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Review

Neurotransmitters in the Modulation of Stress: A Bibliometric Mapping and Visual Analysis (2000–2023)

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Abstract

Stress is a multifaceted response involving physiological, psychological, and behavioural processes, with neurotransmitters such as serotonin, dopamine, and norepinephrine playing key modulatory roles. This study aimed to map global research trends on stress and neurotransmitters, identify thematic clusters, and highlight emerging frontiers relevant to health and disease. A bibliometric analysis was conducted on 4,132 publications indexed in Scopus between 2000 and 2023. Data were retrieved and processed using Excel and Harzing's Publish or Perish, and analyzed with VOSviewer to generate co-authorship, co-occurrence, and citation network visualizations. Publications on stress and neurotransmitters have shown a consistent upward trend over the past two decades. The United States, China, and Japan emerged as the leading contributors. Core keywords included stress, neurotransmitters, serotonin, dopamine, glutamate, depression, anxiety, and oxidative stress. Emerging terms such as antioxidants, neuroprotection, inflammation, BDNF, GABA, acetylcholinesterase, metabolism, and gene expression indicate growing interest in neurochemical pathways and their role in mental and neurodegenerative disorders. The network analysis revealed strong global collaboration and multidisciplinary research across neuroscience, psychology, and molecular biology. This study provides the first comprehensive bibliometric mapping of global research on the links between stress and neurotransmitters. By highlighting established themes and emerging areas such as BDNF-related signaling and metabolic-neurochemical interactions, the findings contribute to a deeper understanding of stress modulation mechanisms. These insights may guide future translational research and inform the development of targeted strategies for managing stress-related physical and mental health disorders.

Keywords

Stress; neurotransmitters; bibliometric analysis; mental health; BDNF; neuroprotection; serotonin; dopamine

1. Introduction

Stress is a complex, multifaceted response triggered when an individual perceives a threat or challenge, initiating a cascade of physiological, psychological, and behavioural reactions. Stress can manifest in various forms, including acute, chronic, episodic acute, psychological, physical, and work-related stress, each with distinct health implications [1]. Chronic and episodic acute stress, in particular, are associated with heightened risks of physical and mental health disorders, such as cardiovascular diseases, anxiety disorders, and neurodegenerative conditions [2, 3]. The physiological mechanisms underlying the stress response involve the coordinated activity of multiple brain regions, including the prefrontal cortex, amygdala, hippocampus, nucleus accumbens, and hypothalamus [4]. These regions interact through intricate feedback loops and the release of specific neurotransmitters and neuromodulators that regulate physiological and behavioural responses to stress, including activation of the hypothalamic–pituitary–adrenal (HPA) axis, modulation of emotional processing, and maintenance of homeostasis.

Neurotransmitters are chemical messengers that facilitate communication between neurons, transmitting signals from presynaptic neurons to postsynaptic receptors across synapses in the brain and throughout the body. Key neurotransmitters such as serotonin, dopamine, and glutamate play a pivotal role in modulating the brain's response to stress, influencing mood, behavior, and various physiological functions [5]. During a stressful event, the hypothalamus activates the HPA axis, triggering the release of neurotransmitters such as norepinephrine and cortisol, which prime the body for a 'fight or flight' response [6]. This cascade also activates brain regions such as the amygdala, which is critical for processing fear and emotional responses, thereby intensifying the stress response [7]. Dysregulation or alterations in neurotransmitter levels have been linked to several neurological and psychiatric disorders, including Parkinson's disease, schizophrenia, depression, and Alzheimer's disease [8-11]. Therefore, a comprehensive understanding of how stress influences neurotransmitter systems is crucial for developing targeted therapeutic strategies to mitigate its detrimental effects on health.

Bibliometrics, a growing field within information science, employs quantitative methods to analyze scientific literature, providing insights into the structure, development, and dynamics of research domains [12]. This analytical approach enables researchers and policymakers to identify influential works, prominent authors, collaboration networks, and emerging trends, and to forecast the future trajectory of specific fields. Several bibliometric studies have explored stress-related topics, including the global landscape of traumatic stress research [13], publication patterns concerning work-related stress [14], the impact of stress during the COVID-19 pandemic [15, 16], and the application of machine learning for stress prediction [17]. More recently, bibliometric analyses have focused on specific molecular and neurobiological domains, such as BDNF and neuroinflammation in depression [18, 19], reflecting a growing interest in the mechanistic underpinnings of stress-related disorders. However, there remains a lack of comprehensive analyses specifically examining the interplay between stress and neurotransmitter systems across multiple neurobiological pathways. Therefore, this study aims to address this gap by providing a comprehensive bibliometric overview and visual analysis of publications on the interplay between stress and neurotransmitters, highlighting trends, key contributors, and emerging research directions in the field. The selected time frame (2000–2023) captures a critical period characterized by major advances in neuroendocrine research, molecular neuroscience, and neuroimaging, which have substantially shaped current understanding of stress-related mechanisms.

2. Materials and Methods

2.1 Data Acquisition and Search Strategy

A literature search was conducted using the Scopus database on 21st July 2025. The Scopus database was selected because it provides a comprehensive collection of global scientific research, extensive coverage across various research categories, a higher number of publications, and a greater citation count [20, 21]. Additionally, it has been widely used in bibliometric analyses. The search strategy employed was as follows: Article title = (“neurotransmitter*” OR “5-HT” OR “serotonin” OR “dopamine” OR “adrenergic” OR “norepinephrine” OR “epinephrine” OR “acetylcholine” OR “ACh” OR “cholinergic” OR “muscarinic” OR “aspartate” OR “aspartic acid” OR “neurokinin*” OR “histamine” OR “monoamine*” OR “oxytocin” OR “glycine” OR “glutamate” or “GABA” OR “gamma-aminobutyric acid” OR “NMDA” OR “N-methyl D-aspartate” OR “AMPA” OR “α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid”) AND (“stress”) AND NOT (“glycine max” OR “glycine soja” OR “monosodium glutamate” OR “glycine betaine”). While restricting the search to article titles enhances specificity and relevance, this approach may have excluded potentially relevant studies in which key terms appear only in abstracts or keywords. This limitation should be taken into account when interpreting the findings. The search was limited to publications from 2000 to 2023. The search date (21st July 2025) served as the data extraction “frozen point” for citation counts. This time frame was selected to ensure the completeness and stability of citation data, as more recent publications may be subject to ongoing indexing and citation updates. All document types except retracted and erratum publications were included in this analysis. Figure 1 demonstrates the screening flowchart of the documents.

Figure 1 Flow diagram of the search strategy for stress and neurotransmitters research between 2000 to 2023.

2.2 Data Extraction and Analytical Tool

Documents were extracted from the Scopus database in Microsoft Excel (.xlsx), Research Information Systems (.ris), and Comma-Separated Values (.csv) formats for analysis. To ensure the accuracy of the results, two independent researchers conducted the literature selection and data extraction. Any discrepancies between the two reviewers were resolved through discussion until consensus was reached. Microsoft Excel was used to calculate document percentages and generate descriptive graphs. Citation metrics were computed using Harzing’s Publish or Perish (PoP) software, while bibliometric mapping and visualization were performed with VOSviewer version 1.6.20 (Universiteit Leiden, Netherlands). VOSviewer provides overlay visualization maps in which node color and distance reflect temporal distribution and relational associations within the research network [22]. The bibliometric indicators analyzed included total publications, total citations, citation trends, subject categories, leading journals, authors, countries, institutions, and keyword co-occurrence patterns.

3. Results

3.1 Publication Outputs and Citation Trends

Of the 6,323 records initially identified and screened, 4,189 fell within the time period from 2000 to 2023. After excluding 54 errata and 3 retracted documents, a total of 4,132 publications were included in the analysis. Original articles accounted for the highest document type (3,674, 88.9%), followed by review articles (264, 6.4%), conference papers (66, 1.6%), book chapters (59, 1.4%), letters (23, 0.6%), and notes (20, 0.5%). Other types of documents, such as short surveys, editorials, books, and data papers, made up less than 0.6% of the total. Among the included publications, 3,959 (95.6%) were in English, while 78 were in Chinese, 36 in Russian, 11 in German, 10 in French, 8 in Portuguese, 7 in Japanese, 5 in Korean, 5 in Persian, 4 each in Spanish and Ukrainian, 2 each in Dutch, Italian, Slovak, and Turkish, and 1 each in Arabic, Czech, Hebrew, Moldavian, Moldovan, Polish, and Romanian.

Figure 2 illustrates the annual publications and citations from 2000 to 2023. Over the past 23 years, publications have steadily increased, reflecting growing interest in the topic and sustained research activity. We anticipate this upward trend will continue. Between 2000 and 2023, the 4,132 publications received 160,485 citations, resulting in an average citation rate of 6,686.88 cites/year and 38.91 cites/paper. The highest annual citation count was in 2014, with 10,815 citations, followed by 2006 with 10,729 citations, and 2012 with 10,711 citations. Of the 4,132 publications, 210 (5.1%) have never been cited, and 701 (16.9%) have been cited fewer than five times. Many of these less-cited publications are relatively recent, published within the past decade.

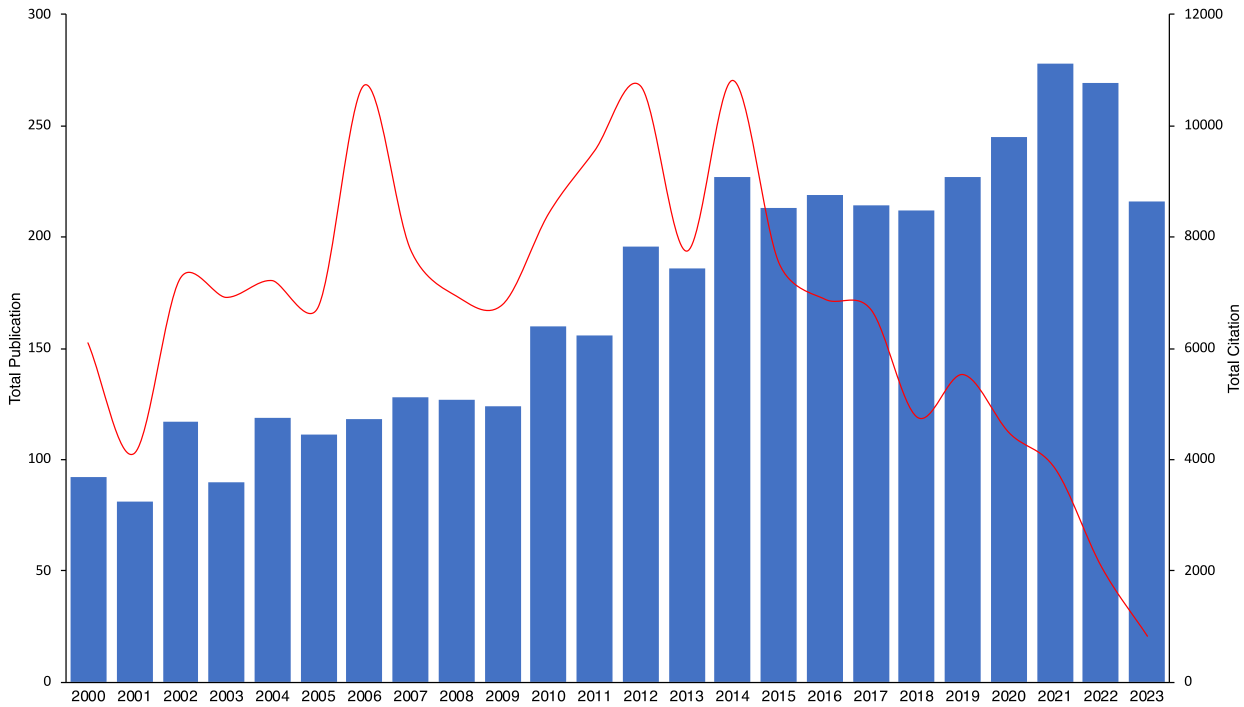

Figure 2 Publication outputs and citation trends by year from 2000 to 2023 on stress and neurotransmitter research.

According to Scopus classification, the 4,132 publications were distributed across 26 subject areas (Table 1). Neuroscience (38.2%), Medicine (38.1%), and Biochemistry/Genetics/Molecular

Biology (37.7%) were the most represented categories, followed by Pharmacology/Toxicology/Pharmaceutics (18.6%), Agricultural and Biological Sciences (11.4%), and Psychology (6.4%). Other areas, including Immunology and Microbiology, Chemistry, and Environmental Science, contributed smaller proportions. The other subject categories contributed to less than 9% of the overall publications under the categories of Chemical Engineering, Veterinary, Nursing, Computer Science, Arts and Humanities, Engineering, Social Sciences, Health Professions, Materials Science, Physics and Astronomy, Dentistry, Earth and Planetary Sciences, Energy, Mathematics, Business, Management and Accounting, and Decision Sciences. This broad disciplinary spread reflects the multidisciplinary nature of stress and neurotransmitter research.

Table 1 Distribution of publications by subject area in stress and neurotransmitter research (2000–2023).

Subject Area	Percentage (%)
Neuroscience	38.2
Medicine	38.1
Biochemistry/Genetics/Molecular Biology	37.7
Pharmacology/Toxicology/Pharmaceutics	18.6
Agricultural and Biological Sciences	11.4
Psychology	6.4
Others	<9

3.2 Distribution by Journals

The analysis identified the leading contributors across journals, authors, highly cited publications, countries, and institutions (Table 2). The top five journals publishing stress and neurotransmitter research were Neuropsychopharmacology (72 articles), Behavioural Brain Research (71), Journal of Neuroscience (64), PLOS One (64), and Brain Research (62). These journals primarily focus on behavioural neuroscience, psychopharmacology, and neurobiology, aiming to explore the neural mechanisms underlying behaviour, the impact of drugs on both animal and human behavior, and the mechanisms underlying these effects.

Table 2 Top contributors in stress and neurotransmitter research.

Category	Top Contributors	No. of Publications	No. of Citations
Journals	Neuropsychopharmacology	72	-
	Behavioural Brain Research	71	-
	Journal of Neuroscience	64	-
	PLOS One	64	-
	Brain Research	62	-
Authors	Popoli M.	18	1,890
	Grace A.A.	17	1,191
	Musazzi L.	17	820
	Kvetnansky R.	15	340
	Puglisi-Allegra S.	14	1,756
Highly Cited Publications	Essential role of BDNF in the mesolimbic dopamine pathway in social defeat stress [23]	-	1,740
	Social support and oxytocin interact to suppress cortisol and subjective responses to psychosocial stress [24]	-	1,569
	Pharmacological inhibition of cystine-glutamate exchange induces endoplasmic reticulum stress and ferroptosis [25]	-	1,368
	The serotonin transporter promoter variant (5-HTTLPR), stress, and depression meta-analysis revisited: Evidence of genetic moderation [26]	-	1,145
	The stressed synapse: The impact of stress and glucocorticoids on glutamate transmission [27]	-	1046
Countries	United States	1,312	75,301
	China	685	16,322
	Japan	279	9,407
	Germany	240	14,663
	Canada	192	11,088
Institutions	McGill University, Canada	52	4,094
	National Institutes of Health, USA	49	3,443
	Yale School of Medicine, USA	49	6,800
	Harvard Medical School, USA	45	2,118
	University of Pittsburgh, USA	43	2,561

3.3 Distribution by Authors

Among the 4,132 documents analyzed, 131 were written by a single author, 371 by two authors, 480 by three authors, and 3,150 by more than three authors. The document with the most authors had 47 contributors. Among individual researchers, Popoli M. was the most prolific, contributing 18 publications with 1,890 citations (Table 1). Grace A.A. and Musazzi L. each published 17 articles, followed by Kvetnansky R. (15) and Puglisi-Allegra S. (14). These authors, largely from neuroscience and psychophysiology backgrounds, also demonstrated high citation impact, underscoring their influence in shaping the field. They remain active in research and continue to publish, with nearly all their publications being cited. Notably, there are close collaborations between authors from the same institution, such as Popoli M. and Musazzi L. of Università degli Studi di Milano in Milan.

3.4 Most-Cited Publications

Several landmark papers have significantly influenced this research area. The most-cited article is “Essential Role of BDNF in the Mesolimbic Dopamine Pathway in Social Defeat Stress” [23], with 1,740 citations, published by Science in 2006 (Table 1). The second most-cited article is “Social Support and Oxytocin Interact to Suppress Cortisol and Subjective Responses to Psychosocial Stress” [24], which received 1,569 citations and was published in Biological Psychiatry in 2003. The third most-cited article, “Pharmacological Inhibition of Cystine-Glutamate Exchange Induces Endoplasmic Reticulum Stress and Ferroptosis” [25], published by eLife in 2014, has 1,368 citations. Of the top ten most-cited publications, only one is a review article, which is “The Stressed Synapse: The Impact of Stress and Glucocorticoids on Glutamate Transmission” [27], while the others are original research articles. The high citation counts of these works likely reflect the originality of their findings and the novel insights they provide, highlighting the central role of neurotransmitter pathways in stress-related mechanisms.

3.5 Most Prolific Countries and Institutions

At the national level, the United States dominated output (1,312 publications; 75,301 citations), followed by China (685; 16,322), Japan (279; 9,407), Germany (240; 14,663), and Canada (192; 11,088) (Table 1). Collectively, these five countries accounted for most of the global productivity and citation impact, reflecting both breadth and depth of research activity. The most active institutions were McGill University (52 publications; 4,094 citations), the U.S. National Institutes of Health (49; 3,443), Yale School of Medicine (49; 6,800), Harvard Medical School (45; 2,118), and the University of Pittsburgh (43; 2,561). These findings indicate strong contributions from North American institutions, particularly in neuroscience and psychiatry.

3.6 Author Co-Authorship Network Analysis

Co-authorship network analysis is a vital tool for examining research collaboration among authors. This study utilized VOSviewer for analysis, selecting co-authorship as the analysis type and authors as the unit of analysis. Parameters were set with a maximum of 25 authors per document and a minimum of 3 documents per author. From a total of 16,415 authors, 381 met these criteria. However, not all these 381 authors are interconnected. Figure 3 (A1 and A2) illustrates the co-authorship network and overlay visualization for the 219 authors. The network visualization map uses colour, circle size, and line thickness to represent clusters, productivity size, and relative link strength (collaboration), respectively [28]. Authors with closer collaborative relationships are depicted with circles that are closer together. Total link strength reflects the cumulative strength of an author's co-authorship connections with other authors.

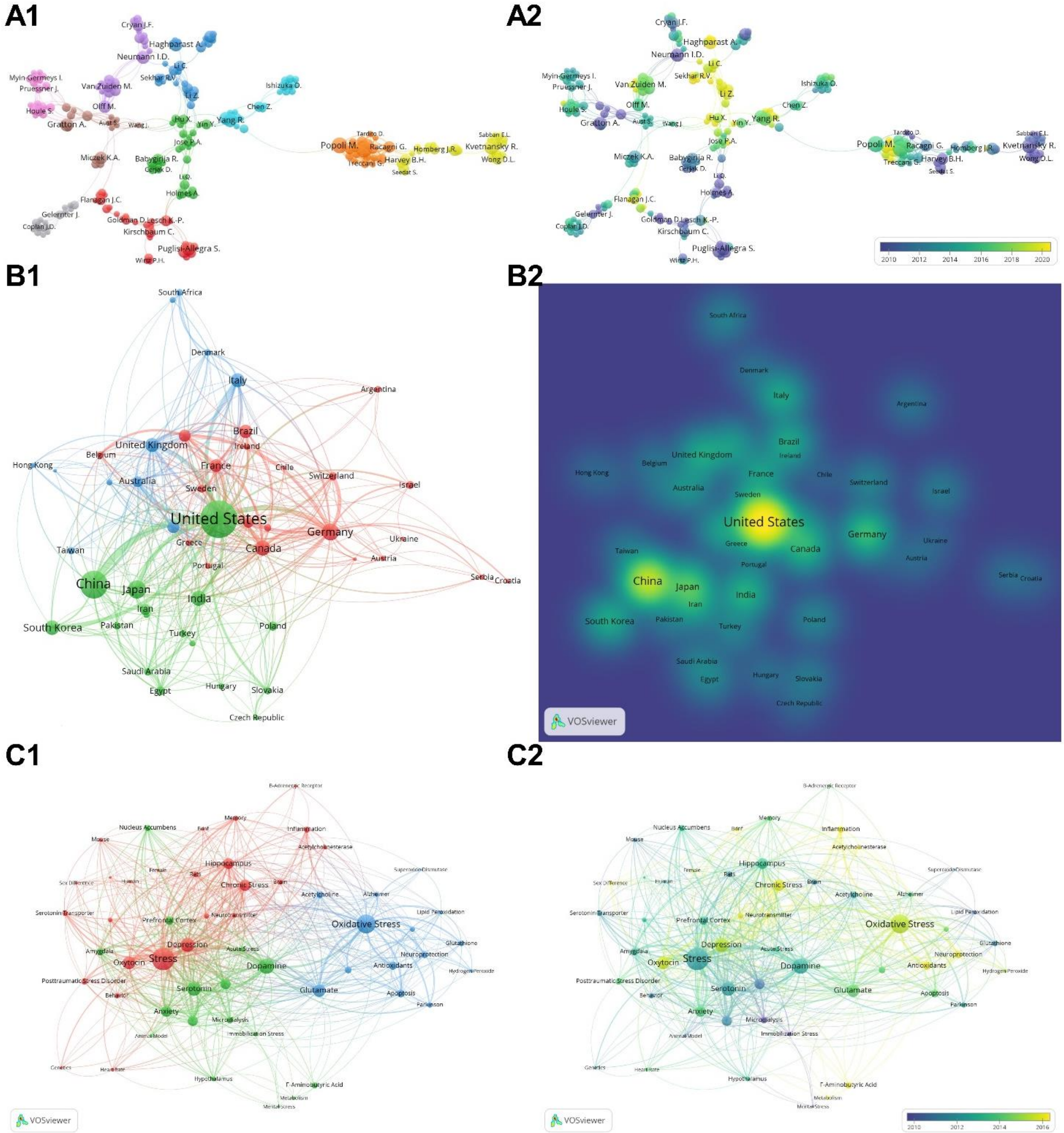

Figure 3 Network visualizations of stress and neurotransmitter research. Author co-authorship networks (A1) and overlay visualization (A2); Country co-authorship networks (B1) and density visualization (B2); Keyword co-occurrence networks (C1) and overlay visualization (C2).

The analysis identified ten clusters representing distinct groups of authors in the field of stress and neurotransmitter research. Cluster 1 (red) comprises 28 authors, Cluster 2 (green) also consists of 28 authors, Cluster 3 (blue) includes 27 authors, Cluster 4 (yellow) contains 26 authors, Cluster 5 (purple) has 20 authors, Cluster 6 (aqua) also has 20 authors, Cluster 7 (orange) includes 19 authors, Cluster 8 (brown) comprises 18 authors, Cluster 9 (pink) contains 17 authors. Cluster 10 (grey) includes 16 authors. Notably, certain clusters, such as Cluster 7 and Cluster 4, are distinctly separate from the others, indicating their weak or distant relationship with the remaining clusters. The overlay visualization reveals that Clusters 1, 4, and 8 were among the pioneers in this research domain, as evidenced by their older publications. Conversely, Clusters 3, 6, and 9 were the emerging clusters, with average publication years ranging from 2016 to 2023.

3.7 Country Co-Authorship Network Analysis

Among the 115 countries that contributed to the published documents, 48 met the threshold, each with at least 10 documents and 10 citations. Figure 3 (B1 and B2) illustrates the co-authorship network and density visualization analysis by country. The network map includes 48 circles, each representing a country. The top five most productive countries—namely, the United States, China, Japan, Germany, and Canada—are depicted with larger circles, indicating higher publication output than other countries. The analysis identified three distinct clusters representing groups of countries in the field of stress and neurotransmitter research. The proximity of the circles indicates closer research collaborations. The largest cluster (red) comprises 21 countries, including Argentina, Austria, Belgium, Brazil, Canada, Chile, Croatia, France, Germany, Greece, Ireland, Israel, Mexico, the Netherlands, Portugal, Serbia, Spain, Sweden, Switzerland, Ukraine, and the United Arab Emirates. The second-largest cluster (green) comprises 16 countries: China, the Czech Republic, Egypt, Hungary, India, Iran, Japan, Pakistan, Poland, Romania, Saudi Arabia, Slovakia, South Korea, Thailand, Turkey, and the United States. The third cluster (blue) includes 11 countries: Australia, Denmark, Hong Kong, Italy, Jordan, Malaysia, Nigeria, the Russian Federation, South Africa, Taiwan, and the United Kingdom. The cluster density visualization highlights denser areas with a high concentration of nodes. The analysis indicates that research on stress and neurotransmitters is most concentrated in the United States, China, and Germany.

3.8 Keywords Co-Occurrence Visualization Analysis

Figure 3 (C1 and C2) displays the network and overlay visualization analyses of co-occurrence among author keywords. A minimum threshold of 10 occurrences was applied, revealing that 55 of the 7,436 keywords met the criteria. In addition to stress and neurotransmitters, commonly used keywords included oxytocin, dopamine, serotonin, glutamate, oxidative stress, depression, and anxiety. The analysis identified three distinct clusters within the author's keyword network. The red cluster (cluster 1, 25 items) contains terms such as acetylcholinesterase, BDNF, behaviour, brain, chronic stress, depression, female, gene expression, genetics, heart rate, hippocampus, human, inflammation, memory, mouse, neurotransmitter, oxytocin, posttraumatic stress disorder, pregnancy, rats, serotonin transporter, sex difference, social stress, stress, and β-adrenergic receptor. The green cluster (cluster 2, 16 items) includes keywords such as acute stress, amygdala, animal model, anxiety, corticosterone, dopamine, hypothalamus, immobilization stress, mental stress, metabolism, microdialysis, norepinephrine, nucleus accumbens, prefrontal cortex, serotonin, and γ-aminobutyric acid. The blue cluster (cluster 3, 8 items) features keywords such as acetylcholine, Alzheimer, antioxidants, apoptosis, glutamate, glutathione, hydrogen peroxide, lipid peroxidation, neuroprotection, neurotoxicity, oxidative stress, Parkinson, reactive oxygen species, and superoxide dismutase. The overlay visualization analysis indicates that newer keywords (from

2016 onwards) include antioxidants, neuroprotection, inflammation, BDNF, γ-aminobutyric acid, acetylcholinesterase, metabolism, and gene expression.

4. Discussion

The findings from the bibliometric and visual analysis highlight the evolving interest in the relationship between stress and neurotransmitters over the past 23 years, marked by a steady increase in research output. This trend underscores the growing recognition of the importance of understanding how stress impacts neurochemical processes and the implications for mental health. The peak years in terms of citations (2006, 2012, and 2014) suggest that key developments or breakthroughs during these periods significantly influenced subsequent research. The growing number of citations can be attributed to the discovery of how brain-derived neurotrophic factor (BDNF) and glutamate play crucial roles in stress responses, significantly advancing our understanding of the neurobiological mechanisms underlying stress [23, 25, 27].

The increasing prominence of keywords such as BDNF and glutamate reflects a broader paradigm shift in neuroscience and psychiatry. Earlier frameworks, particularly the monoamine hypothesis, emphasized neurotransmitter deficiencies as the primary drivers of stress-related and mood disorders [29]. However, contemporary research increasingly highlights the roles of synaptic plasticity and neuroprogression, in which alterations in neuronal connectivity, dendritic remodeling, and neurotrophic signaling pathways are considered central mechanisms. BDNF has emerged as a key mediator of synaptic adaptation under stress, linking environmental stressors to long-term structural and functional brain changes. This shift underscores a transition from a purely neurochemical perspective to a more integrative model encompassing cellular resilience and network-level plasticity. Consistent with this evolution, previous bibliometric studies have also reported a steady increase in research output alongside a growing emphasis on neurobiological mechanisms of stress [13-17]. However, these studies have largely focused on specific domains such as traumatic stress, work-related stress, and pandemic-related stress. In contrast, the present study provides a more focused evaluation of neurotransmitter systems within the broader stress framework. This integrative perspective highlights the increasing complexity of the field and underscores the importance of multidisciplinary approaches for advancing future research.

Similarly, the growing emphasis on oxidative stress and antioxidants reflects an expanding recognition of the metabolic burden imposed by chronic stress. Sustained activation of stress pathways is known to increase reactive oxygen species production, leading to cellular damage, mitochondrial dysfunction, and impaired neuronal survival [30]. These processes are increasingly implicated in the pathophysiology of neurodegenerative disorders, including Alzheimer's and Parkinson's disease [31]. The emergence of neuroprotection and antioxidant-related keywords in recent years suggests a shift towards exploring protective and therapeutic strategies that target oxidative and inflammatory pathways, further bridging the gap between stress biology and neurodegeneration. These findings have opened new avenues for research into targeted therapies for stress-related disorders. Beyond these observations, the increasing prominence of BDNF and related pathways reflects a broader conceptual shift in the field.

The dominance of journals such as *Neuropsychopharmacology* and *Behavioural Brain Research* underscores the field's strong focus on behavioural neuroscience and the mechanisms underlying drug effects on the brain. These journals are well-established platforms for exploring the biochemical and behavioural aspects of stress, reinforcing the interdisciplinary nature of research in this area, which spans medicine, psychology, and cognitive sciences. The presence of well-cited works by leading authors such as Popoli M. and the high publication output from notable institutions such as McGill University and the National Institutes of Health, USA, demonstrates a concentration of expertise and collaboration among leading researchers and institutions.

The analysis also reveals that while the United States leads the field in both productivity and citation impact, other countries, such as China and Japan, have increasingly contributed to the literature, indicating a global expansion of research interest. The co-authorship network suggests strong collaboration between authors from the same institutions, as well as international partnerships. However, certain clusters remain relatively isolated, which may reflect differences in research focus, such as distinct neurobiological pathways or thematic specializations, as well as geographical or institutional collaboration patterns. These findings point to the need for more cross-disciplinary and cross-institutional collaborations to bridge gaps in the literature and promote a more unified approach to studying stress and neurotransmitters. Nevertheless, these interpretations should be considered cautiously, as more detailed network analyses would be required to confirm the underlying drivers of cluster isolation. In addition, the present study focused on core bibliometric indicators and did not incorporate advanced metrics such as the H-index or burst detection analysis, which may provide deeper insights into research impact and emerging trends. Thus, future studies may consider integrating these approaches for a more comprehensive evaluation.

The co-occurrence analysis of author keywords reveals three distinct clusters, each highlighting different aspects of stress and neurotransmitter research. Cluster 1, the largest, centers on stress-related processes, such as chronic stress, depression, oxytocin, serotonin, and neurotransmitter dynamics, indicating a focus on understanding behavioural and hormonal responses to stress. This cluster also includes keywords like BDNF, hippocampus, and inflammation, underscoring investigations into the neurobiological and molecular mechanisms underlying stress and its impact on brain function.

Cluster 2 focuses on neurochemical pathways and brain regions, with keywords such as dopamine, corticosterone, hypothalamus, and nucleus accumbens, indicating a strong interest in the physiological and biochemical effects of acute, anxiety, and mental stress. The emphasis on specific neurotransmitters like dopamine and γ-aminobutyric acid (GABA) suggests a focus on the regulatory roles these chemicals play in stress responses, particularly in prefrontal and limbic brain regions.

Cluster 3 highlights oxidative stress and neuroprotection, with terms such as antioxidants, apoptosis, and neurotoxicity. This cluster's emphasis on neuroprotection and oxidative stress suggests an emerging interest in understanding how oxidative processes and neuroinflammation contribute to stress-induced neuronal damage and the development of neurodegenerative diseases. The presence of keywords related to Alzheimer's and Parkinson's disease indicates that researchers are increasingly exploring the intersection between chronic stress, neurotransmitter imbalances, and neurodegenerative conditions.

Despite the field's growth, the current literature has notable limitations. For instance, a significant proportion of publications have low citation counts, especially recent ones. This may reflect the delayed recognition of emerging research or indicate a saturation of studies that are not sufficiently innovative or differentiated. Furthermore, the dominance of certain regions and institutions may limit diverse perspectives and approaches, highlighting the importance of encouraging participation from underrepresented regions and institutions. Furthermore, this study did not differentiate the nature of research outputs across regions (e.g., clinical versus preclinical studies), which may provide deeper insights into geographical research specialization and should be explored in future investigations. Additionally, the focus remains predominantly on behavioural and pharmacological studies, while other aspects, such as genetic, molecular, and environmental interactions with stress and neurotransmitter dynamics, are less explored.

Future research should aim to diversify the geographical and thematic scope of the field. Exploring the roles of neurotransmitters beyond the commonly studied ones (e.g., dopamine, serotonin) and investigating their interactions with other biological systems, such as the immune system and gut-brain axis, could provide new insights. Additionally, more longitudinal studies examining the long-term effects of stress and neurotransmitter changes are essential to deepen our understanding of chronic stress conditions and their impact on mental health. Integrating multidisciplinary approaches, including genetics, molecular biology, and computational models, may also provide a more comprehensive view of the complex interactions at play.

5. Conclusions

In summary, this bibliometric review underscores the growing body of research exploring the complex relationship between stress and neurotransmitters, highlighting key neurochemical pathways, including those involving serotonin, dopamine, and BDNF. The findings demonstrate the importance of understanding these mechanisms to develop more targeted interventions for stress-related disorders and improve mental health outcomes. The global collaboration and diverse focus areas within the field emphasize stress as a critical area of research with broad implications. Future studies should delve into underexplored neurotransmitters and their interactions with other biological systems, aiming for a more integrative understanding of stress mechanisms.

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Author Contributions

Qamar M: Conceptualization, writing – original draft, formal analysis. Ahmad AH: writing – review and editing. Sulong S: writing – review and editing. Tauseef A: writing – review and editing. Azman KF: Conceptualization, writing – review and editing. All authors have read and approved the published version of the manuscript.

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Competing Interests

The authors have declared that no competing interests exist.

AI-Assisted Technologies Statement

Artificial intelligence (AI) tools were used solely for basic grammar correction and language refinement in the preparation of this manuscript. Specifically, OpenAI's ChatGPT was employed to improve the readability and linguistic clarity of the English text. All scientific content, data interpretation, and conclusions were developed independently by the author. The authors have thoroughly reviewed and edited the AI-assisted text to ensure its accuracy and accept full responsibility for the content of the manuscript.

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