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# Exploring the relationship between negative life events and emotional symptoms in adolescents using a network analysis

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This study used network analysis to explore the association between negative life events and emotional symptoms in Chinese adolescents, with a focus on depression, anxiety, and their comorbid mechanisms. The Adolescent Self-Reporting Life Events Scale (ASLES), the Center for Epidemiological Studies Depression Scale (CES-D), and the Self-Rating Anxiety Scale (SAS) were used to assess 1083 adolescents. Based on the data, three networks were constructed: the negative life events-depression network, the negative life events-anxiety network, and a integrated negative life events-depression-anxiety network. In the depression network, "Depressive mood," "Sadness," and "People dislike me" were core nodes, reflecting emotional and social sensitivity. In the anxiety network, "Panic," "Fear," and "Dizziness" emerged as core nodes, highlighting the role of physiological responses. The integrated network identified "Depressed mood" and "Panic" as key nodes, revealing the overlap and interaction between depression and anxiety. "Academic stress" and "Interpersonal relationships" were consistent bridge nodes across networks, linking negative life events to emotional symptoms and contributing to comorbid mechanisms. These findings suggest that targeting core symptoms and bridge nodes may reduce depression, anxiety, and their comorbidities. This study provides insights into adolescent emotional symptom networks, supporting targeted and comprehensive interventions.

Adolescence is a critical stage for physical and mental development, during which negative life events such as academic pressure, interpersonal conflicts, and family changes are closely linked to the occurrence of emotional symptoms such as depression and anxiety[1]. Extensive research shows that negative life events during adolescence may lead to emotional dysregulation, even developing into more severe mental health issues and potentially impacting long-term functioning[2–4]. Recent evidence also indicates that high-impact life events, such as traumatic experiences, have become increasingly common during adolescence[5,6]. An increasing number of studies have shown that exposure to negative life events serves as a strong predictor of mental health outcomes, with effects that span from childhood into adulthood[7].

Adolescence is a transitional phase marked by rapid development of emotion regulation systems, including the prefrontal cortex and amygdala, alongside physiological and social changes associated with puberty. Together, these factors heighten adolescents' vulnerability to negative life events[8,9]. Additionally, according to the cumulative risk hypothesis, the accumulation of multiple risk factors, rather than specific types of risk, plays a critical role in influencing the mental health of children and adolescents[10]. The negative life events are widely recognized as key contributors to the onset of depression and anxiety in adolescence[11,12]. Research has consistently shown that experiencing adverse events during this stage can significantly increase the likelihood of developing emotional symptoms[13,14]. For instance, Phillips et al. (2015) conducted a cross-lagged study examining the reciprocal relationship between stressful life events and depression over time[12]. Their findings demonstrated that negative life events significantly predicted later depressive symptoms ($P = 0.01$), whereas the predictive effect of depression on subsequent life events was relatively weaker ($P = 0.06$)[9]. Similarly, Binelli (2012) found in a cross-sectional study that exposure to domestic violence in childhood was a significant predictor of

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future social anxiety ($P = 0.03$)[15]. These findings highlight the crucial role of negative life events in the emergence and progression of emotional disorders, reinforcing the need for early intervention strategies to mitigate their long-term impact.

In recent years, network analysis has gained prominence in the study of the unique structures of anxiety and depression symptoms, shedding light on their interrelations and complex symptom dynamics. With respect to anxiety networks, researchers have explored the central features of trait and state anxiety, as well as the robust edges within the network[16–18]. Additionally, some studies have examined the associations between anxiety and other psychological and behavioral factors, such as its links to negative emotions and emotion regulation[19,20], as well as behavioral characteristics such as withdrawal behaviors, social problem solving, smartphone addiction, and sleep problems[21–23]. These findings suggest that anxiety extends beyond isolated symptoms, intertwining with broader psychological and behavioral patterns.

In depression network research, scholars have focused primarily on various dimensions of depression (such as low mood, helplessness, loss of interest, etc.), as well as the interactions between these dimensions[24–27]. Additionally, studies have explored the associations between depression and external factors, including emotion regulation[11], personality traits[28], subjective well-being[29], internet addiction[30], occupational burnout[31], and bullying victimization[32]. These studies reveal the multidimensional nature of depression, indicating that it is driven not only by the interactions of internal symptoms (such as low mood and loss of interest) but also by external factors, highlighting the complexity and broad impact mechanisms of depression.

Additionally, numerous researchers have explored the comorbidity networks of anxiety and depression. A recent systematic review analyzed findings from 33 studies published between 2016 and 2022, covering 179 articles and a total of 78,721 participants across clinical and community samples. The results demonstrated that network models help identify the most influential symptoms in the comorbidity of anxiety and depression (e.g., "Sad mood," "Worry too much," "Uncontrollable worrying"), the most relevant bridging symptoms (e.g., "Sad mood," "Restlessness," and "Motor disturbance"), and the most stable symptom connections (e.g., between "Sleep" and "Energy")[33]. These studies suggest that network models play a critical role in understanding symptom characteristics and interrelations in the comorbidity of anxiety and depression.

Numerous studies have employed network analysis to identify core symptoms (those with the greatest influence within the network) and bridge symptoms (those linking different symptom clusters) in anxiety, depression, and their comorbidity. These studies have significantly advanced the understanding of emotional symptom structures and their interrelations by highlighting the critical nodes and pathways within symptom networks. However, previous studies have focused primarily on the static relationships between symptoms while paying limited attention to external influencing factors, particularly the role of negative life events. Moreover, most studies rely on linear models or traditional causal path analyses, which often assume that individual factors independently affect emotional symptoms. This approach overlooks the differences in the impact of negative stressors on anxiety or depression, as well as the potential complex interactions between symptoms. In reality, the interplay between depression and anxiety symptoms often manifests through specific cross-connections between symptoms, which traditional methods struggle to effectively reveal at the microlevel.

Building on existing studies of symptom networks, this study utilizes network analysis to investigate the microlevel impact of negative life events on anxiety and depression symptoms. Specifically, it aims to elucidate the differential effects of negative life events on anxiety and depression symptoms while uncovering their potential roles in the mechanisms underlying their comorbidity. By mapping intricate symptom interactions, network analysis offers a novel framework to understand how negative life events contribute to the comorbidity of anxiety and depression via specific symptom pathways, potentially guiding targeted interventions.

## Methods
### Participants
This study involved 1,136 Chinese adolescent students who voluntarily participated in the research and completed paper-based questionnaires. None of the participants exhibited significant clinical psychological symptoms. Written informed consent was obtained from both the participants and their parents before data collection. To ensure data quality, participants who failed to respond accurately to a series of attention checks (e.g., selecting "agree" when prompted) were excluded from the analysis. Only participants who successfully passed all attention checks and completed at least 80% of the measures were retained. After data cleaning, the final sample comprised 1,083 valid responses. The mean age of the participants was 14.32 years ($SD = 1.01$), with 52.8% being male ($n = 572$) and 47.2% being female ($n = 511$). The participants were distributed across four grade levels: 30.3% Grade 8 ($n = 328$), 46.6% Grade 9 ($n = 505$), 12.2% Grade 10 ($n = 132$), and 10.9% Grade 11 ($n = 118$).

All the participants and their parents were informed about the purpose of the study, and they were free to withdraw from the study at any time. The Research Ethics Committee of Guangzhou University approved the present study and conducted in accordance with ethical standards.

### Measures
The Adolescent Self-Reporting Life Events Scale (ASLES) consists of 27 items that may induce psychological stress in adolescents, as developed by Liu et al.[34]. The ASLEC includes six factors: interpersonal relationships, academic stress, be punished, loss of friends and property, health and adaptation issues, and others. Participants respond to each event on the basis of whether it occurred over a 1-year period; if it did occur, participants rate their psychological feelings at the time of the event on a scale of 1 (no impact) to 5 (extremely severe). The cumulative stress from all events is calculated as the total amount of stress. In the present study, Cronbach's alpha was 0.87, and the mean interitem correlation (MIC) was 0.21.

The Center for Epidemiological Studies Depression Scale (CES-D) was developed to screen for depression symptoms by measuring the frequency of events and ideas over the past week[35]. It is a 20-item instrument with each item rated on a four-point scale ranging from 0 ("rarely or none of the time") to 3 ("most or all of the time"). There are four subscales: interpersonal problems, somatic complaints, absence of positive affect, and depressed affect. The total score ranges from 0 to 60, and a higher score indicates a greater risk of depression. The CES-D has been validated in a variety of Chinese samples[36]. In the present study, the Cronbach's alpha was 0.93, and the MIC was 0.37.

The Self-Rating Anxiety Scale (SAS) is a self-report scale whose 20 items cover a variety of anxiety symptoms[37], including both psychological (e.g., "I feel afraid for no reason at all") and somatic (e.g., "My arms and legs shake and tremble"). Responses are given on a 4-point scale ranging from 1 (none, or a little of the time) to 4 (most, or all of the time). In the present study, the Cronbach's alpha was 0.83, and the MIC was 0.17.

### Statistical analysis

Network analyses were performed using R 4.4.1. We estimated network models and calculated weights for all possible connections using the graphical LASSO method combined with EBIC model selection. This step was automatically performed with the "*estimateNetwork*" function and the "*EBICglasso*" default option[38]. We used the "*qgraph*" package for network visualization[39], and the "*bootnet*" package (1.4.3) was applied to estimate and illustrate the network model visually[38].

We calculated centrality indices, including strength and expected influence (EI), and Bridge expected influence (BEI). Strength measures a node's overall connections by summing the absolute weights of its edges[38]. Prior research has suggested that node strength is important in the study of psychopathology and tends to be more stable[40]. Expected influence, defined as the sum of the values of all edges connecting to a given node, is more appropriate for networks with both negative and positive edges[41]. The greater the expected influence of a node is, the more important it is in the network. Bridge expected influence, which measures connections between nodes in different communities, was calculated using the R package "*networktools*"[42]. Higher node bridge expected influence values indicate a greater extent of increased risk of contagion to other communities[42]. We also used the R package "mgm" (version 1.2–12) to compute node predictability, reflecting how much a node is connected to its neighbors[43]. Predictability is shown as the area in the rings around each node in the network.

To assess the accuracy and stability of the observed network model, the R package "*bootnet*" (version 1.4.3) was used, which is based on 1000 bootstraps performed for each node[38]. The centrality indices of the expected influence and bridge expected influence were assessed using correlation stability (CS; case-drop bootstrap) coefficients; values greater than 0.25 indicated moderate stability, whereas values greater than 0.5 indicated strong stability. In our network, all CS values were above 0.50, indicating the reliability of the network. In addition, we conducted bootstrapping to test the differences in the centrality indices and bridge expected influence indices of different nodes.

## Results
### Descriptive statistics
The descriptive statistics for negative life events, depression, and anxiety are presented in Table S1 (Supplementary, S).

### Network analysis
*The negative life events-depression network*
The negative life events and depression networks are shown in Fig. 1A and exhibit several important characteristics. First, 171 (52.62%) of the 325 possible edges were not zero, which indicated that these edges were likely to be true edges based on the regularization techniques (see Table S2). Second, the five strongest edges were identified. Within the depression community, three of the strongest edges were between CES12 "Happy" and CES16 "Enjoy life" (weight = 0.40), between CES15 "People are unfriendly" and CES19 "People dislike me" (weight = 0.36), and between CES4 "As good as others" and CES8 "Hopeful about the future" (weight = 0.29). In the negative life events community, the two strongest edges were between A1 "Interpersonal relationships" and A2 "Academic stress" (weight = 0.26) and between A3 "Punishment" and A4 "Loss of friends and property" (weight = 0.25). The bootstrapped difference test for the edge weights revealed that the weights of the five strongest edges were significantly higher than the other edge weights (see Fig. S1). Moreover, the node predictability values ranged from 22.1% (A4: Loss of friends and property) to 65.1% (CES6: Depressive mood), with an average of 44.0%, indicating that, on average, 44.0% of the variance in nodes from the network could be explained by their neighboring nodes (see Fig. 1A and Table S1).

The features of node centrality in the network, including strength and expected influence, are presented in Fig. S2. Notably, the top four nodes with the highest strength and expected influence are identical: CES6 (Depressive mood), CES19 (People dislike me), CES18 (Sadness), and CES7 (Doing everything effort). These findings indicate that these four nodes were significant in terms of strength and expected influence, potentially reflecting their critical role in the overall network. Among these nodes, CES6 (Depressive mood) demonstrated the greatest influence on both strength and expected influence, suggesting that it may serve as a core node within the depression network, significantly contributing to overall levels of depression. To further assess the robustness of these findings, the correlation stability coefficient of node strength and expected influence was calculated. The correlation stability coefficient of node strength and expected influence was 0.75 (> 0.25), indicating that these centrality estimates were highly reliable (see Fig. S3). Moreover, the bootstrapped difference test confirmed that the centrality values of the four strongest nodes were significantly greater than the other nodes (see Figs. S4–S5).

To better understand the associations between the two communities, the bridge expected influence was calculated for each node. Our analysis revealed that nodes A2 (Academic stress) and A1 (Interpersonal
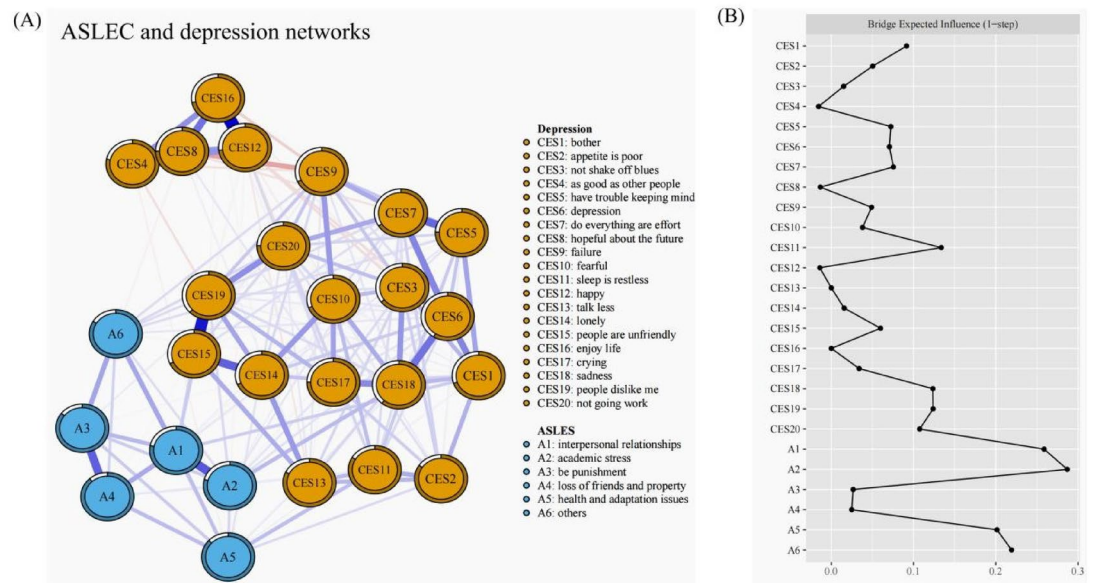
**Fig. 1**. Network structure of the negative life events-depression variables and the bridge expected influence for each node. (**A**) Blue edges represent positive correlations. A thicker edge reflects higher correlation between the nodes. (**B**) The bridge expected influence of each node in the network (raw value).
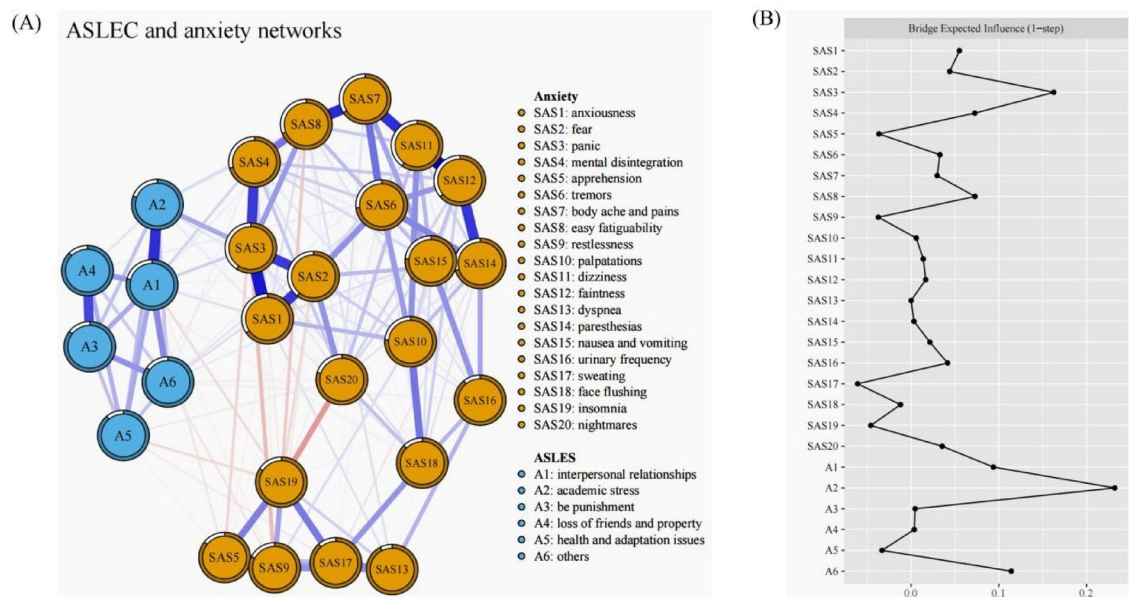


**Fig. 2**. Network structure of the negative life events-anxiety variables and the bridge expected influence for each node. (**A**) Blue edges represent positive correlations. A thicker edge reflects higher correlation between the nodes. (**B**) The bridge expected influence of each node in the network (raw value).

relationships) served as the primary bridges linking the two communities (see Fig. 1B). The correlation stability coefficient of the bridge expected influences was 0.75 (> 0.25), indicating that the estimation of node's bridge expected influences was adequately stable (see Fig. S6). Furthermore, bootstrapped difference tests of the bridge expected influence confirmed the significance of these nodes (see Fig. S7).

*The negative life events-anxiety network*
The negative life events and anxiety networks are shown in Fig. 2A and have several important characteristics. First, 170 (52.31%) of the 325 possible edges were not zero, which indicated that these edges were likely true edges based on the regularization techniques (see Table S3). Second, the five strongest edges were identified in the final network. Within the anxiety community, four of the strongest edges were observed: between SAS11 "Dizziness"
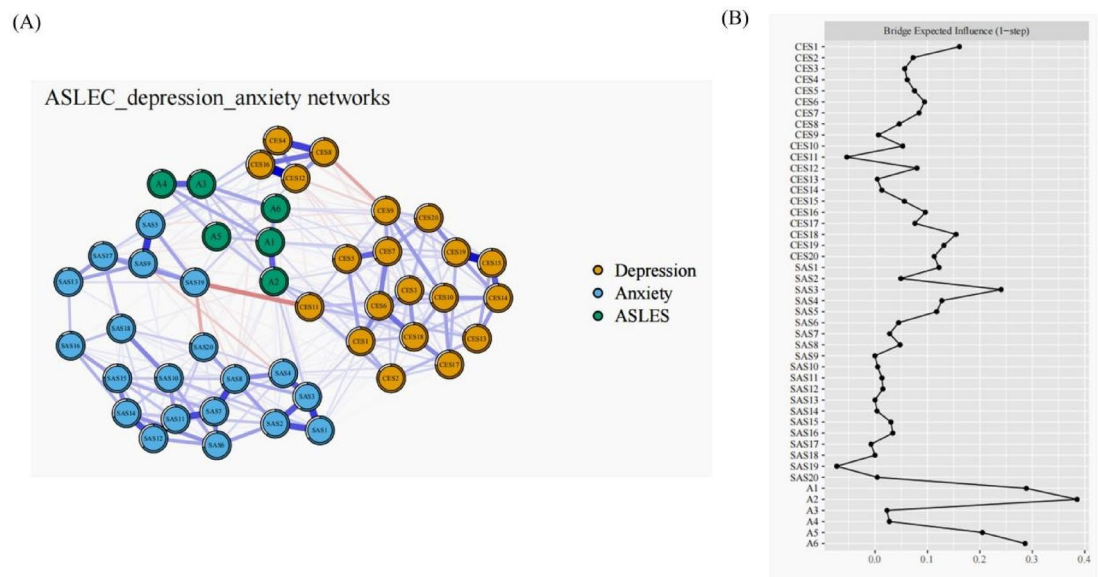
**Fig. 3**. Network structure of the negative life events-depression-anxiety variables and the bridge expected influence for each node. (**A**) Blue edges represent positive correlations. A thicker edge reflects higher correlation between the nodes. (**B**) The bridge expected influence of each node in the network (raw value).

and SAS12 "Faintness" (weight = 0.34), between SAS5 "Apprehension" and SAS9 "Restlessness" (weight = 0.32), between SAS1 "Anxiousness" and SAS3 "Panic" (weight = 0.31), and between SAS7 "Body ache and pains" and SAS8 "Easy fatiguability" (weight = 0.28). In the negative life events community, the strongest edge was between A1 "Interpersonal relationships" and A2 "Academic stress" (weight = 0.27). The bootstrapped difference test for the edge weights revealed that the weights of the five strongest edges were significantly higher than the other edge weights (see Fig. S8). Moreover, node predictability values ranged from 14.3% (SAS13:Dyspnea) to 64.9% (SAS3:Panic), with an average of 39.3%, indicating that, on average, 39.3% of the variance in nodes from the network could be explained by their neighboring nodes (Fig. 2A).

The features of node centrality in the network, including strength and expected influence, are presented in Fig. S9. Notably, the top five nodes for both strength and expected influence are identical: SAS3 (Panic), SAS2 (Fear), SAS11 (Dizziness), SAS12 (Faintness), and SAS14 (Paresthesia). These findings indicate that these five nodes were significant in terms of strength and expected influence, potentially reflecting their critical role in the overall network. Among these nodes, SAS3 (Panic) demonstrated the greatest influence on strength, suggesting that it may function as a core node within the anxiety network, significantly contributing to overall levels of anxiety. To further assess the robustness of these findings, the correlation stability coefficients of node strength and expected influences were calculated. The correlation stability coefficient of node strength and expected influences was 0.75 (> 0.25), indicating that these centrality estimates were adequately stable (see Fig. S10). Furthermore, the bootstrapped difference test for the node strength and expected influences revealed that the strength and expected influences of the five strongest nodes were significantly greater than the other nodes (see Figs. S11–S12).

To better understand the associations between the two communities, we calculate the bridge expected influence for each node. Our analysis revealed that A2 (Academic stress) and SAS3 (Panic) served as the primary bridges linking the two communities (see Fig. 2B). The correlation stability coefficient of the bridge expected influences was 0.67 (> 0.25), indicating that the estimation of node's bridge expected influence was adequately stable (see Fig. S13). Furthermore, bootstrapped difference tests of the bridge expected influences confirmed the significance of these nodes (see Fig. S14).

*The negative life events-depression-anxiety network*
The negative life events-depression-anxiety network is shown in Fig. 3A and has several important characteristics. First, 354 (34.1%) of the 1035 possible edges were not zero. Second, the three strongest edges were identified in the final network. Within the depression community, the strongest edges were between CES12 "Happy" and CES16 "Enjoy life" (weight = 0.38) and between CES15 "People are unfriendly" and CES19 "People dislike me" (weight = 0.36). In the anxiety community, the strongest edge was between SAS11 "Dizziness" and SAS12 "Faintness" (weight = 0.33). The bootstrapped difference test for the edge weights revealed that the weights of the three strongest edges were significantly higher than the other edge weights (see Fig. S15). The results from the modularity analysis[44], which assessed the degree to which nodes formed distinct clusters, yielded a Q value of 0.58. Notably, four clusters emerged, with depression and anxiety items split across two mixed communities, indicating that these items did not form distinct clusters. Moreover, node predictability values ranged from 14.8% (SAS13:Dyspnea) to 66.5% (SAS3:Panic), with an average of 44.0%, indicating that 44.0% of the variance in nodes from the network could be explained by their neighboring nodes (see Fig. 3A and Table S1).

The features of node centrality in the network, including strength and expected influence, are presented in Fig. S16. Notably, the top two nodes with the highest strength and expected influence are identical: CES6 (Depressive mood) and SA3 (Panic). The correlation stability coefficient of node strength and expected influences was 0.75 (> 0.25), indicating that the estimations of node strength and expected influences were adequately stable (see Fig. S17). Furthermore, the bootstrapped difference test confirmed that the strength and expected influence of these two top nodes were significantly greater than the other nodes (see Figs. S18–S19).

To better understand the associations between the three communities, the bridge expected influence was calculated for each node. Our analysis revealed that nodes A2 (academic stress) and A1 (interpersonal relationships) served as the primary bridges linking the three communities (see Fig. 3B). The correlation stability coefficient of the bridge expected influences was 0.75 (> 0.25), indicating that the estimation of node's bridge expected influences was adequately stable (see Fig. S20). Furthermore, bootstrapped difference tests of the bridge expected influence confirmed the significance of these nodes (see Fig. S21).

## Discussion

The present study aimed to explore the relationships between adolescent negative life events and two key emotional symptoms (depression and anxiety) among Chinese students. We used network analysis to construct three models: the negative life events-depression network, the negative life events-anxiety network, and the negative life events-depression-anxiety network. Each network demonstrated acceptable robustness, ensuring the stability and reliability of our findings. Our analysis revealed a highly interconnected symptom network, with no distinct modular structure separating depression and anxiety[44,45]. This result aligns with recent studies on the comorbidity of depression and anxiety, which have shown that symptoms of depression and anxiety often co-occur among adolescents and may share underlying mechanisms such as difficulties in emotional regulation, cognitive distortions, and lack of coping strategies[46,47]. In these network models, the differences in edge weights revealed the strength of associations between symptoms or events. For example, in the depression network, the strong edge weight between "Happy" and "Enjoy life" suggests that these positive emotions often decline simultaneously. This implies that interventions could aim to enhance positive emotions to improve depressive states. In the anxiety network, the strong edge between "Dizziness" and "Faintness" indicates that these physiological symptoms frequently cooccur during anxiety responses. Moreover, in the negative life events network, the strong association between "Interpersonal relationships" and "Academic stress" reflected that these two stressors may simultaneously impact mental health. This suggests that when designing interventions, we should prioritize addressing these key factors. Improving the quality of adolescents' interpersonal relationships or alleviating academic stress may help mitigate the comorbidity of depressive and anxiety symptoms.

In the negative life events-depression network, the centrality analysis revealed that "Depressive mood," "Sadness," and "People dislike me" demonstrated the highest strength, indicating that these symptoms had the strongest connections to the rest of the symptoms in the network, meaning they played a central role in the overall structure of depression-related symptoms. Previous studies have consistently shown that "Depressive mood" and "Sadness" are core symptoms of depression, a finding validated across diverse cultures and populations[27,33,48–50]. Interestingly, our results also identified "People dislike me" as a central symptom among adolescents. This finding is consistent with research conducted with Spanish children and adolescents[51] and may reflect the heightened social sensitivity of adolescents. Moreover, the network structure further reveals specific links between depression symptoms and negative life events. For example, as shown in Fig. 1, academic stress exhibited a strong association with sadness, suggesting that excessive academic pressure may contribute to persistent low mood and emotional distress. Similarly, interpersonal relationship problems were closely linked to the perception that "people are unfriendly," reflecting how negative social experiences can intensify feelings of social rejection and loneliness. This finding highlights the importance of peer relationships during adolescence, particularly how peer acceptance or rejection significantly impacts emotional well-being. Therefore, intervention strategies should focus on improving the quality of adolescents' peer relationships, such as through social skills training and cognitive restructuring strategies to help them cope with social stress more effectively.

In the negative life events-anxiety network, "Panic," "Fear," and "Dizziness" exhibited the highest centrality. The prominence of these symptoms may reflect their crucial role in adolescents' experience of anxiety, particularly "Panic" and "Fear," which are core symptoms of anxiety and align with previous research findings[33,44]. "Dizziness," as a physical response, highlights the role of physiological reactions in anxiety. This implies that physiological symptoms not only are a manifestation of anxiety but also may play a key role in the transmission and maintenance of anxiety symptoms. Therefore, in interventions for anxiety, it is crucial to address not only emotional factors but also physiological approaches. By targeting both emotional and physiological aspects, interventions may be more effective.

In the negative life events-depression-anxiety network, "Depressive mood" and "Panic" emerged as central symptoms, indicating a significant symptom overlap between depression and anxiety. Compared with networks that examine depression or anxiety independently, this integrated network further reveals the close association and mutual influence between the two emotional disorders. This overlap may help explain why etiological research has encountered challenges in identifying unique risk factors for depression and anxiety[52,53]. As central nodes, they not only represent core emotional experiences among adolescents but also reflect a broader spectrum of negative affect, which may most closely mirror underlying neurobiological systems that support negative valence or core appraisals within a cognitive–behavioral framework related to perceived threat or loss[54].

The bridge node analysis revealed that "Academic stress" and "Interpersonal relationships" are critical bridging factors in the negative life events-depression network. These factors represent central aspects of negative life events and serve as triggers for multiple depressive symptoms[55–58]. As bridge nodes, they serve as crucial external influencing factors, offering insights into strategies to alleviate the broad association of these stressors on adolescents' emotional well-being. In response to this, school- and family-level interventions can

help mitigate the impact of academic stress on mental health by adjusting academic expectations, providing emotional support, and fostering a growth mindset[59–61].

In the negative life events-anxiety network, "Academic stress" and "Panic" emerged as key bridging factors, forming a transmission pathway from academic stress → panic → other anxiety symptoms. Academic stress directly or indirectly influences anxiety, whereas symptoms linked to panic are more closely associated with emotional dysregulation. In this pathway, academic stress often acts as the "source," whereas panic serves as a "trigger" or "catalyst" in transmitting stress to other anxiety symptoms, eventually leading to a state of mutual reinforcement[62,63]. In the integrated negative life events-depression-anxiety network, "Academic stress" and "Interpersonal relationships" reemerged as key bridging factors linking depression and anxiety symptoms, indicating that they influence both conditions. The role of these bridging factors reveals a potential comorbid mechanism between anxiety and depression in adolescents. Intervening with these factors may help alleviate depression and reduce anxiety. Additionally, the bridging role of "Panic" in the anxiety network suggests that the influence of academic stress on anxiety may manifest through "Panic," highlighting the potential for graded interventions in anxiety.

One key strength of this study is the use of network analysis, which allows for the examination of the dynamic associations between different depressive symptoms and life events, rather than relying solely on correlational analyses of total scores. This approach provides more granular symptom-level information, enabling the identification of clinically significant high-centrality and bridging symptoms, which can inform more targeted intervention strategies. Furthermore, our study is based on a large adolescent sample and employs rigorous statistical control methods, enhancing the robustness of the findings. However, we also acknowledge the limitations of the study, such as the cross-sectional design, which precludes causal inferences. Therefore, future research could adopt longitudinal or experimental designs to further explore the dynamic processes between negative life events and depressive symptoms.

In conclusion, this study used network analysis to examine the association of negative life events on depression and anxiety symptoms among Chinese adolescents and the comorbidity mechanisms involved. The findings showed that in the depression network, "Depressive mood," "Sadness," and "People dislike me" were core symptoms, reflecting adolescents' sensitivity to emotions and social relationships. In the anxiety network, "Panic," "Fear," and "Dizziness" were core symptoms, highlighting the importance of physiological manifestations. In the integrated network, "Depressive mood" and "Panic" were identified as core nodes, indicating significant overlap and interaction between depression and anxiety. Additionally, "Academic stress" and "Interpersonal relationships" were key bridge nodes linking negative life events to emotional symptom networks, demonstrating their critical roles in comorbidity mechanisms. These findings suggest that targeting core symptoms and bridge nodes could effectively alleviate depression and anxiety while reducing the risk of comorbidities. This study provides new insights into interventions for adolescent emotional problems.

## Data availability
The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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## Author contributions

X.B., W.S., and K.O. contributed to the design, data interpretation, and manuscript drafting. Z.L. participated in data collection, statistical analyses, and manuscript drafting. H.C. conceptualized the study, contributed to the study's design and coordination, conducted measurements, performed statistical analyses, and revised the manuscript, making significant contributions to each stage of the study; T.G. and K.S. were involved in the conception of the study, participated in statistical analyses, and contributed to the manuscript drafting; Y.M. supported the data collection, interpretation, and manuscript review. All authors read and approved the final manuscript, and each has made a significant intellectual contribution to the work.

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## Declarations

### Competing interests

The authors declare no competing interests.

### Ethical approval

All procedures performed in this study involving human participants adhered to the ethical standards of the institutional committee and complied with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

### Informed consent

All students voluntarily participated in the research and none of them had significant clinical psychological symptoms. And all participants and participants' parents gave written informed consent prior to data collection.

### Additional information

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