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A network analysis of academic procrastination, psychological and environmental factors among medical students

Siyu Huang[1,2,3], Zhuo Li[1,2,3], Jianing Li[1,2,3] and Xinfang Ding[4*]

Abstract

Background Academic procrastination is a multifaceted phenomenon influenced by psychological and environmental factors and has potential negative academic and career consequences. However, there are no studies that have comprehensively explored the mechanisms of academic procrastination in medical students. This study conducts a network analysis of seven factors associated with procrastination, to establish a network of academic procrastination, and to explore the academic procrastination network and the relative importance of the different factors.

Methods A sample of 681 students (72.1% women, 27.9% men) completed self-rating questionnaires that measured fear, conscientiousness, self-efficacy, impulsivity, depression, the nature of tasks, teacher traits, and academic procrastination. Two networks were created using regularized partial correlation network analysis (EBICglasso) with scales and items as nodes respectively, to determine the role of psychological and external environmental factors in academic procrastination.

Results Both networks were linkage active, and all variables showed significant correlations. Impulsivity and depression emerged as the central and bridge components, with the highest centrality indices observed for difficulty concentrating and self-hatred.

Environmental factors have the highest expected influence value in the Scale-level network and academic procrastination.

Conclusion The present study shows that impulsivity and depression are key factors in academic procrastination networks in the medical student population, especially difficulty concentrating and self-hatred. It further adds the influential role played by environmental factors.

Trial registration This is an observational study based on surveys and network analysis, and no healthcare intervention was involved. Therefore, it was not registered in any clinical trial registry.

Keywords Academic procrastination, Environmental factors, Depression, Medical Students, Network Analysis

*Correspondence:
Xinfang Ding
dingxinfang@ccmu.edu.cn
Full list of author information is available at the end of the article

Background

Academic procrastination refers to the voluntary delay of intended academic tasks—such as studying for exams or writing papers—in the absence of external constraints [1]. It is characterized by a disconnect between intention and action [2] and is often accompanied by negative emotional experiences such as guilt, anxiety, or regret [3].

Empirical studies indicate that more than half of students habitually postpone important academic work, with reported prevalence rates ranging from 81% to over 90%, and approximately 40% identified as frequent procrastinators [4–6]. Academic procrastination is associated with a range of adverse outcomes [7–10]. Meta-analytic findings have demonstrated a significant negative correlation between procrastination and academic performance [7]. Procrastination increases time pressure, reduces task accuracy and timeliness, and is linked to elevated test anxiety, fear of failure, and psychological stress [11]. It also correlates with poorer well-being [7], and during the COVID-19 pandemic, higher levels of procrastination were associated with increased depressive symptoms and suicidal ideation [12]. While prior research has extensively examined the definition, typology, antecedents, consequences, and interventions for academic procrastination, most studies have focused on general undergraduate populations. In contrast, medical students appear to be particularly vulnerable to procrastination [13, 14]. One recent study reported that approximately 96.1% of medical students exhibited moderate to severe levels of academic procrastination [15].

For medical students, procrastination in learning theoretical knowledge and clinical skills not only hinders personal development but may also compromise patient safety—reflecting a spillover effect of academic delay [16]. This issue is closely tied to the inherent complexity of medical education. The overwhelming volume of theoretical content imposes significant cognitive load, while clinical training demands advanced technical proficiency and patient interaction skills. In practice, students often delay clinical tasks due to a lack of confidence, concerns about patient outcomes, or fear of making mistakes—factors that may further lead to adverse consequences [17]. Moreover, medical students commonly exhibit strong perfectionistic tendencies [18]. Combined with the high standards of precision and accuracy required in the medical field, this makes them especially susceptible to avoidant behaviors and persistent procrastination under sustained pressure.

There is a need for further research on the mechanisms that generate and maintain academic procrastination in specific groups of medical students.

Selection of factors for modeling academic procrastination in medical students

Theoretical framework

To explain the complexity of academic procrastination, several theoretical models have been proposed. Procee et al. [19] outlined a framework covering task, personality, and state factors. Araya-Castillo et al. [20] dentified nine dimensions, including psychological, academic, and time management aspects. Klingsieck [21] further summarized four theoretical perspectives widely used in procrastination research. While valuable, these models often remain broad and lack operational clarity. Moreover, few are tailored to specific groups such as medical students.

Based on Klingsieck's framework, this study examines seven variables across four domains: personality (impulsivity and conscientiousness), clinical factors (depressive symptoms), motivation (fear of failure and academic self-efficacy), and contextual aspects (task nature and teacher traits). The next section details the rationale for selecting each factor.

Psychological factors

Individual personality traits are well-established predictors of academic procrastination, particularly conscientiousness and neuroticisms [22]. Students low in conscientiousness often struggle with organization, self-discipline, and goal-directed behavior, making them more prone to delaying academic tasks [23]. In a meta-analysis of 691 potential predictors, identified task-related responsibility as one of the strongest correlates of procrastination. Neuroticism, characterized by emotional instability and heightened sensitivity to failure, is also linked to procrastination. Students high in neuroticism may use procrastination as a short-term emotion regulation strategy to avoid anxiety or helplessness, which in turn can further impair academic performance [24].

Numerous behavioral studies have demonstrated a strong association between impulsivity and academic procrastination [25]. Students with high impulsivity tend to procrastinate because they undervalue the long-term benefits of goal achievement, resulting in delayed action. Gustavson et al. [26], through a behavioral genetic study, proposed that procrastination may be a by-product of impulsivity due to shared heritable influences. However, Liu and Feng [27] provided evidence for a different explanation. Their neuroimaging research revealed that both traits share a common neural substrate—the dorsolateral prefrontal cortex (DLPFC)—and that the DLPFC fully mediates the effect of impulsivity on procrastination [28]. This suggests that the strong correlation between the two is primarily linked to deficits in self-regulation, rather than a hierarchical causal relationship in which procrastination is merely a consequence of impulsivity. These

findings highlight impulsivity as a core factor in procrastination, with both traits rooted in shared cognitive control mechanisms.

Motivation and volition complement personality traits in shaping procrastinatory behavior. A series of studies have found that self-efficacy and fear of failure are strongly correlated with procrastination [29, 30]. Self-efficacy refers to an individual's belief in their ability to execute actions necessary to achieve specific academic goals. Unlike general confidence, self-efficacy emphasizes task-specific judgments made before and during performance. According to Bandura's theory [31], higher self-efficacy enhances goal-directed behavior, making students more likely to engage with academic tasks rather than avoid them. Supporting this, Theobald et al. employed intensive longitudinal data to examine feedback loops between competence beliefs, value beliefs, procrastination, and goal achievement [32].

Procrastination is also understood as an emotion-focused avoidance strategy. Fear of failure leads individuals to worry that their performance will not meet internal or external standards, thereby activating failure-avoidance motivation. As a result, they may delay task engagement to temporarily escape negative emotions such as anxiety or shame [33]. Although this strategy may reduce emotional discomfort in the short term, it often results in task accumulation, decreased self-efficacy, and heightened feelings of guilt and helplessness over time—ultimately reinforcing the cycle of procrastination.

Depression and academic procrastination are closely linked in a bidirectional, mutually reinforcing relationship. Medical students are particularly vulnerable, as medical training involves intense academic pressure, exposure to illness and death, and health-related anxieties—all of which contribute to elevated depression rates compared to other student populations. depressive symptoms such as anergia and anhedonia undermine intrinsic motivation, while cognitive impairments—including poor concentration and decision-making—further hinder task initiation [34, 35]. According to Gray's BIS theory, heightened punishment sensitivity in depressed individuals also contributes to behavioral inhibition. Procrastination may in turn intensify depressive symptoms. Individuals who procrastinate frequently experience greater emotional reactivity and poorer mood regulation [3], leading to guilt, self-blame, and reduced self-worth [36, 37]. Tice and Baumeister [38] proposed that procrastination can cause depression through self-evaluation failure or impaired self-control. These findings highlight depression as a potential core factor in academic procrastination, operating through motivational, cognitive, and affective mechanisms within a self-perpetuating feedback loop.

Environmental factors

The relationship between psychological factors and academic procrastination has been well described, while the role of external factors such as task characteristics and environmental conditions on procrastination has received little attention. Procee categorized the nature of the task as one of the three main factors affecting procrastination [19]. Klingsieck emphasized the influence of contextual factors such as task nature and teacher traits on academic procrastination [21]. It is true that difficult and boring tasks are more likely to induce procrastination than easy and engaging tasks. In contrast, teacher support was able to reduce procrastination behaviors and play a positive emotion management role.

Application of network analysis to academic procrastination

While many studies have identified factors linked to academic procrastination, most have used linear models—such as regression—that treat procrastination as a dependent variable and examine predictors independently. This overlooks the interdependence and dynamic interplay among variables, limiting insight into the complex nature of procrastinatory behavior.

To address this, network analysis has emerged as a valuable approach in psychology. Rather than assuming a single latent cause, it views behavior as arising from direct interactions among observed variables. In this framework, variables are nodes and their associations (e.g., partial correlations) are edges, forming a network that maps the system's internal structure.

Network analysis offers several advantages over traditional methods: it visualizes structural relationships between variables beyond unidirectional effects, identifies core variables through centrality measures, and detects bridge variables linking sub-networks that may explain behavioral contagion. Additionally, while inherently correlational, this method facilitates hypothesis-building for subsequent causal investigations. However, network results are sensitive to sampling error and should be interpreted with caution. This study applies network analysis to explore the structure of academic procrastination. The aims include:

(1) Test whether impulsivity serves as a central node within the procrastination network;
(2) Identify other potential core influencing factors;
(3) Uncover underlying connectivity patterns that may inform the development of targeted psychological interventions.

Material and methods

Participants

The study received approval from the local ethics committee. All participants provided informed consent online, and data were collected anonymously and stored in encrypted format on a secure platform. Between September and October 2023, a cross-sectional online survey was distributed via QR codes across six medical universities in eastern China. A total of 1,240 responses were collected through Wenjuanxing (www.wjx.cn); after applying quality control criteria (e.g., attention checks, consistency screening; see Supplementary Flowchart 1), 681 valid responses remained. To improve engagement and compensate for participants' time, each student received a small monetary reward (3 RMB). The payment protocol was approved by the ethics committee, and care was taken to ensure that all participation remained fully voluntary. The final sample was 72.1% female, aged 16–29 years (M = 19.9, SD = 0.89). Additional demographic details are provided in Supplementary eTable 3.

Measures

Procrastination Assessment Scale-Students (PASS)

The Procrastination Assessment Scale–Students (PASS) [39] consists of two parts: the first assesses the frequency of procrastination across six academic tasks, while the second explores reasons for procrastination. In this study, we focused on the first part to evaluate procrastination behavior. Each task includes three items, and following Wu et al. [40], we used only the first item from each domain to reduce participant burden—yielding a six-item version measuring frequency of procrastination. Responses were rated on a 5-point Likert scale (1 = never; 5 = always). The Chinese version (PASS-C) [41] has demonstrated good psychometric properties (α = 0.68–0.84; total r = 0.78), and in the current sample, the six-item version showed high internal consistency (Cronbach's α = 0.87).

Barratt Impulsive Scale-Brief (BBIS)

BBIS is an 8-item self-report questionnaire that measures impulsivity on a 4-point scale (1 ='never', 4='always'). Four items (items 1, 4, 5, and 6) are reverse scoring questions. The scale was revised by Morean [42] based on the previous version and introduced to China by Luo Tao [43]. The Chinese veesion showed excellent internal consistency (α = 0.81) and 2-week test–retest reliability (r = 0.85). In this study, Cronbach's alpha was 0.85.

The conscientiousness subscale of the Big-Five Personality Inventory-10 (BFI-10)

BFI-10 is a 10-item inventory that contains five subscales: openness, conscientiousness, extraversion, agreeableness, and neuroticism [44]. The Chinese BFI-10 was validated by Carciofo et al. [45] which Internal consistency for the subscale was α = 0.73, and test–retest reliability over 3 months was r = 0.69. In this study, we used the two-item conscientiousness subscale of the Chinese BFI-10. Responses were recorded on a 7-point Likert scale (1 = "does not apply to me at all", 7 = "applies to me perfectly"). The internal consistency of the subscale was assessed using the Pearson correlation coefficient, which was r = 0.32, p < 0.001. To account for the limited number of items, we also calculated the Spearman-Brown coefficient, which was 0.48, indicating moderate reliability consistent with two-item scales in previous research.

Performance Failure Appraisal Inventory-Short Form (PFAI-S)

The PFAI-S measures the strength of individuals' **fear failure** in five aversive consequences of failing(e.g., experiencing shame, devaluing self-worth) [44]. This dispositional measure was assessed using a 5-point Likert scale (−2='do not believe at all', 0='believe 50% of the time', 2='believe 100% of the time'). The Chinese PFAI-S was adapted by Chen et al. [46] and the scale demonstrated strong internal consistency (α = 0.82) and 4-week test–retest reliability (r = 0. 97). In the present study, the Cronbach's alpha was 0.82.

New General Self-Efficacy Scale (NGSE)

NGSE is an 8-item questionnaire that measures specific self-efficacy in different situations on a 5-point scale (1 ='strongly disagree', 5='strongly agree'). The Chinese NGSE was validated by Zhang and Li in a nationally representative sample (N = 1,478). The scale showed high internal consistency (α = 0.89) and robust structural validity (CFI = 0.95, RMSEA = 0.07) [47]. In the present study, Cronbach's alpha was 0.90.

The Patient Health Questionnaire (PHQ-8)

PHQ-8 is an 8-item self-report inventory that asked participants to indicate how often they have been bothered by possible problems or components over the last 2 weeks on a 7-point Likert scale (0 = not at all, 3 = nearly every day) [48]. The PHQ-8 is a short version of the PHQ-9 which reflects eight of the nine criteria on which DSM-5 diagnosis of major depressive disorder is based, omitting an item that asks about suicidal or self-injurious thoughts, and the Chinese version was validated by Wang et al. [49] exhibiting excellent internal consistency (α = 0.86) and 2-week test–retest reliability (r = 0.84). The Cronbach's alpha in the present study was 0.87.

A scale of the Task Nature and Teacher Traits (STNTT)

The Scale of Task Nature and Teacher Traits (STNTT) was developed for this study to assess task- and teacher-related contributors to academic procrastination. Following the approach of Grunschel et al. [50], each item began with'I delay because…'and was linked to factors contributing to procrastination. Based on literature review and expert consultation, the final version included 16 items across two subscales: Task Nature (10 items, Cronbach's $\alpha = 0.63$) and Teacher Traits (6 items, $\alpha = 0.81$). Items were rated on a 5-point Likert scale. Exploratory factor analysis ($N = 120$) supported a two-factor structure explaining 58.3% of the variance. Construct validity was evidenced by moderate correlations with PASS scores ($r = 0.36$–0.41, $p < 0.01$) and known-groups differences ($p < 0.001$). The questionnaire is presented in Supplementary eTable 3.

Procedure

The local ethics committee provided approval for the present study. All participants signed an online informed consent form before answering the online questionnaire. A cross-sectional design was used in this study and questionnaires were released on the information platform of medical colleges with a QR code powered by www.wjx.cn to recruit undergraduate medical students from September to October of 2023. Every participant took about 8 min to complete the questionnaire and was paid 3 RMB for their labor.

Network analysis

Three steps were used to estimate and evaluate the problematic behavioral symptom network as suggested by Zarate et al. [51]: 1) Estimating the statistical model; 2) Analyzing the structure of the network; 3) Evaluating the accuracy and stability of the network's parameters [52]. First, we used the R package qgraph to construct partial correlation networks for academic procrastination. To reduce spurious connections, we applied the graphical LASSO regularization method with an extended Bayesian information criterion (EBIC), using a tuning parameter (γ) of 0.25 to determine the optimal sparsity level.

In this study, networks with scales (Scale-level Network) and entries (Item-level Network) as nodes were established separately. Aiming to avoid Berkson's bias (i.e., selection of clinical populations by total symptom score negatively affects network recovery performance [53], we introduced scale total scores to create Scale-level Network. Again, given the high degree of heterogeneity in depressive symptoms, procrastination behavior, etc., we introduced individual entries from each scale independently to create Item-level Network.

Then, to determine the central behavior of the network structure, the study calculated four centrality indices, namely strength, betweenness, closeness, and expected influence via R package qgraph. Strength indicates the sum of absolute edge weights connecting any particular node to all other nodes. Betweenness indicates the number of shortest paths connecting any two nodes, while the closeness is the inverse of the sum of the total lengths of all shortest paths from any particular node to all other nodes. Expected influence was of particular interest, as it incorporates both positive and negative edge weights, thus offering a more accurate measure of a node's overall influence in psychological symptom networks, where inhibitory and activating relationships coexist [51]. Prior research has shown that expected influence is more appropriate than strength in psychological networks, particularly when the directionality and polarity of symptom interactions matter [54].

In addition, bridge centrality indices were calculated using the networktools package (version 1.5.0), including bridge strength, bridge closeness, bridge betweenness, and bridge expected influence. These indices estimate the extent to which a symptom connects distinct symptom communities. The use of bridge centrality is theoretically grounded in transdiagnostic research, where bridge components may explain comorbidity and symptom spread between domains (e.g., between procrastination and affective components) [55]. Specifically, bridge expected influence was used to assess the cumulative potential of components to activate nodes across communities, identifying key targets for potential intervention. Higher values of expected influence or bridge expected influence suggest greater functional importance in the activation and maintenance of the symptom network.

The network estimation and bootstrapping were conducted with bootnet 1.4.3 packages to assess the accuracy and stability of the observed network model. First, the accuracy of edge weights was evaluated by calculating 95% confidence intervals using a non-parametric bootstrap approach (1,000 bootstrap samples). Second, bootstrap difference tests were used to understand the variability of edge weights. Finally, the stability of node strengths was evaluated by computing the correlation stability (CS) coefficient using a case-dropping bootstrap approach. In network analysis, ensuring the stability of the results is paramount to establish the reliability of the findings.

Results

Descriptive statistics and correlation analyses

Supplementary eTable 1 shows the descriptive statistics of the total sample. Table 1 presents the correlation analysis of the scales related to academic procrastination. All the variables were significantly correlated with academic procrastination.

Table 1 Correlation analysis of scales related to academic procrastination

Variables	1	2	3	4	5	6	7
1. Fear	–						
2. Conscientiousness	-.198[a]	–					
3. Self-Efficacy	-.135[a]	.475[a]	–				
4. Impulsivity	.149[a]	-.631[a]	-.494[a]	–			
5. Depression	.277[a]	-.326[a]	-.338[a]	.370[a]	–		
6. Nature of tasks	.170[a]	-.173[a]	-.138[a]	.233[a]	.263[a]	–	
7. Teacher Trait	.048	-.160[a]	-.066	.179[a]	.210[a]	.493[a]	–
8. Academic Procrastination	.140[a]	-.438[a]	-.358[a]	.459[a]	.412[a]	.280[a]	.246[a]

[a] At the 0.01 level (two-tailed), the correlation is significant

Network estimation

Figure 1 (Scale-level Network) shows the network model of the nodes for the scale totals assessing Impulsivity, Conscientiousness, Fear of Failure, Self-Efficacy, Depression, Task Nature, and Teacher Traits. Of the 28 possible edge weights, 22 showed a non-zero relationship (78.57%), indicating a substantial association. In the Scale-level Network, Academic Procrastination was located in the center of the network with an average edge weight of 0.04, with the strongest estimated positive edge strengths between Task Nature and Teacher Traits ($r = 0.422$), and Impulsivity and Academic Procrastination with a stronger positive edge strength ($r = 0.205$). The strongest negative edge ($r = -0.385$) was found between Conscientiousness and Impulsivity. Additional information on the edge weights is shown in Supplementary eTable 4. Impulsivity showed the highest level of strength (2.508), followed by Conscientiousness (2.247) and Academic Procrastination (1.144).

In addition, Depression showed the highest level of closeness (0.431) and betweenness (2.000) and high intensity (2.198). The two nodes with the strongest expected influence are the Task Nature (1.274) and Teacher Traits (1.042), both of which are conditions of the external environment, which suggests that environmental factors have the highest influence in the whole network (see Fig. 2 and

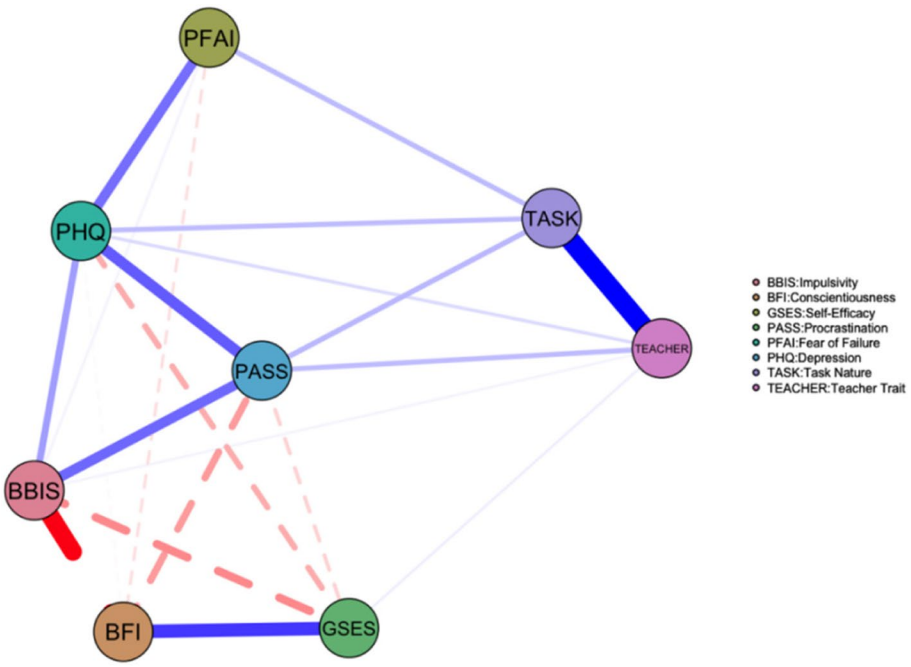

Fig. 1 Factors of academic procrastination network. Note. The eight nodes represent seven factors that may influence academic procrastination, and the edges represent biased correlations for EBIC-LASSO regularization. Blue edges represent positive relationships, red edges represent negative relationships, and wider, more saturated edges represent stronger relationships

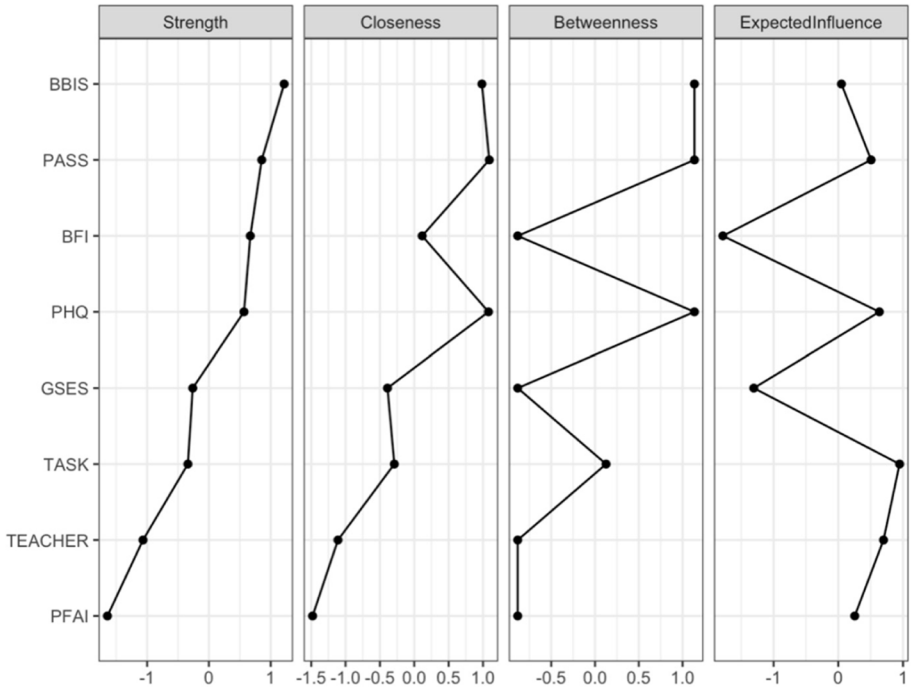

Fig. 2 Centrality indices for the Scale-Item Network. *Note.* The horizontal axis represents standardized (Z) centrality. The vertical axis represents factors that may be associated with academic procrastination

supplementary eTable.5 for details). Strength reflects the likelihood of activating one symptom followed by the activation of other features, whereas expected influence takes into account not only the strength of the connections, but also the global structure of the network and the positive and negative relationships between the nodes, which better identifies the factors that have the highest influence on the whole network compared to the other centrality indices.

Regarding bridge components, impulsivity and depression had the highest values of expected bridge influence and bridge strength (see Fig. 3).

Figure 4 (Item-level Network) shows the network model consisting of each entry in the above scale. The network consists of 8 correlates with a total of 45 entries. Of the 990 possible edge weights, 277 were non-zero (28.0%), of which were positively correlated (60.5%) with a mean weight of 0.016. In Item-level Network, item 7

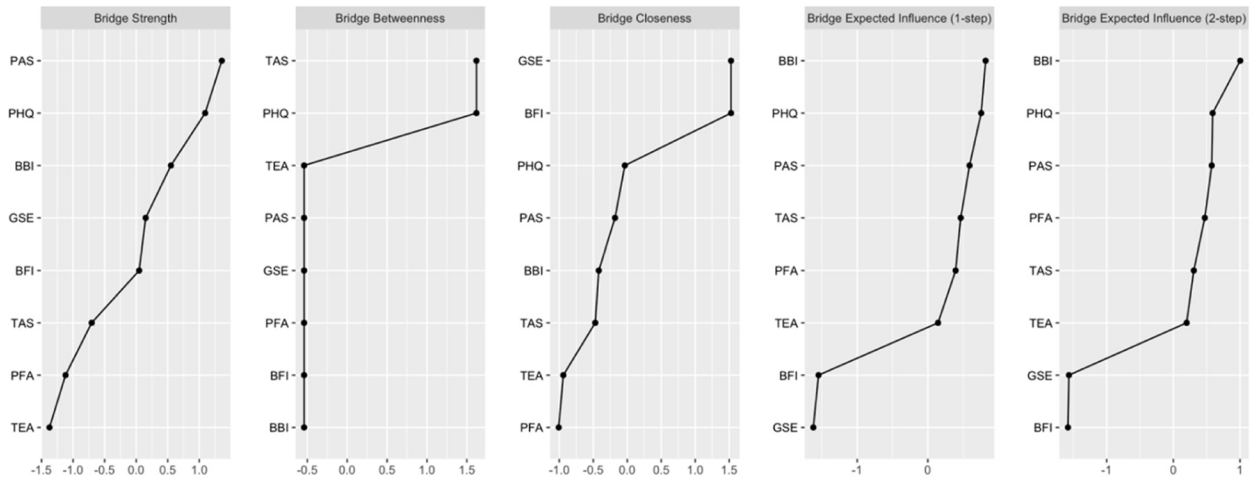

Fig. 3 Bridge centrality plot for Scale-level network. *Note.* The horizontal axis represents sums of weights and frequency of bridge components across different forms of problematic be haviors. The vertical axis represents each symptom of different disorders

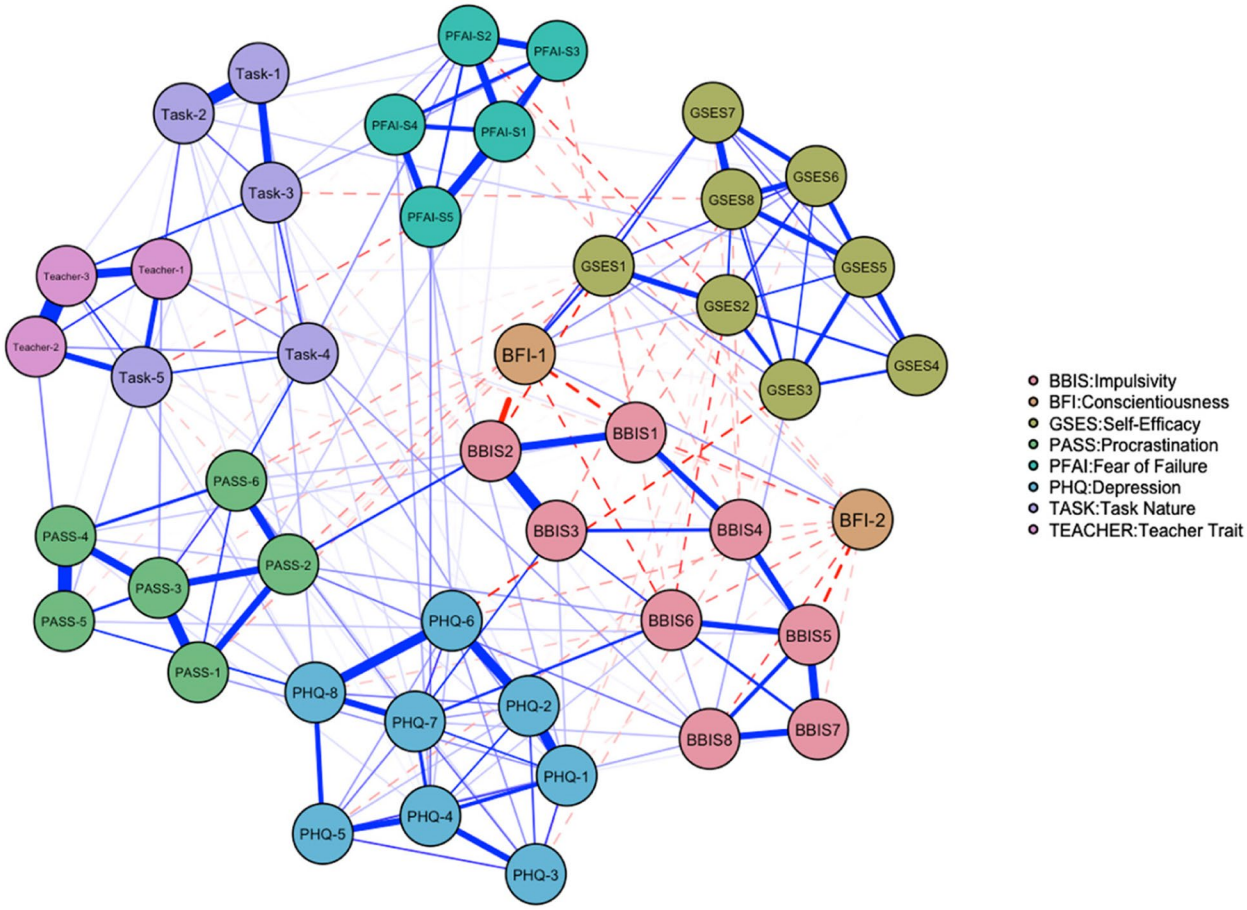

Fig. 4 Factors of Academic Procrastination Network. *Note.* The 45 nodes represent features associated with academic procrastination, and the edges represent biased correlations for EBIC-LASSO regularization. Blue edges denote positive relationships, red edges denote negative and broader, more saturated edges denote stronger relationships

of PHQ (difficulty concentrating) had the highest intensity (13.298), betweenness (41.00), and expected influence (8.062). Meanwhile, the item 6 of PHQ (self-hatred) had the second highest intensity (10.560) and proximity (0.006) and the highest betweenness (82.00). Interestingly, all entries on the PHQ scale had higher expected influence than the nodes in the other scales (see Fig. 5 and Supplementary eTable.6 for details on the centrality index).

Network stability

As shown in Fig. 6, the level of stability of the scale network's expected influence (EI) and intensity centrality values was acceptable (CS coefficients both equal to 0.751), indicating that 75.1% of the participants could be removed from the analysis without significantly altering the structure of the network. The precision of the edges was found to be satisfactory as measured by the non-parametric CI, with lower CIs indicating more accurate edge estimates (see Supplementary Fig. 1). A considerable number of edge weight comparisons were statistically significant according to the bootstrap difference test (see Supplementary eFigure 2). The EI and intensity centrality values of the Item-level Network both indicate excellent levels of stability (both CS coefficients equal to 0.751) (see Supplementary Fig. 3), and the non-parametric CI test is shown in Supplementary Fig. 4.

Discussion

To our knowledge, this study is among the first to use network analysis to examine the relationship between procrastination and psychological and environmental factors in medical students. Two networks, scale-level and item-level, were constructed, offering preliminary insights into mechanisms that may underlie academic procrastination. Both central and bridge nodes were impulsivity and depression, with PHQ item 7 (difficulty concentrating) and item 6 (self-hatred) playing potentially important roles. Situational factors also appeared to influence the network, and their modification may have broader implications for related variables.

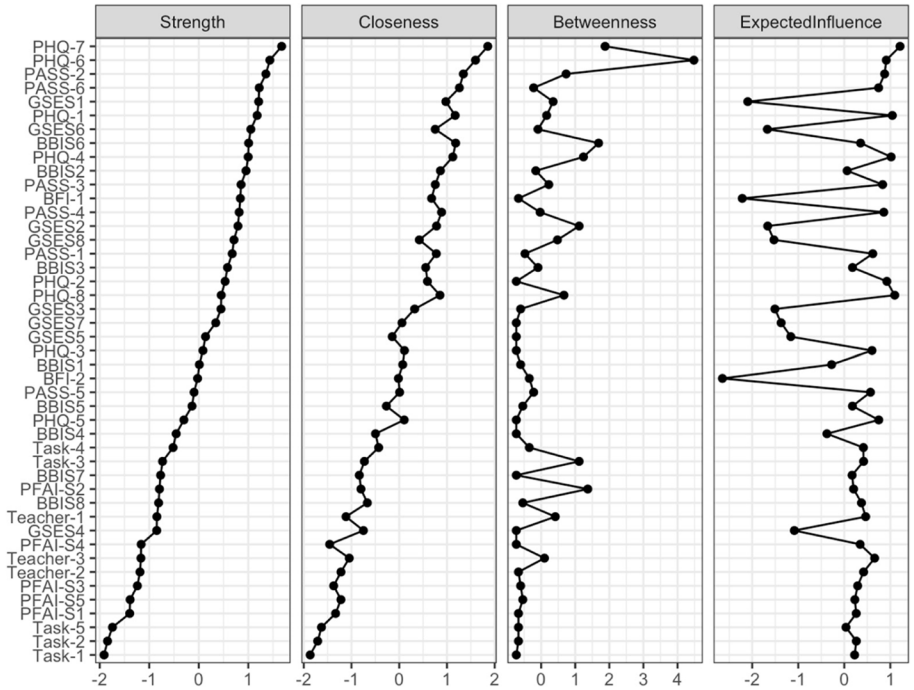

Fig. 5 Centrality Indices. *Note.* The horizontal axis represents standardized (Z) centrality. The vertical axis represents factors that may be associated with academic procrastination

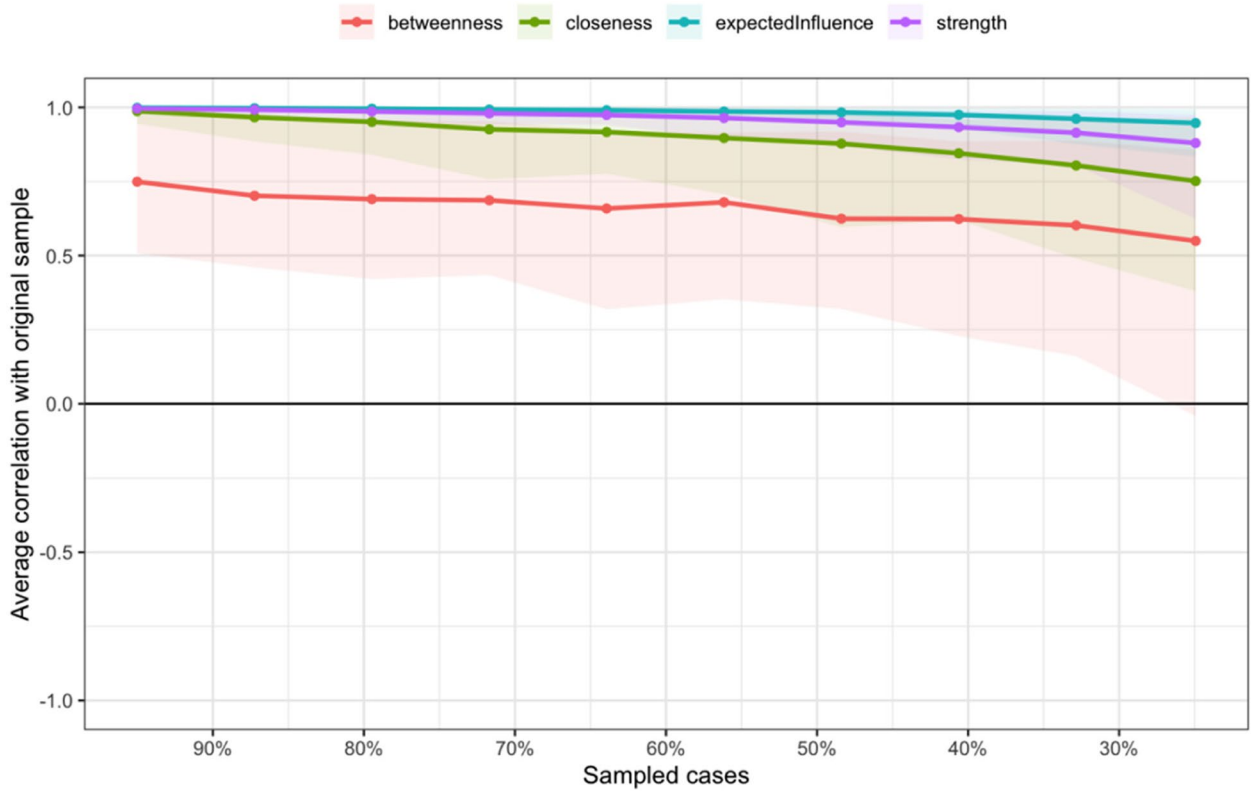

Fig. 6 Coefficient Stability (CS) for Strengthes, Closeness and Betweenness. *Note.* The centrality indices obtained for 100% samples and a subset of asymptotic samples decreasing to 30%

1. The central and bridging role of impulsivity in the procrastination network

In the scale-level network, impulsivity emerged as both a central and bridging node, and showed the strongest direct association with academic procrastination. This finding aligns with existing neuroimaging studies, suggesting that the neural basis of procrastination may involve dysregulation between the prefrontal and limbic systems. Resting-state fMRI research has shown that activity in the ventromedial prefrontal cortex (vmPFC) is positively associated with procrastination, reflecting its overactivation in reward evaluation and emotional processing. In contrast, reduced activity in the anterior prefrontal cortex (aPFC) indicates impaired executive control. These findings suggest a possibility that individuals with high impulsivity may be more likely to defer academic tasks due to vmPFC-driven emotional responses and insufficient top-down regulation from the aPFC [47]. Further research may indicates that procrastination may also stem from a tendency toward "effort discounting," in which individuals overestimate the immediate effort required to complete a task and underestimate the cost of delaying it, may result in task postponement [56]. This bias is closely linked to reduced effort-encoding signals in the dorsomedial prefrontal cortex (dmPFC). Individuals with high impulsivity may be more susceptible to this mechanism, tending to avoid tasks in the moment and shift focus to imagined future scenarios. These findings are consistent with earlier behavioral research, which showed that highly impulsive individuals are more easily distracted by immediately pleasurable activities and thus more likely to procrastinate [57].

In the network structure, impulsivity served as a bridge node, potentially linking emotional, cognitive, and behavioral domains. This suggests possible pathways for future mechanism-oriented research. At the item level, impulsivity, depression, and academic procrastination formed a tightly connected triangle. Psychologically, impulsive individuals tend to overestimate negative outcomes and underestimate positive ones, potentially contributing to to cognitive patterns such as self-blame, overgeneralization, and rumination—closely related to depressive tendencies [58]. Fan et al. [59] found that state anxiety predicted academic procrastination via partial mediation by ego depletion, indicating that negative emotions may deplete self-regulatory resources and increase vulnerability to both procrastination and depressive states. From a neurochemical perspective, impulsivity has been linked to serotonin system dysfunction, a key factor in depression [60, 61].

This study also found a strong negative correlation between impulsivity (BBIS) and conscientiousness (BFI), with high edge weight, supporting the role of impulsivity in procrastination. DeWitte and Schouwenburg [62] emphasized that lack of perseverance, a core facet of impulsivity, may explain its strong link with procrastination and its inverse relation to conscientiousness. In the item-level network, BBIS2 (self-control), BBIS3 (attention), PHQ6 (negative self-image), and PASS2 (exam preparation) were identified as key nodes. Furthermore, voxel-based morphometry (VBM) analysis by Hu et al. [63] showed that procrastination was positively associated with gray matter volume in the parahippocampal gyrus (PHG) and orbitofrontal cortex (OFC), and negatively associated with the middle frontal gyrus (MFG) and inferior frontal gyrus (IFG), reinforcing the involvement of neural regions related to self-control, emotion regulation, and future-oriented processing—consistent with the current findings.

2. Effects of depressive symptoms, attentional difficulties, and negative self-concept on academic procrastination

The mechanisms connecting depression and procrastination might be complex and multifaceted, with inconclusive evidence from previous studies. For example, the Exercise-Health model posits that perceived stress mediates depression [64, 65], although this mediating role diminishes over time [66]. Other factors, such as rumination, shame [67], guilt [68], regret [69], and anger, also play roles in the relationship between depression and procrastination.

At the item-level, entries from the depression scale consistently showed higher expected influence values compared to those from other scales, with item 7 of the PHQ (difficulty concentrating) and item 6 of the PHQ (self-hatred) standing out with the highest strength and betweenness. These findings suggest that depression, particularly difficulty concentrating and self-hatred, as potential key factors sustaining the network. When people are inattentive, they may have difficulty processing and retaining information effectively. This cognitive overload may be overwhelming and may decrease productivity, which might create a backlog of work and increase procrastination [70]. The lack of attention also makes people underestimate the strength of future punishments, overestimate immediate reward stimuli, and have difficulty making long-term reward choices, could be linked to procrastination.

Besides, previous studies have shown that self-hatred and self-blame, in addition to sadness, are central to depressive networks in non-clinical adolescents [71]. According to Beck's [72] cognitive theory of depression, negative self-referential thinking puts individuals at

greater risk for depression, as reported by a large body of empirical evidence [73, 74]. Also, feelings of failure may cause individuals to avoid completing tasks, and over time, this avoidance behavior may reinforce procrastination. Large-scale network analyses have shown that the functional connectivity between the frontoparietal network (FPN) and the cingulo-opercular network (CON) is significantly stronger in non-procrastinators compared to procrastinators [75], suggesting that impaired self-regulation may underlie procrastination. This may be linked to characteristics of the Chinese education system, which emphasizes exam performance and academic rankings. Such a competitive environment could heighten students'anxiety and sense of helplessness in the face of academic demands. For medical students in particular, academic performance is closely tied to future career prospects. Under the combined pressures of achievement expectations, parental demands, and limited attention to mental health, students may be more prone to self-blame and negative self-evaluation when encountering challenges, potentially increasing emotional distress and the likelihood of procrastination [26].

3. The significant potential impact of task nature and teacher traits

Current research on academic procrastination has paid less attention to contextual factors [76]. Our study found that task nature and teacher traits had significant impact on the network, with the strongest edge weights between these two variables in the scale-item network. Teacher traits, such as their ability to foster student interest, may influence the nature of tasks, which in turn affects procrastination [77]. The relationship between these factors is particularly relevant in medical schools, where teachers maintain strong control over tasks and course scheduling.

Although academic procrastination is widely recognized, intervention studies targeting this issue remain limited [78]. Given the multifactorial nature and intervention challenges of academic procrastination, it is recommended that interventions for medical students primarily target impulsivity and depression, while also encouraging medical schools to foster a more supportive and adaptive learning environment. Self-control therapy, which emphasizes self-monitoring, self-evaluation, and self-reinforcement, has been shown to be effective in reducing both depressive symptoms and procrastination [79, 80]. Clear goal-setting strategies, such as SMART goals, may help reduce impulsivity [79]. Targeted improvements in the psychological environment may also reduce procrastination. Regarding situational factors such as task demands and teacher characteristics, educators could implement programs to enhance students' self-efficacy and goal-directed behavior. Creating opportunities for success, encouraging positive self-talk, and providing constructive feedback could boost students' confidence [24, 80]. For students with severe or persistent procrastination, neurointerventions may be considered. Non-invasive techniques such as transcranial direct current stimulation (tDCS) or transcranial magnetic stimulation (TMS) targeting the dorsolateral prefrontal cortex (DLPFC) have shown potential in enhancing self-control and reducing procrastination, though these approaches remain experimental.

This study identifies impulsivity, depression, and environmental factors as core contributors to academic procrastination among Chinese medical students, offering potentially useful intervention targets tailored to this specific population. It also provides psychological entry points for future research into the neural mechanisms underlying procrastination at the brain network structure–function level.

This study has several limitations. First, the cross-sectional design limits the ability to examine temporal dynamics and causal relationships in the psychological network. Longitudinal studies with multiple time points are needed to explore how network structures evolve over time. Second, the use of self-report measures may introduce bias due to subjectivity and recall error. Future research could incorporate objective indicators, such as actual delays in assignment submission. Third, academic procrastination was not categorized in this study. Prior research distinguishes between active and passive procrastination, which may have different psychological profiles and consequences. Future studies should consider this distinction to enhance explanatory precision.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40359-025-02916-5.

Suppplementary Material 1.

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Authors' contributions
The concept and study design were formed by SY. H and XF. D. Data acquisition was conducted by SY. H JN. L and Z. L. Data analysis and explanation was conducted by SY. H and XF. D. Drafting of the manuscript and figures was contributed by SY. H and XF. D.

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Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The studies were approved by the Ethics Committee of Capital Medical University(approval number: Z2023SY033) and therefore has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All persons who were included in this study gave their informed consent prior to the begin of their participation. Informed consent was obtained from all individual participants included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]School of Basic Medicine, Capital Medical University, Beijing, China. [2]Beijing Key Laboratory of Mental Disorders, National Clinical Research Center for Mental Disorders & National Center for Mental Disorders, Beijing Anding Hospital, Capital Medical University, Beijing, China. [3]Advanced Innovation Center for Human Brain Protection, Capital Medical University, Beijing, China. [4]School of Medical Humanities, Capital Medical University, Youanmenwai, Xitoutiao, No.10, Jieping Building, Room 304, Beijing 100069, China.

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