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The association between online learning, perceived parental relationship, anxiety, and depression symptoms among secondary school students: insight from symptom network and cross-lagged panel network approach

Yanqiang Tao^{1,2}, Haiqun Niu³, Qihui Tang^{1,2}, Shujian Wang^{1,2}, Liang Zhang⁴, Gang Liu^{5*} and Xiangping Liu^{1,2*}

Abstract

Introduction Anxiety and depression often co-occur in adolescents, with factors from family and school playing a significant role in the comorbidity. However, network analysis has not examined and clarified the detailed bridge and central symptoms of this comorbidity caused by online learning and perceived parental relationships across different COVID-19 times.

Methods Over four months, 2,356 secondary school students completed the Patient Health Questionnaire-9 and Generalized Anxiety Disorder Scale-7. Participants were divided into harmonious and disharmonious groups based on their answers to a question about parental conflicts.

Results The results indicated that adolescents perceiving more parental conflicts showed a denser comorbidity network after four months of online learning. Significant bridge symptoms decreased from three to two across two waves in the harmonious group, while in the disharmonious group, they increased from two to three. The number of central symptoms increased from one in wave 1 to three in wave 2 for the harmonious group, while four in wave 1 decreased to two in wave 2 for the disharmonious group. Furthermore, the CLPN analysis revealed that the strongest positive cross-lagged edge intensity between symptoms was anhedonia—energy in the harmonious group, with anhedonia being the most trigger symptom. In contrast, for the disharmonious group, guilt—suicide and trouble relaxing—excessive worry were the strongest cross-lagged edge, and trouble relaxing was the most trigger symptom.

Conclusion These findings may have implications for interventions designed to promote adolescent mental health in the context of online learning and parental conflicts.

Keywords Online learning, Perceived parental relationship, Anxiety, Depression, Adolescents, Network analysis

*Correspondence:

Gang Liu
dliugang@126.com
Xiangping Liu
89034@bnu.edu.cn

Full list of author information is available at the end of the article



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Introduction

Anxiety and depression are commonly observed to co-occur at high rates [1], often referred to as a “comorbidity problem” in clinical studies [2]. Individuals reporting such comorbidity have been found to exhibit cognitive decline and sleep difficulties [3], face challenges in everyday functioning [4], and may even exhibit self-injurious behavior and suicidal ideation [5]. Globally, the World Health Organization (2021) [6] has reported that one in seven individuals aged 10–19 experiences a mental disorder, with depression and anxiety being prominent among this age group. The mental health condition of adolescents in China may be of particular concern. The Epidemiological Survey of Mental Disorders among Children and Adolescents in China, launched on October 10, 2021, revealed an overall prevalence of mental disorders of 17.5% among individuals aged 6–16, with anxiety disorder accounting for 4.7% and major depressive disorder for 2.0% [7]. A more recent study focusing on Chinese adolescents aged 10–19 years found an alarming prevalence of depression at 24.6%, indicating that one in four adolescents experiences depression [8]. Given that adolescence is a critical developmental phase [9] and adolescents are at higher risk of mental disorders compared to adults, it is essential to conduct extensive research to better understand the occurrence of comorbidity during this stage of life. Throughout the extensive literature, factors from family and school have been the focus of research addressing correlates of mental health in adolescents [10].

Given the crucial role parents play in the developmental trajectory of their children, particularly during adolescence [11], an increasing number of scholars have directed their attention toward examining the impact of specific parental conflicts on children’s health outcomes [12, 13]. Previous studies have consistently demonstrated the detrimental effects of parental conflicts on the comorbidity of anxiety and depression [14–16]. Drawing upon the family system theory [17, 18], the family can be viewed as a fundamental emotional unit that maintains homeostasis within the system. Any conflicts between parents can disrupt this equilibrium and render children more vulnerable to psychological problems when they perceive the instability within the system [19]. This notion aligns closely with the emotional security theory (EST), which posits that perceived conflictual parental relationships engender emotional insecurity and subsequently elevate the risk of psychological problems [20, 21].

Furthermore, within the cognitive-contextual theory framework [22], the cognitive appraisal of parental conflict plays a crucial role in determining the extent to which children are affected by such conflict. Specifically,

when children perceive parental conflict as a threat to themselves (perception of threat) or attribute the conflict to themselves (self-blame), they are more likely to experience internalizing problems [23]. Consistent with this theory, a study by Gao et al. [19] revealed that children who blame themselves for parental conflict are susceptible to depression, whereas those who perceive the conflict as a threat to their well-being are more prone to anxiety. Additionally, a systematic review examining key parental factors associated with increased risk for depression and anxiety among adolescents aged 12–18 further underscores the significant impact of conflictual parental relationships on adolescents’ mental health [24]. Addressing parental conflict can be critical in prevention programs targeting young individuals at risk of depression and anxiety disorders. Therefore, it is imperative to further investigate and elucidate the influence of perceived parental relationships on the comorbidity of anxiety and depression among adolescents.

Regarding school factors, it is undeniable that the Internet has gradually become an indispensable component of the education sector, particularly facilitating the implementation of online learning during special periods and situations [25, 26]. However, engaging in remote educational activities from home presents challenges for students, as they must adapt to the new norm of limited face-to-face interaction with classmates, a critical aspect during adolescence when such interaction is most needed [27]. Consequently, online learning has emerged as a topic of concern when examining students’ psychological well-being [13, 28–30]. A study conducted by Hasan and Bao [31] revealed that the sudden shift to online learning significantly increased students’ psychological stress. Similarly, another study reported a higher prevalence of insomnia, depression, and anxiety symptoms among students primarily reliant on online learning compared to those engaged in traditional face-to-face instruction [32]. These negative effects may be attributed to prolonged exposure to the Internet, as students seek emotional outlets online when deprived of face-to-face communication with peers and personal space at home [5].

Importantly, early exposure to the Internet has been established as a significant contributing factor to psychiatric disorders, including attention-deficit hyperactivity disorder, depression, and social anxiety disorder [33]. Additionally, the risk of developing depression and anxiety disorders increases with prolonged exposure to electronic devices [34]. The situation becomes even more intricate when considering parental relationships. Students may experience emotional distress when exposed to prolonged parental conflicts without respite during the period of homeschooling. Furthermore, the added responsibility on parents due to online learning and the

potential strain resulting from the perceived ineffectiveness of online instruction [35] may lead to increased arguments over their children's academic performance. Consequently, adolescents are more likely to internalize blame for conflictual parental relationships, increasing their vulnerability to anxiety and depression. However, few studies have investigated comorbidity among adolescents by considering both parental relationships and online learning.

Previous studies examining diagnoses or latent factors may have approached the study of psychopathology at an inappropriate level by considering these disorders as unobservable factors generating specific observable symptoms, which is similar to the diagnosis of physical diseases [36]. However, there is an important difference between physical diseases and mental disorders. Physical diseases can be attributed to a worked-out etiology, stating that symptoms arise from common pathogenic pathways, while mental disorders imply a flock of symptoms taken together empirically, with the cause remaining unknown [37]. In addition, symptoms in mental disorders can interact with each other, and one symptom can be triggered by another symptom. Indeed, the network theory indicated that the complex interactions between symptoms can be viewed as a network, with symptoms categorized as nodes and connections between two symptoms conceptualized as edges, which clarifies the interacting patterns between symptoms and deepens the understanding of mental disorders [38]. Adopting the perspective of the network theory of psychopathology, it becomes evident that mental disorders emerge from direct causal interactions among their constituent symptoms [37]. Diagnostic comorbidity can arise from causal relationships between symptoms of two disorders (bridging edges) or shared symptoms that connect to other symptoms of both disorders (bridge symptoms) [38]. Furthermore, the density of symptoms within a network can serve as an indicator of future mental health problems [39]. Despite the high prevalence of comorbid anxiety and depression in adolescents [40], limited attention has been given to the impact of online learning and parental relationships. Valuable insights regarding the activation of specific symptoms within the network of comorbid depression and anxiety due to online learning, as well as the influence of parental relationships on the structure of this network, have yet to be explored. Additionally, studies employing cross-sectional data on related topics can only offer a limited understanding of the temporal and causal relationships proposed by the network theory. Therefore, longitudinal data are essential for modeling the temporal relationships between symptoms [41].

This study employs a cross-lagged panel network (CLPN) modeling approach to investigate the impact

of online learning and perceived parental relationships on the longitudinal changes of the anxiety-depression comorbidity network structure. CLPN modeling is well-suited for examining the temporal associations between symptoms [42]. The specific aims of this study are: (1) to elucidate the comorbidity network structures of anxiety-depression symptoms at different time points; (2) to identify the bridge symptoms and top central symptoms when examining the effect of online learning on the comorbidities of anxiety-depression; and (3) to explore longitudinal differences in the comorbidity network structures when testing the effect of perceived parental relationship.

Method

Participants and procedure

This study was a joint project with the government to investigate children's mental health in Harbin, China, during COVID-19. The teacher distributed a link to an electronic questionnaire to the students, who voluntarily completed the questionnaire. The data from 35 middle and high schools located in Harbin was collected in the current study. The initial data was gathered in February 2022 from 10,104 students, utilizing an online questionnaire program (<https://www.wjx.cn>) on their smartphones. Each student who agreed to participate in the study was required to complete the online questionnaire. Subsequently, in June 2022, the second wave of data was collected from 8,390 students in the same manner after four months of the students taking online courses. Due to the impact of COVID-19, these students were required to study online at home instead of taking offline classes at schools during these four months (from February 2022 to June 2022). Given that the current data was collected through an online questionnaire program and all items had to be answered, after matching datasets from both waves based on students' phone numbers, a total of 2,356 secondary school students were ultimately matched, within the age range of 11 to 18 years old.

To assess the level of marital harmony between parents in a family, we measure a question: "How often do your parents argue per week?" Participants are asked to rate their answers on a scale of 1–4, where 1 represents "never arguing", 2 represents "at least twice", 3 represents "half the time", and 4 represents "every day". Participants in this study were assigned to either the harmonious marriage group (coded as 1) or the disharmonious marriage group (coded as 2, 3, or 4) based on their responses in two waves of rating. Specifically, participants who responded with 1 in both two waves were assigned to the harmonious marriage group, while those who responded with 2, 3, or 4 in both waves or either one wave were assigned to the disharmonious marriage group.

In this study, a total of 1,339 students were recruited from two groups: the disharmonious marriage group ($n=379$, 49.9% females, $Mean_{age}=13.81$, $SD_{age}=1.38$) and the harmonious marriage group ($n=960$, 44.7% females, $Mean_{age}=13.78$, $SD_{age}=1.31$). Prior to participating in the assessment, both students and their parents provided signed informed consent. This study was conducted in accordance with the ethical standards of the Beijing Normal University ethical committee (Reference number: 202112220085).

Measures

At the beginning of the study, all participants were asked to provide basic demographic information, such as their gender, age, grade level (middle school or high school), and whether they resided in a county or a city. This information was collected during the initial assessment, used to characterize the study sample, and recorded as covariate variables for network analysis.

Generalized Anxiety Disorder Scale (GAD-7)

The GAD-7 is a reliable and valid seven-item questionnaire used to measure the severity of anxiety symptoms over the last two weeks [43], which measures the frequency of seven anxiety symptoms on a scale ranging from 0 (not at all) to 3 (nearly every day). For example, item 1 is “Feeling nervous, anxious or on edge” and represents the symptom of nervousness. The Chinese version of the GAD-7 has been a valid and reliable screening tool for depression in adolescents [44]. The GAD-7 demonstrated high internal consistency in two separate waves, with coefficients of 0.94 and 0.95 for harmonious marriage groups and 0.94 and 0.93 for disharmonious marriage groups.

Patient Health Questionnaire (PHQ-9)

The PHQ-9 is a widely-used questionnaire with nine items assessing depression symptoms [45]. Participants rate each item on a scale of 0 (not at all) to 3 (nearly every day), with a possible total score ranging from 0 to 27. For example, item 1 is “Little interest or pleasure in doing things” and represents the symptom of anhedonia. The Chinese version of the PHQ-9 has been rigorously validated and is considered an effective screening tool for depression in the general Chinese population [46]. The PHQ-9 demonstrated high internal consistency in two separate waves, with coefficients of 0.91 and 0.93 for harmonious marriage groups and 0.92 and 0.92 for disharmonious marriage groups.

Statistical analysis

We conducted all analyses using R version 4.2.2 [47]. To explore the interrelationship between anxiety and

depression symptoms in both harmonious and disharmonious marriage groups, we used the cross-sectional symptom networks (CSSNs) [48] and the cross-lagged panel networks (CLPNs) approach [49]. CSSNs were estimated using the extended Bayesian information criterion (EBIC) graphical least absolute shrinkage and selection operator (LASSO) method to shrink and obtain a sparser and easier symptom network structure. Each node in the network represented a symptom, and each edge represented the adjusted correlation coefficient between the two nodes. Line thickness represented the strength of the association. Red and green edges represented negative and positive correlations, respectively. The R package *bootnet* 1.4.3 [50] was used for symptom network estimation and visualization.

CLPNs were conducted to unravel the connections between the first and second assessments over time by using the *glmnet* package [49]. A CLPN can depict how one single node (i.e., symptom) at the first time point predicts other nodes at the second time point after adjusting all other variables at the first time point. The directed edges of each node pointing to itself signify the autoregressive coefficients, and the directed edges pointing to other nodes signify the cross-lagged coefficients. The color of the arrows represents the positive or negative of the effect, with green arrows indicating positive effects and red arrows indicating negative effects. Line thickness indicates the strength of the association.

The node centralities were characterized by the expected influence (EI) in the cross-sectional networks and by the out-expected influence (OEI) and in-expected influence (IEI) in the CLPNs. We validated the accuracy and stability of the networks using bootstrapping approaches implemented in the R package *bootnet* 1.4.3 [50]. To estimate the stability of centrality indices, we used a case-dropping procedure that provides the correlation stability coefficient (CS-C), which should be ≥ 0.25 . The detailed data analysis process is provided in the supplementary material.

Results

Symptom network structures and accuracy and stability

Our study investigated the symptom interconnectivity of anxiety and depression within harmonious and disharmonious marriage groups across two waves. We identified four cross-sectional anxiety-depression networks (see Fig. 1) and found that the pattern of symptom interconnectivity varied between the two groups and across waves. Specifically, in the harmonious group during wave 1, the strongest edge was between GAD1 and GAD2, while during wave 2, it shifted to GAD3 and GAD4. In contrast, within the disharmonious group, the strongest edge during wave 1 was between GAD2 and GAD4, while

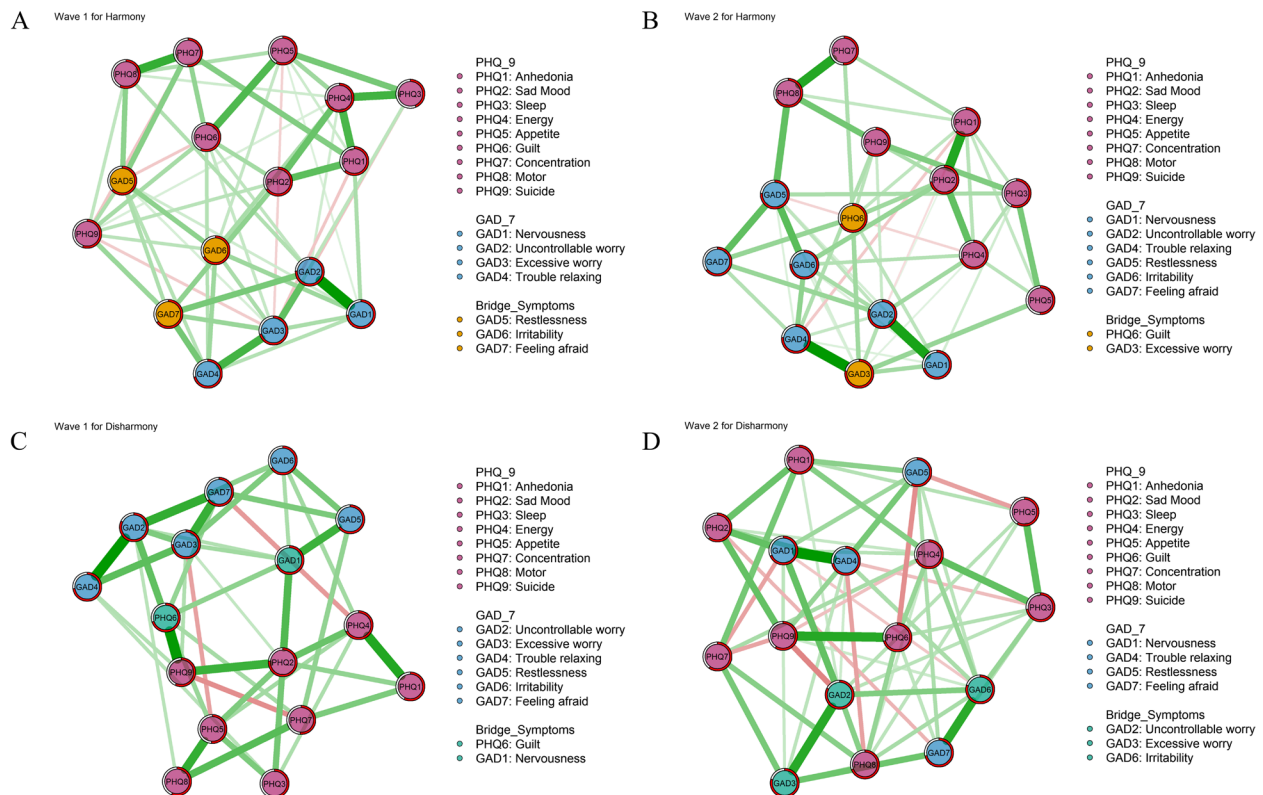


Fig. 1 Network structures. **A** the harmony group at the first time point. **B** the harmony group at the second time point. **C** disharmony group at the first time point. **D** disharmony group at the second time point

during wave 2, it shifted to GAD1 and GAD4 (see Tables S1-S4 in the supplemental material).

The centrality index (i.e., EI) is plotted in Fig. 2. Firstly, results revealed that within the disharmonious group, four core symptoms emerged during wave 1, consisting of two sub-symptoms each of anxiety and depression, namely nervousness (#GAD1) and uncontrollable worry (#GAD2), sad mood (#PHQ2), and guilt (#PHQ6). However, during wave 2, only two core anxiety symptoms remained: uncontrollable worry (#GAD2) and irritability (#GAD6). In contrast, within the harmonious group, the number of core symptoms increased from one (i.e., energy, #PHQ4) during wave 1 to three during wave 2 (i.e., uncontrollable worry #GAD2, excessive worry #GAD3, and restlessness #GAD5), indicating a distinct pattern of interconnected symptoms of anxiety and depression that evolved differently from the disharmonious group over time (see Fig. 2).

As depicted in Fig. 3, it is discernible that within the disharmonious group, there was a notable increase in the number of bridge symptoms (bridge EI, Z score above 1) from two (GAD1 and PHQ6) during wave 1 to three (GAD2, GAD3, and GAD6) during wave 2. In contrast, the harmonious group exhibited a decrease in the

number of bridge symptoms from three (GAD5, GAD6, and GAD7) during wave 1 to two (GAD3 and PHQ6) during wave 2.

The nonparametric bootstrap procedure results indicate that the 95% confidence intervals of all edges were narrow (Fig. S1), and most comparisons among edge weights and node centrality were statistically significant within harmonious and disharmonious marriage groups across two waves (Figs. S2, S3), suggesting that the current results are trustworthy. The case-drop bootstrapping results indicated strong stability of the EI and bridge EI centrality ($CS-C=0.13$, $CS-C=0.28$; $CS-C=0.21$, $CS-C=0.44$) both in wave 1 and wave 2 networks in the harmonious group (see parts A and B in Fig. S4). Similarly, the case-drop bootstrapping results indicated strong stability of the EI and bridge EI centrality ($CS-C=0.13$, $CS-C=0.36$; $CS-C=0.05$, $CS-C=0.36$) both in wave 1 and wave 2 networks in the disharmonious group (see parts C and D in Fig. S4).

Cross-lagged panel networks and accuracy and stability

The CLPNs are plotted in Fig. 4 (parts A and B) in the harmonious and disharmonious group, and corresponding edge weights are presented in Tables S5 and

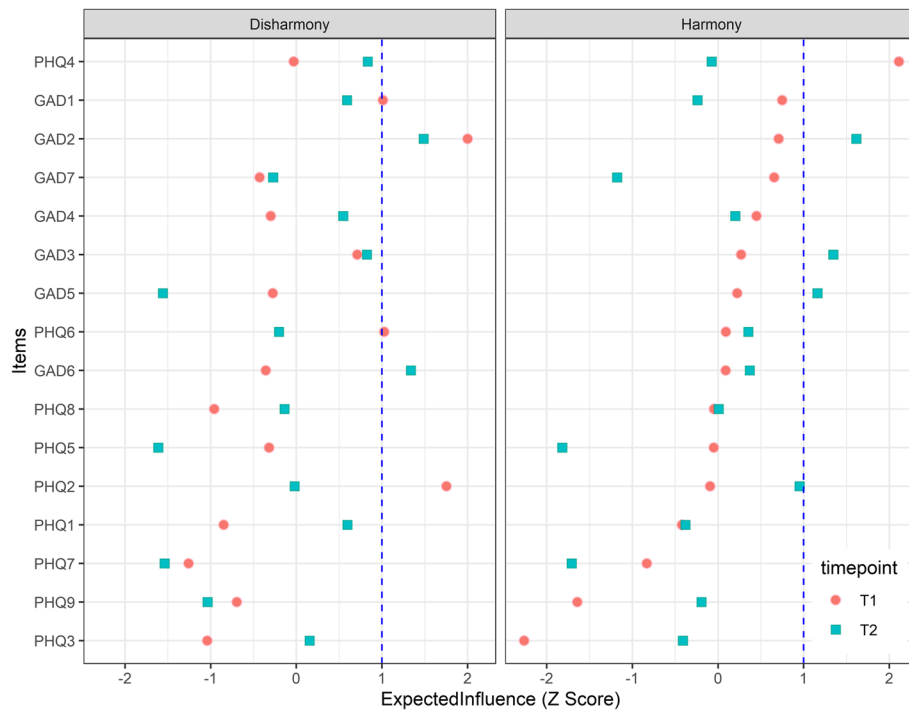


Fig. 2 Centrality index (EI) for harmony and disharmony group across two waves

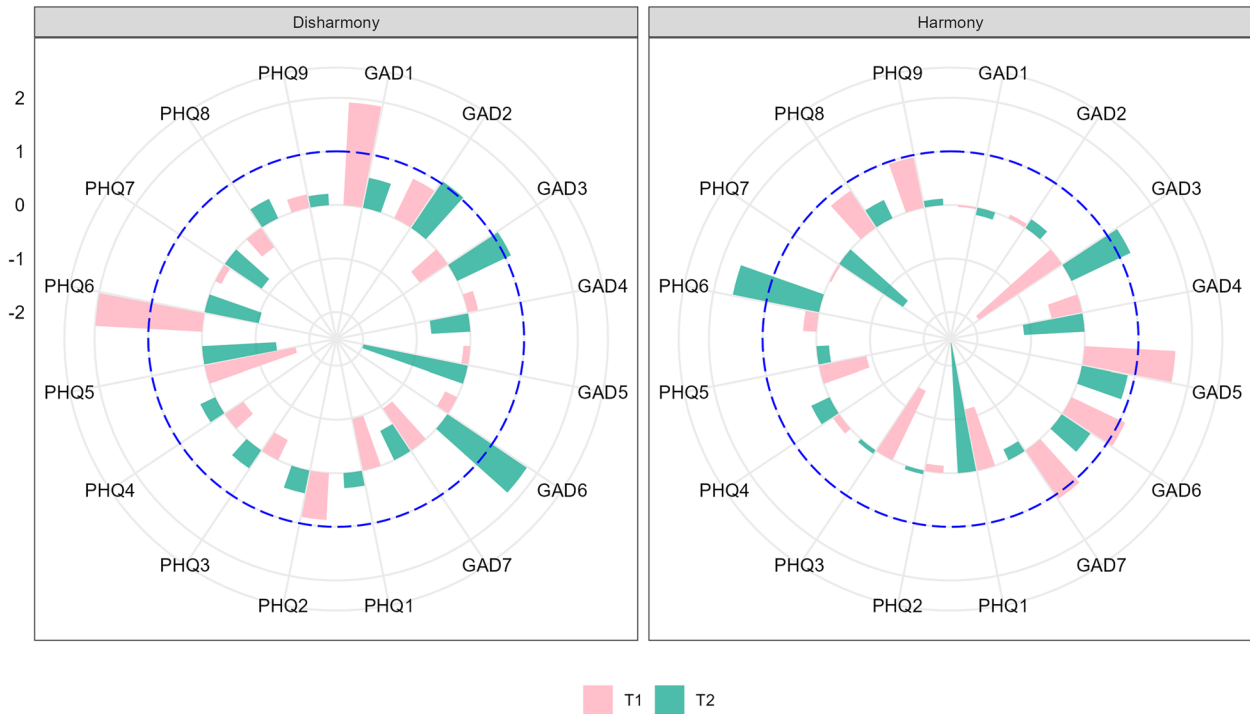


Fig. 3 Bridge centrality index (bridge EI) for harmony and disharmony group across two waves

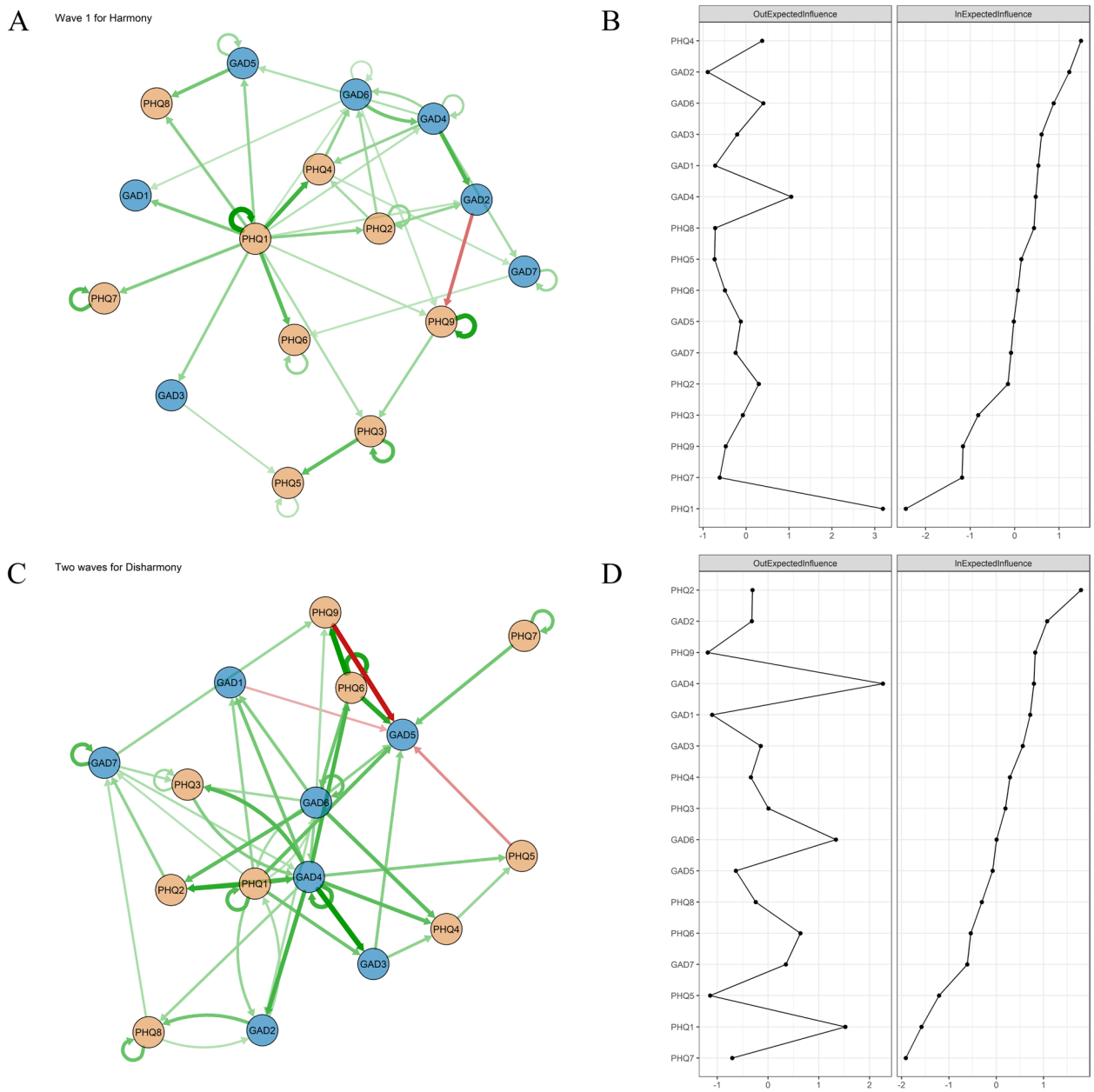


Fig. 4 The cross-lagged panel network structures. **A** the harmony group. **B** centrality indices (*OEI* and *IEI*) of all items in the harmony group. **C** The disharmony group. **D** centrality indices (*OEI* and *IEI*) of all items in the disharmony group

S6. In the harmonious group, the strongest positive cross-lagged edges were from anhedonia to energy, whereas the strongest negative cross-lagged edge was from uncontrollable worry to suicide. In the disharmonious group, the strongest positive cross-lagged edges were from guilt to suicide and from trouble relaxing to excessive worry, while the strongest negative cross-lagged edge was from suicide to restlessness.

The CLPN's centrality estimates are plotted in Fig. 4 (parts C and D). In the harmonious group, anhedonia (PHQ1) had the highest out-EI and significantly greater out-EI than 3 of the 16 other symptoms in the network (see Fig. S5). On the other hand, energy and uncontrollable worry had the highest in-EI, indicating that they were strongly prospectively predicted by other symptoms. Specifically, energy had significantly greater in-EI

than 3 of the 16 other symptoms, while uncontrollable worry had significantly greater in-EI than 5 of the 16 other symptoms (see Fig. S5). In the disharmonious group, trouble relaxing (GAD4) had the highest out-EI. On the other hand, sad mood and uncontrollable worry had the highest in-EI, indicating that other symptoms strongly prospectively predicted them. Specifically, the sad mood had significantly greater in-EI than 2 of the 16 other symptoms, while uncontrollable worry had significantly greater in-EI than 1 of the 16 other symptoms (see Fig. S6).

The results of the nonparametric bootstrap procedure indicate that the 95% confidence intervals of all edges were narrow, and most comparisons among edge weights and node centrality were statistically significant compared to other edge weights and nodes within CLPN. The case-drop bootstrapping results indicated strong stability of the in-EI and out-EI centrality ($CS-C=0.28$, $CS-C=0.13$; $CS-C=0.21$, $CS-C=0.13$) both in the harmonious and disharmonious group (see Fig. S7).

Network comparison test (NCT)

NCT revealed that structure invariance and global strength invariance between the harmonious and disharmonious group and across two waves are depicted in Table 1.

First, we compared the global strength invariance across two waves in the harmonious and disharmonious groups and found no significant difference in the global strength invariance ($p > 0.05$), as shown in Fig. S8. Similarly, structure invariance was not significantly different in the harmonious group across the two waves (see part A Fig. S9). However, structure invariance ($M=0.39$, $p=0.003$) was significantly different in the disharmonious group across the two waves (see part B in Fig. S8, all p values > 0.05 after Holm-Bonferroni corrections).

Table 1 Network comparison tests between the harmonious and disharmonious groups and across two waves

Comparison	Global strength invariance	Network structure invariance
T1 Ha – T2 Ha	$p=0.09$	$p=0.39$
T1 Disha – T2 Disha	$p=0.89$	$p=0.003$
T1 Ha—T1 Disha	$p=0.69$	$p=0.33$
T2 Ha – T2 Disha	$p=0.65$	$p=0.07$

Ha indicates the harmonious group. Disha indicates the disharmonious group. T1 means wave 1. T2 means wave2. p -values were adjusted for Bonferroni-Holm correction

After a comparison between the harmonious and disharmonious groups at different waves (see parts C and D in Fig. S9), there was no significant difference in structure ($p > 0.05$) or global strength ($p > 0.05$).

Discussion

The present study aimed to examine the impact of online learning and perceived parental relationships on anxiety and depression among secondary school students. To achieve this, we utilized a symptom network analysis and a cross-lagged panel network approach. Data were collected both before and after a four-month period of homeschooling, and participants were categorized into harmonious and disharmonious marriage groups based on their reported frequency of parental arguments. Through our analysis, we identified distinct bridge symptoms, central symptoms, and changes in symptom-symptom relationships within the anxiety-depression network structures of adolescents from the harmonious and disharmonious marriage groups over time.

The results of the network comparison test indicate that, overall, there is a denser and more complex network structure in the disharmonious marriage group after four months of online learning. Specifically, the structure invariance was found to be significant in the disharmonious group across the two waves. Another notable and relevant finding is that in the disharmonious group, the number of significant bridge symptoms increases from two (guilt, nervousness) in wave 1 to three (irritability, excessive worry, uncontrollable worry) in wave 2. Conversely, in the harmonious group, the number of significant bridge symptoms decreases from three (restlessness, irritability, feeling afraid) in wave 1 to two (guilt, excessive worry) in wave 2. According to van Borkulo et al. [51], a tightly connected network is considered to be a “riskier” network, as the activation of one symptom can quickly spread to other symptoms, leading to the development of more chronic symptoms over time. Likewise, bridge symptoms also can increase the risk of contagion to other disorders [35]. In terms of the denser network structure, our findings suggest that during the online learning period, adolescents who perceive parental conflicts may experience more severe symptoms of anxiety and depression or be exposed to multiple risk factors that contribute to the comorbidity of these disorders in disharmonious families. This finding is consistent with previous empirical studies, which highlight the influential role of perceived parental conflict as a significant correlate of individuals’ mental health problems [19, 52]. Furthermore, it is concerning that an emotionally challenging family environment resulting from parental conflict can further increase children’s vulnerability as they transition into adolescence [53].

In addition, the divergent changes in the number of bridge symptoms may be attributed to the greater impact of online learning on adolescents from disharmonious families compared to those from harmonious families. One plausible explanation is that individuals who perceive more parental conflicts are likely to experience heightened negative emotions and may employ the Internet as a self-medication strategy to cope with their emotional distress [54, 55]. Online learning, in this context, provides a convenient avenue for accessing the Internet. As highlighted by numerous scholars, smartphones can be readily utilized to alleviate emotions, escape stressful situations, and seek social support whenever necessary [56]. On the other thing, since online learning at home tend to make parental responsibilities greater and may further increase the risk of parental conflict, thus adolescents who experience more parental conflicts may be more likely to spend time on the Internet under the guise of online learning than those with harmonious parental relationships, leading to more psychological problems. As previous studies have confirmed, the intensity and time of electronic device usage are positively correlated with various mental health problems, and the risk of developing depression and anxiety disorders among the student sample increases with exposure time to electronic devices [5, 57]. Taken together, the above results remind us that students who perceive more parental conflicts are at increased risk for comorbidities of depression and anxiety, and that the increased number of bridge symptoms for students from those families implies that online learning affects adolescents from different families differently, which requires attention in the subsequent intervention and treatment process.

Interestingly, the change in the number of central symptoms in these two groups was reversed, as shown by the fact that one symptom (i.e., energy from depression) in wave 1 increased to three (i.e., uncontrollable worry, excessive worry, and restlessness from anxiety) in wave 2 for the harmonious group, while four symptoms (i.e., Sad mood and guilt from depression, nervousness and uncontrollable worry from anxiety) in wave 1 decreased to two (i.e., uncontrollable worry and irritability from anxiety) in wave 2 for the disharmonious group. The change in the number of central symptoms in this current study suggests two things. First, the comorbid symptoms of adolescents from disharmonious families are more diverse and complex than those from harmonious families before the implementation of homeschooling. This is in line with the results found by Khurshid et al. [58], showing that high parental conflict is significantly related to internalizing problems for adolescents. And second, after four months of

online learning, the comorbid symptoms of adolescents are all concentrated in anxiety sub-symptoms, regardless of the perceived parental relationships. Meanwhile, it is worth noting that after four-month online learning, uncontrollable worry became the most central symptom for both groups. From a causal systems perspective, the centrality of a symptom within a network indicates its significance in both the development and persistence of the network [59]. As such, highly central symptoms are considered crucial in understanding the etiology and maintenance of the network. When these key symptoms are activated, they have the potential to influence the activation of other symptoms, known as predicted symptoms. Consequently, these central symptoms provide valuable insights into identifying optimal treatment targets, with particular emphasis on addressing symptoms such as uncontrollable worry.

As for the CLPN analysis, the results have presented differences in the symptom-to-symptom relationships, as the strongest positive cross-lagged edge intensity between symptoms in the harmonious group is anhedonia—energy, while that in the disharmonious group include guilt—suicide and trouble relaxing—excessive worry. This finding is consistent with a previous study, showing that guilt—suicide Ideation and anhedonia – energy had the strongest association among junior and senior high school students [60]. But our study further clarified the symptoms in adolescents from different families. We speculate that adolescents from harmonious families may be more concerned about the limited social, professional, and physical activities caused by online learning. Such restriction prevents them from interacting with the outside environment, contributing to psychological symptoms such as anhedonia [61]. Additionally, energy refers to the feeling of unwillingness or incompetence to complete physical and mental activities [62]. To some extent, homeschooling limits adolescents' engagement in entertainment activities. As scholars mentioned before, a lack of regular exercise can cause fatigue [63], which may further develop into sedentariness and lead to depression [64]. Thus, it is understandable that adolescents in harmonious families show such symptom-to-symptom associations.

In the case of adolescents from disharmonious families, the added responsibility placed on them due to online learning may evoke feelings of guilt regarding their parents' extended roles as teachers and coaches for their academic and extracurricular activities [65]. This situation presents new opportunities for conflict, leading adolescents to attribute parental disagreements to themselves. Consequently, they may experience a sense of hopelessness regarding the potential for

change within their home environment. Moreover, the limited emotion regulation abilities typically observed during adolescence make them more susceptible to risky behaviors, including nonsuicidal self-injury or suicidal tendencies [66].

Regarding the central predictive symptoms, the results of the current study indicate that anhedonia, a symptom of depression, holds the highest centrality among the harmonious group. Energy, another symptom of depression, and uncontrollable worry from anxiety are identified as predicted symptoms within this group. In contrast, trouble relaxing emerges as the most central symptom within the disharmonious group, with sad mood from depression and uncontrollable worry from anxiety identified as the predicted symptoms. These findings suggest that although adolescents from different family backgrounds may exhibit varying symptoms, they tend to share similar symptoms, such as uncontrollable worry, after four months of online learning. These results further support the notion that online learning may have adverse effects on students' long-term mental well-being.

The present study stands out as one of the pioneering longitudinal investigations examining the effects of online learning and perceived parental relationships on adolescents' mental health. Despite its notable strengths, it is crucial to acknowledge several limitations. Firstly, the analysis of data was confined to four months of online learning. Future research should encompass longer durations to capture potential variations over time. Secondly, it is essential to consider additional factors such as gender and grade when exploring changes in the anxiety-depression network structure, as these variables may provide valuable insights into the comorbidity. Thirdly, the current study was conducted during the time of COVID-19, and that the frequency of arguments between couples may have been higher than in other normal periods, so the grouping methodology of this study may not apply to other periods. Additionally, the particular context of COVID-19 needs to be taken into account in interpreting and generalizing the results of this study. Fourthly, it is important to note that perceived parental relationships and mental health-related information were obtained through self-rating scales, which may be less reliable compared to clinical diagnoses. Thus, future studies should strive for more standardized study designs to enhance the robustness of the findings. Finally, since the current research design did not take into account the graded severity of anxiety and depressive symptoms in middle school students at the beginning of online learning, confounding factors like the graded levels of anxiety and depressive symptoms in the students themselves may

also have an impact on the relationship between the harmony of parental marriage and anxiety and depressive symptoms after four months of online learning.

Implications

Our study stated that under the circumstances of the pandemic and online learning, parental conflicts may serve as an important risk factor for depression and anxiety among Chinese adolescents. Indeed, efficient guidance and intervention targeted to help decrease the frequency of parental conflict are urgently needed. Moreover, considering that trouble relaxing is identified as the most central symptom among adolescents with a higher level of parental conflicts, the current study may imply that interventions that guide adolescents to perceive parental conflicts more reasonably and regulate emotion could be effective.

Conclusions

Our study contributes valuable evidence regarding the association between online learning, perceived parental relationships, and anxiety-depression comorbidity among Chinese adolescents. Notably, we found that adolescents who perceive more parental conflicts exhibited a denser comorbidity network structure after four months of online learning. Moreover, the number of significant bridge symptoms decreased from three (restlessness, irritability, feeling afraid) in wave 1 to two (guilt, excessive worry) in wave 2 for the harmonious group, while the disharmonious group showed an increase from two (guilt, nervousness) to three (irritability, excessive worry, uncontrollable worry) across the two waves.

In addition, we observed changes in the number of central symptoms over time. For the harmonious group, the number increased from one symptom (energy) in wave 1 to three (uncontrollable worry, excessive worry, and restlessness) in wave 2. Conversely, the disharmonious group exhibited a decrease from four symptoms (sad mood, guilt, nervousness, uncontrollable worry) in wave 1 to two (uncontrollable worry and irritability) in wave 2. Furthermore, our cross-lagged panel network analysis highlighted the strongest positive cross-lagged edge intensity between symptoms, namely anhedonia—energy in the harmonious group, with anhedonia identified as the most central symptom. In contrast, the disharmonious group showed guilt—suicide and trouble relaxing—excessive worry as the strongest positive cross-lagged edge intensities, with trouble relaxing being the most central symptom. These findings provide valuable insights into the treatment of anxiety and depression comorbidity and may have implications for clinical practice.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12889-024-19675-4>.

Supplementary Material 1.

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Authors' contributions

Study design: XL and GL. Data collection: LZ. Analysis and interpretation: YT. Drafting of the manuscript: YT. Critical revision of the manuscript: HN, SW, and QT.

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Availability of data and materials

Analytic code for this work is available in the supplementary material, and data was available upon request from the corresponding author.

Declarations

Ethics approval and consent to participate

All the experiments in this study were conducted in accordance with the relevant guidelines and regulations. The research was examined and approved by the ethics committee of Beijing Normal University (Reference number: 202112220085). Informed consent was obtained from all students, and their parents included in the study.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Author details

¹Faculty of Psychology, Beijing Normal University, Beijing 100875, China. ²Beijing Key Laboratory of Applied Experimental Psychology, National Demonstration Center for Experimental Psychology Education, Beijing 100875, China.

³School of Psychology, Nanjing Normal University, Nanjing 210024, China.

⁴College Students' Mental Health Education Center, Northeast Agricultural University, Harbin 150030, China. ⁵Department of Psychiatry, Affiliated Nanjing Brain Hospital, Nanjing Medical University, Nanjing 210029, China.

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