research, developmental insights, and lasting impact. From 1990 to 2023, an



analysis of academic research in cognitive sciences publications revealed that these institutions have played a crucial role in advancing the study of counterfactual reasoning. Trinity College Dublin has 17 papers that demonstrate its significant contribution to the advancement of our knowledge of counterfactual reasoning, with a notable citation count of 284. Universität Salzburg has 11 publications, including "Counterfactual Reasoning: From Childhood to Adulthood," which has garnered 99 citations. The University of Birmingham specializes in studying the developmental elements of counterfactual thinking and executive functioning, with 76 citations. Harvard University has authored eight articles on counterfactual reasoning, with "Normality and actual causal strength" receiving 84 citations. University College London has eight articles, with "Do we do?" receiving 161 citations. Stanford University has seven publications, with 84 citations to one of these articles. The Universidad Nacional de Educacion a Distancia (UNED) has seven articles focusing on conditional reasoning. Yale University has six papers specifically investigating causal superseding, while the University of Toronto emphasizes the importance of examining counterfactual reasoning from a developmental standpoint, especially in young children. The Universidad de Granada also focuses on the study of conditional reasoning and counterfactual thinking.

### ***The Most Prolific Authors.***

The statistics provided in response to the fourth research question, "Which educational institutions have made the most significant contributions to the study of counterfactual reasoning in publications on cognitive sciences from 1990 to 2023?" Several such establishments are highlighted, as indicated in Table 3.

Table 3

#### ***Top 10 Authors in the Field of Counterfactual Reasoning in Cognitive Sciences***

#	Authors	TP*	TC*	H-index	Most cited publication	Publisher
1	Byrne, Ruth M.J.	105	4,607	34	Conditionals: A theory of meaning, pragmatics, and inference	American Psychological Association
2	Perner, Josef	148	16,149	53	Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception	Elsevier
3	Hu, Jie	51	864	16	Consistent gene signature of schizophrenia identified by a novel feature selection strategy from comprehensive sets of	Oxford University Press

					transcriptomic data	
4	Rafetseder, Eva	26	509	10	Counterfactual reasoning: From childhood to adulthood	Elsevier
5	García-Madruga, Juan Antonio	59	731	15	Normative data on the n-back task for children and young adolescents	Frontiers Media SA
6	Gerstenberg, Tobias	66	1,174	18	Causal responsibility and counterfactuals	Wiley-Blackwell
7	Lagnado, David A.	144	3,646	32	Judgments of cause and blame: The effects of intentionality and foreseeability	Elsevier
8	Moreno-Ríos, Sergio	42	284	10	Are conjunctive inferences easier than disjunctive inferences? A comparison of rules and models	SAGA JOURNAL
9	Beck, Sarah R.	79	1,929	28	Children's thinking about counterfactuals and future hypotheticals as possibilities	Wiley-Blackwell
10	Ganea, Patricia A.	74	2,125	28	Transfer between picture books and the real world by very young children	Wolters Kluwer Health

\*TP= TOTAL PUBLICATIONS, \*TC= TOTAL CITATIONS

The most prolific authors are shown in Table 3. Between 1990 and 2023, a comprehensive analysis of counterfactual reasoning in cognitive sciences revealed a wide range of scholarly efforts and significant influences. Ruth M.J. Byrne, a prominent figure in the field, has written 105 papers, with her most important work, "Conditionals: A Theory of Meaning, Pragmatics, and Inference," receiving 4,607 citations. Josef Perner has contributed 148 articles, with "Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception" receiving 16,149 citations. Jie Hu's interdisciplinary research on counterfactual reasoning has significant implications, particularly in understanding psychiatric disorders. Oxford University Press's publication, "Consistent gene signature of schizophrenia identified by a novel feature selection strategy from comprehensive sets of transcriptomic data," demonstrates this. Eva Rafetseder's "Counterfactual Reasoning: From Childhood to Adulthood," emphasizing developmental aspects, and Juan Antonio García-Madruga's 59 publications provide valuable insights into normative data on cognitive abilities in children. These authors have significantly enhanced our understanding of counterfactual reasoning and its impact on human cognition.

### The Primary Research Keywords and Trends

In response to the fifth inquiry, "Over the last decade, what have been the most prominent research terms concerning counterfactual reasoning in publications on cognitive sciences from 1990 to 2023?" The figure illustrates the principal research terms and their frequency of occurrence, as shown by the information presented in Figure 4.

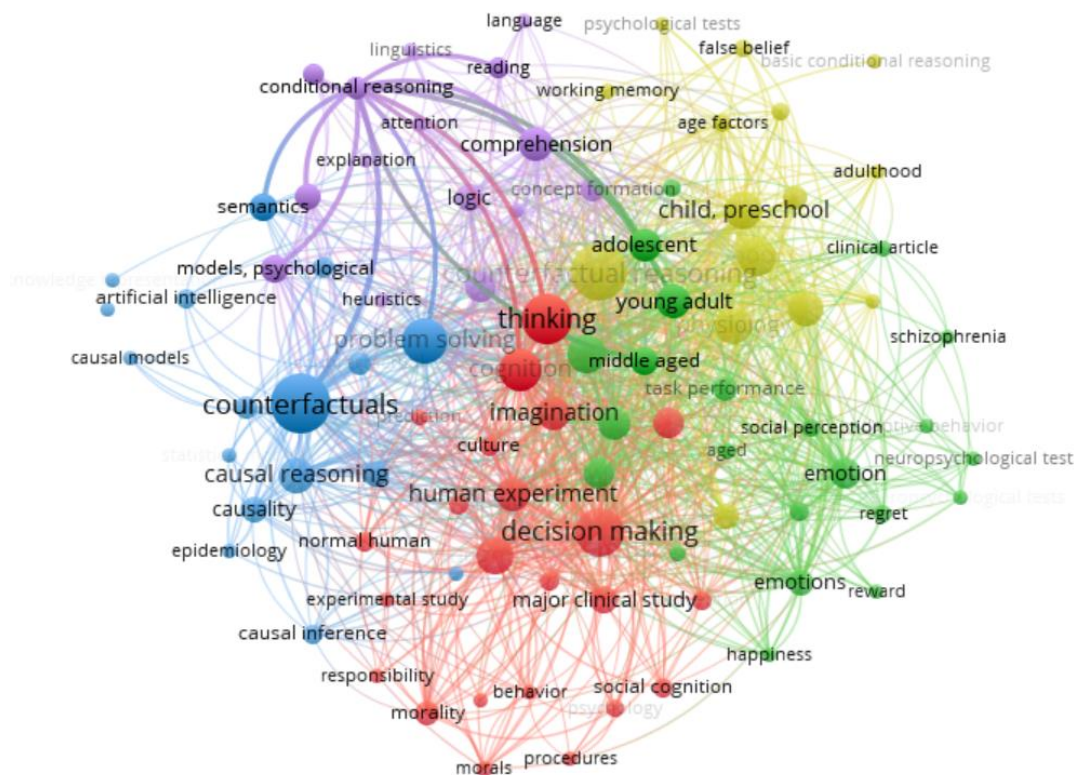


Figure 4: keywords co-occurrences

The occurrences of the core research terms are shown in Figure 4. The study of counterfactual reasoning in cognitive science articles from 1990 to 2023 has revealed significant research interests and topics. The terms "counterfactual reasoning," "thinking," "decision-making," and "cognitive" are key, indicating a focus on understanding the mental processes involved in decision-making and their impact on human behavior. The interdisciplinary approach of combining psychology and cognitive science is evident in the study of problem-solving, child development, and the cognitive and brain systems that underlie counterfactual reasoning. The multidisciplinary viewpoint emphasizes the intricate interaction between cognitive processes and physiological components, emphasizing the need for comprehensive research methods that incorporate both psychological and biological perspectives. The widespread use of these study terms demonstrates the complexity and diversity of counterfactual reasoning research in the cognitive sciences. This analysis provides guidance for future research initiatives, facilitating a deeper understanding of the cognitive processes involved in counterfactual reasoning and their implications for human behavior and decision-making. The outcomes of this bibliometric investigation demonstrate a range of scholarly publications that enhance our understanding of the connection between counterfactual thinking and cognitive sciences. The increasing number of articles, the diverse range of countries and organizations involved, and the frequency of certain themes and keywords all indicate the expanding importance of counterfactual thinking in the field of cognitive research. The

findings emphasize the interdisciplinary aspect of counterfactual research, displaying the combined endeavors of scholars, technologists, and experts from several nations. This research provides valuable insights into the existing body of knowledge and establishes a foundation for future investigations that will consistently influence the development of the cognitive sciences. It enhances our understanding of human cognition and decision-making processes in various contexts and disciplines.

### **Discussion**

Counterfactual thinking is an important aspect of the cognitive sciences because it aids in comprehending thought processes, decision-making, and learning from prior experiences of individuals. This article presents a complete perspective on the influence of counterfactual reasoning on cognitive sciences, based on a careful bibliometric study. The findings demonstrate the advancement and development of an academic field characterized by diverse contributions from many countries and organizations, along with an increasing emphasis from experts.

### ***Trends in Publication and Geographic Distribution***

The field of cognitive sciences has shown a consistent rise in research focus on counterfactual reasoning, peaking in 2023 with a total of 31 articles. This trend indicates significant advancements in research methods and interdisciplinary approaches, emphasizing the importance of counterfactual reasoning in understanding cognitive processes. The increasing interest is reflected in the contributions from diverse nations. The United States leads with 91 publications, followed by the UK with 68. Notable additional contributors include Canada, Spain, Germany, and Ireland. The global distribution of research highlights the cooperative nature of the field, emphasizing the need for international collaboration to advance knowledge in the cognitive sciences.

To enhance the contributions of Middle Eastern countries in the field of cognitive sciences, we may propose a number of recommendations. Initially, it is imperative to enhance the allocation of financial resources and other necessary means to bolster cognitive science research. This will facilitate the conduct of top-notch studies and the development of groundbreaking approaches. Creating research centers and institutions specifically focused on cognitive science can establish a robust foundation for ongoing research endeavors. Furthermore, promoting international relationships and partnerships with esteemed institutions and academics around the world would enhance knowledge sharing and facilitate joint projects. Promoting interdisciplinary approaches by combining cognitive science with disciplines like artificial intelligence, psychology, and neurology can result in thorough and influential research findings. Investing in education and training programs to cultivate proficient cognitive sciences researchers will guarantee a consistent flow of expertise in the region. By implementing these tactics, countries in the Middle East can make a substantial contribution to and gain advantages from the worldwide progress in cognitive sciences, namely in the field of counterfactual reasoning.

### ***Influential Journals and Educational Institutions***

Trinity College Dublin, Universität Salzburg, and Harvard University are all significant contributors, with a total of 17 articles from Trinity College Dublin. These institutions have greatly propelled the discipline forward through influential research, namely in the areas of developmental and theoretical elements of counterfactual reasoning. Other journals should

promote high-quality research activities, publishing studies that advance theoretical and developmental elements. This can be achieved by creating multidisciplinary study venues and dedicating special issues to emergent cognitive science themes. Journals should also promote collaboration through conferences and symposiums, focusing on rigorous peer-review processes and constructive comments. Additionally, journals should prioritize mentorship programs and funding for creative research projects to support early-career researchers.

### ***Prolific Authors and Research Keywords***

Highly productive writers in this discipline recognize the continuous commitment and achievements of outstanding scholars. Counterfactual reasoning research forms the essential foundation for current understanding and future advancements in this field. Their work, along with that of other exceptionally active scientists, highlights the crucial importance of individual research in advancing the field. In addition, examining keyword extracts from primary sources provides significant insights into the extensive and complex nature of the area, encompassing topics such as "counterfactual reasoning," "thinking," "decision-making," and "cognitive." Furthermore, it implies a particular focus on cognitive processes and human conduct. The integration of psychology, cognitive science, and biology in the interdisciplinary approach highlights the complex nature of investigations into counterfactual thinking.

### **Conclusions**

The bibliometric analysis highlights the growing significance of counterfactual reasoning in the cognitive sciences, driven by interdisciplinary research. It underscores the need for continuous cooperation and diverse methodologies to understand cognitive processes and their impact on human decision-making. The study highlights the interdisciplinary nature of counterfactual research, involving scholars, technologists, and experts from various countries. This research provides valuable insights into existing knowledge and lays the groundwork for future studies, influencing the development of cognitive sciences and improving our understanding of human cognition and decision-making processes across various disciplines.

### **Competing Interests**

The Author of This Publication Declares there are No Competing Interests.

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