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# Test Anxiety Research (2014–2024) A Keyword Co-occurrence Analysis with Implications for Educational Practice

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**Abstract.** Test anxiety not only plays a significant role in shaping students' academic performance and mental health but also brings forth new challenges for the design and implementation of educational interventions. This study employs keyword co-occurrence network analysis to systematically explore core themes and development trends of test anxiety from 2014 to 2024. Based on 1,620 articles retrieved from the Scopus database, VOSviewer software was employed to analyze the clustering structure of author-keywords and index-keywords. The study finds that research on test anxiety has primarily focused on areas such as academic performance, gender differences, self-efficacy, psychological intervention, and the COVID-19 pandemic. In recent years, the scope of research in this field has expanded to include self-regulated learning, subject-specific anxiety, and mental health issues among high-pressure populations, aligning closely with the United Nations Sustainable Development Goals of “quality education” and “good health and well-being”. This field research shows a trend of cross-integration among disciplines such as psychology, education, medicine, and neuroscience. However, cross-cultural comparisons, long-term mechanisms, and the neurophysiological basis of test anxiety have not received sufficient attention. Future research urgently needs to adopt a cross-cultural perspective, explore individualized intervention pathways, and further uncover the neural mechanisms of test anxiety to better respond to the urgent need to improve education quality and promote mental health globally.

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## 1. Introduction

As global educational competition continues to intensify, test anxiety has become a critical risk factor undermining students' psychological well-being and academic achievement, underscoring the urgent need for comprehensive research and targeted interventions. Test anxiety is typically defined as the emotional response states of tension, worry, and physiological arousal individuals experience when coping with exams, assessments, or other high-stakes academic situations (Chin et al., 2017; Von Der Embse et al., 2018). In contemporary educational contexts, academic assessments span a student's entire learning journey, often accompanied by test-related anxiety and stress (Apostolidis & Tsiatsos, 2021; Dagli et al., 2024). Some scholars argue that while moderate anxiety may stimulate motivation to a certain extent, an excessive amount of anxiety can drain cognitive resources and consequently impair learning effectiveness (Cai et al., 2024). High levels of test anxiety can lead to a decline in students' performance in important academic assessments, further affecting their motivation and self-efficacy (Ersozlu & Karakus, 2019; Hart & Ganley, 2019; Mammarella et al., 2018), and this negative effect is not limited to specific subjects or ages (Carey et al., 2017; Caviola et al., 2022; Zhang, 2019).

In the existing literature, test anxiety is often regarded as a complex and multidimensional form of anxiety, typically comprising two main components: "worry" and "tension" (Brady et al., 2018; Chin et al., 2017; Putwain & Daly, 2014). "Worry" is the negative cognitive aspects of academic failure, social evaluation, and personal self-worth (Chin et al., 2017; Putwain et al., 2015), while "tension" is associated with physiological arousal, including an accelerated heart rate, perspiration, and shortness of breath (Chin et al., 2017; Tian et al., 2024). Previous research has indicated a significant negative correlation between test anxiety and academic achievement (Sun et al., 2025).

Within academic contexts, students often need to cope with various tests and evaluations several times. It may lead to adverse outcomes if individuals cannot regulate emotional arousal effectively. For example, in a social science empirical study, Turan & Meral (2018) found students experiencing high test anxiety tended to exhibit avoidance-based learning strategies during examination preparation, ultimately compromising their academic performance (Hyseni & Hoxha, 2018; Steinmayr et al., 2018). Moreover, the relationship between test anxiety and academic performance is not one-way. Some longitudinal studies using cross-lagged models suggest test anxiety further undermines students' confidence and motivation in subsequent assessments and may lead to higher levels of anxiety (Chin et al., 2017; Jamieson et al., 2016; Steinmayr et al., 2016). However, the individual's academic achievement also can, in turn, affect their level of anxiety: When students perceive academic pressure or doubt their abilities, they tend to worry more about failure in subsequent assessments (Brady et al., 2018; Putwain et al., 2016).

Although test anxiety is often conceptualized as anxiety about the testing process itself, individuals may exhibit specific types of anxiety across different subject domains or competency contexts. A typical example is math anxiety (Caviola et al., 2022; Ersozlu & Karakus, 2019). Math anxiety and test anxiety tend to be positively correlated, and their core mechanism also involves worry and physiological arousal (Cassady et al., 2025; Morsanyi et al., 2014). A recent meta-analysis demonstrated math anxiety exerts a particularly pronounced effect on mathematics-related assessments, closely interacting with factors such as general test anxiety and working memory load (Caviola et al., 2022).

Similarly, findings from Hart and Ganley's (2019) large-scale study among American adults confirmed the strong associations between math anxiety, general anxiety, and test anxiety, highlighting its detrimental impact on mathematical performance. Further studies suggest math anxiety may also negatively affect cognitive reflection, potentially triggering avoidance behaviors in daily life situations or tasks, thus intensifying a cycle of anxiety (Morsanyi et al., 2014). On the other hand, foreign language anxiety (particularly in English language assessments) is also closely associated with test anxiety. A recent meta-analysis revealed a significant negative correlation between FLA and language performance ( $r = -0.34$ ), with listening anxiety showing the strongest correlation, while reading and test anxiety had comparatively weaker effects (Zhang, 2019).

Another study found cognitive test anxiety significantly predicted college students' English test scores. Although most participants reported low anxiety in class and exams, they still commonly experienced marked anxiety during oral expression, suggesting oral anxiety plays an important role in foreign language learning (Zheng & Cheng, 2018). In addition, science examinations also elicit specific forms of anxiety. As in mathematics and foreign language learning, students' emotional responses to science examinations may adversely affect their test performance. Notably, biofeedback interventions have been shown to alleviate anxiety and enhance self-efficacy in science testing contexts (Apostolidis & Tsiatsos, 2021), highlighting the need to explore further the manifestations and regulatory mechanisms of subject-specific test anxiety.

In response to the adverse impacts of test anxiety, a variety of intervention strategies have been proposed, including cognitive behavioural therapy (CBT), mindfulness-based stress reduction (MBSR), biofeedback techniques, relaxation training, and coping skills training (Apostolidis & Tsiatsos, 2021; Sun et al., 2025; Brady et al., 2018; Cassady et al., 2025; Jamieson et al., 2016). However, these strategies face common limitations, including insufficient tracking of long-term effectiveness, limited evidence on cross-cultural applicability, and a lack of consideration for the impact of individual differences on intervention efficacy (Cassady et al., 2025; Brady et al., 2018; Jamieson et al., 2016).

Extensive research has confirmed test anxiety has a significant negative impact on students' academic performance and mental health. However, existing research still has two prominent limitations. First, a large body of literature remains focused on associations between test anxiety and single variables – for example,

the relationships between math anxiety and variables such as cognitive performance, and gender (Hart & Ganley, 2019)—while lacking a systematic synthesis of the broader research landscape. Second, although some studies have attempted to establish intervention tools or anxiety rating systems (Cassady et al., 2025), interdisciplinary findings remain largely fragmented, and no unified theoretical framework has emerged (Radevic & Milovanovic, 2024).

This study adopts keyword co-occurrence network analysis as the technical pathway (Van Eck & Waltman, 2020) and explicitly employs the multidimensional theory of test anxiety as its conceptual framework (Putwain et al., 2015; Putwain et al., 2016; Chin et al., 2017; Brady et al., 2018). According to this theory, test anxiety is structured around two central dimensions: a cognitive facet (“worry”) and a physiological-emotional facet (“tension”). The former involves pessimistic appraisals of test performance and anticipated failure, while the latter encompasses the bodily arousal and emotional reactions elicited during evaluative situations.

Meanwhile, this study adopts an interdisciplinary knowledge integration perspective and employs keyword co-occurrence network analysis to systematically reveal the core themes and developmental trends in test anxiety research. Keyword co-occurrence network analysis categorizes high-frequency keywords into thematic clusters through clustering algorithms and visually illustrates the relationships and thematic structures among these keywords using network diagrams (Ersozlu & Karakus, 2019; Van Eck & Waltman, 2010). It aids in identifying foundational knowledge and trending topics and reveals underexplored or overlooked research areas (King et al., 2024; Wan et al., 2024).

Specifically, this study aims to identify the structural knowledge landscape, key research themes, and evolving interdisciplinary connections in this domain. Based on a co-occurrence analysis of author- and index-keywords, this study seeks to answer the following research questions:

- (1) RQ1: What are the core themes and trends of test anxiety research from 2014 to 2024?
- (2) RQ2: How are the different themes within test anxiety research interrelated, and how do these interconnections reflect the trend of interdisciplinary integration?
- (3) RQ3: What critical issues remain underexplored in the current test anxiety research, particularly regarding cross-cultural differences, long-term mechanisms of influence, and interdisciplinary integration?

By answering these questions, this study not only promotes the study of test anxiety to be holistic and systematic at the theoretical level but also clarifies the key areas of future psychological and educational intervention at the practical level. In recent years, reviews of research have emerged as an important supplementary tool to systematic reviews. Among these, bibliometric reviews are particularly well-suited to providing an empirically grounded, replicable, and multi-faceted perspective on knowledge production within a given field. Therefore, this study systematically examined the structure, evolution, and gaps

in test anxiety research from 2014 to 2024 using a bibliometric approach.

## **2. Literature review**

To address the above RQs, it is necessary to first conduct a systematic review of existing bibliometric studies in the field of test anxiety in recent years to clarify the progress made in current research and identify unresolved research gaps, thereby laying a theoretical foundation for the present study.

### **2.1 Overview of Bibliometric Approaches**

Bibliometric analysis is a systematic quantitative research method commonly using keyword co-occurrence, author collaboration, and co-citation analysis to uncover a research field's hot topics, knowledge structure, and evolutionary trends (Passas, 2024; Kumar, 2025). Unlike narrative and systematic reviews, this method emphasizes data-driven, structured analysis and visual presentation. It is particularly suitable for systematically reviewing large-scale literature samples and identifying research trends (Öztürk et al., 2024). At present, keyword co-occurrence analysis is one of the most widely used techniques in bibliometric research, as it effectively identifies the correlations and cluster characteristics among high-frequency keywords (Passas, 2024). Commonly used tools include VOSviewer and CiteSpace. The former is more suitable for keyword clustering and visualization analysis, while the latter excels in burst term detection and frontier research analysis (Kumar, 2025).

In recent years, this method has been applied across various disciplines, addressing topics including prior knowledge, numerical ability, and psychological adaptation, and has yielded relatively systematic and structured findings (Bittermann et al., 2023; Ma & Ismail, 2025; Soheili & Lanz, 2025; Ganti et al., 2025). These studies indicate bibliometric analysis has a strong explanatory power in clarifying the knowledge landscape and development trends of complex cross-disciplinary topics. Given that the issue of test anxiety involves interdisciplinary elements across education, psychology, and medicine, the use of bibliometric methods helps to review its research hotspots, thematic correlations systematically, and interdisciplinary trends from a macro-structural perspective, thereby addressing the limitations of traditional reviews in structural integration and topic identification.

### **2.2 Bibliometric Studies on Test Anxiety**

In recent years, review studies have focused on test anxiety and its related fields, particularly those employing bibliometric analysis methods to uncover research hotspots, disciplinary evolution, and structural characteristics, which provide important methodological references and entry points for this study. Existing literature has primarily focused on adjacent subfields of test anxiety, such as mathematics anxiety and science anxiety. Studies have shown math anxiety correlates with motivation, self-efficacy, gender differences, and test performance (Ersozlu & Karakus, 2019). In another study, research on math anxiety was classified into three major groups: "cognitive mechanisms"; "psychological variables"; and "educational background" finding the citation patterns among author groups were relatively differentiated, but the research focuses tended to

converge (Radević & Milovanović, 2024). Review studies in the scientific anxiety field have also found frequent co-occurrence of keywords such as "self-efficacy", "students", and "science anxiety", indicating a high degree of overlap between this topic and test anxiety in terms of population characteristics and psychological mechanisms (Khafizova et al., 2024). In addition to discipline-related anxiety, existing studies have also examined the comorbidity of anxiety and depression among adolescent populations. Systematic reviews targeting the primary school stage indicate math anxiety, epidemic stress, and bullying incidents are closely related to adverse psychological reactions, and intervention focus has increasingly focused on areas such as mindfulness and emotion regulation (Fu et al., 2024).

Another bibliometric research related to academic stress highlights the continuous upward trend of anxiety and emotional burden among college students, especially medical students (Dagli et al., 2024). Regarding methodological tools, most reviews employed VOSviewer or CiteSpace to visualize keyword co-occurrence networks and evolutionary trends, further confirming the effectiveness of bibliometric analysis in structural mapping and frontier identification (Passas, 2024; Kumar, 2025). For example, in medical and educational psychology research, researchers have revealed the clustering evolution structure of psychological variables through large-scale database retrieval and network analysis techniques (Bittermann et al., 2023; Ganti et al., 2025). Another research combines bibliometric methods with systematic review methods, achieving complementarity between quantitative and qualitative aspects in topic identification and literature integration (Ma & Ismail, 2025).

In summary, although existing studies have provided a solid foundation for understanding the knowledge structure of anxiety themes, there remain the following gaps in the core research on "test anxiety" : (1) The lack of an overall structural analysis from 2014 to 2024. (2) The research trends of test anxiety concerning cross-cultural, long-term mechanisms of action, and interdisciplinary integration have not yet been systematically explored. Therefore, this study uses the Scopus database as its data source, employing keyword co-occurrence network analysis to systematically identify the core issues and evolution trends in test anxiety research. It aims to provide new empirical support for this field's theoretical sorting and intervention practice.

### 3. Method

This study belongs to bibliometric analysis based on keyword co-occurrence analysis and is not a systematic review, meta-analysis, or scoping review. It aims to reveal the research hotspots, trends, and evolution characteristics in test anxiety through quantitative keyword co-occurrence analysis methods.

#### 3.1 Database Selection

Test anxiety negatively affects students' cognition, emotion, and academic behavior. It is associated with impaired concentration, low self-esteem, and avoidance behaviors (Cassady & Johnson, 2002; Zeidner, 1998). These effects justify sustained research attention to this construct. The Scopus database was the data-source for this study because: it is one of the largest indexed databases of

peer-reviewed literature, offering extensive and comprehensive coverage, and a reliable quality control mechanism (Harzing & Alakangas, 2016); it includes a larger range of journal related to disciplines relevant to the research topic (test anxiety) than other academic databases (e.g., Web of Science, ERIC, PubMed); it provides more detailed bibliographic metadata.

### **3.2 Criteria for Inclusion and Exclusion**

The retrieval was conducted on February 1, 2024, using the Scopus database with the preliminary search query: TITLE-ABS-KEY ("Test Anxiety" OR "Exam Anxiety" OR "Examination Anxiety"). The following inclusion and exclusion criteria were directly applied during the search process. The inclusion criteria were: (1) Formally published articles in English peer-reviewed journals; (2) The publication year is between 2014 and 2024. The exclusion criteria were as follows: (1) duplicate records; (2) publications outside the 2014–2024-time range; (3) non-English literature; and (4) non-journal article literature types, such as reviews, conference papers, book chapters, reviews, etc. After the preliminary search and screening under the above-mentioned restrictive conditions, 1,620 journal papers meeting the requirements were identified and included in the subsequent analysis (see Figure 1).

### **3.3 Data Collection and Availability**

To ensure the transparency and repeatability of the analysis process, the researchers retrieved and fully exported detailed metadata for all 1,620 documents (including title, abstract, keywords, author, publication year, journal name, etc.) from the Scopus database on February 1, 2024. After exporting the data in CSV format, it was uploaded to the Zenodo platform. Public link: <https://doi.org/10.5281/zenodo.15401595>.

### **3.4 Data Cleaning and Harmonization**

During the data cleaning phase, this study found high-frequency keywords such as "human", "humans", "male", and "female", which lack thematic distinctiveness, significantly interfered with the clustering structure (Radević & Milovanović, 2024). Therefore, these keywords were excluded from the formal analysis to enhance the clarity of clustering topics and improve the interpretability of the research findings.

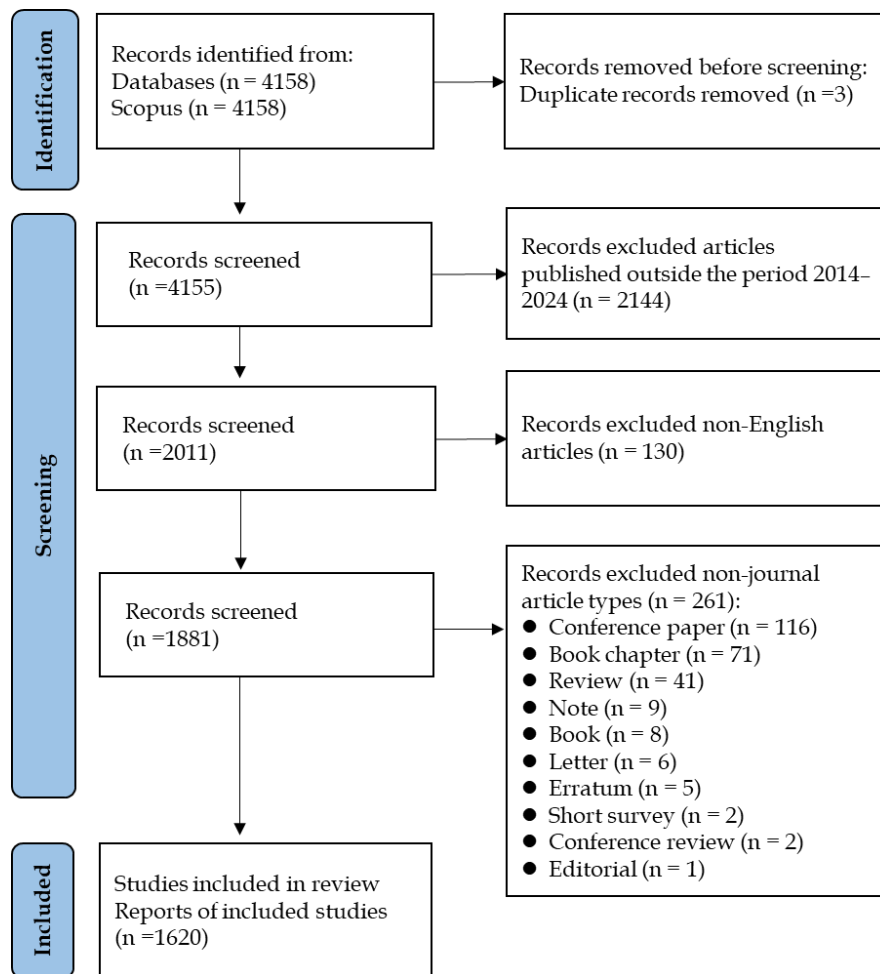


Figure 1. Flow Diagram of the Literature Search and Selection Process (adapted from PRISMA; Page et al., 2021)

### 3.5 Data Analysis

This study utilized VOSviewer (version 1.6.16; Van Eck & Waltman, 2020) to perform co-occurrence network analysis and visualization for author-keywords and index-keywords. The parameter settings were as follows: (1) In the Author-keyword co-occurrence analysis, the minimum number of occurrences was set at 15, meaning a keyword had to appear at least 15 times in the dataset for inclusion (Radević & Milovanović, 2024). Of the 3,709 author-keywords, 45 reached this threshold, resulting in five clusters. (2) In the index-keywords co-occurrence analysis, the minimum occurrence threshold for keyword was set at 40, meaning a keyword had to appear at least 40 times (Radević & Milovanović, 2024). Among the 4,674 indexed keywords, 66 met this threshold, forming three clusters. (3) Additionally, during the preliminary analysis phase, it was found the index-keywords such as “human,” “humans,” “male,” and “female”, which lack thematic distinctiveness, significantly disrupt the clustering structure. Therefore, these keywords were excluded from formal analysis to enhance the clarity of clustering themes and the interpretability of research findings (Radević & Milovanović, 2024).

In the keyword co-occurrence network map generated by VOSviewer, the size of nodes represents the frequency of keywords in the analysis literature, while the thickness of the links between nodes reflects the co-occurrence strength of keywords. Keywords are automatically grouped into different clusters using VOSviewer's built-in clustering algorithm. Researchers subsequently conducted an in-depth induction and analysis of the keyword thematic structure, research trends, and hotspot distribution in the field of test anxiety based on network maps and clustering outcomes, aiming to comprehensively reveal this domain's knowledge landscape.

Given the dominance of English in international academic communication and the need for comparability of research findings, this study includes only English-language journal articles. However, such language limitations may lead to the limitation of cross-cultural generalization, and future research should consider including multilingual literature to enhance the cross-cultural validity of the conclusions. Moreover, the keyword co-occurrence network analysis method entails certain limitations, such as the potential influence of keyword selection and threshold configuration on clustering outcomes, which may result in the omission of low-frequency yet significant research themes. Meanwhile, semantic differences among keywords or the presence of synonymous keywords may, to some extent, affect the accuracy and interpretability of the clustering results.

## 4. Result Result

### 4.1 Author-keywords co-occurrence network analysis

To provide an in-depth answer to RQ1, this section analyzes the author-keywords co-occurrence network (see Figure 2). The keyword "test anxiety" occupies a core position in the network structure, with the highest total link strength (TLS = 503) and frequency of occurrence (Occ = 601), reflecting its dominant position in this field (Van Eck & Waltman, 2020). Centering on this core node, the keyword network is further divided into five clusters (see Table 1), reflecting research in this field has expanded from a single focus to multiple cross-directions, demonstrating the diversification of content and the segmentation trend of research orientations. Specifically, as follows:

In the purple cluster, the strong co-occurrence of "test anxiety" and "math anxiety" suggests a close relationship between these two anxiety types within academic research, especially in the field of subject-specific anxiety. "Math anxiety" has a normalized citation frequency of 1.866 (Avg. norm. cit. = 1.866, derived from Table 1), indicating the high level of attention this topic receives in test anxiety research. The frequent co-occurrence of "gender" and "gender differences" in the cluster reveals the impact of gender variations on subject-specific anxiety. In addition, the appearance of "adolescence" reflects the focus of anxiety research on the adolescent group. The blue cluster revolves around "anxiety" and "academic achievement," reflecting the strong correlation between anxiety and academic performance, particularly within specific populations. The high normalized citation frequency of "academic achievement" (1.589) further indicates that the topic has received significant focus within test anxiety research. The prominent co-occurrence of "nursing students" and "nursing" within the cluster indicates

research on anxiety in the nursing groups has become a focal point.

In the red cluster, “stress”, “depression”, and “covid-19” emerge as core keywords, indicating test anxiety research has extended into the field of mental health, particularly in the context of the COVID-19 pandemic. “Covid-19” has an average publication year of 2022.773 (Avg. pub. year = 2022.773, derived from Table 1), indicating it has become a new hotspot in the field of test anxiety. Meanwhile, the relatively high normalized citation frequency of “depression” (1.170) underscores the significance of mental health issues in anxiety research, particularly during times of social crisis. The green cluster reflects the close co-occurrence between test anxiety and psychological variables such as self-efficacy and self-regulated learning. “Self-regulated learning” (1.719) has garnered substantial academic attention in anxiety-related studies.

Additionally, the frequent appearance of keywords like “academic performance”, “self-efficacy”, and “motivation” further reflects the broad relevance of psychological variables in test anxiety research. At the same time, the high frequency of “university students” suggests the student population has gradually become an important object of research on test anxiety and psychological variables, especially within the context of higher education. The yellow cluster focuses on research related to psychometric instruments and psychological traits, including keywords such as “validity”, “reliability”, and “achievement goals”.

Notably, the relatively high normalized citation frequency of “achievement goals” (1.712) indicates this concept has received considerable attention in test anxiety research, particularly in educational psychology. Moreover, the relatively high normalized citation scores of “perfectionisms” (1.361) and “self-esteem” (1.083) reflect continued scholarly attention to the link between individual psychological characteristics and test anxiety. The emergence of “mindfulness” (1.021) further demonstrates the correlation between psychological intervention methods and research on test anxiety.

Based on the above analysis, this study preliminarily identifies the key aspects of research hotspots and trends in test anxiety. Clustering topics (such as subject anxiety, mental health, psychological variables, measurement tools, etc.) reflect test anxiety research's diversity and interdisciplinary integration trends. It is particularly noteworthy that emerging hotspots such as “COVID-19”, “nursing students”, and “self-regulated learning” reflect a recent trend in research focus on more specific and practical problem areas.



Table 1: Analysis of Author-keywords and Associated Metrics

| ID   | Label                   | Cluster | Weight (Links) | Weight (TLS) | weight (Occ.) | score (Avg.pub. year) | score (Avg. cit.) | score (Avg.norm. cit.) |
|------|-------------------------|---------|----------------|--------------|---------------|-----------------------|-------------------|------------------------|
| 122  | adolescent              | red     | 12             | 23           | 18            | 2020.611              | 6.944             | 0.548                  |
| 126  | adolescents             | red     | 17             | 48           | 33            | 2020.697              | 8.758             | 0.640                  |
| 272  | assessment              | red     | 19             | 44           | 34            | 2020.824              | 8.794             | 0.851                  |
| 802  | covid-19                | red     | 19             | 35           | 22            | 2022.773              | 8.046             | 1.048                  |
| 876  | depression              | red     | 20             | 76           | 59            | 2019.220              | 22.746            | 1.170                  |
| 1165 | exam anxiety            | red     | 20             | 34           | 36            | 2020.417              | 6.528             | 0.488                  |
| 1652 | intervention            | red     | 10             | 24           | 18            | 2021.333              | 13.000            | 1.044                  |
| 1950 | medical education       | red     | 12             | 18           | 18            | 2020.889              | 15.389            | 1.063                  |
| 1956 | medical students        | red     | 12             | 36           | 27            | 2020.926              | 9.296             | 0.627                  |
| 1972 | mental health           | red     | 17             | 36           | 25            | 2020.840              | 13.600            | 0.681                  |
| 2719 | quality of life         | red     | 10             | 17           | 18            | 2019.111              | 18.556            | 1.227                  |
| 3230 | stress                  | red     | 24             | 68           | 45            | 2019.422              | 15.644            | 0.827                  |
| 49   | academic performance    | green   | 33             | 107          | 68            | 2020.309              | 19.324            | 1.416                  |
| 77   | achievement             | green   | 10             | 22           | 16            | 2019.500              | 24.686            | 1.301                  |
| 650  | cognitive test anxiety  | green   | 11             | 18           | 22            | 2019.682              | 22.818            | 1.330                  |
| 1522 | higher education        | green   | 14             | 31           | 30            | 2021.433              | 10.567            | 1.132                  |
| 1752 | latent profile analysis | green   | 15             | 20           | 15            | 2021.400              | 17.867            | 1.028                  |
| 1767 | learning                | green   | 12             | 23           | 16            | 2020.563              | 11.438            | 0.642                  |
| 2078 | motivation              | green   | 26             | 91           | 70            | 2019.686              | 15.743            | 0.993                  |
| 2993 | self-efficacy           | green   | 26             | 103          | 57            | 2020.175              | 14.912            | 1.028                  |
| 3016 | self-regulated learning | green   | 11             | 20           | 18            | 2020.000              | 30.000            | 1.719                  |
| 3019 | self-regulation         | green   | 14             | 28           | 16            | 2019.938              | 19.875            | 1.061                  |
| 3582 | university students     | green   | 17             | 35           | 32            | 2020.532              | 6.688             | 0.567                  |
| 22   | academic achievement    | blue    | 18             | 53           | 39            | 2020.205              | 22.282            | 1.589                  |
| 57   | academic self-efficacy  | blue    | 4              | 19           | 17            | 2020.471              | 17.235            | 1.042                  |

|      |                    |        |    |     |     |          |        |       |
|------|--------------------|--------|----|-----|-----|----------|--------|-------|
| 223  | anxiety            | blue   | 42 | 232 | 256 | 2019.762 | 15.914 | 0.902 |
| 992  | education          | blue   | 17 | 36  | 20  | 2019.850 | 17.600 | 1.105 |
| 2239 | nursing            | blue   | 10 | 30  | 16  | 2020.250 | 9.813  | 0.947 |
| 2248 | nursing students   | blue   | 12 | 35  | 29  | 2019.897 | 8.448  | 0.537 |
| 3286 | students           | blue   | 18 | 54  | 33  | 2020.091 | 6.667  | 0.427 |
| 3414 | test anxiety scale | blue   | 5  | 19  | 23  | 2018.913 | 13.783 | 0.837 |
| 86   | achievement goals  | yellow | 13 | 30  | 18  | 2018.833 | 41.611 | 1.712 |
| 676  | college students   | yellow | 14 | 42  | 26  | 2019.192 | 16.115 | 0.948 |
| 2020 | mindfulness        | yellow | 16 | 46  | 31  | 2019.903 | 18.258 | 1.021 |
| 2450 | perfectionism      | yellow | 13 | 29  | 18  | 2020.222 | 18.167 | 1.361 |
| 2791 | reliability        | yellow | 5  | 29  | 18  | 2018.333 | 12.444 | 0.604 |
| 2995 | self-esteem        | yellow | 16 | 30  | 16  | 2020.000 | 18.000 | 1.083 |
| 3607 | validity           | yellow | 8  | 32  | 20  | 2019.100 | 7.700  | 0.435 |
| 121  | adolescence        | purple | 13 | 31  | 20  | 2019.500 | 23.800 | 1.221 |
| 1361 | gender             | purple | 23 | 65  | 37  | 2020.135 | 18.189 | 0.939 |
| 1364 | gender differences | purple | 8  | 14  | 15  | 2019.467 | 16.933 | 0.987 |
| 1896 | math anxiety       | purple | 10 | 24  | 20  | 2019.100 | 31.500 | 1.866 |
| 1910 | mathematics        | purple | 13 | 23  | 16  | 2020.250 | 26.938 | 1.462 |
| 3400 | test anxiety       | purple | 43 | 503 | 601 | 2019.943 | 15.120 | 1.033 |
| 3680 | worry              | purple | 14 | 31  | 20  | 2019.350 | 17.600 | 0.967 |

*Note: TLS: Total Link Strength; Occ.: Occurrences; Avg. Pub. Year: Average Publication Year; Avg. Cit.: Average Citations; Avg. Norm. Cit.: Average Normalized Citations.*

*Decimal values in Avg. Pub. Year indicates the proportion of the year passed (e.g., 2022.773≈ September 2022).*

## 4.2 Index-keywords co-occurrence network analysis

To answer RQ2 and RQ3 further, this section conducts an analysis based on the Index-keywords co-occurrence network (see Figure 3). Compared with author-keywords, indexed keywords more comprehensively reflect the multidimensional characteristics of database literature in research objects, method paths, and disciplinary coverage, thereby facilitating the identification of knowledge boundary expansion and methodological integration trends in test anxiety research.

Index-keywords co-occurrence network analysis reveals the keywords can be divided into three main clusters (see Table 2). The red cluster primarily focuses on the psychological features of test anxiety, approaches to its measurement, and the academic issues among different student populations. The keywords are classified into three major groups: (1) participants-related terms, such as “university student”, “medical student”, “adolescent”, etc., which emphasize adolescents and young adults are key target populations in the research. (2) Measurement-related terms, including “questionnaire”, “cross-sectional studies”, and “self-report”, etc., which indicate the prevalent application of survey instruments and cross-sectional study approaches. (3) Research theme-related terms, like “test anxiety”, “psychology”, “academic achievement”, “mental stress”, and “self-concept”, etc., highlighting the connections between test anxiety and psychological theory, academic performance, and emotional distress.

Notably, “test anxiety” has the most recent average publication year (2022.142, derived from Table 2), further suggesting increasing scholarly attention to this topic. Additionally, the high normalized citation frequencies of “self-report” and “mental stress” reflect the significance of psychological characteristics in test anxiety research. Although the red cluster highlights different student populations, it lacks explicit attention to cross-cultural factors. This suggests cultural variation in test anxiety remains an understudied area, as emphasized in RQ3.

The blue cluster centers on anxiety-related clinical measurements, research methodologies, and features of adult groups. Keywords are categorized as follows: (1) target population terms, such as “adult”, “middle aged”, and “nursing student”, etc., reflecting the widespread academic focus on specific age and professional cohorts. (2) Measurement-related terms, “anxiety assessment”, “test anxiety scale”, “randomized controlled trial”, and “state trait anxiety inventory”, etc., emphasize the critical role of anxiety assessment tools and empirical approaches. (3) Thematic keywords, like “anxiety”, “anxiety disorders”, and “emotion”, etc., reflect key research interests in the manifestation and diagnosis of clinical anxiety.

Although “test anxiety scale” has an earlier average publication year (2016.609), it holds the highest normalized citation frequency (1.293, derived from Table 2), indicating a significant long-term academic impact. Furthermore, the higher normalized frequency of “emotion” also reflects the importance of the affective state in anxiety research. The evolution of research methods and objects within this cluster suggests the academic community is attempting to explore test anxiety’s stability and underlying mechanisms

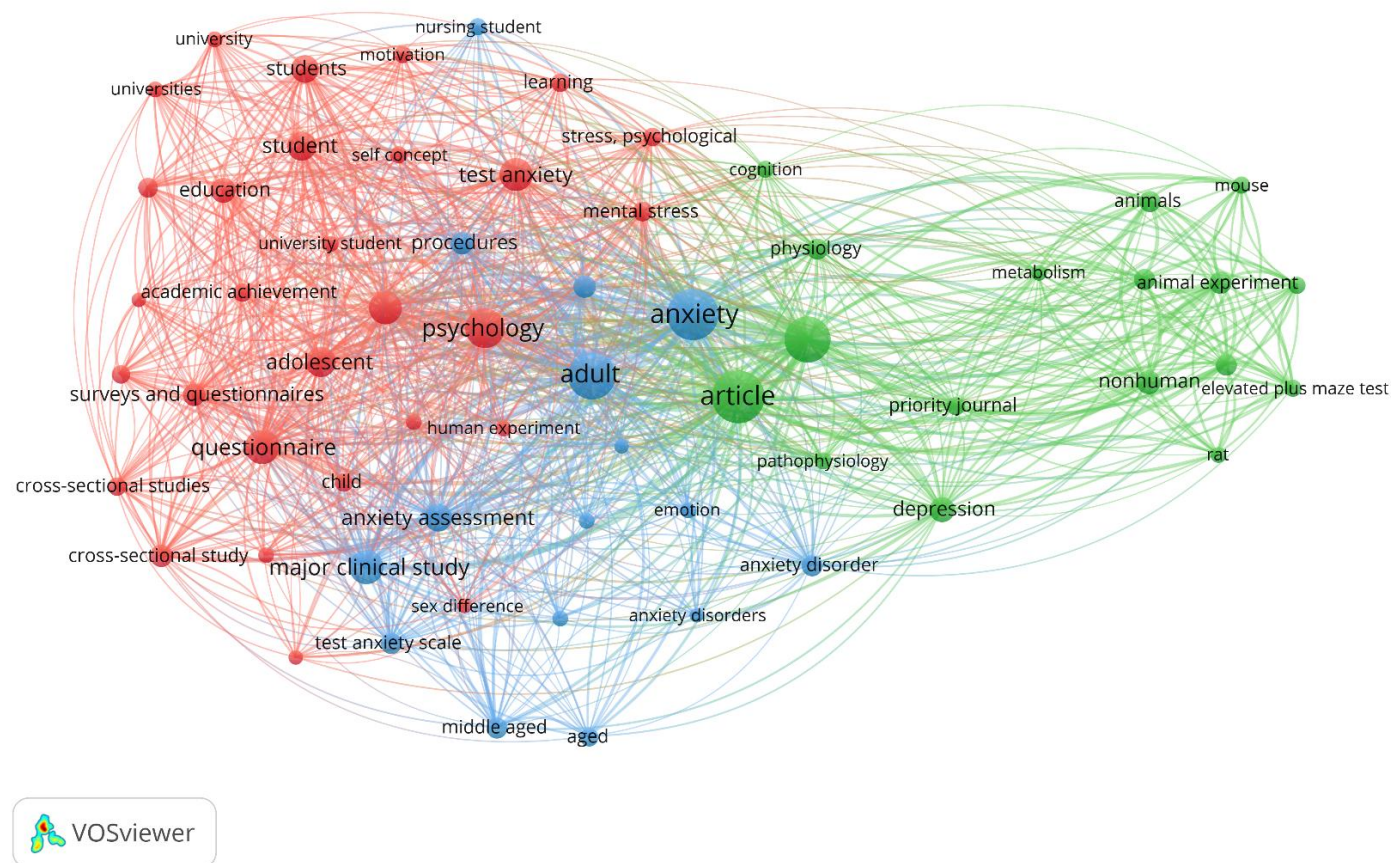
through long-term longitudinal or experimental designs, thereby responding to the concern about long-term mechanisms raised in RQ3.

The green cluster focuses on animal experiments, physiological mechanisms, and basic medical research. Specific keywords include: (1) research object-related terms, such as "nonhuman" and "animals" etc., highlights the important role of animal models in anxiety research. (2) Experimental method-related terms, like "controlled study" and "animal experiments", reflect the general application of animal models and tightly controlled experiments in the investigation of anxiety mechanisms. (3) Research topic-related terms, including "metabolism", "physiology" and "depression", etc., show the significance of metabolic processes and comorbidity issues in anxiety research. The keyword "metabolism" has the highest normalized citation frequency (1.836), underscoring the significant academic impact of metabolic mechanisms.

Additionally, the relatively recent average publication years of keywords such as "open field test" and "mouse" (2020.189) indicate exploratory behavior test and mouse models have become emerging research hotspots. The notable normalized citation frequency of "priority journal" further indicates this field has long been a focus of internationally high-impact journals. This cluster focuses on neurophysiological mechanisms and the use of animal models, which aligns with the dimension of interdisciplinary integration highlighted in RQ3.

Moreover, although "cognition" (green cluster), "mental stress" (red cluster), and "major clinical study" (blue cluster) belong to different clusters, they are closely connected to other nodes, reflecting the distinctly interdisciplinary nature of the keyword network. Compared to author-keywords, index-keywords exhibit a broader degree of interdisciplinary integration: It reflects the traditional focus of education and psychology on test anxiety and encompasses areas such as medicine, physiology, and animal experiments. This reflects the theoretical and methodological comprehensiveness of the literature indexed in the database.

Overall, the co-occurrence analysis of author-keywords and Index-keywords emphasizes different emphases of research dimensions, disciplinary boundaries, and method applications, complementing each other and jointly revealing the core structure and peripheral expansion of test anxiety, thus providing a multidimensional perspective for understanding the development trends in this field.



**Figure 3. Visualization Network of Index-Keywords**

*Note: Clusters reflect broader thematic areas and interdisciplinary connections within test anxiety research*

Table 2: Analysis of Index-Keywords and Associated Metrics

| ID   | Label                      | Cluster | Weight (Links) | Weight (TLS) | weight (Occ.) | score (Avg. year) | pub. | score (Avg. cit.) | score (Avg. norm. cit.) |
|------|----------------------------|---------|----------------|--------------|---------------|-------------------|------|-------------------|-------------------------|
| 29   | academic achievement       | red     | 53             | 688          | 67            | 2019.836          |      | 14.418            | 0.930                   |
| 88   | adolescent                 | red     | 57             | 1615         | 166           | 2019.241          |      | 22.386            | 1.140                   |
| 727  | child                      | red     | 56             | 536          | 68            | 2019.250          |      | 18.691            | 1.054                   |
| 1020 | cross-sectional studies    | red     | 52             | 706          | 65            | 2019.431          |      | 12.631            | 0.889                   |
| 1021 | cross-sectional study      | red     | 54             | 949          | 96            | 2019.958          |      | 10.083            | 0.717                   |
| 1142 | diagnosis                  | red     | 51             | 471          | 46            | 2019.544          |      | 16.717            | 0.880                   |
| 1329 | education                  | red     | 52             | 1021         | 113           | 2018.903          |      | 17.708            | 0.903                   |
| 1349 | educational measurement    | red     | 49             | 724          | 76            | 2018.368          |      | 19.921            | 0.951                   |
| 2054 | human experiment           | red     | 52             | 450          | 50            | 2020.220          |      | 12.360            | 1.052                   |
| 2348 | learning                   | red     | 59             | 566          | 68            | 2020.015          |      | 13.706            | 0.909                   |
| 2569 | medical student            | red     | 49             | 667          | 69            | 2019.971          |      | 11.710            | 0.777                   |
| 2603 | mental stress              | red     | 61             | 883          | 74            | 2018.649          |      | 25.297            | 1.179                   |
| 2747 | motivation                 | red     | 56             | 483          | 57            | 2019.544          |      | 17.316            | 1.062                   |
| 3432 | prevalence                 | red     | 57             | 411          | 42            | 2018.881          |      | 21.048            | 0.892                   |
| 3531 | psychology                 | red     | 61             | 2919         | 289           | 2018.910          |      | 21.446            | 1.063                   |
| 3590 | questionnaire              | red     | 57             | 2127         | 218           | 2019.459          |      | 15.711            | 0.957                   |
| 3853 | self-concept               | red     | 54             | 535          | 56            | 2019.839          |      | 22.000            | 1.173                   |
| 3862 | self-report                | red     | 53             | 476          | 45            | 2019.689          |      | 27.467            | 1.526                   |
| 3924 | sex difference             | red     | 58             | 430          | 42            | 2019.048          |      | 22.405            | 1.028                   |
| 4175 | stress, psychological      | red     | 61             | 782          | 65            | 2018.400          |      | 25.339            | 1.166                   |
| 4184 | student                    | red     | 57             | 1457         | 150           | 2019.867          |      | 19.573            | 1.164                   |
| 4202 | students                   | red     | 53             | 1255         | 142           | 2020.289          |      | 20.345            | 1.355                   |
| 4208 | students, medical          | red     | 48             | 461          | 44            | 2019.386          |      | 14.500            | 0.931                   |
| 4244 | surveys and questionnaires | red     | 57             | 1099         | 98            | 2019.194          |      | 19.714            | 0.989                   |

|      |                         |       |    |      |     |          |        |       |
|------|-------------------------|-------|----|------|-----|----------|--------|-------|
| 4325 | test anxiety            | red   | 61 | 1628 | 197 | 2022.142 | 7.685  | 1.064 |
| 4500 | universities            | red   | 53 | 558  | 47  | 2019.809 | 23.106 | 1.368 |
| 4501 | university              | red   | 53 | 585  | 51  | 2019.647 | 22.431 | 1.316 |
| 4506 | university student      | red   | 50 | 427  | 47  | 2019.617 | 14.553 | 1.019 |
| 4665 | young adult             | red   | 59 | 1997 | 195 | 2018.677 | 19.754 | 0.980 |
| 219  | animal                  | green | 48 | 902  | 82  | 2019.988 | 21.707 | 1.433 |
| 223  | animal experiment       | green | 44 | 1042 | 95  | 2019.790 | 19.979 | 1.257 |
| 225  | animal model            | green | 43 | 894  | 80  | 2019.775 | 21.588 | 1.310 |
| 227  | animals                 | green | 48 | 921  | 84  | 2019.845 | 21.929 | 1.421 |
| 314  | article                 | green | 61 | 4614 | 509 | 2019.959 | 15.277 | 1.003 |
| 826  | cognition               | green | 61 | 551  | 55  | 2019.818 | 14.291 | 0.833 |
| 956  | controlled study        | green | 61 | 3673 | 387 | 2019.894 | 16.811 | 1.060 |
| 1115 | depression              | green | 60 | 1183 | 118 | 2019.746 | 23.034 | 1.328 |
| 1377 | elevated plus maze test | green | 34 | 643  | 56  | 2019.750 | 23.821 | 1.320 |
| 2614 | metabolism              | green | 55 | 538  | 46  | 2019.348 | 27.283 | 1.836 |
| 2756 | mouse                   | green | 33 | 551  | 53  | 2020.189 | 20.736 | 1.350 |
| 2952 | nonhuman                | green | 50 | 1120 | 103 | 2019.893 | 19.078 | 1.220 |
| 3049 | open field test         | green | 33 | 609  | 54  | 2020.148 | 14.463 | 1.071 |
| 3149 | pathophysiology         | green | 57 | 596  | 54  | 2018.519 | 26.167 | 1.083 |
| 3302 | physiology              | green | 61 | 902  | 89  | 2019.292 | 24.944 | 1.191 |
| 3445 | priority journal        | green | 61 | 773  | 68  | 2017.177 | 30.279 | 1.210 |
| 3616 | rat                     | green | 33 | 514  | 47  | 2019.660 | 17.362 | 1.178 |
| 96   | adult                   | blue  | 61 | 3789 | 404 | 2019.354 | 16.718 | 1.033 |
| 121  | aged                    | blue  | 48 | 524  | 61  | 2018.803 | 20.213 | 0.983 |
| 271  | anxiety                 | blue  | 61 | 4354 | 492 | 2019.443 | 17.772 | 1.012 |
| 272  | anxiety assessment      | blue  | 57 | 1454 | 148 | 2018.804 | 21.324 | 1.025 |
| 273  | anxiety disorder        | blue  | 60 | 870  | 84  | 2019.941 | 19.941 | 1.170 |
| 274  | anxiety disorders       | blue  | 57 | 444  | 43  | 2019.698 | 24.279 | 1.163 |
| 790  | clinical article        | blue  | 49 | 456  | 51  | 2019.804 | 10.039 | 0.657 |

|      |                               |      |    |      |     |          |        |       |
|------|-------------------------------|------|----|------|-----|----------|--------|-------|
| 886  | comparative study             | blue | 61 | 448  | 44  | 2018.659 | 20.659 | 1.260 |
| 1384 | emotion                       | blue | 60 | 429  | 46  | 2020.044 | 14.500 | 1.291 |
| 2486 | major clinical study          | blue | 60 | 1899 | 215 | 2019.674 | 17.842 | 1.123 |
| 2656 | middle aged                   | blue | 56 | 780  | 84  | 2018.083 | 18.750 | 0.863 |
| 3002 | nursing student               | blue | 47 | 402  | 58  | 2019.603 | 12.103 | 0.650 |
| 3453 | procedures                    | blue | 58 | 955  | 100 | 2019.120 | 19.810 | 1.026 |
| 3609 | randomized controlled trial   | blue | 58 | 923  | 96  | 2019.885 | 14.635 | 0.966 |
| 4128 | state trait anxiety inventory | blue | 50 | 453  | 46  | 2019.283 | 21.130 | 1.155 |
| 4328 | test anxiety scale            | blue | 55 | 892  | 87  | 2016.609 | 32.920 | 1.295 |

*Note: TLS: Total Link Strength; Occ.: Occurrences; Avg. Pub. Year: Average Publication Year; Avg. Cit.: Average Citations; Avg. Norm. Cit.: Average Normalized Citations.*

*Decimal values in Avg. Pub. Year indicate the proportion of the year passed (e.g., 2022.142  $\approx$  February 2022).*

## 5. Discussion

Based on the co-occurrence network analysis of author-keywords and index-keywords, this study systematically reviews the hot topics, thematic aggregation, and interdisciplinary trends in test anxiety research from 2014 to 2024. Compared with traditional narrative reviews, bibliometric methods reveal the relational structure among research topics through visual mapping, providing empirical support for the variable mechanism, the adaptability of measurement tools, and the integration pathways of discipline. The following will conduct a systematic discussion around three research questions (RQ1 - RQ3).

### 5.1 Core Topics and Frontier Trends in Test Anxiety Research (RQ1)

In response to RQ1, this section distills five research themes based on the author's keyword co-occurrence network. First, the purple cluster reveals sex differences and subject-specific anxiety are among the core topics in current research. The high academic impact of math anxiety further validates the importance of this type of anxiety in research (Caviola et al., 2022; Ersozlu & Karakus, 2019; Morsanyi et al., 2014). Previous studies consistently indicate females experience significantly higher levels of negative emotions in test anxiety, particularly in math anxiety (Ballen et al., 2017; Hart & Ganley, 2019; Putwain & Daly, 2014).

Although this gender difference has been widely supported by empirical evidence, its underlying psychological mechanisms and sociocultural factors—such as self-efficacy, cultural expectations, and the internalization of gender roles—have not been thoroughly examined (Hu et al., 2024; Tao & Hong, 2014). Moreover, this phenomenon may also be related to limitations in individual cognitive resources, such as reduced working memory capacity and diminished cognitive reflection ability (Morsanyi et al., 2014). Therefore, future research should further explore the underlying psychological mechanisms of gender differences and clarify the universality and specificity of domain-specific anxiety from the perspective of cross-cultural to provide a solid theoretical foundation for practical interventions.

Second, the blue cluster highlights a close association between test anxiety and academic performance in specific groups (e.g., nursing students). This finding aligns with the prevailing literature trend regarding academic achievement as a central variable (Steinmayr et al., 2016; Putwain et al., 2015; Von Der Embse, et al., 2018). Meanwhile, the development and validation of relevant measurement tools have continued to be a major research focus. Prior research has confirmed test anxiety issues are particularly prominent among specific groups, such as nursing students (Cassady et al., 2025), possibly due to the pressure associated with occupational requirements and instructional models.

Existing intervention studies suggest students' academic buoyancy is instrumental in reducing the negative effects of test anxiety (Putwain et al., 2015). Mindfulness training and cognitive reassessment strategies have also been shown to reduce test anxiety and improve examination performance effectively (Sun et al., 2025; Brady et al., 2018). Thus, ongoing research is needed to develop and validate specific measurement tools and intervention strategies tailored to different occupations and subject areas to mitigate the negative impact of test

anxiety effectively.

Third, the red cluster demonstrates the comorbidities between test anxiety and broader mental health issues (such as depression and stress) and highlights explicitly the psychological adverse effects of COVID-19 on student populations. This reflects the current research community's strong focus on real-world social crises (King et al., 2024; Tian et al., 2024). Previous studies have confirmed changes in the home learning environment, lack of social support, and disarray of daily life during the pandemic significantly exacerbated test anxiety and negative emotions among student populations, particularly adolescents (Trigueros et al., 2020; Fernández-Castillo, 2021; Lane et al., 2022). Furthermore, the cognitive worry dimension of test anxiety has been shown to have long-term adverse effects on both subjective well-being and mental health (Steinmayr et al., 2016, 2018).

Future research should investigate the long-term psychological impacts of test anxiety in the context of epidemic or similar societal crises, as well as the underlying mechanisms involved, especially the design of psychological interventions targeting adolescents or specific high-stress groups (such as medical students and graduate students) and further examine the effectiveness of different social support models and campus environment optimization strategies in alleviating test anxiety.

Fourth, the green cluster illustrates the close association between self-efficacy and self-regulated learning and test anxiety and academic performance, which is highly consistent with the conclusions of previous research (Roick & Ringeisen, 2017). Although this study, based on keyword co-occurrence analysis, cannot directly validate causal relationships between variables, previous research has further confirmed students with higher levels of self-regulated learning skills typically exhibit lower levels of test anxiety and better academic performance (Broks et al., 2024; Yamada et al., 2017).

Furthermore, Existing studies have also emphasized the role of motivation and self-regulated learning strategies in mitigating academic stress and enhancing academic performance (Lim & Yeo, 2021). It is noteworthy that self-efficacy, as a crucial psychological resource, has been clearly shown to predict test anxiety significantly negatively; the higher the self-efficacy in students, the lower their test anxiety, and the better their academic performance (Roick & Ringeisen, 2017). Future research could further explore the mechanisms and applicability of self-regulated learning skills and self-efficacy in various contexts and academic fields, to promote more precise and effective educational interventions.

Fifth, the yellow cluster focuses on the development of test anxiety measurement tools and the importance of psychological trait factors. The concurrent appearance of the keywords "validity" and "reliability" suggests the effectiveness and dependability of measurement instruments have remained a core focus in test anxiety research. These measurement tools are crucial for studying the impact of psychological traits on the relationship between test anxiety and academic performance. Previous research indicates psychological traits like perfectionism,

self-esteem, and mindfulness significantly moderate the relationship between test anxiety and academic performance (Endleman et al., 2022; Wan et al., 2024; Hyseni & Hoxha, 2018). Specifically, individuals with self-directed perfectionism typically exhibit higher self-efficacy and lower test anxiety, whereas socially prescribed perfectionism is closely associated with increased levels of test anxiety (Endleman et al., 2022). At the same time, individuals with higher levels of self-esteem tend to cope better with the stress induced by test anxiety, exhibiting better academic performance (Hyseni & Hoxha, 2018). Therefore, future research should emphasize the validation of psychometric tools' validity and reliability across different cultural contexts to enhance the global applicability of the tool and further explore the specific mechanism of these psychological traits affecting test anxiety to develop more accurate intervention programs.

To conclude, test anxiety research over the past decade has shown a trend of expansion from the traditional cognitive-performance path to multidimensional topics such as gender, mental health, motivation regulation, and psychological traits. The research questions gradually focus on reality, complexity, and intervention orientation, presenting a highly specialized and integrated research pattern.

## **5.2 Interconnections Among Research Themes and Interdisciplinary Integration (RQ2)**

In response to RQ2, this section explores the characteristics of topic correlation and disciplinary integration in combination with the co-occurrence network of index-keywords. Firstly, the red cluster analysis shows the strong connection between psychology and academic achievement and the widespread application of psychometric tools in test anxiety studies, highlighting the long-standing attention in this field. Especially the high co-occurrence weight of "test anxiety" and "psychology", indicates the psychological perspective continues to play a dominant role in understanding examination anxiety and its underlying mechanisms.

Existing research has consistently demonstrated test anxiety negatively affects students' academic performance, particularly with detrimental effects on academic motivation and self-efficacy (Steinmayr et al., 2016; England et al., 2017). These findings further validate the complex relationship between anxiety and academic achievement and remind us to consider the moderating role of psychological factors in research (Endleman et al., 2022). Moreover, prior studies have shown psychological traits such as perfectionism and self-efficacy significantly moderate the relationship between test anxiety and academic performance (Wan et al., 2024; Hyseni & Hoxha, 2018), further emphasizing the crucial role of individual psychological characteristics in test anxiety research.

Secondly, the blue cluster highlights the growing recognition of the importance of test anxiety measurement tools and clinical research. The high citation frequency of anxiety assessment tools such as "test anxiety scale" indicates their widespread use and enduring impact within the academic community. Meanwhile, the frequent appearance of methods such as "randomized controlled trials" reflects the recent trend in anxiety research based on experimental interventions. Previous

studies indicate intervention strategies like mindfulness training and cognitive relating have shown significant effectiveness in alleviating test anxiety (Sun et al., 2025;). Future research should further explore the efficacy of these interventions in cross-cultural contexts and develop personalized intervention strategies tailored to different educational and occupational contexts.

The keywords of green clustering indicate the current research on anxiety has gradually expanded to physiology and neuroscience. Exploring physiological mechanisms, metabolic function, and neurobiology is crucial for understanding test anxiety's physiological and psychological processes. The high normalized citation frequency of the keyword "metabolism" further verifies the prominent academic impact of metabolic mechanisms in anxiety research (Ersozlu & Karakus, 2019). In recent years, research based on animal experiments has gradually emerged as the main method for exploring the mechanisms of anxiety. Previous studies have shown = the physiological mechanisms of anxiety not only involve changes in hormone levels but may also affect brain function and behavioral performance (Morsanyi et al., 2014; Radević & Milovanović, 2024). Future research might combine neurophysiological and behavioral approaches to examine test anxiety mechanisms from a multi-layered approach and contribute fresh perspectives to the interdisciplinary study.

Furthermore, the associations between keywords such as "cognition", "mental stress" and "major clinical study" across different clusters reflect the intersection and integration of education, psychology, physiology, and clinical medicine (King et al., 2024; Tian et al., 2024). This phenomenon suggests research on test anxiety is not confined to the traditional fields of psychology and education, but has gradually expanded into multiple dimensions, including neurobiology, clinical intervention, and sociocultural dimensions.

Particularly under the influence of global social crises (e.g., COVID-19), the role of social and environmental factors (such as campus environment and socioeconomic status) in individuals' anxiety responses has increasingly attracted the attention of researchers (King et al., 2024). Future research should continue to strengthen interdisciplinary collaboration and explore how these factors influence the occurrence and development of test anxiety through neuroendocrine and brain functional regulatory mechanisms.

### **5.3 Pressing Issues in Adjacent Fields of Test Anxiety Research Requiring Breakthroughs (RQ3)**

Based on further analysis of the retrieval keyword network, there are still the following three key areas to be broken through in the current research: First, in terms of cross-cultural measurement adaptation, terms such as "questionnaire" and "self-report" frequently appear, whereas keywords like "cultural adaptation" and "measurement invariance" are notably absent, reflecting the need further to improve the cross-cultural applicability of the measurement tools. Second, in terms of constructing long-term mechanisms, existing research is predominantly based on cross-sectional designs. It has yet to develop dynamic studies guided by "longitudinal study" and "developmental trajectory", making it difficult to fully uncover the evolutionary trajectory and long-term consequences of test anxiety.

Third, at the level of interdisciplinary integration, although terms such as “physiology” and “animal experiment” indicate growing attention to physiological mechanisms, the neuroscience dimension remains largely absent, making it difficult to support systematic modeling at the cognitive-emotion-neural level. Furthermore, regarding issues such as gender and subject-specific anxiety, current theoretical explanations have yet to deeply engage with the mechanism construction of sociocultural variables (e.g., “stereotype threat”, “gender roles”, etc.), which limits the structural understanding of individual differences.

#### **5.4 Limitations of Research**

Although keyword co-occurrence network analysis can intuitively present the overall trends of test anxiety research, this method has certain limitations and potential analytical biases. First, this analysis method is limited to identifying co-occurrence relationships among keywords, without the capacity to explore causal links, underlying mechanisms, or intricate interaction patterns between specific variables, leading the research findings to focus more on describing overall trends rather than offering detailed interpretations of underlying psychological mechanisms.

Secondly, the reliance on English-language literature from the Scopus database, though contributing to data standardization and representativeness, may entail inherent linguistic and cultural biases. This could result in the marginalization of research produced in non-English-speaking contexts, thereby restricting the cross-cultural validity and universality of the study’s conclusions. Moreover, keyword selection is inherently subject to both subjectivity and contingency. Neither author-defined keywords nor database-assigned index terms can always accurately capture the substantive content of individual studies, which may lead to representational bias in the analysis.

Finally, it should be noted that the cluster analysis method adopted in this study may have potential limitations: (1) The outcomes of clusters are subject to the influence of keyword selection criteria, which may result in the insufficient visibility of some research themes that are low in frequency but important; (2) In the network graph, the position and connections of keywords reflect statistical co-occurrence relationships, rather than explicit theoretical or causal relationships; (3) Ambiguity in keywords semantics or the existence of synonymous terms may result in some nodes being either underestimated or overestimated in meaning.

Such factors may partially compromise the accuracy of result interpretation and the generalizability of the study's findings. To mitigate the above-mentioned impacts, this study incorporated methodological optimizations such as sensitivity testing during the analysis process and interpreted the analysis results in combination with the judgment of domain experts and validation against relevant literature, to enhance the structural validity of clustering structure and the robustness of the research conclusion.

### 5.5 Directions for Future Research

Future research in test anxiety should focus on three areas: (1) Strengthen the cross-cultural comparative study of test anxiety. Future research should foster cross-country and multi-center cooperation, examine the cultural uniqueness of Asia, Africa, and Latin America, and explore how cultural factors influence anxiety's cognitive and emotional mechanisms, to provide theoretical basis and empirical support for global education policies and interventions. (2) Explore the long-term developmental mechanism of test anxiety. Future studies are encouraged to incorporate longitudinal tracking design, ecological transient assessment, and machine learning analysis to gain a more nuanced understanding of the dynamic progression of test anxiety throughout individual development, elucidating the enduring influence of anxiety on students' psychological well-being, social adjustment, and educational pathways, and contribute to the development of more precise and impactful intervention strategies. (3) Deepen interdisciplinary comprehensive research. Future studies need to further integrate technical means in the fields of psychology, education, physiology, and cognitive neuroscience (such as fMRI, EEG, neurofeedback, VR technology, physiological index monitoring, etc.), build a cross-level integrated research framework, and systematically reveal the neurophysiology-cognitive-emotional interaction mechanism in examination situations.

## 6. Conclusion

This study employed keyword co-occurrence network analysis to review the knowledge structure and development trends of test anxiety research from 2014 to 2024 and proposed three key findings. Initially, the study constructed a thematic map of the field, identifying close connections between test anxiety and factors such as academic performance, self-efficacy, and mental health, and clarifying the central role of this topic in educational psychology and academic adaptation. Secondly, linkages were observed among different keyword clusters, indicating anxiety assessment tools, subject-specific anxiety, and specific populations are persistent areas of interest. Thirdly, the results reveal a significant increase in interdisciplinarity, expanding into medicine, physiology, and neuroscience. This suggests that scholars need cross-disciplinary cooperation to optimize students' mental health and academic performance.

By analyzing the network structure, researchers can effectively identify widely recognized important literature, authors, and journal resources in the academic community, thereby gaining deeper insights into the field's evolutionary trajectory and research emphasis. At the application level, this study recommends policymakers and practitioners pay attention to the heterogeneous manifestations of test anxiety and develop more targeted intervention strategies by integrating approaches such as self-efficacy and mindfulness.

## 7. Declarations

This study did not involve direct contact with human participants or any animal experiments; therefore, no ethical approval was required. The research exclusively used publicly available published literature and complies with all ethical standards, including the legal requirements of the Declaration of Helsinki.

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