



BASIC RESEARCH ARTICLE



The role of mindfulness and dysexecutive functioning in the association between depression and COVID-19-related stress: cross-sectional and longitudinal analyses

Chengjin Hong^{a,b}, Cody Ding^c, Shuge Yuan^{a,b}, Yue Zhu^{a,b}, Mengyan Chen^{a,b} and Dong Yang^{a,b}

^aFaculty of Psychology, Southwest University, Chongqing, People's Republic of China; ^bKey Lab of Cognition and Personality (Ministry of Education), Southwest University, Chongqing, People's Republic of China; ^cEducation Science & Professional Programs, University of Missouri-St. Louis, St. Louis, MO, USA

ABSTRACT

Background: Since the COVID-19 outbreak, the severity of college student's mental health has increased, with depression being the most prominent. This study's primary purpose was to explore (1) whether the perceived stress of COVID-19 was associated with depression through sequential mediation of mindfulness and dysexecutive function and also (2) the temporal association among mindfulness, dysexecutive function and depression.

Methods: We performed two studies to evaluate dysexecutive function as a mechanism through which mindfulness impacts depression under the stress of the COVID-19 pandemic. Study 1 used a sequential mediation model to test the mediating role of mindfulness and dysexecutive function between the perceived stress of COVID-19 and depression based on 1,665 emerging adults. Study 2 used a random-effect, cross-lagged panel model (RE-CLPM) to test the directionality among mindfulness, dysexecutive function, and depression based on 370 emerging adults.

Results: The cross-sectional study showed that perceived stress of COVID-19 was positively associated with depression through the sequential mediation of mindfulness and dysexecutive function (effect: 0.08, 95%CI = [0.07, 0.10]), also through the mediation of mindfulness (effect: 0.05, 95%CI = [0.03, 0.06]) and dysexecutive function (effect: 0.08, 95%CI = [0.06, 0.10]) separately. The RE-CLPM study indicated that dysexecutive function mediates the reciprocal relation between mindfulness and depression at the within-person level.

Conclusion: These results suggest that dysexecutive function is an intermediate psychological mechanism that exacerbates depression under pandemic-related stress. Mindfulness can predict dysexecutive function and subsequently improve depression. As depression under pandemic-related stress can weaken the mindful state, long-term mindfulness practices are needed to maintain mental health during COVID-19.

El papel de la atención plena y el funcionamiento disejecutivo en la asociación entre la depresión y el estrés relacionado con COVID-19: análisis transversales y longitudinales

Antecedentes: Desde el brote de COVID-19, la gravedad de la salud mental de los estudiantes universitarios ha aumentado, siendo la depresión la más prominente. El propósito principal de este estudio fue explorar (1) si el estrés percibido por COVID-19 estaba asociado con la depresión a través de la mediación secuencial de la atención plena y la función disejecutiva, y también (2) la asociación temporal entre la atención plena, la función disejecutiva y la depresión.

Métodos: Realizamos dos estudios para evaluar la función disejecutiva como un mecanismo a través del cual la atención plena afecta la depresión bajo el estrés de la pandemia de COVID-19. El Estudio 1 usó un modelo de mediación secuencial para probar el papel mediador de la atención plena y la función disejecutiva entre el estrés percibido de COVID-19 y la depresión, basado en 1665 adultos emergentes. El Estudio 2 usó un modelo de panel cruzado de efectos aleatorios (RE-CLPM) para probar la direccionalidad entre la atención plena, la función disejecutiva y la depresión, basado en 370 adultos emergentes.

Resultados: el estudio transversal mostró que el estrés percibido de COVID-19 se asoció positivamente con la depresión a través de la mediación secuencial de atención plena y función disejecutiva (efecto: 0.08, IC 95% = [0.07, 0.10]), también a través de la mediación de atención plena (efecto: 0.05, IC del 95 % = [0.03, 0.06]) y función disejecutiva (efecto: 0.08, IC del 95 % = [0.06, 0.10]) por separado. El estudio RE-CLPM indicó que la función disejecutiva media la relación recíproca entre la atención plena y la depresión a nivel interno de la persona.

ARTICLE HISTORY

Received 16 January 2023
Revised 15 May 2023
Accepted 23 May 2023

KEYWORDS

Mindfulness; Depression;
Dysexecutive function;
Perceived stress of COVID-19;
RE-CLPM

PALABRAS CLAVE

Atención plena; Depresión;
Función disejecutiva; Estrés
percibido de COVID-19; RE-
CLPM

关键词

正念; 抑郁; 执行功能失调;
COVID-19感知应激; RE-
CLPM

HIGHLIGHTS

- Dysexecutive function is a potential cognitive risk factor of depression under pandemic stress using cross-sectional data.
- The random effect cross-lagged panel model (RE-CLPM) demonstrated temporal association among mindfulness, dysexecutive functions, and depression.
- Long-term mindfulness practices are needed to maintain mental health under COVID-19 stress.

CONTACT Dong Yang yangd@swu.edu.cn Faculty of Psychology, Southwest University, No. 2 Tiansheng Road, Chongqing 400715, People's Republic of China; Key Lab of Cognition and Personality (Ministry of Education), Southwest University, Chongqing 400715, People's Republic of China

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

Conclusión: Estos resultados sugieren que la función disejecutiva es un mecanismo psicológico intermedio que exacerba la depresión bajo el estrés relacionado con la pandemia. La atención plena puede predecir la función disejecutiva y, posteriormente, mejorar la depresión. Dado que la depresión bajo el estrés relacionado con la pandemia puede debilitar el estado de atención, se necesitan prácticas de atención plena a largo plazo para mantener la salud mental durante el COVID-19.

正念和执行功能失调在抑郁和 COVID-19 相关应激之间关联中的作用：横断面和纵向分析

背景: 自COVID-19疫情爆发以来,大学生心理健康问题日益严重,其中抑郁最为突出。本研究旨在探讨 (1)COVID-19 感知应激是否通过正念和执行功能失调的序列中介与抑郁相关,以及 (2) 正念、执行功能失调和抑郁之间的时间关联。

方法: 我们进行了两项研究,以评估执行功能失调作为正念在 COVID-19 疫情应激下影响抑郁的机制。研究 1 使用序列中介模型,以基于 1,665 名新成年者检验了正念和执行障碍功能在 COVID-19 感知应激与抑郁之间的中介作用。研究 2 使用随机效应、交叉滞后模型 (RE-CLPM) 来检验 370 名新成年者的正念、执行功能失调和抑郁之间的方向性。

结果: 横断面研究表明,COVID-19 的感知应激与抑郁通过正念和执行功能失调的顺序中呈正相关(效应: 0.08, 95%CI = [0.07, 0.10]),也分别通过正念(效果: 0.05, 95%CI = [0.03, 0.06])和执行功能失调(效果: 0.08, 95%CI = [0.06, 0.10])的中介呈正相关。RE-CLPM 研究表明,执行功能失调在个体水平上中介正念与抑郁之间的相互关系。

结论: 这些结果表明,执行功能失调是在疫情相关应激下加剧抑郁的中间心理机制。正念可以预测执行功能失调,从而改善抑郁。由于疫情相关应激下的抑郁会削弱正念状态,因此需要长期正念练习才能在 COVID-19 期间保持心理健康。

1. Introduction

From 2001 to 2020, the prevalence of self-reported depressive symptoms increased by 34% (Shorey et al., 2022), and COVID-19 increased the risk of major depression by 27.6% (Daly & Robinson, 2022). A longitudinal study reported increased mental health problems among adults during the COVID-19 pandemic and showed the greatest increase among college-aged participants (18–24 years) (Pierce et al., 2020). Approximately 37% of college students worldwide have reported depressive symptoms during the COVID-19 pandemic (Wang et al., 2021). Executive function is the top-down cognitive regulation process to exclude interference from irrelevant stimuli and achieve specific goals, including inhibition, working memory, information process, and cognitive flexibility (Diamond, 2013). According to the cognitive depression theory, dysexecutive function over mood-congruent material may cause negative biases in attention and working memory, resulting in increased use of maladaptive emotion regulation strategies and depression (LeMoult & Gotlib, 2019).

Evidence from meta-analysis studies has suggested that depression severity is associated with dysexecutive function (McDermott & Ebmeier, 2009) and may exacerbate working memory deficits (Nikolin et al., 2021). The response inhibition defect of negative materials may be a key mechanism related to the increased risk of depression (Joormann, 2010). The role of dysexecutive functions in depression can be seen in the dual process of cognitive vulnerability to depression: associative and reflective. The reflective mode is effortful and slow, whereas the associative

mode is adverse. Individuals with depression engage in negative automatic processing and negative thinking, potentially leading to negative cognitive or emotional responses. When reflective processing, the automatic correcting processing, is biased, non-adaptive mood onset weakens cognitive resources, leading to a downward spiral (see Figure 1). According to this theory, reflection can be triggered when one has sufficient cognitive resources and is aware that associative processing violates our expectation (Beevers, 2005). Executive function is necessary for reflective processing, allowing individuals to reprocess information elaboratively (Zelazo, 2020).

The individual differences in dysexecutive function and depression can be considered from the framework of the cognitive diathesis-stress model. Specifically, cognitive diathesis, including dysfunctional attitudes and negative attribution schemata, interacts with perceived stress (Lewinsohn et al., 2001). From a neurodevelopmental perspective (Zelazo, 2020), adverse childhood experiences make individuals more susceptible to stress and impair executive function. For example, Liston et al. (2009) found that prolonged stress adversely influences prefrontal function during executive function tasks. However, when the perceived stressor is removed, these individuals return to lower stress levels one month later, reducing long-term dysexecutive function.

These theories and findings suggest that interventions for depression are possible by addressing stress and dysexecutive function. In this regard, mindfulness intervention may allow individuals with depression to improve their executive functions and trigger reflective processing, as suggested by the Monitor and Acceptance

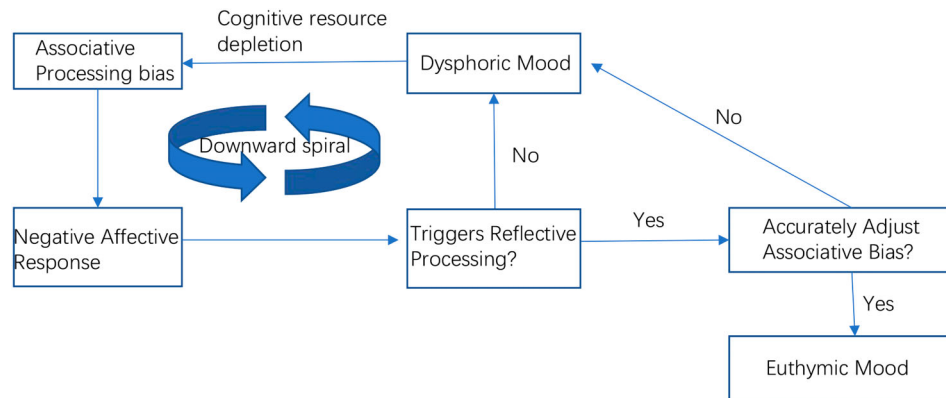


Figure 1. A dual process of the cognitive vulnerability of depression.

Theory (MAT) (Lindsay & Creswell, 2017). From the view of MAT, awareness is a skill that explains how mindfulness improves executive function, and acceptance is important for lowering affective reactivity. These two abilities explain how mindfulness improves negative affectivity like depression (Lindsay & Creswell, 2017). Moreover, the brain region activated by mindfulness interventions and executive function overlapped, mainly in the PFC and ACC (Rogers et al., 2004; Tang et al., 2015). Mindfulness interventions can enhance executive control by improving the prefrontal lobe's ability to regulate the entire limbic system (Tang et al., 2015).

In addition, the Broaden-and-Build Theory (BBT) and Mindfulness-to-meaning (MMT) show how mindfulness can help minimize depression. According to BBT, mindfulness intervention can produce positive emotions, and the repeated experience of positive emotions can spiral into a sense of happiness, improving the function of brain regions related to emotion regulation. Conversely, negative emotional experiences can create a downward spiral, potentially leading to depression (Garland et al., 2010). MMT is proposed based on BBT to answer how mindfulness intervention produces positive emotions. The theory proposed that the decentralized mechanism of mindfulness can reduce automated cognitive responses and enhance positive emotions, thereby expanding the range of attention and enhancing cognitive flexibility. This change in cognitive ability allows individuals to reappraise stressors, generate positive emotions, and construct a sense of meaning in life (Garland et al., 2015).

Generally speaking, dysexecutive function seems to be an essential risk factor for depression, which the pandemic stress could further exacerbate. Mindfulness explains the change of dysexecutive function, subsequently alleviating depression. Mindfulness's decentering (metacognition) mechanism enables individuals to adopt a bystander perspective on everyday stress, thus freeing up more cognitive resources to alleviate dysexecutive function and decrease perceived pandemic stress. Nevertheless, stress may also negatively

influence reflection processing and impaired mindfulness state (Zelazo, 2020). In order to test the relations among these variables, study 1 used cross-sectional data to determine whether perceived stress of COVID-19 was associated with depression through the mediation of dysexecutive function and mindfulness. Study 2 used longitudinal data to explore temporal association among mindfulness, dysexecutive function, and depression.

2. Brief introduction of study 1

As discussed previously, dysexecutive function makes it difficult for people to suppress negative information, allowing it to enter their working memory and leading to potential depression (Joormann, 2010). Based on MAT and BBT discussed above, mindfulness practice may reduce depression symptoms by enhancing executive function. Although executive function plays a role in how mindfulness affects depression, perceived stress may impair it and interfere with mindfulness (Spada et al., 2008). Thus, in Study 1, we tested four hypotheses based on the sequential mediation model, as depicted in Figure 2, using cross-sectional data.

Hypothesis 1 (H1): perceived stress of COVID-19 is positively correlated with depression.

Hypothesis 2 (H2): mindfulness mediates between the perceived stress of COVID-19 and depression.

Hypothesis 3(H3): dysexecutive function mediates between the perceived stress of COVID-19 and depression.

Hypothesis 4 (H4): mindfulness and dysexecutive function play sequential mediation between the perceived stress of COVID-19 and depression.

3. Method of study 1

3.1. Participants and procedure

Random sampling was employed to recruit 2,000 participants from several universities and communities

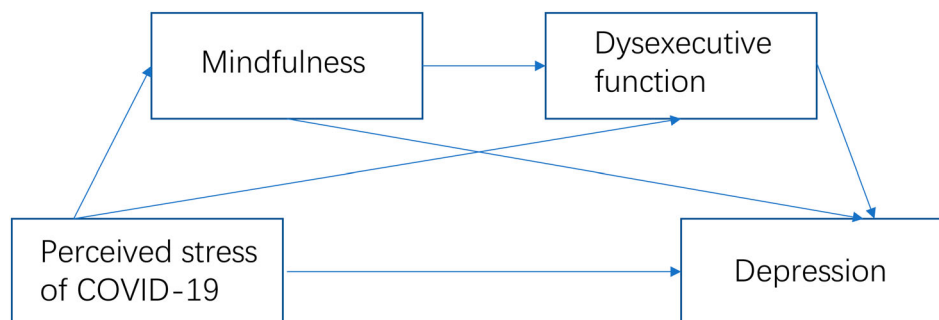


Figure 2. The conceptual model of the sequential mediation role of mindfulness and dysexecutive function.

in Chongqing, Guangxi, and Hubei provinces in December 2021. The university sample was stratified by college year (i.e. freshman, sophomore, junior, and senior). Questionnaires were completed through an online survey platform. Data from 335 participants were omitted because they did not provide valid responses to the detector items (i.e. ‘please choose the third option’) or took less than 5 min to complete all questions. The final sample included 1,665 participants, with 768 males and 897 females. The age of the participants ranged from 18 to 25 ($M = 21.3$; $SD = 1.35$) years. Informed consent was obtained from all participants before the study started. This study was approved by the academic committee of Southwest University (number H22037).

3.2. Measures

3.2.1. Perceived stress scale adapted for COVID-19 (PSS-10-C)

The Perceived Stress Scale adapted for COVID-19 (PSS-10-C) was modified from the PSS-10, designed to assess perceived stress from COVID-19. All items describe situations related to pandemic stress (i.e. I have felt affected as if something serious will happen unexpectedly with the epidemic). This scale includes ten items and scores from 1 to 4. The average score was created by averaging responses across all items, and the higher score indicated greater perceived stress for COVID-19 (Pedrozo-Pupo et al., 2020). The confirmatory factor analyses show that PSS-10-C is a valid and reliable tool for assessing COVID-19 related stress among emerging adults ($\chi^2 = 295.6$; $df = 34$; $p < .001$; $\chi^2/df = 8.7$; RMSEA = 0.08; 90%CI, 0.07–0.09; CFI = .93; TLI = .91; SRMR = .05) (Campo-Arias et al., 2021). Cronbach’s α in the current study was 0.72.

3.2.2. Dysexecutive questionnaire (DEX)

The Dysexecutive Questionnaire (DEX) has 20 items, with a self-reported rating scale designed to measure dysexecutive symptoms, including intentionality, inhibition, positive affect, and negative affect executive

memory. This scale is scored from 1-5. The average score was created by averaging responses across all items, and higher scores indicate greater dysexecutive function (Burgess et al., 1998). The DEX was reported to have good reliability and validity for the early detection of prefrontal dysfunction (Pedrero-Pérez et al., 2015). The Cronbach’s α of this scale in the current study was 0.93.

3.2.3. Mindfulness attention awareness scale (MAAS)

The Mindfulness Attention Awareness Scale (MAAS) was designed to measure self-awareness and has only one factor, mindfulness. This scale includes 15 items and is scored from 1-6. The average score was created by averaging responses across all items, and the higher the ability to be self-aware (Brown & Ryan, 2003). The Chinese version of the MAAS appears to be a reliable and valid instrument to assess levels of mindfulness in a Chinese college population (Deng et al., 2012). The Cronbach’s α of this scale in the current study was 0.91.

3.2.4. Centre for epidemiological studies depression scale (CES-D)

The Center for Epidemiological Studies Depression Scale (CES-D) was designed to measure depression symptoms in the general population (Radloff, 1977). This scale consists of 20 items for somatic symptoms, depressive, and positive emotions (Yen et al., 2000). The response scale was from 1 to 4, with 1 indicating low depression and 4 indicating high depression. The average score was created by averaging responses across all items, and higher scores indicate a higher level of depressive symptoms. CES-D was reported to have good reliability and validity for Chinese university students (Jiang et al., 2019). The Cronbach’s α of the CES-D in the current study was 0.91.

3.2.5. Childhood trauma questionnaire-short form (CTQ-SF)

The childhood trauma questionnaire-short form (CTQ-SF) was designed to assess childhood trauma before the age of 16 years. This scale has 28 items, including physical neglect, physical abuse, emotional neglect, emotional

abuse, and sexual abuse, and is scored from 1-5. The average score was created by averaging responses across all items, and higher total scores indicate greater childhood trauma (Bernstein et al., 2003). The Cronbach's α of the CTQ-SF in the current study was 0.90. Because childhood traumatic experience can influence depressive symptoms (Hill, 2003), this study used it as a covariate.

4. Data analysis of Study 1

We excluded cases who responded to the detection items incorrectly or completed the survey in less than 5 min to ensure the questionnaire's validity. We first conducted a descriptive statistical analysis of the key variables. Then, we tested common method bias (e.g. variation due to the same data acquisition method, project's characteristics, or the subjects' response bias) in the survey instruments using Harman's single-factor test (Podsakoff et al., 2003). The first factor's cumulative variance contribution rate of less than 40% indicated no significant common method bias, and this rate was 28.9% in the current study, suggesting no common method bias. Third, to test the four hypotheses, we chose Model 6 from PROCESS macro. A total of 5,000 samples were constructed, each with a sample size of 1,665 (Hayes & Rockwood, 2020). Again, because childhood traumatic experiences can influence depressive symptoms, this study used it as a covariate.

5. Results of Study 1

5.1. Descriptive statistics and correlations

Table 1 presents the descriptive statistics of the variables. Perceived stress of COVID-19, dysexecutive function, depression, and childhood trauma showed significant positive correlations, and mindfulness was negatively correlated with them, which is consistent with what we expected. Since childhood trauma was positively correlated with depression, we used it as a covariate in the cross-sectional mediation analysis. There was no significant correlation between gender and depression in this study.

5.2. The effect of perceived stress of COVID-19 on depression: a sequential mediation of mindfulness and dysexecutive function

The result showed the significant direct effect of the perceived stress of COVID-19 on depression was 0.14 (95% CI = [0.10, 0.18]). The indirect effect of mindfulness as a mediation variable was 0.05 (95% CI = [0.03, 0.06]). The indirect effect of dysexecutive function as a mediation variable was 0.08 (95% CI = [0.06, 0.10]). The indirect effect of sequential mediation of mindfulness and dysexecutive function

was 0.08 (95% CI = [0.07, 0.10]). All these indirect effects were statistically significant, supporting all four hypotheses. The regression analysis for the sequential mediation model is shown in Table 2.

6. Discussion of Study 1

The findings of this study supported all four hypotheses. Consistent with earlier studies (Liu & Wang, 2021; Zandifar et al., 2020), the perceived stress of COVID-19 was positively associated with depression. This relation is mediated through dysexecutive function. This mediation effect is expected, given that the central executive network (CEN) regulates cognition and emotion from the top down and is easily affected by perceived stress (Datta & Arnsten, 2019). The relation between the perceived stress of COVID-19 and depression is also mediated by mindfulness. This was also expected, given that the advanced function of metacognition, which depends on reflection processing, is likewise sensitive to perceived pandemic stress (Zelazo, 2020). The basic mechanism of mindfulness, metacognition, acts as an advanced cognitive self-regulation technique that enables depressed people to observe stressful events from a bystander perspective without getting engaged (Bennett et al., 2021).

More interestingly, mindfulness and dysexecutive function played a sequential mediation role between the perceived stress of COVID-19 and depression. The findings supported the BBT and MMT. The decentering mechanism of mindfulness is associated with positive emotion, which increases cognitive flexibility and reduces dysexecutive function. It is also associated with a sense of meaning and lower depression (Bennett et al., 2021; Garland et al., 2010; Garland et al., 2015). Stress and unfavourable feelings can, in turn, negatively impact mindfulness and impair metacognition, which can involve threatening messages about the self, such as the fear of being infected by a virus. Subsequently, it leads to cognitive narrowing, impairs reflective processing, and causes dysexecutive function (Zelazo, 2020) and depression (LeMoult & Gotlib, 2019). The results of the sequential mediation study indicate that the cognitive self-regulation system composed of mindfulness and executive function is susceptible to the perceived pandemic stress.

However, in Study 1, cross-sectional data were used to illustrate the sequential mediation relation rather than temporal association among variables. In Study 2, longitudinal data were used to explore the directionality among variables to fill the gap in Study 1.

7. Brief introduction of Study 2

Based on our literature review, mindfulness practice may reduce dysexecutive function, which may reduce depressive symptoms. However, the opposite is also

Table 1. Descriptive statistics and correlations.

	M	SD	1	2	3	4	5
Mindfulness	3.81	0.85	1				
Perceived stress of Covid-19	2.34	0.42	−0.36**	1			
Dysexecutive functions	2.32	0.67	−0.72**	0.42**	1		
Depression	1.96	0.50	−0.62**	0.41**	0.72**	1	
Childhood trauma	1.85	0.57	−0.34**	0.15**	0.37**	0.55**	1

Note: M = mean; SD = standard deviation.

Two-tailed test. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

possible. Executive function and metacognition are components of the cognitive self-regulation system, and a decline in executive function may result in a decrease in mindfulness since the executive function can be easily damaged by stress or depression (Roebbers, 2017). Given this possibility, we expect that there is a bidirectional relation between dysexecutive function, depression, and mindfulness. Thus, we hypothesized that:

Hypothesis 5 (H5): The level of mindfulness at time 1 affects depression at time 3 through dysexecutive function at time 2.

Hypothesis 6 (H6): Depression at time 1 affects mindfulness at time 3 through dysexecutive function at time 2.

We examined the directionality of mindfulness, dysexecutive function, and depression using longitudinal data based on the random-effect, cross-lagged panel model (RE-CLPM). This approach allows the disaggregation of between-person variation from within-person variation, such as gender and personality (Wu et al., 2018). RE-CLPM can also be used to investigate whether the change of one variable (such as mindfulness) at the time (t1) would affect the change of another variable (such as dysexecutive function) at the time (t2) after controlling the within-person variations.

8. Methods of Study 2

8.1. Participants

A total of 534 emerging adults from several universities and communities were recruited to complete questionnaires via an online platform. The data were collected every three months from June 2021 to

December 2021 ($n_1 = 534$, $n_2 = 451$, and $n_3 = 390$). The current study used data from 370 participants who completed all three surveys (47.8% male; $M_{\text{age at time 3}} = 21.0$; $SD = 1.59$), excluding those who did not provide valid responses to the detector items. Attrition analyses were conducted to examine whether the participants with complete data differed from those who dropped out at T3. Multivariate analysis of variance (MANOVA) revealed no significant differences in all the variables between the two groups in the first – and second-wave survey ($F = 2.175$, $p = .09$).

8.2. Measures of Study 2

We used the MAAS, DEX, and CES-D to measure mindfulness, dysexecutive function, and depression, respectively, as we did in Study 1. The CTQ-SF was used to assess childhood trauma and treated as a covariate, as in Study 1. All Cronbach's α values were greater than 0.87 in three measurements.

8.3. Procedure of Study 2

Participants completed the questionnaires via an online platform. They were invited to the social media group in the first wave so that we could trace them in subsequent data collection. Informed consent was obtained from the participants at each wave of data collection to complete all the items before submission. The study was approved by the academic committee of Southwest University (number H22038).

8.4. Data analyses of Study 2

First, SPSS 20.0 was used to calculate correlations and Cronbach's α of the key variables. Second,

Table 2. Regression analysis for the sequential mediation model ($N = 1665$).

Variables	M1			M2			Y		
	B	SE	t	B	SE	t	B	SE	t
X	−.633	0.045	−14.122***	0.295	0.028	10.680***	0.141	0.200	7.080***
M1				−.475	0.014	−33.257***	−.090	0.128	−6.991***
M2							0.338	0.017	19.849***
Y									
C							0.275	0.014	19.383***
R^2	0.208			0.563			0.632		
F	218.54***			713.237***			712.989***		

Note: X = perceived stress of COVID-19; M1 = mindfulness; M2 = Dysexecutive function; Y = depression; SE = Standard error; C = Childhood trauma.

Two tailed test, *** $p < 0.001$.

confirmatory factor analysis (CFA) was used to evaluate measurement invariance for all measures across the three waves. Measurement invariance is the premise for comparing data collected at different time points, which ensures the consistent psychological significance of one questionnaire in the measurement at different time points. Changes in the comparative fit index (ΔCFI) that did not exceed 0.01 and changes in root mean square error of approximation ($\Delta RMSEA$) that did not exceed 0.015 were considered indicators of measurement invariance (Chen, 2007). Third, a random-effect, cross-lagged panel model (RE-CLPM) was used to examine the temporal association between mindfulness, dysexecutive function, and depression. The Mplus 8.0 was used to run RE-CLPM. The significant mediation effects were tested using a 5,000-bootstraping procedure, and if the 95% confidence interval (CI) did not include 0, the mediation effect was significant.

9. Results of Study 2

9.1. Descriptive statistics and correlations

Table 3 shows descriptive statistics and correlations for the key variables. As we expected, mindfulness, dysexecutive function, and depression were significantly correlated in the three waves. Childhood trauma was measured in the third wave, and the correlation between childhood trauma and depression was 0.52 ($p < .01$). Since gender and age were not significantly correlated with depression, we did not use them in the analysis.

9.2. Measurement invariance

In the current study, mindfulness ($\Delta CFI = 0.01$; $\Delta RMSEA = 0.002$), dysexecutive function ($\Delta CFI = 0.01$; $\Delta RMSEA = 0.001$), and depression ($\Delta CFI = 0.006$; $\Delta RMSEA = 0.001$) all showed scalar measurement invariance, suggesting that data comparison across waves was meaningful.

9.3. Random-effect, cross-lagged panel models

We used the RE-CLPM to test the longitudinal, within-subjects relation between mindfulness, dysexecutive function, and depression. These results support a reciprocal relation between mindfulness and depression. Time 1 mindfulness significantly predicted Time 2 dysexecutive function ($B = -0.124$, 95%CI = $[-0.201, -0.047]$), and Time 2 dysexecutive function predicted Time 3 depression ($B = 0.131$, 95%CI = $[0.049, 0.206]$). In addition, Time 1 depression significantly predicted Time 2 dysexecutive function ($B = 0.228$, 95%CI = $[0.120, 0.333]$), and

Time 2 dysexecutive function significantly predicted Time 3 mindfulness ($B = -0.264$, 95%CI = $[-0.457, -0.068]$). All autoregressive paths are shown in Figure 3. The indirect effects of mindfulness on depression from Time 1 to Time 3 were -0.016 (95%CI = $[-0.031, -0.002]$), and the direct effect was -0.079 (95%CI = $[-0.128, -0.036]$). The indirect effect of depression on mindfulness from Time 1 to Time 3 was -0.06 (95%CI = $[-0.102, -0.017]$), while the direct effect was not significant (see Table 4).

10. Brief discussion of Study 2

This study's results supported both hypotheses. The relation between mindfulness and depression is bidirectional through dysexecutive function. Our study result was consistent with that of Allen et al. (2012), which revealed that the mindfulness intervention group displayed high levels of the dorsolateral prefrontal cortex (DLPFC) and dorsal anterior cingulate cortex (dACC) activation during response inhibition of unfavourable stimuli, and the activated brain areas were closely associated with those in charge of executive control. From the cognitive perspective to depression proposed by LeMoult and Gotlib (2019), depression and executive function interact. Long-term depression, on the other hand, affects synaptic plasticity, impairs prefrontal function, and causes dysexecutive function (Selemon, 2013), which disrupts the cognitive self-regulation system and reduces the state of mindfulness (Roebbers, 2017).

11. General discussion

Our results are consistent with the cognitive diathesis-stress model, suggesting maladaptive cognitive and stress interactions will trigger depressive symptoms (Lewinsohn et al., 2001). Moreover, our result supported the MAT proposed by Lindsay and Creswell (2017) and the BBT proposed by Fredrickson and Joiner (2002). Mindfulness intervention leads to broadened awareness, a state of mindfulness that has been shown to enhance attentional processes, especially executive function (Im et al., 2021; Müller et al., 2021). For example, the neural mechanism of executive function deficiency in patients with depression involves decreased activation of the anterior cingulate gyrus, enhanced activation of the amygdala, and reduced internal functional connectivity of the frontal limbic system, and MBI can improve these brain regions (Disner et al., 2011; Y. Y. Tang et al., 2015). Furthermore, the high executive function interacts with the non-judgemental attitude of mindfulness to reduce depression (Lindsay & Creswell, 2017).

Interestingly, our study found that the level of depression predicted mindfulness after six months

Table 3. Descriptive statistics and Pearson correlations for key variables.

	T1M	T2M	T3M	T1DF	T2DF	T3DF	T1DE	T2DE	T3DE
T1M	1								
T2M	0.66**	1							
T3M	0.62**	0.70**	1						
T1DF	-0.67**	-0.60**	-0.58**	1					
T2DF	-0.57**	-0.70**	-0.61**	0.70**	1				
T3DF	-0.55**	-0.65**	-0.72**	0.66**	0.75**	1			
T1DE	-0.60**	-0.51**	-0.47**	0.68**	0.56**	0.55**	1		
T2DE	-0.49**	-0.59**	-0.53**	0.54**	0.72**	0.64**	0.65**	1	
T3DE	-0.48**	-0.51**	-0.58**	0.54**	0.55**	0.66**	0.64	0.66**	1
M	3.83	3.85	3.72	2.40	2.40	2.42	1.93	1.92	2.06
SD	0.72	0.72	0.77	0.62	0.64	0.65	0.49	0.49	0.47

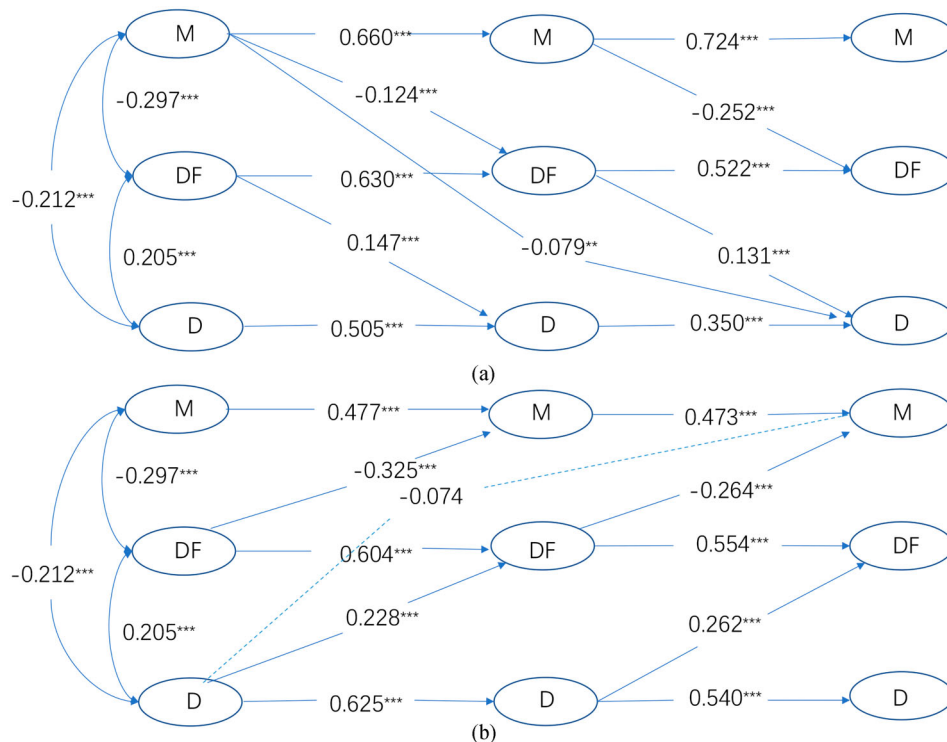
Note: M = Mindfulness; DF = Dysexecutive function; DE = Depression.

Two-tailed test, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

through the mediation of dysexecutive function. As the cognitive theory of depression suggests, deficits in executive function over mood-congruent material are associated with depression, contributing to negative attentional, memorial, and self-reference bias and maladaptive emotional regulation strategies such as rumination (LeMoult & Gotlib, 2019), reducing the usefulness of mindfulness. A study has shown that the anterior cingulate cortex (ACC) and the autonomic nervous system (ANS) are brain regions shared by mindfulness and executive function (Yi-Yuan Tang et al., 2012). The abnormality of ACC will cause difficulty of inhibition (Allen et al., 2012), and dysfunctional ANS will impair emotional regulation ability (Kreibig, 2010), which narrows the range of cognition and weakens the metacognition of mindfulness (Roebbers, 2017).

11.1. Clinical implication

There are several clinical implications in our studies. First, since emerging adults experience numerous pressures and are vulnerable to depression, mindfulness interventions can be used as a mental health course for university students. Second, our results show that mindfulness can effectively predict executive function and depression. MAT also points out that the awareness component of mindfulness can effectively improve executive function, and the synergistic effect of awareness and acceptance can alleviate emotional disorders, so future studies may employ experimental designs to separate the distinct effects of mindfulness's awareness and acceptance components to explore the mechanisms how mindfulness is associated with depression. Third, our longitudinal

**Figure 3.** The result of RE-CLPM. (a) The RE-CLPM of mindfulness to depression. (b) The RE-CLPM of depression to mindfulness.

Note: M = mindfulness; DF = Dysexecutive function; D = depression; Two-tailed test * $p < .05$, ** $p < .01$, *** $p < .001$. The solid line indicates significant paths, and the dotted line indicates a non-significant path.

Table 4. Direct and indirect effects on mindfulness, dysexecutive functions, and depression.

Effects	B	SE	CI (95%)	
			Lower	Upper
M→DF→D (indirect)	−0.016*	0.009	−0.031	−0.002
D→DF→M (indirect)	−0.06*	0.026	−0.102	−0.017
M→D (direct)	−0.079*	0.028	−0.128	−0.036
D→M (direct)	−0.075	0.079	−0.205	0.054

Note: M = Mindfulness; DF = Dysexecutive functions; D = Depression; B = Standardized coefficients; SE = Standardized error.
Two-tailed test, * $p < .05$; ** $p < .01$; *** $p < .005$.

study has shown that depression is negatively associated with the state of mindfulness by impairing executive function. The prevalence of depression in emerging adults experiencing persistent stress may increase, highlighting the value of ongoing mindfulness training for treating depression.

11.2. Limitations

Several limitations should be considered when interpreting the study results. First, observational data from self-reports makes deducing a causal relation among variables challenging. Second, we did not measure traumatic symptoms or other stress incidents, only the perceived stress from the pandemic. Third, because the study data were from emerging adults, it is important to be cautious when extrapolating its conclusions to other populations due to this group's unique pressures and neurodevelopmental traits. Fourth, given that data is cross-sectional with many partial mediations in Study 1, the results would benefit from conducting other model to strengthen and refine interpretations of the primary model.

12. Conclusion

Our results suggest mindfulness and dysexecutive function as intermediate psychological mechanisms between pandemic-related stress and depression, showing a temporal association among mindfulness, dysexecutive function, and depression. As a group psychological intervention, mindfulness intervention is viable for large-scale promotion in universities and communities to reduce depression among emerging adults susceptible to depression during the post-pandemic era. Executive functions could be a psychological index of mindfulness interventions to reduce depression.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Fundamental Research Funds for the Central Universities [Grant Number

SWU2009101]; National Natural Science Foundation of China [Grant Number 71472156]; Chongqing Planned Social Science Research Program [Grant Number 2020TBWT-ZD07].

Data availability statement

Please load the original data of this article via <https://github.com/Chengjin-1/CJ-1.git>.

ORCID

Chengjin Hong  <http://orcid.org/0000-0002-3842-9967>

Reference

- Allen, M., Dietz, M., Blair, K. S., van Beek, M., Rees, G., Vestergaard-Poulsen, P., Antoine, L., & Roepstorff, A. (2012). Cognitive-affective neural plasticity following active-controlled mindfulness intervention. *The Journal of Neuroscience*, 32(44), 15601–15610. <https://doi.org/10.1523/JNEUROSCI.2957-12.2012>
- Beevers, C. G. (2005). Cognitive vulnerability to depression: A dual process model. *Clinical Psychology Review*, 25(7), 975–1002. <https://doi.org/10.1016/j.cpr.2005.03.003>
- Bennett, M. P., Knight, R., Patel, S., So, T., Dunning, D., Barnhofer, T., Smith, P., Kuyken, W., Ford, T., & Dalgleish, T. (2021). Decentering as a core component in the psychological treatment and prevention of youth anxiety and depression: A narrative review and insight report. *Translational Psychiatry*, 11(1), 288. <https://doi.org/10.1038/s41398-021-01397-5>
- Bernstein, D. P., Stein, J. A., Newcomb, M. D., Walker, E., Pogge, D., Ahluvalia, T., Stokes, J., Handelsman, L., Medrano, M., Zule, W., & Desmond, D. (2003). Development and validation of a brief screening version of the childhood trauma questionnaire. *Child Abuse & Neglect*, 27(2), 169–190. [https://doi.org/10.1016/S0145-2134\(02\)00541-0](https://doi.org/10.1016/S0145-2134(02)00541-0)
- Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, 84(4), 822. <https://doi.org/10.1037/0022-3514.84.4.822>
- Burgess, P. W., Alderman, N., Evans, J., Emslie, H., & Wilson, B. A. (1998). The ecological validity of tests of executive function. *Journal of the International Neuropsychological Society*, 4(6), 547–558. <https://doi.org/10.1017/S1355617798466037>
- Campo-Arias, A., Pedrozo-Pupo, J. C., & Herazo, E. (2021). Review of the COVID-19 pandemic-related perceived stress scale (PSS–10–C). *Revista Colombiana de Psiquiatria (English ed.)*, 50(3), 156. <https://doi.org/10.1016/j.rcpeng.2021.02.002>
- Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural equation modeling: a multidisciplinary journal*, 14(3), 464–504. <https://doi.org/10.1080/10705510701301834>
- Daly, M., & Robinson, E. (2022). Depression and anxiety during COVID-19. *The Lancet*, 399, 518. [https://doi.org/10.1016/S0140-6736\(22\)00187-8](https://doi.org/10.1016/S0140-6736(22)00187-8)
- Datta, D., & Arnsten, A. F. (2019). Loss of prefrontal cortical higher cognition with uncontrollable stress: Molecular mechanisms, changes with age, and relevance to treatment. *Brain Sciences*, 9(5), 113. <https://doi.org/10.3390/brainsci9050113>

- Deng, Y.-Q., Li, S., Tang, Y.-Y., Zhu, L.-H., Ryan, R., & Brown, K. (2012). Psychometric properties of the Chinese translation of the mindful attention awareness scale (MAAS). *Mindfulness*, 3(1), 10–14. <https://doi.org/10.1007/s12671-011-0074-1>
- Diamond, A. (2013). Executive functions. *Annu Rev Psychol* 64, 135–168. <https://doi.org/10.1146/annurev-psych-113011-143750>
- Disner, S. G., Beevers, C. G., Haigh, E. A. P., & Beck, A. T. (2011). Neural mechanisms of the cognitive model of depression. *Nature Reviews Neuroscience*, 12(8), 467–477. <https://doi.org/10.1038/nrn3027>
- Fredrickson, B. L., & Joiner, T. (2002). Positive emotions trigger upward spirals toward emotional well-being. *Psychological Science*, 13(2), 172–175. <https://doi.org/10.1111/1467-9280.00431>
- Garland, E. L., Farb, N. A., Goldin, P. R., & Fredrickson, B. L. (2015). The mindfulness-to-meaning theory: Extensions, applications, and challenges at the attention-appraisal-emotion interface. *Psychological Inquiry*, 26(4), 377–387. <https://doi.org/10.1080/1047840X.2015.1092493>
- Garland, E. L., Fredrickson, B., Kring, A. M., Johnson, D. P., Meyer, P. S., & Penn, D. L. (2010). Upward spirals of positive emotions counter downward spirals of negativity: Insights from the broaden-and-build theory and affective neuroscience on the treatment of emotion dysfunctions and deficits in psychopathology. *Clinical Psychology Review*, 30(7), 849–864. <https://doi.org/10.1016/j.cpr.2010.03.002>
- Hayes, A. F., & Rockwood, N. J. (2020). Conditional process analysis: Concepts, computation, and advances in the modeling of the contingencies of mechanisms. *American Behavioral Scientist*, 64(1), 19–54. <https://doi.org/10.1177/0002764219859633>
- Hill, J. (2003). Childhood trauma and depression. *Current Opinion in Psychiatry*, 16(1), 3–6. <https://doi.org/10.1097/00001504-200301000-00002>
- Im, S., Stavas, J., Lee, J., Mir, Z., Hazlett-Stevens, H., & Caplovitz, G. (2021). Does mindfulness-based intervention improve cognitive function? A meta-analysis of controlled studies. *Clinical Psychology Review*, 84, 101972. <https://doi.org/10.1016/j.cpr.2021.101972>
- Jiang, L., Wang, Y., Zhang, Y., Li, R., Wu, H., Li, C., Tao, Q. (2019). The reliability and validity of the center for epidemiologic studies depression scale (CES-D) for Chinese university students. *Frontiers in Psychiatry*, 10, 315. <https://doi.org/10.3389/fpsy.2019.00315>
- Joormann, J. (2010). Cognitive inhibition and emotion regulation in depression. *Current Directions in Psychological Science*, 19(3), 161–166. <https://doi.org/10.1177/0963721410370293>
- Kreibitz, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology*, 84(3), 394–421. <https://doi.org/10.1016/j.biopsycho.2010.03.010>
- LeMoult, J., & Gotlib, I. H. (2019). Depression: A cognitive perspective. *Clinical Psychology Review*, 69, 51–66. <https://doi.org/10.1016/j.cpr.2018.06.008>
- Lewinsohn, P. M., Joiner Jr, T. E., & Rohde, P. (2001). Evaluation of cognitive diathesis-stress models in predicting major depressive disorder in adolescents. *Journal of Abnormal Psychology*, 110(2), 203. <https://doi.org/10.1037/0021-843X.110.2.203>
- Lindsay, E. K., & Creswell, J. D. (2017). Mechanisms of mindfulness training: Monitor and acceptance theory (MAT). *Clinical Psychology Review*, 51, 48–59. <https://doi.org/10.1016/j.cpr.2016.10.011>
- Liston, C., McEwen, B. S., & Casey, B. (2009). Psychosocial stress reversibly disrupts prefrontal processing and attentional control. *Proceedings of the National Academy of Sciences*, 106(3), 912–917. <https://doi.org/10.1073/pnas.0807041106>
- Liu, Q., & Wang, Z. (2021). Perceived stress of the COVID-19 pandemic and adolescents' depression symptoms: The moderating role of character strengths. *Personality and Individual Differences*, 182, 111062. <https://doi.org/10.1016/j.paid.2021.111062>
- McDermott, L. M., & Ebmeier, K. P. (2009). A meta-analysis of depression severity and cognitive function. *Journal of Affective Disorders*, 119 (1-3): 1–8. <https://doi.org/10.1016/j.jad.2009.04.022>
- Müller, C., Dubiel, D., Kremeti, E., Lieb, M., Streicher, E., Siakir Oglou, N., Mickel, C., & Karbach, J. (2021). Effects of a single physical or mindfulness intervention on mood, attention, and executive functions: Results from two randomized controlled studies in university classes. *Mindfulness*, 12(5), 1282–1293. <https://doi.org/10.1007/s12671-021-01601-z>
- Nikolin, S., Tan, Y. Y., & Schwaab, A., et al. (2021). An investigation of working memory deficits in depression using the n-back task: A systematic review and meta-analysis. *Journal of Affective Disorders*, 284, 1–8. <https://doi.org/10.1016/j.jad.2021.01.084>
- Pedrero-Pérez, E. J., Ruiz-Sánchez-de-León, J. M., & Winpenny-Tejedor, C. (2015). Dysexecutive Questionnaire (DEX): Unrestricted structural analysis in large clinical and non-clinical samples. *Neuropsychological Rehabilitation*, 25(6), 879–894. <https://doi.org/10.1080/09602011.2014.993659>
- Pedrozo-Pupo, J. C., Pedrozo-Cortés, M. J., & Campo-Arias, A. (2020). Perceived stress associated with COVID-19 epidemic in Colombia: An online survey. *Cadernos de Saude Publica*, 36. <https://doi.org/10.1590/0102-311x00090520>
- Pierce, M., Hope, H., Ford, T., Hatch, S., Hotopf, M., John, A., Kontopantelis, E., Roger, W., Simon, W., Abel Kathryn, M., & McManus, S. (2020). Mental health before and during the COVID-19 pandemic: A longitudinal probability sample survey of the UK population. *The Lancet Psychiatry*, 7(10), 883–892. [https://doi.org/10.1016/S2215-0366\(20\)30308-4](https://doi.org/10.1016/S2215-0366(20)30308-4)
- Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88 (5), 879. <https://doi.org/10.1037/0021-9010.88.5.879>
- Radloff, L. S. (1977). The CES-D scale. *Applied Psychological Measurement*, 1(3), 385–401. <https://doi.org/10.1177/014662167700100306>
- Roebbers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental Review*, 45, 31–51. <https://doi.org/10.1016/j.dr.2017.04.001>
- Rogers, M. A., Kasai, K., Koji, M., Fukuda, R., Iwanami, A., Nakagome, K., Fukuda, M., & Kato, N. (2004). Executive and prefrontal dysfunction in unipolar depression: A review of neuropsychological and imaging evidence. *Neuroscience Research*, 50(1), 1–11. <https://doi.org/10.1016/j.neures.2004.05.003>
- Selemon, L. D. (2013). A role for synaptic plasticity in the adolescent development of executive function. *Translational Psychiatry*, 3(3), e238–e238. <https://doi.org/10.1038/tp.2013.7>
- Shorey, S., Ng, E. D., & Wong, C. H. (2022). Global prevalence of depression and elevated depressive symptoms

- among adolescents: A systematic review and meta-analysis. *British Journal of Clinical Psychology*, 61(2), 287–305. <https://doi.org/10.1111/bjc.12333>
- Spada, M. M., Nikčević, A. V., Moneta, G. B., & Wells, A. (2008). Metacognition, perceived stress, and negative emotion. *Personality and Individual Differences*, 44(5), 1172–1181. <https://doi.org/10.1016/j.paid.2007.11.010>
- Tang, Y. Y., Holzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience*, 16(4), 213–225. <https://doi.org/10.1038/nrn3916>
- Tang, Y. Y., Yang, L., Leve, L. D., & Harold, G. T. (2012). Improving executive function and its neurobiological mechanisms through a mindfulness-based intervention: Advances within the field of developmental neuroscience. *Child Development Perspectives*, 6(4), 361–366. <https://doi.org/10.1111/j.1750-8606.2012.00250.x>
- Wang, C., Wen, W., Zhang, H., Ni, J., Jiang, J., Cheng, Y., Zhou, M., Ye, L., Feng, Z., Luo, H., Liu, W., & Ge, Z. (2021). Anxiety, depression, and stress prevalence among college students during the COVID-19 pandemic: A systematic review and meta-analysis. *Journal of American College Health*, 1–8. <https://doi.org/10.1080/07448481.2021.1960849>
- Wu, W., Carroll, I. A., & Chen, P.-Y. (2018). A single-level random-effects cross-lagged panel model for longitudinal mediation analysis. *Behavior Research Methods*, 50(5), 2111–2124. <https://doi.org/10.3758/s13428-017-0979-2>
- Yen, S., Robins, C. J., & Lin, N. (2000). A cross-cultural comparison of depressive symptom manifestation: China and the United States. *Journal of Consulting and Clinical Psychology*, 68(6), 993. <https://doi.org/10.1037/0022-006X.68.6.993>
- Zandifar, A., Badrfam, R., Yazdani, S., Arzaghi, S. M., Rahimi, F., Ghasemi, S., Khamisabadi, S., Mohammadian Khonsari, N., & Qorbani, M. (2020). Prevalence and severity of depression, anxiety, stress and perceived stress in hospitalized patients with COVID-19. *Journal of Diabetes & Metabolic Disorders*, 19(2), 1431–1438. <https://doi.org/10.1007/s40200-020-00667-1>
- Zelazo, P. D. (2020). Executive function and psychopathology: A neurodevelopmental perspective. *Annual Review of Clinical Psychology*, 16(1), 431–454. <https://doi.org/10.1146/annurev-clinpsy-072319-024242>
- Zhu, X., Yan, W., Lin, X., Que, J., Huang, Y., Zheng, H., Liu, L., Deng, J., Lu, L., & Chang, S. (2022). The effect of perceived stress on cognition is mediated by personality and the underlying neural mechanism. *Translational Psychiatry*, 12(1), 199. <https://doi.org/10.1038/s41398-022-01929-7>