Associations between trait and state perceived stress and daily moods: COVID-19 stressful experiences as a moderator

Mingjun Xie[1] · Ye Feng[2] · Yanjia Zhang[1] · Hongfeng Zhang[3] · Danhua Lin[1]

Abstract

Drastically disrupting daily routines, the global pandemic of COVID-19 has posed critical mental health threats to adolescents and young adults worldwide. Many of the extant empirical findings, however, have focused on individuals' psychological adjustment during the initial phase of the pandemic. It is less clear how COVID-19 stressful experiences impact young people's daily lives in the post-pandemic "new normal." Drawing on 7-day diary reports, the present study fills this gap by examining: (1) how daily perceived stress impacted daily emotional adjustment; and (2) the moderating effects of COVID-19 stressful experiences on these associations among 582 Chinese young adults ($M_{age} = 18.12$, $SD = .65$; 69% females). Results indicated that higher levels of both trait (i.e., average levels) and state (i.e., daily fluctuations) perceived stress were associated with greater negative and anxious moods, and that prior pandemic-related experiences exacerbated the adverse impact of both trait and state perceived stress on daily moods. Specifically, young adults reporting greater COVID-19 stressful experiences demonstrated poorer emotional adjustment (i.e., lower levels of positive mood and higher levels of negative mood) on days when they had more fluctuations in perceived stress; the aggravating impact was stronger when the average levels of perceived stress were higher. By illuminating the moderating effects of COVID-19 stressful experiences, this study contributes to the limited, but burgeoning, research examining the prolonged impact of the COVID-19 health crisis on daily emotional adjustment in post-pandemic life.

Introduction

Research has documented the detrimental impact of stress on physiological (e.g., decreases in telomere length; Mathur et al., 2016) and psychological (e.g., eliciting negative emotions; Troy et al., 2019) well-being. Prior studies, however, have primarily focused on individuals' emotional responses to stress prior to the coronavirus disease 2019 (COVID-19) pandemic, one of the defining global health crises that have been disrupting people's daily routines and jeopardizing physical and mental health among children, adolescents, and adults worldwide. As of October 2022, this pandemic has swept through 223 countries and areas/territories with more than 619 million people infected and over 6.5 million deaths globally (WHO, 2022). Research findings indicate that this global pandemic has brought about accumulatively stressful experiences (Masten & Motti-Stefanidi, 2020), largely due to mandatory quarantine during the outbreak (e.g., Ye, Yang et al., 2020), worries over families infected with COVID-19 (Deng et al., 2021), or disrupted daily lives (Magson et al., 2021). The pandemic-related stressful experiences have posed critical mental health threats by increasing emotional disorders among adolescents and young adults (Branje & Morris, 2021). Nonetheless, many of

Mingjun Xie and Ye Feng contributed equally to this work.

✉ Danhua Lin
danhualin@bnu.edu.cn

1 Institute of Developmental Psychology, Beijing Normal University, Beijing 100875, China

2 Department of Psychology, Fordham University, The Bronx, NY, USA

3 Faculty of Humanities and Social Sciences, Macao Polytechnic University, Macau, China

the extant empirical findings have focused on individuals' psychological adjustment during the initial phase of the pandemic. Less clear is how COVID-19 stressful experiences impact young people's daily lives in the post-pandemic "new normal" (Hussong et al., 2021). Guided by a life course perspective (Benner & Mistry, 2020) and life experience theory (Baltes et al., 1999; Rosenthal, 1993) for the pandemic's effects, the present study filled in this gap by examining: (1) the associations between daily perceived stress and emotional adjustment among Chinese young adults in post-pandemic time; and (2) the moderating effects of COVID-19 stressful experiences on these associations.

The impact of the COVID-19 pandemic on emotional well-being

The COVID-19 pandemic presents critical challenges for individuals and families' emotional health, an observation made among adolescents, young adults, and middle-aged adults across continents and regions, including America (e.g., Canada, the United States; see Gladstone et al., 2021; McArthur et al., 2021), Asia (e.g., China, Philippines; see Tee et al., 2020; Xin et al., 2020), Australia (Magson et al., 2021; Munasinghe et al., 2020), Europe (e.g., Italy; see Forte et al., 2021; Orgilés et al., 2021), and the Middle East area (e.g., Israel; see Lahav, 2020). A recent meta-analysis of 29 studies indicated that, compared to pre-pandemic mental health, the global prevalence of child and adolescent depression and anxiety symptoms during COVID-19 have doubled (Racine et al., 2021). Life course perspectives for understanding the impact of COVID-19 posit that the COVID-19 pandemic, similar to other sociohistorical catastrophes (e.g., prior pandemics such as SARS and H1N1, the 9/11 terrorist attacks), serves as "turning points" exerting both immediate and protracted effects on developmental outcomes (Benner & Mistry, 2020). Research examining other global disasters (e.g., the Great Recession) also evidences prolonged consequences jeopardizing well-being of populations at different ages (Shores & Steinberg, 2019). Another useful framework might be life experience theory (e.g., Baltes et al., 1999; Rosenthal, 1993), which suggests that moving across adolescence and emerging adulthood, people are exposed to a wide range of experiences, and the cumulative experiences (particularly those stress-related, negative life events; see Gluck & Bluck, 2013) would contribute to subsequent individual development. Related to the context of the COVID-19 pandemic, how individuals perceive and understand this defining global health crisis would be impactful on their daily stress and moods.

Daily perceived stress and emotional experiences

Prior studies examining acute emotional responses after stress exposure have primarily focused on the impact of stress on positive and negative moods (see Starcke & Brand, 2016 for a review). Empirical research demonstrates that stress usually elicits greater negative moods and lower levels of positive moods, and these findings are consistently observed among populations in regular situations (e.g., college students, local community samples; Richardson, 2017; Troy et al., 2019), in sociocultural disadvantaged contexts (e.g., people living in poverty; Torres & Santiago, 2018; Uink et al., 2018), and under pandemic conditions (e.g., adolescents and young adults during the COVID-19 pandemic; Deng et al., 2021; Xia et al., 2021). Although the links between stress and moods are established (Troy et al., 2019), the direction and strength of their associations may be dependent on individual knowledge, experiences, and perceptions of contexts. Specifically, maladaptive emotional regulation (e.g., suppression) could aggravate the negative impact of daily stress on positive mood (Richardson, 2017). The extent to which ethnically/racially minorities learn about and explore their own culture (i.e., ethnic identity exploration) moderated the links between stress and mood, such that greater identity exploration could exacerbate ethnically/racially diverse adolescents' negatively emotional responses to family stress (Torres & Santiago, 2018).

Daily diary assessments not only capture the daily associations between stress and emotional well-being, but also examine the impact of both the intensity of and variability in stress on daily moods (Trull et al., 2015). The intensity of stress refers to the average levels (or "trait-like," stable components) of stress that depicts between-person differences in perceived stress (hereinafter, *trait perceived stress*), whereas the variability in stress reflects the degree of fluctuations (or "state-like," changing components) in stress that describes within-person changes in perceived stress (hereinafter, *state perceived stress*) across days (Sliwinski et al., 2009). Earlier research emphasized the contributing role of state stress in predicting daily emotional experiences (DeLongis et al., 1988). A recent study observed that higher levels of state perceived stress (i.e., greater fluctuations in daily stress) were associated with more changes in daily moods during the COVID-19 pandemic, particularly among young adults who reported greater trait perceived stress (i.e., higher intensity of stress; Xia et al., 2021). Considering that the unpredictable pandemic situations likely induce more changes in daily perceived stress (Collier Villaume

et al., 2021), it is important to examine how trait and state perceived stress jointly shape emotional experiences in the post-pandemic era, which will be addressed in the present study. Given the negative consequences of daily perceived stress on emotional well-being (Deng et al., 2021; Richardson, 2017; Troy et al., 2019; Xia et al., 2021), we hypothesized that both trait and state perceived stress would be positively associated with poorer daily emotional adjustment (see Fig. 1 for the conceptual path diagram, paths a_1 and a_2).

COVID-19 stressful experiences as a moderator

Prior research has examined people's experiences related to the COVID-19 pandemic, including knowledge and perceptions (e.g., understanding of how COVID-19 is transmitted; Tee et al., 2020), stressors or stressful experiences (e.g., being quarantined or living alone during the outbreak, feeling out of control in the pandemic; Lahav, 2020; Ye, Wu et al., 2020; Ye, Yang et al., 2020), worries and concerns (e.g., worries about families getting COVID-19; Deng et al., 2021), and distress (e.g., being stressful about disruptions in daily lives; Campione-Barr et al., 2021; Magson et al., 2021). These studies observed that stressful experiences associated with the COVID-19 pandemic posed critical challenges for young people's mental health, such as increasing daily perceived stress (Collier Villaume et al., 2021) and eliciting negative emotional experiences (Deng et al., 2021). A recent meta-analysis of 25 studies (including 120 effect sizes) indicated that pandemic-related stressful experiences (i.e., fear of COVID-19) were associated with higher levels of stress and emotional disorders, e.g., anxiety and depression (rs = 0.34 to 0.47; Cikrikci et al., 2022). Similar findings were observed in both cross-sectional comparison and longitudinal daily diary studies. Specifically, individuals experiencing greater COVID-19 stress exhibited higher levels of anxiety-related mood disorders (Asmundson et al., 2022). The impact of COVID-19 pandemic on emotional development tends to be long-term.

For instance, adolescents and young adults in the Netherlands reported their daily moods during the initial and later COVID-19 lockdown (May 2020 and November 2020), and demonstrated decreases in daily positive mood (e.g., vigor) and increases in daily negative moods (e.g., depression and tension) over time (Green et al., 2021).

Compared to an abundant amount of research investigating the direct associations between COVID-19 stressful experiences and mental health, studies exploring the moderating effects of pandemic-related challenges remain sparse. Available research observes that for individuals who experienced higher levels of COVID-19 worries, their prior use of emotion regulation strategies was not able to adjust their emotional responses under pandemic conditions (Deng et al., 2021). The examination of possible moderation effects of COVID-19 stressful experiences on longer-term psychological adaptation is more limited. According to the life course framework for understanding the impact of COVID-19 on developmental trajectories (Benner & Mistry, 2020), individuals who encountered significantly more stressors during COVID-19 might be particularly vulnerable to the longer-term impact of the pandemic, and therefore, tended to exhibit more psychological challenges in their post-pandemic lives. Given the overwhelming, cascading, and long-lasting effects of the COVID-19 pandemic on people's healthy development (Masten & Motti-Stefanidi, 2020), it is necessary to explore the aggravating or mitigating effects of individuals' differential susceptibility to this global health crisis on their subsequent psychological adaptation. Applied to this study, how people perceived the COVID-19 pandemic as a myriad of stressful experiences may moderate their emotional responses to daily perceived stress in their post-pandemic lives. Specifically, considering the detrimental impact of pandemic-related stressors on individuals' emotional well-being (Cikrikci et al., 2022; Deng et al., 2021; Green et al., 2021), we hypothesized that COVID-19 stressful experiences would be positively associated with maladaptive emotions (e.g., higher levels of negative and

Fig. 1 Conceptual Path Diagram
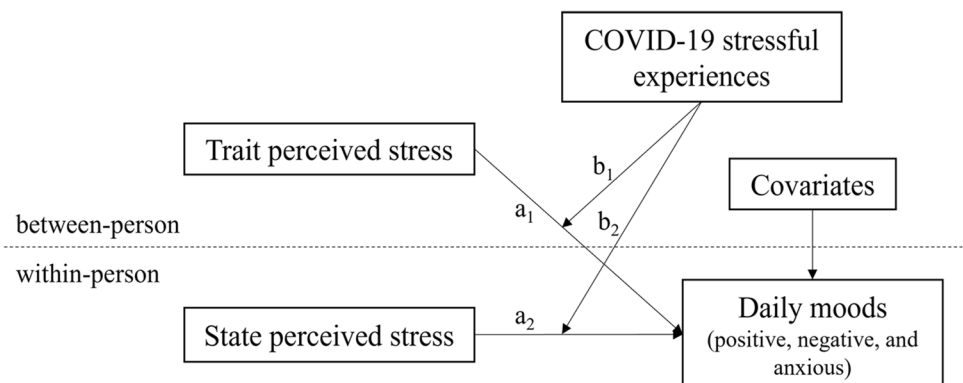
anxious moods) and would exacerbate the negative effects of both trait and state perceived stress on individuals' daily moods (paths b_1 and b_2 in Fig. 1).

The present study

Using 7-day diary reports conducted with Chinese young adults, this study investigates the impact of state and trait perceived stress on daily moods and the moderating effects of COVID-19 stressful experiences on these associations. First, we hypothesized that greater state and trait perceived stress would be associated with lower levels of emotional adjustment, manifested as less positive mood and more negative and anxious moods (Hypothesis 1; paths a_1 and a_2 in Fig. 1). Next, given prior findings on the pernicious impact of COVID-19 on mental health (Collier Villaume et al., 2021; Deng et al., 2021), we hypothesized that pandemic-related stressful experiences would result in less favorable emotional adjustment (Hypothesis 2). Finally, as suggested by life course perspectives (Benner & Mistry, 2020) and life experience theories (Baltes et al., 1999; Rosenthal, 1993) and empirical research examining the prolonged consequences of other global crises (Shores & Steinberg, 2019), we hypothesized that COVID-19 stressful experiences would aggravate the adverse effects of both state and trait perceived stress on daily emotional experiences in post-pandemic life (Hypothesis 3; paths b_1 and b_2 in Fig. 1).

Method

Participants

Data used in this study were drawn from the first wave of an on-going 4-year longitudinal study assessing the associations between stress and psychological adaptation among Chinese undergraduate students. The primary goal of the research project is to delve into how prior COVID-19-related experiences impact students' 4-year college adaptation in post-pandemic "new normal." As such, the project focuses on the class of 2024, the cohort who started their college studies in fall 2020 after the initial outbreak of the COVID-19 pandemic (around February 2020). A total of 610 first-year college students were recruited to participate in the study. Twenty-eight participants were excluded from the current study due to nonparticipating on either the person-level or daily-level surveys, yielding a final sample of 582 students (69% females; $M_{age} = 18.12$, $SD = 0.65$, range = 16–22 years old). This study measured Chinese young adults' socioeconomic status using their subjective socioeconomic status (SSS) and prior exposure to adversities (e.g., migrant experiences). Participants' SSS was evaluated using a graphical

representation of a ladder with 1–10 rungs (Adler et al., 2000), with higher scores reflecting higher levels of SSS. On average, participants' SSS was of medium level ($M = 4.83$, $SD = 1.45$, range = 1–10). Approximately 34% of the participants reported having experiences of being left behind (i.e., who stayed in their original villages during childhood with one or both of their parents relocating for employment opportunities in urban areas). Nearly 14% of them had migrant experiences (i.e., following their parents who migrated to urban areas). Participants were at 12th grade and preparing for *Gaokao* (the National College Entrance Examination in China) at home via online courses during the pandemic outbreak (from January to April 2020), and 37.1% of the participants had lived in Hubei province, the initial pandemic center in China.

Procedure

The participants were recruited from two public universities in Wuhan, Hubei province and two public universities in Beijing, China in September 2020. Recruitment was done through electronic advertising on WeChat groups; the research team also contacted school administrators to distribute information via online presentations. This study was approved by the authors' institutional review board. The participants were informed of the study requirements prior to the administration of questionnaires, and only the participants with signed informed consents enrolled in the study. Students first met in groups (approximately 50 people) and completed the paper-and-pen questionnaire to provide demographics and retrospectively reported their prior stressful experiences related to the COVID-19 pandemic (the person-level survey, conducted from October to November 2020). After that, they were sent an online link to complete daily diary surveys each night before bed for 7 consecutive days to evaluate their daily perceived stress and moods (daily-level surveys, conducted in November 2020). The designed sample size of the analysis is 4070 daily responses nested within 582 participants, and the cluster size was 7 days. There were 39 daily responses were missing on all studied items. Since the missing data rate in the present study is 1% (less than the 5–10% cut-off to affect statistical analyses; Dong & Peng, 2013), these responses were excluded in analysis, resulting a final analytical sample of 4035 responses with no missing values.

Measures

Perceived stress (daily-level) Daily perceived stress was assessed using an adapted daily measure of the short version of the Perceived Stress Scale (Cohen et al., 1983), a measure translated and validated among Chinese samples (Zhang et al., 2022), which was also used to assess

individuals' perceived stress under pandemic conditions (e.g., Alwaqdani et al., 2021; Fong et al., 2021; Meyer et al., 2022). Four items were included (e.g., "Today, how often have you felt that you were unable to control the important things in your life?") and rated on a 5-point scale (1 = *never*, 5 = *very often*). The daily perceived stress scores were partitioned into "trait" (reflecting between-person differences) and "state" (reflecting within-person variations) components. Trait perceived stress was calculated as the person-mean centered score, and state perceived stress was calculated as the differences between person-mean and daily perceived stress scores. The *M*, *SD*, and ICC are displayed in Table 1. The daily-level measure reliability was calculated using multilevel factor analysis (Lai, 2021). The between-level and within-level reliability is 0.34 and 0.37, respectively. Therefore, the between-level and within-level composites were suboptimal in measuring the construct.

Moods (daily-level) Daily moods were assessed using the adapted Profile of Mood States (McNair et al., 1971), a measure translated and validated among Chinese samples (Chen et al., 2002; Zhang et al., 2020), which was also employed to examine individuals' daily moods during the COVID-19 pandemic (e.g., Foa et al., 2022; Janeczko et al., 2020; Zhang et al., 2020). The present study focused on three types of moods: (1) positive (4 items: "happy," "calm," "joyful," and "excited"); (2) negative ("sad," "hopeless," "discouraged," and "blue"); and (3) anxious ("anxious," "nervous," "unable to concentrate," and "on edge") moods. Participants were asked to rate the levels of mood states based on how they were feeling on that day. All items were rated on a 5-point scale (1 = *not at all*, 5 = *extremely*), with higher scores reflecting higher levels of a specific mood.

The *M*s, *SD*s, and ICCs of each mood state are displayed in Table 1. The between-level and within-level reliabilities are 0.72 and 0.57 for positive mood, 0.84 and 0.70 for negative mood, and 0.79 and 0.59 for anxious mood, respectively. Overall, the reliability was good for both the between- and within-level composites score for measuring person-level constructs as well as within-person constructs for the three types of daily moods.

COVID-19 stressful experiences (person-level) Participants' prior stressful experiences related to the COVID-19 pandemic were assessed using a self-constructed scale adapted from existing measures evaluating pandemic-related experiences, including the SARS-related stressful events checklist (Main et al., 2011) and the COVID-19 fearful experiences scale (Cao et al., 2020). Based on thorough psychometric results using bi-factor exploratory factor analyses (see Appendix), one general factor and four specific factors were identified: (1) information-related stressful experiences (4 items, e.g., "Hearing about or reading too many passive news of COVID-19"); (2) disease/life-related stressful experiences (5 items, e.g., "Having been in contact with patients with suspected or confirmed COVID-19"); (3) academic-related stressful experiences (3 items, e.g., "Being less efficient and delayed in learning when studying from home"); and (4) back-to-school related stressful experiences (3 items; e.g., "Being uncomfortable about studying in school after returning to school"). The remaining 3 items (e.g., "Having family financial difficulties due to the pandemic") only loaded on the general factor. Participants were asked to report how often each type of experience occurred during the pandemic using a 5-point scale (0 = *never*, 4 = *always*). Item scores were averaged to provide a mean score ranging from 0 to 4, with higher scores indicating more COVID-19 stressful experiences. The Cronbach's alpha for the scale is 0.82.

Table 1 Correlations, Descriptive Statistics, and Demographic Differences of Primary Variables

	1	2	3	4	5	Age	SSS	Gender	Left-behind	Migration	Hubei
1. COVID-19 Stress	—	-0.20[***]	0.26[***]	0.32[***]	0.09	0.03	-0.08[***]	1.95	9.75[***]	5.60[***]	0.44
2. Positive Mood	N/A	—	-0.29[***]	-0.34[***]	0.06	0.03[**]	0.13[***]	-1.35	-2.14[**]	-5.29[***]	-3.44[***]
3. Negative Mood		-0.22[***]	—	0.77[***]	0.12[***]	-0.04[**]	-0.06[***]	-2.12[**]	-1.16	-0.66	-0.29
4. Anxious Mood		-0.19[***]	0.53[***]	—	0.20[***]	-0.02	-0.08[***]	-1.59	-2.43[**]	-0.18	2.44[**]
5. Perceived Stress		-0.03[**]	0.03	0.09	—	-0.00	-0.01	3.15[**]	1.92	0.73	-0.55
M	1.10	3.26	1.46	1.83	1.84						
SD	0.49	0.78	0.67	0.74	0.37						
ICC	N/A	0.74	0.70	0.72	0.69						

Correlations for between-person associations are presented above the diagonal, and correlations for within-person associations are presented below the diagonal. The correlations were obtained by decomposing the observed correlations into the pooled correlations within groups and the weighted correlations of the means between groups. SSS = subjective socioeconomic status; ICC = Intra-class correlations. Moods and Perceived Stress were measured at daily-level, and COVID-19 stressful experiences were measured at person-level, thus no within-person associations reported for COVID-19 stressful experiences. Differences on gender, left-behind status, migration status, and whether lived in Hubei were tested by t-test and *t* statistics were reported. For age and SES, correlations were reported

[**] $p < .01$, [***] $p < .001$

Covariates Since prior research demonstrates sociodemographic differences (e.g., gender, age, families socioeconomic status) in stress and its impact on mood (Masumoto et al., 2016; Green et al., 2021), six covariates were included in analysis, including: (1) participants' gender; (2) age; (3) SSS; (4) prior experiences of being left-behind; (5) prior migrant experiences; and (6) whether they had lived in Hubei (the pandemic center in China, which might be associated with their COVID-19 stressful experiences).

Data analytic strategy

Preliminary data analysis including normality check and outlier detections were conducted and no substantial violations were identified. Descriptive statistics were calculated for all demographic variables. Mixed effects multilevel models were used to analyze the associations between COVID-19 stressful experiences, daily perceived stress, and daily mood (see Fig. 1 for the conceptual path diagram). All analyses were performed in R (R Core Team, 2019), using the package "lme4" (Bates et al., 2015) for fitting mixed effects model and package "interaction" (Long, 2019) for plotting and probing interactions. For each outcome variable, three steps of models were estimated. In step 1, the unconditional means models were tested and used to calculate the intra-class correlations (ICCs), which provided information about how much of the total variance in each outcome variable is within-person variance and how much is between-person variance. In step 2, the model tested within-person (i.e., state) and between-person (i.e., trait) effects of perceived stress on the outcomes. To differentiate the state versus trait component of the predictor, the predictor was split into two components: (a) state perceived stress (within-person): daily variation from a person's mean level of daily perceived stress, and (b) trait perceived stress (between-person): a person's average perceived stress across days. The interaction effects of state and trait perceived stress were tested to examine whether the association between state perceived stress and daily moods differed by the levels of trait perceived stress. In step 3, COVID-19 stressful experiences were included to examine the interaction/moderation effects on the relationships between both trait and state perceived stress and daily moods, such that COVID-19 stressful experiences were tested as a person-level (Level 2) predictor and daily perceived stress and daily moods were tested at daily-level (Level 1). All between-person effects were centered at grand-mean and within-person effects were centered at person-mean to facilitate the interpretation of the results. Participants' gender (0 = female, 1 = male), age, SSS, whether lived in Hubei during the pandemic (0 = living in Hubei, 1 = living out of Hubei), prior experiences of being left behind (0 = no, 1 = yes), and prior migrant experiences (0 = no, 1 = yes) were included as covariates. A significant standardized regression coefficient with Satterthwaite approximation for degrees of freedom produced by R "lmerTest" indicated a significant moderation effect (Kuznetsova et al., 2017).

Results

Descriptive analyses

Table 1 summarizes the descriptive statistics for studied variables. Results observed that perceived stress was negatively correlated with positive mood at within-person level ($r = -0.03$, $p < 0.01$), and positively correlated with negative ($r = 0.12$, $p < 0.001$) and anxious ($r = 0.2$, $p < 0.001$) moods at between-person level, suggesting that: (1) within individuals, as perceived stress increased, their positive mood decreased; and (2) across individuals, those with higher levels of perceived stress tended to have higher levels of anxious and negative moods. COVID-19 stressful experiences was a person-level variable and negatively correlated with positive mood ($r = -0.2$, $p < 0.001$) and positively correlated with negative ($r = 0.26$, $p < 0.001$) and anxious ($r = 0.32$, $p < 0.001$) moods. That is, participants with higher levels of COVID-19 stressful experiences also reported lower levels of positive mood and higher levels of negative and anxious moods. However, the correlations were small in terms of the effect sizes, representing weak associations between the studied variables. Significant sociodemographic differences in the studied variables were also found by participants' age, gender, SSS, and prior adverse experiences ($ps < 0.05$), and therefore, these variables were controlled for in the main analyses.

The effects of trait and state perceived stress on moods (Hypothesis 1)

In step 1, results from unconditional model (Table 1) shown that the *ICC*s of the measures range from 0.69 to 0.74, suggesting a substantial variance can be explained by between-persons effects. However, contextual and daily variability is also evident. These values are consistent with the ICCs of other studies (e.g., 0.40 to 0.88, see Deng et al., 2021). These results indicated that the use of multilevel modeling is necessary to capture the daily and individual differences.

The top half of Table 2 summarizes the multilevel analyses examining the main effects of participants' daily perceived stress on daily moods. The results of fixed effects indicated a positive association between perceived stress and

Table 2 Multiple Regression Analyses for the Interactions of Perceived Stress and COVID-19 Stressful Experiences in Predicting Daily Moods

	Positive Mood			Negative Mood			Anxious Mood		
		95% CI			95% CI			95% CI	
	$\hat{\beta}$(SE)	Lower	Upper	$\hat{\beta}$(SE)	Lower	Upper	$\hat{\beta}$(SE)	Lower	Upper
Step 2: Perceived Stress									
Fixed Effects									
Trait Perceived Stress	0.12 (0.09)	-0.06	0.29	0.24** (0.08)	0.09	0.39	0.43*** (0.08)	0.27	0.60
State Perceived Stress	-0.15 (0.09)	-0.32	0.02	0.16** (0.07)	0.02	0.29	0.28*** (0.08)	0.13	0.44
Trait×State	-0.32 (0.26)	-0.84	0.19	0.36 (0.21)	-0.05	0.77	0.49** (0.24)	0.02	0.96
Random Effects									
Intercept	0.44			0.31			0.39		
State Perceived Stress	1.83			1.06			1.45		
Intercept-slope Correlation	-0.08			0.12			0.11		
Residual	0.11			0.10			0.11		
Step 3: COVID Stress × Perceived Stress									
Fixed Effects									
Trait Perceived Stress	0.1 (0.09)	-0.08	0.28	0.25** (0.08)	0.09	0.40	0.41*** (0.08)	0.25	0.57
State Perceived Stress	-0.07* (0.04)	-0.15	0.00	0.06* (0.03)	0.00	0.13	0.27*** (0.08)	0.11	0.42
COVID Stress	-0.26*** (0.06)	-0.38	-0.15	0.32*** (0.05)	0.23	0.42	0.43*** (0.05)	0.33	0.54
Trait×COVID	-0.39* (0.2)	-0.78	0.00	0.35** (0.17)	0.02	0.68	0.33** (0.16)	0.00	0.66
State×COVID	-0.35*** (0.08)	-0.50	-0.20	0.24*** (0.07)	0.10	0.38	0.47*** (0.25)	0.01	0.65
Trait×State	0.1 (0.11)	-0.13	0.32	0.14 (0.1)	-0.06	0.35	0.31* (0.18)	0.00	0.95
Trait×State×COVID	-0.65** (0.24)	-0.97	-0.03	1.67*** (0.22)	1.16	2.01	0.65 (0.52)	-0.37	1.66
Random Effects									
Intercept	0.4			0.26			0.34		
State Perceived Stress	0.13			0.33			1.45		
Intercept-slope covariance	-0.18			0.43			0.08		
Residual	0.16			0.13			0.11		

Mixed effects multilevel models were used to analyze the moderation effect of COVID-19 stressful experiences. COVID Stress = COVID-19 Stressful Experiences. Gender, age, SSS, prior experiences of being left-behind, migrant experiences, and whether lived in Hubei during pandemic were included as covariates in all models. For variables measured at the daily level, day of the study (i.e., 1 to 7) was controlled for to adjust for method artifacts of daily diary studies. Moods and Perceived Stress were measured at daily-level, and COVID-19 stressful experiences were measured at person-level

* $p < .05$, ** $p < .01$, *** $p < .001$

negative mood, both across (trait perceived stress, $\hat{\beta} = .24$, $p = 0.00$, 95% $CI = [0.09, 0.39]$) and within persons (state perceived stress, $\hat{\beta} = .16$, $p = 0.02$, 95% $CI = [0.02, 0.29]$). That is, participants with higher overall perceived stress tended to report greater negative mood, and participants with greater variations in daily perceived stress also reported higher levels of negative mood on a given day. The within-person associations between state perceived stress and negative mood were not moderated by trait perceived stress.

For anxious mood, both trait ($\hat{\beta} = .43$, $p < 0.001$, 95% $CI = [0.27, 0.60]$) and state perceived stress ($\hat{\beta} = .28$, $p < 0.001$, 95% $CI = [0.13, 0.44]$) significantly predicted daily anxious mood. As participants' overall perceived stress increased, their daily anxious mood also escalated. The significant effect of state perceived stress indicated that, on any given day, if participants experienced higher-than-usual perceived stress, they also experienced greater anxious mood. The effects of state perceived stress on anxious mood were moderated by trait stress level ($\hat{\beta} = .49$, $p = 0.04$, 95% $CI = [0.02, 0.96]$), such that greater trait perceived stress amplified the effects of state perceived stress on anxious mood. No significant effects were observed between both trait and state perceived stress and positive mood.

Taken together, the findings indicated that both state and trait perceived stress had negative consequences for negative and anxious moods. Moreover, the interaction effects between state and trait perceived stress on anxious mood suggested that participants with higher overall perceived stress were more likely to be affected by greater fluctuations in daily perceived stress.

The moderating effects of COVID-19 stressful experiences (Hypotheses 2 and 3)

The bottom half of Table 2 summarizes the results of models examining the moderation effects of person-level COVID-19 stressful experiences on the associations between trait and state perceived stress on daily moods. First, COVID-19 stressful experiences had direct cross-level effects on all daily mood outcomes: Participants with more COVID-19 stressful experiences had lower positive mood ($\hat{\beta} = -.26$, $p < 0.001$, $CI = [-0.38, -0.15]$), higher negative mood ($\hat{\beta} = .32$, $p < 0.001$, $CI = [0.23, 0.42]$), and higher anxious mood ($\hat{\beta} = .43$, $p < 0.001$, $CI = [0.33, 0.54]$), above and beyond the effects of trait & state stress. Moreover, COVID-19 stressful experiences moderated the relationships between state perceived stress and positive ($\hat{\beta} = -.35$, $p < 0.001$, 95% $CI = [-0.50, -0.20]$), negative ($\hat{\beta} = .24$, $p < 0.001$, 95% $CI = [0.10, 0.38]$), and anxious ($\hat{\beta} = .47$, $p < 0.001$, 95% $CI = [0.01, 0.65]$) moods, suggesting that participants with higher level of COVID-19 stress experiences were more likely to be impacted by daily fluctuations of perceived stress in terms of their daily emotional well-being. Results also observed significant moderation effects of COVID-19 stressful experiences on the associations between trait perceived stress and anxious ($\hat{\beta} = .33$, $p < 0.01$, 95% $CI = [0.00, 0.66]$)

and negative ($\hat{\beta} = .35$, $p < 0.001$, 95% $CI = [0.02, 0.68]$) moods, implying that the detrimental effects of trait perceived stress on daily moods were exacerbated by COVID-19 stressful experiences.

Finally, there were significant three-way interactions between trait perceived stress × state perceived stress × COVID-19 stressful experiences on positive ($\hat{\beta} = -.65$, $p = 0.007$, 95% $CI = [-0.97, -0.03]$) and negative ($\hat{\beta} = 1.67$, $p < 0.001$, 95% $CI = [1.16, 2.01]$) moods. Simple effect analyses were conducted to explore the three-way interactions. Figure 2 plotted the simple slopes of daily perceived stress on positive mood at different levels of trait perceived stress and COVID-19 stressful experiences. Specifically, COVID-19 stressful experiences exacerbated the negative effects of state perceived stress on positive mood, and the exacerbating effects were stronger at higher (relative to lower) levels of trait perceived stress. For participants experiencing lesser COVID-19 stressful experiences (-1 SD, the left plot of Fig. 2), the impact of state perceived stress on positive mood was not significant at all levels of trait perceived stress. For participants with medium level of COVID-19 stressful experiences (mean, the middle plot of Fig. 2), state perceived stress negatively impacted positive mood when participants had lower levels of trait perceived stress ($\hat{\beta} = -.11$, $p < 0.05$). For participants with greater
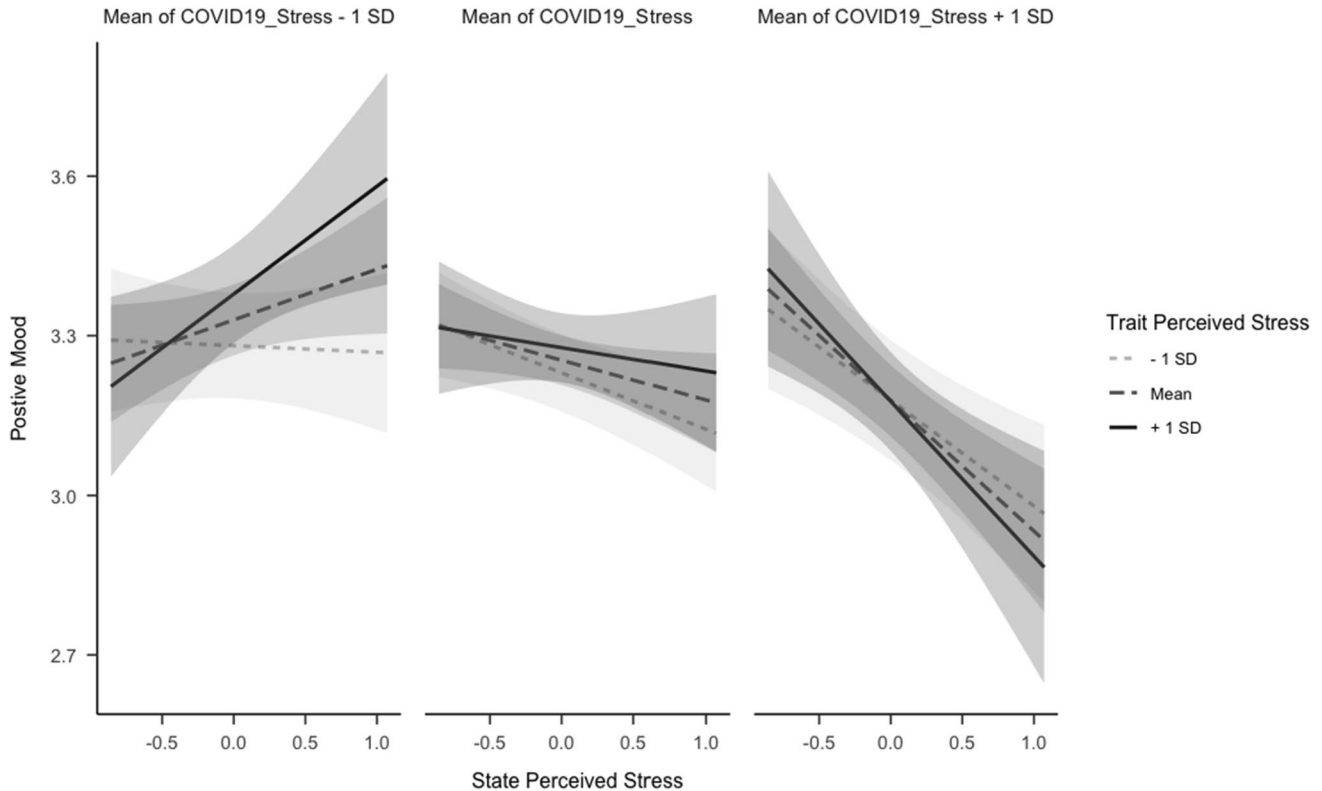

Fig. 2 Simple Slopes of Three-Way Interaction Effects on Positive Mood. Note. COVID19 Stress = COVID-19 Stressful Experiences
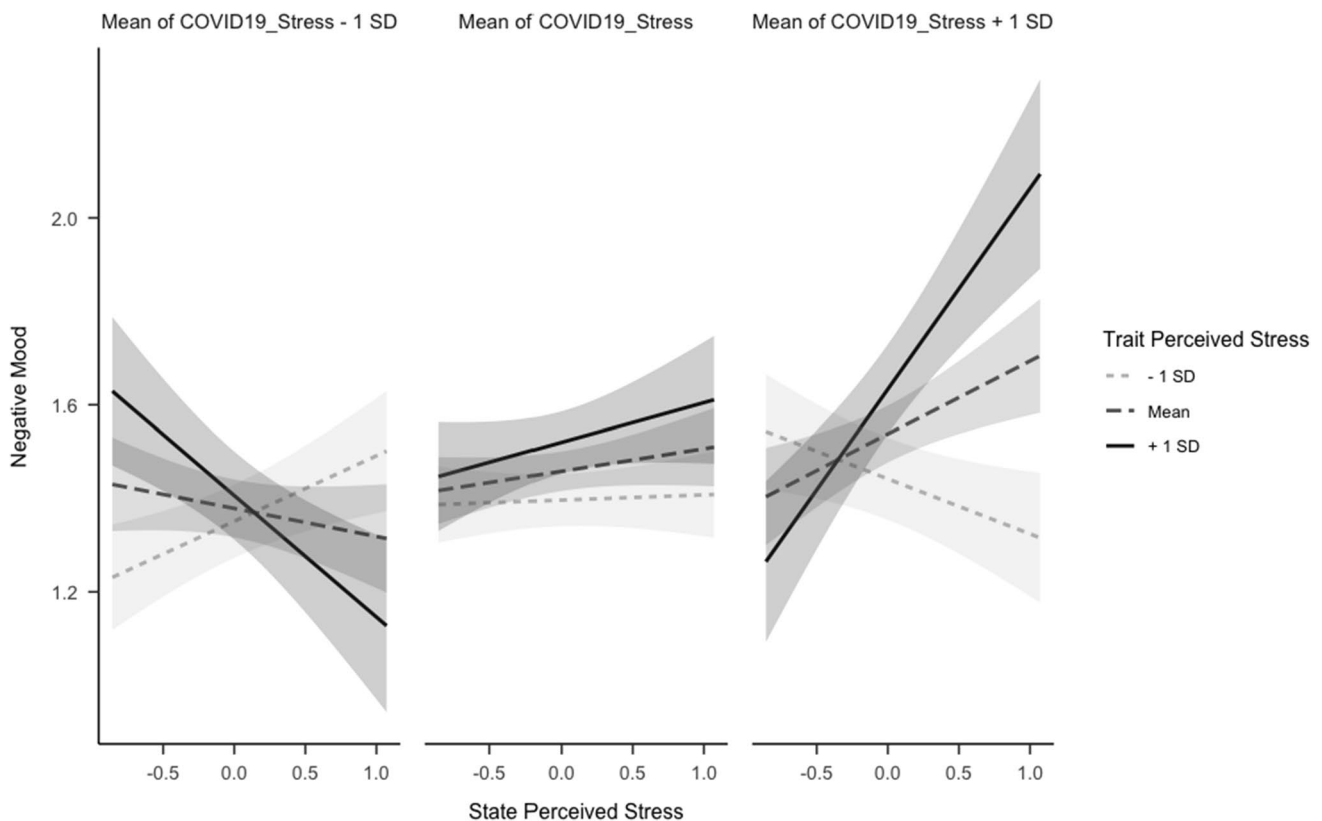
COVID-19 stressful experiences (+ 1 *SD*, the right plot of Fig. 2), state perceived stress negatively affected positive mood at all levels of trait perceived stress; the higher the trait perceived stress, the stronger the detrimental impact was (-1 *SD*: $\widehat{\beta} = -.20$, $p < 0.001$; mean: $\widehat{\beta} = -.24$, $p < 0.001$; + 1 *SD*: $\widehat{\beta} = -.29$, $p < 0.05$).

Figure 3 displayed the simple slopes of daily perceived stress on negative mood. Specifically, for participants reporting more (relative to lesser) COVID-19 stressful experiences, their state perceived stress had stronger impact on negative mood. For participants experienced lesser COVID-19 stressful experiences (-1 *SD*, the left plot of Fig. 3), state perceived stress was positively associated with negative mood when trait perceived stress was low ($\widehat{\beta} = .14$, $p < 0.001$). For participants reporting medium levels of COVID-19 stressful experiences (mean, the middle plot of Fig. 3), no significant impact was observed for state perceived stress on negative mood at all levels of trait perceived stress. For participants with greater COVID-19 stressful experiences (+ 1 *SD*, the right plot of Fig. 3), state perceived stress was positively associated with negative mood; the higher the trait perceived stress, the stronger the impact was (mean: $\widehat{\beta} = .17$, $p < 0.001$; + 1 *SD*: $\widehat{\beta} = .46$, $p < 0.001$).

Discussion

Drawing upon life course perspectives (Benner & Mistry, 2020) and life experience theory (Baltes et al., 1999; Rosenthal, 1993) for the pandemic's effects, the present study examined the associations between both the levels of and fluctuations in daily perceived stress and daily moods and the moderating effects of COVID-19 stressful experiences on these associations using daily diary reports. Results indicated the positive links between daily perceived stress and negative emotions, and that prior pandemic-related experiences exacerbated the adverse impact of both state and trait perceived stress on daily moods. By illuminating the moderating effects of stressful experiences related to pandemic conditions, this study contributes to the limited, but burgeoning, research examining the prolonged impact of the COVID-19 health crisis on daily emotional adjustment in the post-pandemic "new normal."

Our findings observed the detrimental effects of both state and trait perceived stress on negative emotions. Specifically, higher levels of perceived stress and more fluctuations in daily stress were associated with greater negative and anxious moods. The impact of state perceived stress on anxious mood was aggravated especially for individuals who

Fig. 3 Simple Slopes of Three-Way Interaction Effects on Negative Mood. *Note*. COVID19 Stress = COVID-19 Stressful Experiences

experienced higher levels of overall perceived stress. These findings are consistent with prior observations on the role of trait perceived stress in aggravating the pernicious effects of state perceived stress on daily moods (Xia et al., 2021). Of note, both the main effects of and interaction between state and trait perceived stress on positive mood were not significant, aligning with research demonstrating that daily stressful experiences were not associated with daily positive mood (Mereish et al., 2021). However, it should also be noted that prior stressful experiences pertinent to COVID-19 were associated with lower levels of post-pandemic positive mood. One explanation is that different forms and sources of stress (e.g., person-level stress related to prior adversities versus daily-level stress in everyday life) could elicit nuanced emotional responses. Since positive and negative moods are not simply the opposite valences of affect, but rather two distinct constructs of emotional states (Troy et al., 2019), it is important to examine both types of emotional responses to stress exposure. This study contributes uniquely to the existing literature on stress and moods (mostly focusing on negative emotions; see Troy et al., 2019) by elucidating the specificity with regards to the differential effects of person-level, pandemic-related stressful experiences and daily-level perceived stress on emotional adjustment among young adults in post-pandemic life.

Another contribution of this study is the investigation of the longer-term impact of COVID-19 stressful experiences on post-pandemic daily moods. Results observed that COVID-19 stressful experiences were associated with lower levels of positive mood and higher levels of negative and anxious moods. Illuminating the cascading effects of COVID-19 experiences on subsequent emotional adjustment in daily life, these findings extend the literature on the immediate, detrimental impact of COVID-19 on mental health (see Cikrikci et al., 2022 for a meta-analysis), using cross-sectional (e.g., Asmundson et al., 2022; Ye, Yang et al., 2020), longitudinal (e.g., Green et al., 2021; Magson et al., 2021), and daily diary (e.g., Collier Villaume et al., 2021; Deng et al., 2021) data.

More importantly, our findings observed significant moderation effects of prior experiences of COVID-19 on the associations between post-pandemic perceived stress and daily moods. Specifically, compared to those experiencing lesser pandemic-related stress, young adults reporting greater COVID-19 stressful experiences demonstrated poorer emotional adjustment (i.e., lower levels of positive mood and higher levels of negative mood) on days when they had more fluctuations in perceived stress (i.e., greater state perceived stress); the aggravating impact of COVID-19 stressful experiences was stronger when their perceived average levels of daily stress were higher (i.e., greater trait perceived stress). These findings are possibly explained using the sensitizing effects of prior exposure to adversities (Masten & Narayan, 2012); applied to the present study,

individuals who reported more stressful experiences during COVID-19 might be more vulnerable to the adverse effects of daily stress. Moreover, although the strict epidemic preventive measures against the spread of COVID-19 (such as large-scale lockdowns, mandatory quarantine, and school closures) had been widely lifted after the most severe period of the outbreaks in China (from January to April 2020), moderate restrictions are retained for Chinese college students, including but not limited to keeping social distance and wearing masks on campus and in class. It is possible that for young adults who were more susceptible to the detrimental impact of the pandemic (manifested as more stressful experiences associated with the COVID-19 pandemic), their daily life was more likely to be affected by the post-pandemic preventive measures. This study contributes uniquely to research on COVID-19 and psychological adaptation by elucidating the long-lasting implications of the pandemic, particularly for those with greater susceptibility to COVID-19 stressors, for a more protracted period of time.

Finally, although the three-way interactions between both state and trait perceived stress and COVID-19 stressful experiences were not associated with daily anxious mood among Chinese young adults, their anxious emotion was significantly impacted by the main effects of both the levels of and fluctuations in perceived stress, and these associations were moderated by COVID-19 stressful experiences. These findings are line with prior research observing the consequences of daily stressors for eliciting greater daily anxious mood (Livingston et al., 2020). Recent empirical and review studies examining individuals' emotional responses to COVID-19 also demonstrate the links between the pandemic and elevated anxious mood (Green et al., 2021; Salah et al., 2021) and more anxiety symptoms (Asmundson et al., 2022; Cikrikci et al., 2022), with the prevalence ranging from 26% to 27.3% (Ma et al., 2021; Pashazadeh Kan et al., 2021). Given that anxious mood could lead to mental health disorders (e.g., depressed mood, suicidal ideation and attempts) in regular contexts (Orri et al., 2018; Starr & Davila, 2012) and under pandemic conditions (Salah et al., 2021), it would be informative for future work to explore the implications of the prolonged impact of COVID-19 related stressors on anxious mood for individuals' psychological adaptation in post-pandemic life.

Limitations

It is important to note several limitations when interpreting the findings. First, this study focused solely on emotional adjustment (i.e., daily moods) after the pandemic. Since prior research observes compromises in health outcomes across physical (e.g., poorer sleep quality and greater sleep disorders; Ma et al., 2021; Salah et al., 2021) and behavioral

(e.g., increases in screen time and Internet use; Munasinghe et al., 2020) domains, future work should examine the longer-term impact of pandemic-related stressors on health and possible moderation effects of COVID-19 stressful experiences on outcomes of multiple domains. Second, this study included only one wave of daily diary reports to examine post-pandemic emotional adjustment. Young adults' emotional responses to stress during COVID-19 might be less pronounced across time (Collier Villaume et al., 2021). As such, future studies could benefit from collecting multiple time points of daily diary data on perceived stress and moods to investigate whether the moderating effects of COVID-19 stressful experiences would mitigate or exacerbate the associations between daily stress and moods for a more protracted period of time. Third, COVID-19 related stress may change over time (e.g., Schachter et al., 2022) depending on pandemic situations (e.g., COVID-19 burden such as infections, illness, hospitalization, and deaths) and epidemic preventive measures against the spread of COVID-19 (e.g., mandatory quarantine, school closures) implemented at the moment. Therefore, it would be informative to evaluate pandemic-related stress using longitudinal design to unpack the intricate links between pandemic-related stress and moods (Katz & Yovel, 2022). Fourth, the power analysis suggested that while most of the fixed effects have satisfactory statistical power, some of them (e.g., three-way interaction between trait and state perceived stress and COVID-19 stressful experiences for anxious mood) were slightly underpowered, which may pose challenges for generalizing the findings. However, we believe that the benefits of this study outweigh the statistical deficiencies. Finally, the limited representativeness of the sample (i.e., young adults in China) constrains the generalizability of the findings. Future research examining post-pandemic emotional adjustment among populations at different ages (e.g., children, middle-aged adults) across diverse national contexts, particularly those in countries at different phases of the pandemic, would be informative for unpacking nuanced emotional responses to, and recovery from, the COVID-19 pandemic.

Implications and conclusions

Despite the limitations, the present study contributes uniquely to the literature by expanding the dearth of research on the long-lasting, cascading effects of the COVID-19 pandemic on individuals' emotional well-being. Theoretically, this study provides important empirical support for life course perspectives for the pandemic's effects (Benner & Mistry, 2020) and advances this framework by informing studies examining the long-term impact of the global epidemic on people's stress and emotions in the post-pandemic daily life. Practically, by elucidating the aggravating role

of pandemic-related stressful experiences in the associations between perceived stress and daily moods, this study points to important implications for intervention programs focusing on bolstering people's psychosocial recovery and adaptation in the post-pandemic "new normal." Specifically, practitioners and trained counseling professionals working closely with college students should be aware of the longer-term consequences of COVID-19 stressful experiences on subsequent emotional well-being. It is also important for colleges and universities to provide more tailored institutional resources to better support young adults who encountered greater challenges during the initial stage of this global health crisis, particularly under conditions of circulating precautious and quarantined measures in the post-pandemic era.

Appendix

Exploratory factor analyses (EFA) were conducted to investigate the factor structure of the COVID-19 Stress Experiences scale. The original scale included 19 items (Appendix A). The initial examination of items' descriptive statistics suggested disproportionate number of responses of item 13 (i.e., "Limited access to online devices during COVID-19"), considering the fact that the survey was conducted online, this item was removed from the scale for further EFA analysis. Next, the factor structure of the 18 items scale was examined using principal component analysis with varimax rotation. Using Kaiser rule (i.e., eigenvalue greater than 1), the analysis yielded five factors explaining a total of 41% of the variance of the data. To examine the theoretical model of the COVID-19 Stressful Experience scale, bi-factor EFA analyses (i.e., all items are loaded on a general stress factor and also loaded on their domain specific factors) were conducted using the orthogonal bi-quartimin and bi-geomin rotations to test the solutions with one general factor and 1to 6 specific factors using M*plus* version 8.3 (Muthen & Muthen, Los Angeles, CA, USA). The best solution was selected based on both the model interpretability and model fit indices. Item-factor loading structure was determined based on statistical significance of loading parameters and the magnitude of loadings.

Model comparisons between established bi-factor model and unidimensional model, correlated first-order factor model, and second-order factor model were conducted to test if the bi-factor model was the best solution. In bi-factor analysis, a five-factor exploratory bifactor solution provided the best fit to the data ($\chi^2(116) = 142.08$, $p < 0.001$, RMSEA = 0.04, CFI = 0.97). All items loaded on the general factor with standardized factor loadings ranged from.26 to.57. One general factor and four specific factors were identified: (1) information-related stressful

experiences (4 items); (2) disease/life-related stressful experiences (5 items); (3) academic-related stressful experiences (3 items); and (4) back-to-school related stressful experiences (3 items). The remaining 3 items only loaded on the general factor. Confirmatory factor analysis was estimated based on the accepted bifactor EFA structure, and the model fit was acceptable ($\chi^2(115) = 278.17$, $p < 0.001$, RMSEA = 0.05, CFI = 0.93). The results of model comparisons between bifactor model, unidimensional model (RMSEA = 0.11, CFI = 0.56), correlated first-order factor model (RMSEA = 0.08, CFI = 0.86) and second-order factor model (RMSEA = 0.08, CFI = 0.85) suggested that the bifactor model fits better to the data.

COVID-19 Stressful Experiences Scale

From the outbreak of the pandemic (early February 2020) to the end of the National College Entrance Examination (early July 2020), how often did the following stressful events (or feelings) occur? Please select the option that best describes your situation (0 = *Never,* 1 = *Seldom,* 2 = *Sometimes,* 3 = *Often,* 4 = *Always*).

Information-Related Subscale:

1. Hearing or seeing other people talking about the severity and contagiousness of COVID-19.
2. Hearing about or reading too many passive news of COVID-19.
3. Being difficult to tell real news from fake news of COVID-19.
7. Being worried about the next outbreak of COVID-19 in China.

Disease/Life-Related Subscale:

4. Not being able to get enough personal protective equipment (e.g., masks, disinfectants).
5. Having been in contact with patients with suspected or confirmed COVID-19.
6. Having relatives or friends with confirmed COVID-19 or showing similar symptoms.
8. Having conflicts with families due to different lifestyles (e.g., staying up late) or personal protective measures (refusing to wear masks).
9. Being uncomfortable to stay with families all the time.

Academic-Related Subscale:

12. Not being able to communicate with teachers in time when studying from home.
14. Being less efficient and delayed in learning when studying from home.

16. Feeling regretful and guilty for not studying hard when studying from home.

Back-to-school Related Subscale:

10. My relationships with classmates and friends are fading due to not being able to see them frequently in the pandemic.
11. Although returning to school, communication with classmates and friends is still not convenient due to strict infection prevention and control measures.
15. Being uncomfortable about studying in school after returning to school.

General Stress

17. Daily life has been disrupted by the pandemic (e.g., not being able to go shopping).
18. Having family financial difficulties due to the pandemic.
19. Feeling not being able to control the future because of COVID-19.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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