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Test Anxiety and Trait Anxiety in Adolescence: Same or Different Structures?

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ABSTRACT

Objectives: Test anxiety is positively correlated with trait anxiety. However, the precise relationship between the two is not clear. Are they two independent constructs that share a high degree of comorbidity, or the same construct manifesting in different situations (e.g., test anxiety as a special type of trait anxiety)?

Methods: The present study employed two advanced analysis tools (latent profile analysis and network analysis) to evaluate the connectivity pattern between test anxiety and trait anxiety in a sample of adolescent students ($N = 475$, Mean age = 13.49).

Results: The latent profile analysis revealed that all participants could be classified into three groups (low-risk, moderate-risk, and high-risk) based on their scores on two scales measuring test anxiety and trait anxiety, indicating a high degree of comorbidity between test and trait anxiety. The network analysis found that test anxiety and trait anxiety formed two relatively distinct communities, suggesting that they are two independent structures.

Conclusions: Together, this study provides a novel insight into the structural relationship between test anxiety and trait anxiety, indicating that while they are distinct constructs, they frequently coexist. The clinical implications for our understanding of the etiology, diagnosis and treatment of test and trait anxiety are discussed.

> *"We live in a test-conscious, test-giving culture in which the lives of people are in part determined by their test performance."*
>
> —— Seymour Sarason, 1959

1 | Introduction

Test anxiety is a phenomenon characterized by an individual's physiological, behavioral, and other reactions in evaluative situations, accompanied by concerns about potential negative consequences or failure (Zeidner 1998). Test anxiety is widespread and appears to become more prevalent in adolescence (10-19 years old), a unique period of rapid brain development which brings about various stress and adjustment problems, including anxiety disorders. In the United Kingdom and the United States, the incidence of high-test anxiety among secondary school students ranges from 10% to 30% (Putwain and Daly 2014; von der Embse et al. 2014), whereas in China, the incidence is between 28% and 35% (Huang and Zhou 2019). The negative effects of test anxiety are far-reaching, as high test anxiety not only adversely affects students' subjective well-being (Steinmayr et al. 2016), impairs their executive function and academic performance (O'Donnell 2017; Song et al. 2021;

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von der Embse et al. 2018; Wei et al. 2022), but also increases their risk for anxiety, depression, illicit drug dependence, and poor school performance in adulthood (Pine et al. 1998; Woodward and Fergusson 2001). Therefore, understanding the symptom pattern and structure of test anxiety in adolescence is crucially important for improving the mental health and cognitive ability of the youth.

Test anxiety appears to encompass two components: a stable *trait* and a transient *state*, as test-anxious students are often high in trait anxiety and report more intense levels of state anxiety when taking tests (Spielberger and Vagg 1995). A strong association between trait anxiety and test anxiety has been demonstrated before(Burhan et al. 2020; Huang 2018; Wan et al. 2024). *Test anxiety can thus be interpreted as a situation-specific personality trait* (Spielberger and Vagg 1995), where individuals with trait test anxiety are prone to be anxious in any assessment situation (Hong 1998) and trait anxiety is the best predictor of test anxiety (Hodge et al. 1997). This high correlation between test anxiety and trait anxiety is not surprising, given that in psychological studies, scales or questionnaires that are used to measure a person's level of test anxiety (Liu et al. 2021; Putwain et al. 2021a; Wan et al. 2024) also focus to a large extent on his/her trait anxiety (Bertrams et al. 2010; Onyeizugbo 2010).

Test anxiety is a complex construct, with concerns about failure and cognitive interference serving as key indicators within modern frameworks of test anxiety (Lowe et al. 2008; Segool et al. 2014). These models propose that the cognitive aspects of test anxiety are often accompanied by anxious emotions like tension and panic, as well as physical signs of stress such as autonomic arousal. Research shows that worry is a stronger predictor of poor test performance, suggesting that negative thought patterns have a greater impact on outcomes than physical symptoms of anxiety (Morris and Liebert 1970). Similarly, trait anxiety is understood as a construct shaped by the interaction of thoughts, feelings, and behaviors. Intrusive thoughts and the persistent inability to let go of disappointments are seen as central components of trait anxiety (Heeren et al. 2018), much like the cognitive interference found in test anxiety. However, unlike test anxiety, trait anxiety is less focused on physical arousal and more on negative emotional states (Spielberger et al. 1983).

Relevant empirical research has further pointed out that these two also share certain components. Individuals with test anxiety exhibit a specific attentional bias towards test-related threat stimuli (Hu et al. 2023; Zhang et al. 2019) as well as inhibitory deficits for general irrelevant interference stimuli (Song et al. 2021; Wei et al. 2022; Zhang et al. 2019). Interestingly, this general inhibition deficit has also been observed in individuals with trait anxiety (Hu et al. 2023; Kamboureli and Economou 2023). However, the available evidence so far is not adequate to answer the question of how these two constructs are precisely linked. Do they always co-occur (comorbidity), how much do they overlap in certain psychological functions or processes (e.g., emotional worry, attentional bias, cognitive interference, autonomic reactions, etc.)? To what extent are they independent of one another? Identifying their structural relationship is critically important for understanding the mechanisms underlying test and trait anxiety, and for developing effective interventions. For example, if test anxiety is an independent construct, treatments targeting the general anxiety may not work. Highly specialized intervention strategies targeting testing-induced anxiety may need. On the other hand, if there is a high comorbidity between test anxiety and trait anxiety and both share common etiological and psychological mechanisms, it may be possible to use the same anxiety treatments to reduce test anxiety.

This study aimed to address these questions by using two advanced techniques: latent profile analysis and network analysis. Latent profile analysis (LPA) is a new human-centered statistical analysis method which explains the correlation between continuous external variables through latent class variables and realizes the local independence of explicit variables. It was used here to determine whether there is comorbidity between test and trait anxiety, and whether high test and trait anxiety subgroups can be identified in a student population (von der Embse et al. 2014). Compared with traditional methods such as mean segmentation and cluster analysis, LPA classifies people more accurately and objectively based on model fitting estimation and different characteristics (variables) of individuals (Magidson and Vermunt 2002). Using this method, we recently found that the incidence pattern of depression and premenstrual syndrome in Chinese female college students can be divided into four categories (low symptoms, predominantly PMS, predominantly depression, and combined PMS–depression). The heterogeneity of depression and premenstrual syndrome can thus be effectively distinguished (Hou and Zhou 2021). This study uses LPA for two main purposes. First, to determine whether test anxiety and trait anxiety can be distinctly separated, specifically identifying subgroups of individuals who experience only test anxiety or only trait anxiety without the presence of the other. Second, the analysis seeks to explore the comorbidity between test anxiety and trait anxiety, identifying whether a subgroup exists that exhibits both conditions. This foundational analysis lays the groundwork for further exploration of the comorbid network between test anxiety and trait anxiety.

To further examine the comorbidity pattern or structural relationship between test anxiety and trait anxiety, we used a network analysis. This new method differs from the confirmatory factor analysis, such as those used by Kazelskis et al. (2000) who investigated the structural differences between math anxiety and test anxiety. The network analysis method presents the features and information of a specific system in the form of a network. The system is composed of “nodes” and “edge”. In the network analysis model based on observed variables, nodes are observed variables such as attitudes and feelings, while edges are the relationships between these observed variables (Borsboom and Cramer 2013). Another essential concept is community. Nodes in the same community are closely connected but sparsely connected with nodes in other communities. Nodes in a network constitute one or more communities depending on (a) the position of nodes concerning other nodes, (b) the number of edges between nodes, and (c) the thickness/strength of the edges between nodes (Putwain et al. 2021a). The network analysis has been successfully used to investigate the structural relationship among test anxiety, generalized anxiety

disorder and panic disorder (Putwain et al. 2021a), and the relationship between expectation and awe (Gocłowska et al. 2023). However, no research has applied this method to the study of test anxiety and trait anxiety.

By conceptualizing the items of the test anxiety and trait anxiety scale as nodes in an interacting network, we sought to examine whether these nodes are represented as different or interpenetrating communities. This method also allowed us to determine whether the comorbidity of test anxiety and trait anxiety is caused by the overlapping scale structure, as proposed by Garber and Weersing (2010). Specifically, if test anxiety is only a special form of trait anxiety (i.e., not an independent structure), the nodes of the two scales would interpenetrate, and two independent communities cannot be formed. On the other hand, if test anxiety and trait anxiety are independent structures, the nodes of the two scales would form two independent communities. Based on the available evidence, we hypothesized that test and trait anxiety are relatively independent structures which frequently co-occur (i.e., there is a comorbidity between the two). Given the high incidence of test anxiety among Chinese adolescents (Huang and Zhou 2019; Tao and Hong 2014), we collected data from a sample of secondary school students (aged 13–15) to test our hypothesis.

2 | Methods

2.1 | Participants

Data from a sample of 475 participants with a mean age of 13.49 years (SD = 0.58) were collected from a secondary school in China. The sample consisted of 248 male students and 227 female students. A web-based survey tool was used to collect the data, and the link to the survey was distributed to the participants by the liaison teacher. Because we used the survey tool that prompted the students to complete the questionnaire, there was no missing data. The project was approved by the Research Ethics Committee of the Department of Psychology at Nanjing University.

2.2 | Measures

2.2.1 | Multidimensional Test Anxiety Scale (MTAS; Putwain et al. 2021b)

MTAS measure a student's level of test anxiety. It consists of 16 question items made up of four subscales, including (a) worry (e.g., "During a test/exam, I worry that I gave the wrong answers"), (b) cognitive interference (e.g., "During tests/exams, I find it hard to concentrate"), (c) nervousness (e.g., "Just before I take a test/exam, I feel panicky"), and (d) physiological indicators (e.g. "During a test/exam, I experience stomach discomfort"). The scale used a five-point Richter scale (1 = strongly disagree, 3 = neither, 5 = strongly agree). In this study, Cronbach's alpha coefficient of the total scale and 4 subscales of MTAS ranged from 0.791 (physiological indicators) to 0.935 (total scale), indicating that this scale has the high internal consistency in this sample.

2.2.2 | State-Trait Anxiety Inventory- Trait (STAI-T; Spielberger et al. 1983)

STAI-T was used to measure levels of trait anxiety of the participants. STAI has 20 items (e.g., "I feel like a failure"), and items indicating no anxiety (e.g., "I feel happy") were scored in reverse. The scale uses a four-point Richter score (1 = never, 2 = sometimes, 3 = often, 4 = always). In this study, the internal consistency alpha coefficient of the STAI-T scale was 0.834.

2.3 | Data Analysis

2.3.1 | Latent Profile Analysis

LPA was calculated using Mplus 8.0 maximum likelihood (ML) estimates, and subjects were divided into potential subgroups based on their approved item-level responses to MTAS and STAI-T. In this study, we evaluated one to five classes of solutions of the LPA model and compared them according to the fit index. The selected fitting indexes were Akaike Information Criterion (AIC), sample-size adjusted Bayesian Information Criterion (aBIC), Lo-Mendell-Rubin adjusted likelihood ratio test (LMR), and entropy. Lower AIC and aBIC values indicate better model fit, LMR tests whether a model with k profiles provides a significantly better fit than a model with K-1 profiles, and entropy is used to measure the quality of classification accuracy. A value closer to 1 indicates a more accurate underlying classification (Celeux and Soromenho 1996; Hix-Small et al. 2004; Hou and Zhou 2021; Putwain et al. 2021a). Referring to the method by Hou and Zhou (2021)., we primarily examined the model fit results of 1-class to 5-class LPA models.

2.3.2 | Network Analysis

Network analysis uses the qgraph package in R 4.2.1 to calculate and visualize networks (Epskamp et al. 2012). To avoid the possibility of false positive edges in a network with multiple parameter estimates, a graphic LASSO (Least Absolute Shrinkage and Selection Operator) regularization model was adopted in this study (Fried et al. 2018). The graph presents

TABLE 1 | Descriptive statistics of MTAS and STAI-T ($n = 475$).

Scale	Range	$M \pm SD$	SKew	kurtosis	McDonald's ω
MTAS	16–80	44.72 ± 15.62	−0.15	−0.74	0.95
STAI-T	22–79	44.05 ± 9.26	0.35	0.15	0.89

Abbreviations: MTAS, Multidimensional Test Anxiety Scale; STAI-T, State-Trait Anxiety Inventory-Trait.

nodes as circles, test anxiety as yellow nodes, and trait anxiety as blue nodes. Connections between nodes are represented as edges, thicker edges indicate a stronger correlation between two nodes, green edges represent a positive correlation, and red edges represent a negative correlation. In this study, the qgraph package, combined with the extended Bayesian Information Criterion (EBIC) model selection (Foygel and Drton 2010), was used to automatically implement the LASSO regularization of graphs. This selection method consists of two steps. First, 100 network models with different sparsity degrees are estimated. Second, the model with the lowest EBIC was selected, and the hyperparameter gamma was set to 0.5 (Heeren and McNally 2018).

To investigate the connections between test anxiety and trait anxiety, we used the networktools package in R to calculate Bridge Expected Influence (BEI). This measure helps determine how certain symptoms, represented as nodes, act as bridges between different clusters within the network (Cervin et al. 2020; Jones 2017). BEI was calculated with the bridge function, which evaluates both the strength and number of connections each node has with nodes in other clusters. Higher BEI scores suggest that these nodes play a key role in linking separate communities, emphasizing their importance in the co-occurrence of test and trait anxiety symptoms.

Meanwhile, we calculated the betweenness, closeness, and strength of nodes within the separate networks of MTAS and STAI-T. The betweenness, closeness and strength of nodes were calculated to quantify the importance of each node in the graphic LASSO network (Opsahl et al. 2010). The larger the value, the more important the node is in the network. Betweenness is equal to the number between the length of the shortest path between any pair of other nodes; closeness represents the average distance of a node from all other nodes in the network and is calculated as the inverse of the weighted sum of the shortest path lengths from all other nodes in the network to a given node; strength is the sum of the weights of the edges attached to the node. To better compare and explain the three index values, this study converted them into Z-scores.

TABLE 2 | Model fit indices for profile solutions.

	AIC	aBIC	LMR	Entropy
1-class	48,635.66	48,935.42		
2-class	45,440.21	45,894.02	< 0.001	0.941
3-class	44,139.57	44,747.42	0.0028	0.937
4-class	43,635.62	44,397.51	0.6460	0.925
5-class	43,093.12	44,009.05	0.7356	0.95

Note: The values in the LMR are *p* values related to Lo-Mendell-Rubin in comparing fit between models.
Abbreviations: AIC, Akaike information criterion; aBIC, sample size-adjusted Bayesian information criterion.

3 | Results

3.1 | Descriptive Statistics

The descriptive statistical results are shown in Table 1. Skewness and Kurotsis (in the range of ±1) show that the data were normally distributed. The McDonald's ωs values were further calculated, which showed that the internal consistency of each scale was good. Pearson correlation results showed that MTAS and STAI-T were positively correlated ($r = 0.45$, $p < 0.001$).

3.2 | Latent Profile Analysis

The fitting indexes of the first to fifth solutions of the LPA model are shown in Table 2. As the number of profiles increased, model fit improved, as indicated by the lower AIC and aBIC values. At the same time, the classification accuracy decreased with the decrease of entropy and increased in the 5-class. LMR showed that the 4-class had no statistically significant advantage compared with the 3-class ($p = 0.6460$), while the 3-class had a statistically significant advantage compared with the 2-class ($p = 0.0028$). Based on the results of LMR, the 3-class was finally selected as the optimal LPA class solution (Bounoua et al. 2021).

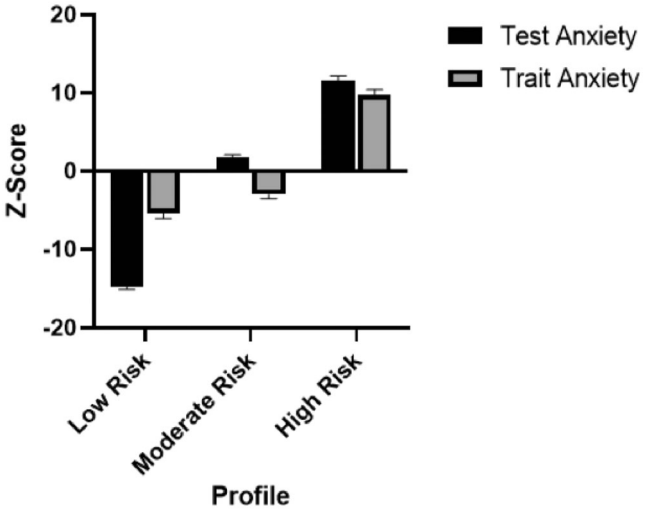

FIGURE 1 | Mean standardized scores for test anxiety and trait anxiety for the 3-profile solution (Error bars are 95% CIs.).

TABLE 3 | Model estimated means, standard errors, and counts for 3-profile solution.

	Low Risk ($M \pm SD$)	Moderate Risk ($M \pm SD$)	High risk ($M \pm SD$)
Test Anxiety	-14.7 ± 4.47	1.73 ± 4.97	11.6 ± 6.54
Trait Anxiety	-5.35 ± 8.41	-3.00 ± 7.53	9.76 ± 7.69
n	132 (27.8%)	207 (43.6%)	136 (28.6%)

The average potential z scores of the three models on the MTAS and STAI-T scales are shown in Table 3 and Figure 1. The population can be divided into three groups: low-risk ($n = 132$, 27.8%), moderate-risk ($n = 207$, 43.6%) and high risk ($n = 136$, 28.6%). Univariate analysis of variance showed significant differences in MTAS scores for all potential categories, $F(2,472) = 829.4$, $p < 0.001$. The score of high-risk MTAS was significantly higher than that of moderate-risk ($p < 0.001$), which in turn, was significantly higher than that of low-risk ($p < 0.001$). At the same time, the potential categories of STAI-T scale score difference were significant, $F(2,472) = 151.7$, $p < 0.001$. Post hoc comparison showed that the high-risk STAI-T score was significantly higher than the moderate-risk ($p < 0.001$), which in turn, was significantly higher than the low-risk ($p = 0.019$). The separability of the three models was thus confirmed.

3.3 | Network Analysis

The graphical LASSO network of MTAS and STAI-T is presented in Figure 2, where the edges between nodes indicate regularized partial correlations, effectively mitigating spurious correlations between nodes. For convenience, all nodes' scale items are listed in Table 4. As can be seen in Figure 2, the nodes did not form a unified community but were instead divided into two relatively distinct communities. Specifically, compared to trait anxiety, the nodes in the test anxiety community were more closely linked, demonstrating stronger and more frequent connections among various nodes within this community. The same was observed for nodes in trait anxiety communities compared to those in test anxiety. Notably, STAI-T2 did not appear to be closely connected to either community, indicating that it is an independent node. Within the trait anxiety community, two small clusters with less clear edges can still be found (one cluster includes nodes STAI-T1, STAI-T3, STAI-T6, STAI-T7, STAI-T10, STAI-T13, STAI-T14, STAI-T16, STAI-T19 which are reversely scored). Within the test anxiety community, nodes MTAS2, MTAS6, MTAS10, and MTAS14 are more connected with nodes in the trait anxiety community compared to other nodes. These four nodes constitute the cognitive interference dimension in the MTAS scale.

Table 5 presents the BEI values for all nodes. Among them, the MTAS14 node has the highest BEI value at 0.1759. The BEI values for STAI-T19 and STAI-T20 are also relatively high, at 0.1368 and 0.0977, respectively. On the other hand, several nodes, including MTAS8, MTAS10, STAI-T4, STAI-T6, and STAI-T10, have a BEI value of 0.0000, indicating no bridging influence.

Figure 3 depicts the centrality index of all nodes of MTAS in the network. The node MTAS15 showed the highest strength and closeness and the node MTAS16 showed the highest betweenness. Nodes with high centrality were more closely related to other nodes. Node MTAS6 showed the lowest strength, closeness, and betweenness. Nodes with low centrality may be considered peripheral symptoms. Figure 4 depicts the centrality index of all nodes of STAI-T in the network. The node STAI-T18 showed the highest strength, while the node STAI-T11 showed the highest closeness and the node STAI-T12 showed the highest betweenness. Node STAI-T2 showed the lowest strength, closeness, and betweenness.

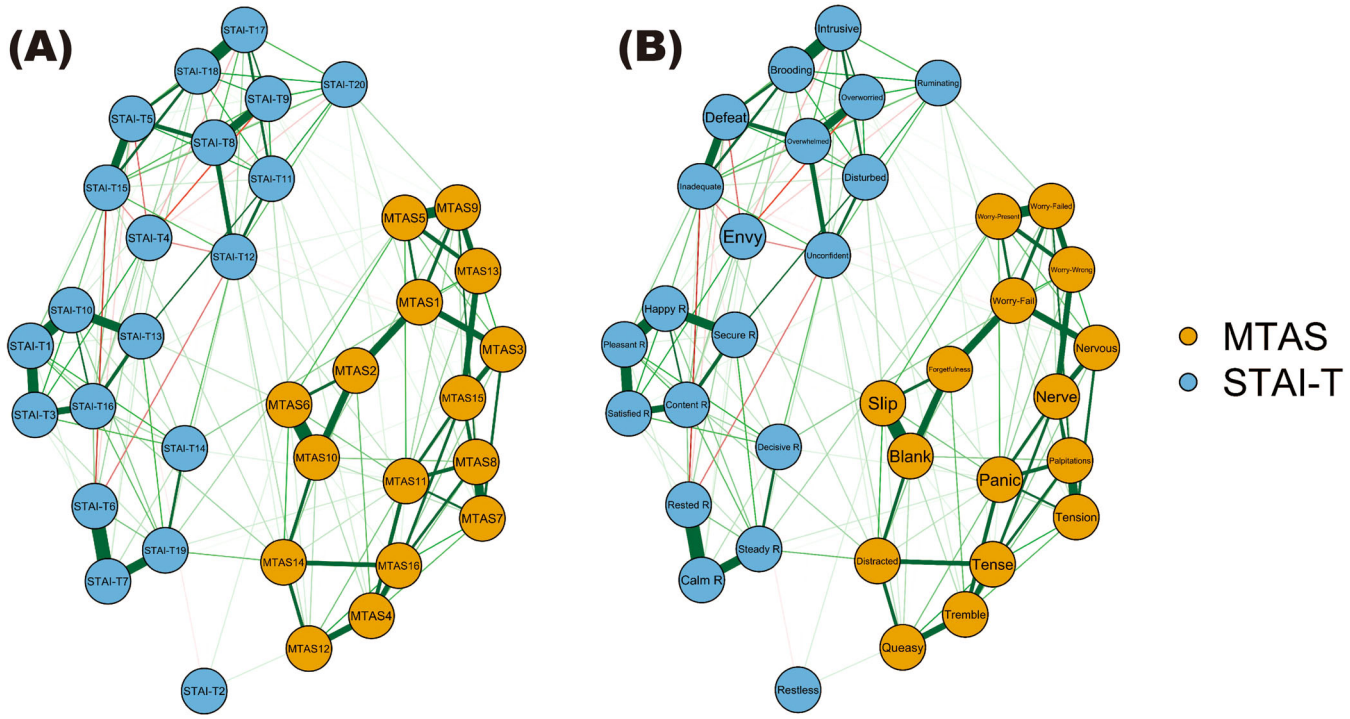

FIGURE 2 | Graphical LASSO network based on regularized semi-partial correlations between nodes (A) Test anxiety indicators (MTAS1-MTAS16) and trait anxiety indicators (STAI-T1-STAI-T20) labeled with questionnaire item numbers. (B) Nodes with simplified labels summarizing questionnaire items; nodes marked with an 'R' indicate reverse-scored items. *Note:* Green edges represent positive, and red edges negative. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 4 | Items included in the network analysis.

Code	Item
MTAS1	Before a test/exam, I am worried I will fail. (W)
MTAS2	I forget previously known material before taking a test/exam. (CI)
MTAS3	Even when I have prepared for a test/exam I feel nervous about it. (T)
MTAS4	Before I take a test/exam my hand trembles. (PI)
MTAS5	During tests/exams, I worry about the consequences of failing. (W)
MTAS6	I forget facts I have learnt during tests/exams. (CI)
MTAS7	I feel tense before taking a test/exam. (T)
MTAS8	My heart races when I take a test/exam. (PI)
MTAS9	After a test/exam, I am worried I have failed. (W)
MTAS10	During tests/exams, I forget things that I have learnt. (CI)
MTAS11	Just before I take a test/exam, I feel panicky. (T)
MTAS12	During a test/exam I experience stomach discomfort. (PI)
MTAS13	During a test/exam, I worry that I gave the wrong answers. (W)
MTAS14	During tests/exams, I find it hard to concentrate. (CI)
MTAS15	Before a test/exam, I feel nervous. (T)
MTAS16	During a test/exam, my muscles are tight. (PI)
STAI-T1	I feel pleasant. (R)
STAI-T2	I feel nervous and restless.
STAI-T3	I feel satisfied with myself. (R)
STAI-T4	I wish I could be as happy as other seems to be.
STAI-T5	I feel like a failure.
STAI-T6	I feel rested. (R)
STAI-T7	I am calm, cool, and collected. (R)
STAI-T8	I feel that difficulties are piling up so that I cannot overcome them.
STAI-T9	I worry too much over something that really doesn't matter.
STAI-T10	I am happy. (R)
STAI-T11	I have disturbing thoughts.
STAI-T12	I lack self-confidence.
STAI-T13	I feel secure. (R)
STAI-T14	I make decisions easily. (R)
STAI-T15	I feel inadequate.
STAI-T16	I am content. (R)
STAI-T17	Some unimportant thoughts run through my mind and bothers me.
STAI-T18	I take disappointments so keenly that I can't put them out of my mind.
STAI-T19	I am a steady person. (R)
STAI-T20	I get in a state of tension or turmoil as I think over my recent concerns and interests.

Abbreviations: CI, cognitive interference; PI, physiological indicators; R, Reverse scored; T, tension; W, worry.

4 | Discussion

Test anxiety and trait anxiety often co-occur in the same individuals (Burhan et al. 2020; Huang 2018; Wan et al. 2024), suggesting a potentially high degree of comorbidity between these two constructs. However, no previous studies have directly examined the comorbid pattern of test anxiety and trait anxiety using human-centered methods. In this study, we first employed an exploratory latent profile analysis to investigate the comorbidity of test anxiety and trait anxiety in adolescents. Next, we utilized the network analysis approach to further examine the structural relationship between test anxiety and trait anxiety. Our findings indicate that the existing comorbidity between test anxiety and trait anxiety is not simply due to the superficial overlap in scale structure, but rather reflects that they are two distinct psychological constructs with unique

TABLE 5 | Bridge Expected Influence (BEI) values for each node in the network.

Code	BEI
MTAS1	0.001
MTAS2	0.024
MTAS3	0.008
MTAS4	0.041
MTAS5	0.064
MTAS6	0.098
MTAS7	0.048
MTAS8	0.000
MTAS9	0.066
MTAS10	0.000
MTAS11	0.077
MTAS12	0.056
MTAS13	0.054
MTAS14	0.176
MTAS15	0.019
MTAS16	0.016
STAI-T1	0.049
STAI-T2	0.037
STAI-T3	0.013
STAI-T4	0.000
STAI-T5	0.003
STAI-T6	0.000
STAI-T7	0.008
STAI-T8	0.014
STAI-T9	0.025
STAI-T10	0.000
STAI-T11	0.084
STAI-T12	0.079
STAI-T13	0.031
STAI-T14	0.073
STAI-T15	0.023
STAI-T16	0.000
STAI-T17	0.023
STAI-T18	0.052
STAI-T19	0.137
STAI-T20	0.098

etiological and psychological components, as our network analysis showed that the nodes of test anxiety and trait anxiety scales formed two distinct communities with prominent edges.

Based on the scores obtained from the trait anxiety and test anxiety scale items, we could effectively categorized the participants into three subgroups through LPA: the low-risk group (27.8% of the sample), which displayed low test anxiety and low trait anxiety; the moderate-risk group (43.6% of the sample), which showed moderate test anxiety and moderate-low trait anxiety; and the high-risk group (28.6% of the sample), which exhibited high test anxiety and high trait anxiety. They differed significantly in the scores from the test anxiety scale and trait anxiety scale. This finding confirms our hypothesis that test anxiety and trait anxiety present a high degree of comorbidity in adolescent students. This result is also consistent with Putwain et al. (2021a), who used LPA and identified the co-occurrence of test anxiety, panic disorder and generalized anxiety in adolescents.

From the three-category results of the LPA, we can observe that the z-scores for test anxiety are notably more extreme than those for trait anxiety. The participants in this study were all from secondary school in China, where the emphasis on exams is much greater than in elementary schools, marking a crucial turning point for the rise of test anxiety (Huang and Zhou 2019). The heightened z-scores for test anxiety compared to trait anxiety may be due to the adolescents facing specific and intense pressures from the exam environment, which could intensify test anxiety responses beyond their general levels of trait anxiety. Trait anxiety, on the other hand, tends to be more diffuse and less influenced by environmental factors. This distinction suggests that test anxiety is more closely tied to grade level (the importance and frequency of exams) and can be further amplified by social factors surrounding exams. Future research could confirm these findings by examining other age groups, such as adults who are no longer subject to exams.

Compared to the traditional variance-centric approaches, the network analysis provides novel insights into comorbidities and interventions for different symptoms by examining the nodes that are more critical in the network (higher node centrality) and whether specific nodes are responsible for connecting different communities (bridge nodes). This method has been widely employed to explore the mechanism of anxiety disorders (Heeren and McNally 2018) and to examine the relationship among various symptoms or multiple mental disorders (Blake et al. 2018). The symptom represented by MTAS14, “During tests/exams, I find it hard to concentrate,” stands out for having the highest BEI value, underscoring its crucial role as a bridge between test anxiety and trait anxiety. This suggests that concentration difficulties during exams not only reflect test anxiety but also serve as a key link to broader issues related to trait anxiety. Similarly, STAI-T19, “I am a steady person,” and STAI-T20, “I get in a state of tension or turmoil as I think over my recent concerns and interests,” showed significant BEI values. These bridge symptoms may indicate that individuals who are less emotionally stable and more prone to tension are experiencing interconnected symptoms that impact both their test performance and overall emotional well-being.

On the other hand, symptoms like MTAS8, “My heart races when I take a test/exam,” and MTAS10, “During tests/exams, I forget things I have learned,” while closely tied to test anxiety, had relatively low BEI values. This suggests that although these symptoms are prominent within the test anxiety community, they don't strongly connect with broader trait anxiety, indicating that their impact is more isolated to test anxiety alone.

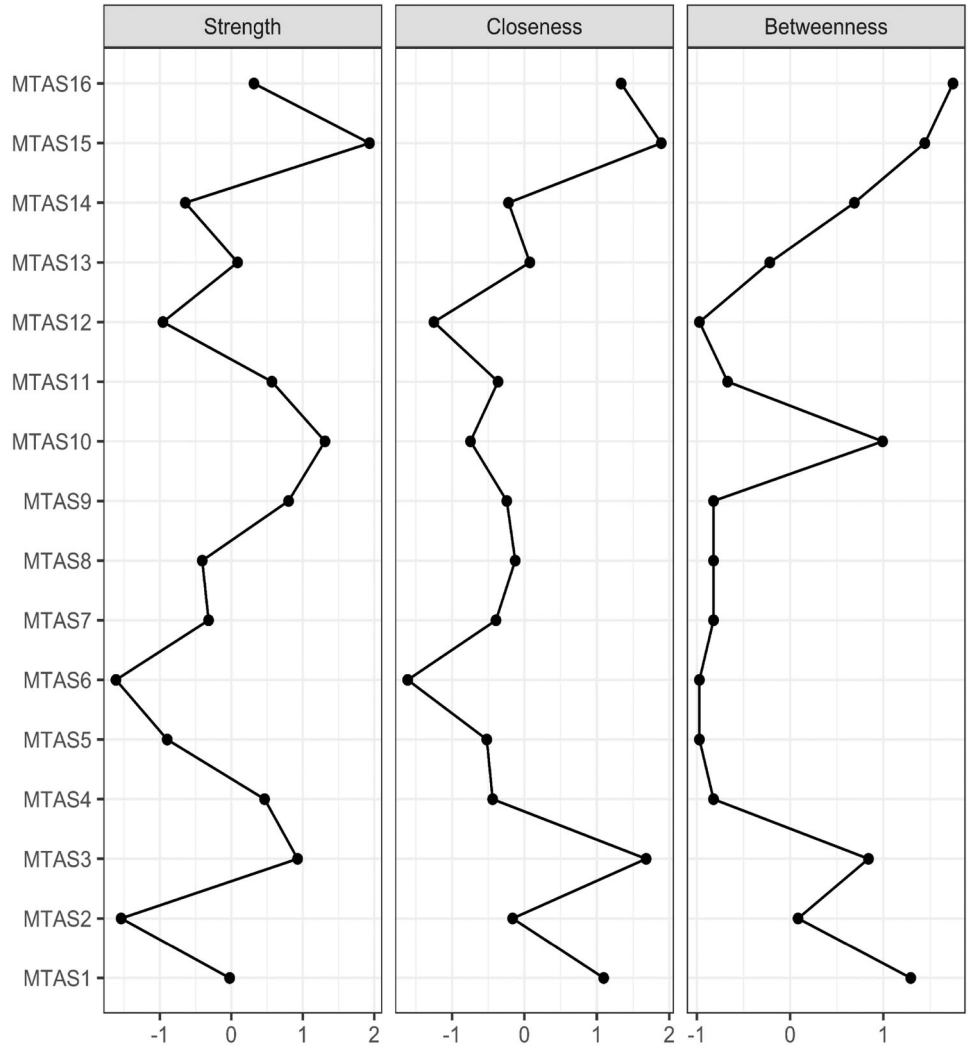

FIGURE 3 | Centrality plots for graphical LASSO network depicting the betweenness, closeness, and strength of each node in the MTAS network.

Additionally, STAI-T4, "I wish I could be as happy as others seem to be," and STAI-T6, "I feel rested," which relate more to general emotional well-being and restfulness, showed minimal bridging influence. This might suggest that these aspects of trait anxiety don't significantly influence, or aren't significantly influenced by, test anxiety-specific symptoms, pointing to different mechanisms at play in these experiences.

In the MTAS network, the nodes MTAS15, "Before a test/exam, I feel nervous" and MTAS16 "During a test/exam, my muscles are tight" showed the highest centrality, suggesting that nervous anticipation and physical tension are deeply interconnected within the framework of test anxiety. This underscores their key role in interventions aimed specifically at addressing test anxiety. In the STAI-T network, the nodes STAI-T18, "I take disappointments so keenly that I can't put them out of my mind", STAI-T11, "I have disturbing thoughts", and STAI-T12, "I lack self-confidence" exhibited high centrality, highlighting their significant influence on individuals dealing with trait anxiety. Interestingly, the high-centrality nodes did not overlap with the bridge nodes, indicating that the mechanisms driving the comorbid network differed from those underlying pure test anxiety or trait anxiety. This distinction reinforces the idea that test anxiety and trait anxiety are separate constructs within the broader category of anxiety disorders. Understanding this difference is crucial for developing targeted treatment approaches and for gaining insight into the specific mechanisms of anxiety disorders.

Another interesting finding from the network analysis was that the cognitive interference nodes (MTAS2, MTAS6, MTAS10, and MTAS14), compared to other nodes in the test anxiety community, were more closely connected to the nodes in the trait anxiety community and displayed more connections with those nodes (see Figure 2), indicating the important contribution of *cognitive interference* to the comorbidity between test anxiety and trait anxiety. As cognitive interference is characterized by difficulties with memory and concentration, as exemplified by the item "During tests/exams, I find it hard to concentrate" (Putwain et al. 2021b), it is possible that individuals with high test anxiety are more susceptible to task-independent interfering stimuli than those with low anxiety, reflecting their reduced attention control capacity. Irrelevant stimuli that may impair test performance can be categorized into two types: internal distracting stimuli and external threatening stimuli. Internal distracting stimuli refer to an individual's excessive worry about the result of a task, which can

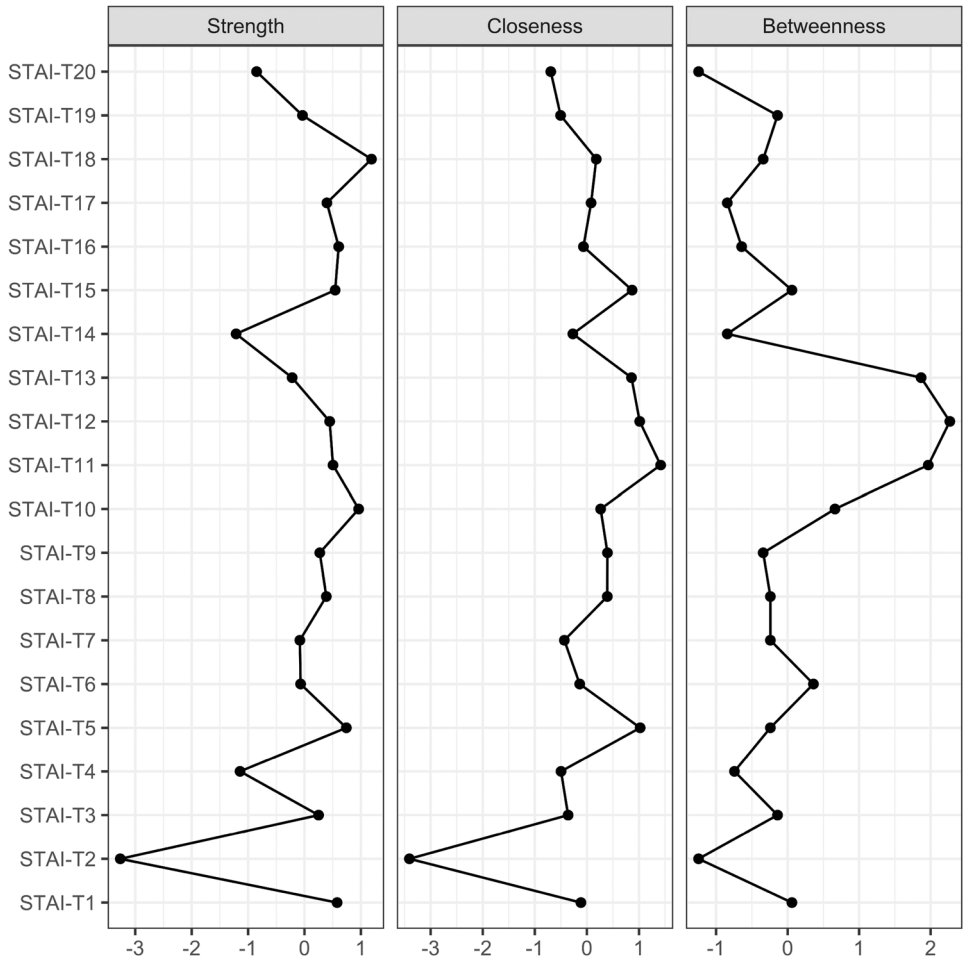

FIGURE 4 | Centrality plots for graphical LASSO network depicting the betweenness, closeness, and strength of each node in the STAI-T network.

consume attention control resources and affect the processing efficiency of the top-down attention control system. External threatening stimuli refer to information that can cause anxiety in individuals. The existence of such information can affect the bottom-up attention control system. For instance, individuals with high test anxiety may have an attention bias towards test-related vital information when attempting to focus attentional resources (Corbetta and Shulman 2002; Eysenck et al. 2007; Hu et al. 2023).

Several empirical studies have reported that individuals with both trait and test anxiety struggle with suppressing distracting stimuli (Hu et al. 2023; Kamboureli and Economou 2021; Song et al. 2021; Wei et al. 2022). Furthermore, the cognitive dimension of test anxiety appears to have a stronger association with trait anxiety. Specifically, in a regression analysis, trait anxiety was found to be a predictor of cognitive test anxiety, which could be attributed to the fact that the cognitive dimension of test anxiety is not limited to the time period during the test itself but extends to before and after the test as well (Burhan et al. 2020). Consequently, it is likely that *cognitive interference* is a major component that contributes to the comorbidity of high test and trait anxiety.

The results of the present study have significant implications for the treatment intervention of the comorbid test and trait anxiety condition. As discussed above, cognitive interference, identified as the bridge node in the network analysis, may be a potential cause of the comorbidity of test anxiety and trait anxiety. If confirmed, we could target cognitive interference through interference inhibitory training to treat test anxiety and trait anxiety concurrently. In fact, it has been shown that cognitive training based on the Stroop, Simon, and Flanker tasks is capable of enhancing individuals' interference inhibitory ability (Aydmune et al. 2019; Liu et al. 2016; Talanow and Ettinger 2018). This would be a fruitful area for future research, as there is currently no research on the efficacy of interference inhibitory training in anxiety intervention.

Our network analysis indicates that intrusive thinking may be a core symptom of anxiety, thus, could serve as another effective intervention target for the comorbidity of test and trait anxiety. Previous intervention studies have demonstrated that mindfulness and written expression interventions can effectively reduce both trait anxiety and test anxiety (Carsley and Heath 2018; Danoff-Burg et al. 2006; Hamidi et al. 2020; Relojo-Howell and Stoyanova 2019), potentially by improving intrusive emotional thinking. While there is currently a lack of empirical evidence directly confirming intrusive thinking as an effective target and mechanism of anxiety comorbid intervention, this finding provides a novel target for future interventions targeting the comorbidity between test anxiety and trait anxiety.

Extensive research on trait anxiety and test anxiety has pointed to the vital role of parent-child interaction, the family environment, and parents' academic expectations (Brandmo et al. 2019; Peleg-Popko 2002; Teichman and Ziv 1994), as important contributing factors to the comorbidity between test anxiety and trait anxiety. Many family studies have found a significant association between anxiety disorders and parenting styles (Lebowitz et al. 2016). Children whose parents tend to use authoritarian parenting styles have higher test anxiety (Nejad et al. 2014), and a father's authoritarianism is a significant risk factor for adolescent test anxiety (Butt et al. 2014). Similarly, children with the authoritarian parenting style often score higher on trait anxiety (Wolfradt et al. 2003). Authoritarian parents often use harsh verbal criticism and physical punishment, and are less warm to their children, which increase anxiety levels in their children (Pinquart 2017). Children may also imitate their parents' fear behavior, thereby affecting their anxiety levels (Huta 2012). Future studies may benefit from including family and environmental risk factors as a potential factor in the profile and network analysis of test anxiety and trait anxiety.

This study has several limitations. First, the data utilized in this study were cross-sectional observational, which explored the correlation between variables but could not establish the causal relationship between symptoms (DeYoung and Krueger 2018). Second, cross-sectional data collected at a single time point can only reflect the variable relationship between individuals and cannot provide insight into the temporal relationship within individuals across time (Bringmann 2016). Third, this study focused solely on the structural relationship between test anxiety and trait anxiety. We did not examine the structural relationship between test anxiety and social anxiety, another important construct sharing the structural overlap with both test anxiety and trait anxiety (Bögels et al. 2010; Kavakci et al. 2014). Fourth, although the LPA effectively classified the population into three distinct anxiety risk groups, it remains unclear whether there are notable differences in cognitive and emotional task performance between these groups—specifically, how anxiety uniquely affects the underlying patterns within each group. Future research should focus on these differences to better understand the specific impacts of anxiety on individual functioning. Fifth, one notable limitation of this study is the lack of clinical anxiety measurement within the sample. This omission may introduce potential confounding factors, as it restricts our ability to distinguish between normal and clinical levels of anxiety. Finally, this study utilized self-report measures to assess test and trait anxiety. Future studies should consider using longitudinal tracking data or intensive time series data collected through multiple sampling time points to better illustrate the causal relationships between test anxiety and trait anxiety symptoms (Robinaugh et al. 2020). In addition, the symptom patterns of test and social anxiety could be investigated to enrich the understanding and research of test anxiety. Complementary data from clinical interviews should also be collected to cross-validate our results and further test our hypothesis.

5 | Conclusions

Using the latent profile analysis and network analysis, this study demonstrates that test anxiety and trait anxiety are comorbid but independent structures in adolescents. Future studies should further investigate the etiological and psychological basis of the comorbidity between test anxiety and trait anxiety and focus on testing the effectiveness of various intervention techniques for adolescent test anxiety.

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