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Exploring the influence of learning modality preferences and COVID-19 infection experiences on depressive mood in Chinese students

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The COVID-19 pandemic has significantly impacted the mental health of children and adolescents worldwide. While various factors contributing to this phenomenon have been explored, the role of learning style preferences remains underexamined. This cross-sectional study, conducted between October and November 2020, involved over 20,000 participants, including students from junior high school, senior high school, and undergraduate levels. Significant differences in depressive mood levels were observed among individuals with different learning modality preferences upon the return to traditional, in-person learning. Students with in-person learning preferences exhibited lower depression levels, while students with no preference for either learning style outperformed devotees of remote learning. The highest depression occurred among those endorsing neither learning mode. Importantly, the impact of these preferences on depressive moods was found to be moderated by COVID-19 infection experiences. The findings highlight the nuanced relationship between learning style preferences, COVID-19 infection experiences, and mental health outcomes among students. Acknowledging the moderating effect of infection experiences is crucial for developing targeted interventions and adapting pedagogical approaches post-pandemic. This study contributes valuable insights into the complex relationships shaping the mental well-being of students amidst educational disruptions caused by the pandemic.

Keywords COVID-19 infection experiences, Depressive mood, Learning modality preferences

The COVID-19 pandemic has profoundly impacted the lives and mental health of children and adolescents worldwide[1]. Previous research indicates this population has suffered increased mental health issues due to factors like family situations, social isolation, and individual characteristics[2,3]. Among students, the transition in learning modalities has garnered extensive attention from scholars. Specifically, affected by COVID-19, schools worldwide transitioned from traditional offline teaching to online teaching. This shift was a response to pandemic challenges and the need for continuous education while prioritizing public health and safety[4]. With the expansion of online teaching and learning, many scholars have examined the impact of online education[5,6], and further compared the outcomes of different learning modalities.[7–10]。 Subsequently, research has shifted focus from the methods themselves to how students' perceptions of these methods affect their mental health. For instance, Pelucio et al.[11]. investigated the impact of Brazilian university students' attitudes toward online learning (ranging from very poor to very good) on depression. Similarly, Sergi et al.[12]. examined how the perceived quality of distance learning influences depression. However, one potentially underexamined factor affecting students' mental health is learning modality preferences. After experiencing a period of online learning different from traditional offline learning, students may have gained clearer insights into their preferred learning modalities. Indeed, during the period of online learning, Amir[13] found that undergraduate students of the dentistry program at the Faculty of Dentistry Universitas Indonesia had personal preferences for learning methods. They discovered that 44.2% of

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students preferred distance learning over offline learning. Previous research has shown that individuals' subjective preferences for objective methods significantly impact outcomes[14]. Therefore, this study suggests that we should not overlook the influence of learning modality preferences on students' mental health.

In China, at the very beginning of COVID-19, online learning platforms and tools were also utilized to enable students to attend classes, submit assignments, and engage with educational materials from their homes[15]. As public health conditions improved and schools reopened in September 2020, individuals returned to conventional classrooms.

To clarify whether learning modality preferences can impact students' mental health and to expand on the current studies which have primarily focused on mental health problems caused by the COVID-19 crisis during home quarantine[16], the first objective of this study is to explore the effects of learning modality preferences—such as preferring distant learning, preferring in-person learning, both being acceptable, or neither being acceptable—on depressive mood after returning to traditional in-person learning. Specifically, research indicates that experiencing normal stress in both daily and major life events is linked to an increased likelihood of heightened psychological distress and a greater risk of developing depression and anxiety later in life[17,18]. There is no doubt that learning is a major event for students. Learning occupies a lot of time for children and adolescents. Learning modality preferences reflect personal learning needs which, if satisfied, can improve academic outcomes and mitigate educational stress[13]. Unsatisfied preference alignment however, can adversely influence learning attitudes, confidence, motivation, and other psychological states over time. Besides, switching between online and offline teaching may have different psychological effects on students with different learning modality preferences[19]. For example, students who prefer offline learning may adapt more quickly when they return to class; Students who have adapted to online learning may face even greater pressure to adapt. This can further contribute to mental health disparities. Accordingly, it is vital we investigate if transitioning back to in-person formats induces differential mental health effects depending on prior learning preferences. Such insights can inform support strategies to promote the emotional wellbeing of students amidst these educational disruptions. They also exemplify the need to tailor post-pandemic pedagogical approaches to learning preferences.

Additionally, the investigation also seeks to discern whether COVID-19 infection before returning to offline learning moderates the relationships between learning mode preferences and depressive mood. Previous research suggests that individuals who have infected with COVID-19 may exhibit heightened psychological resilience and coping abilities, potentially leading to a greater appreciation and valuation of learning opportunities[20]. Consequently, for the infected cohort, the influence of learning mode preferences on depressive mood may be diminished due to their increased resilience. Nevertheless, conflicting findings indicate that individuals with a history of COVID-19 infection may manifest depressive symptoms[21], such as low vigor and low dedication[22]. In accordance with this perspective, for the infected group, learning mode preferences may exert a more pronounced influence on depressive mood due to potential challenges in adapting to learning styles incongruent with personal preferences, thereby engendering a sense of compulsion to engage in less preferred activities. Facing the conflicting findings on whether a history of COVID-19 infection leads to heightened psychological resilience and coping abilities or to depressive symptoms, the insights from Lee et al.[23]. and Ozbay et al.[24] may help us better understand this issue. Specifically, Lee et al., through a meta-analysis integrating 33 studies worldwide, concluded that governments that enacted stringent measures to contain the spread of COVID-19 benefitted not only the physical but also the mental health of their populations during the pandemic. Additionally, Ozbay et al.[24]. emphasized that when facing pressures, such as COVID-19 infection experiences, obtaining psychological resilience and external support is crucial. During the COVID-19 outbreak in 2020, the Chinese government indeed enacted stringent measures, providing comprehensive support from material to spiritual aspects. Accordingly, this study suggests that among students in China, experiences of infection may lessen the effect of learning mode preferences on depressive mood. The support and resilience acquired during the pandemic likely helped mitigate the negative effects of learning modality mismatches on depressive mood among infected students. The examination of whether infection experiences moderate the relationship between learning mode preferences and depression aims to enhance our comprehension of the repercussions of COVID-19 infection on affected individuals.

Methods

Study design and participants

This study employed a cross-sectional, face-to-face survey conducted during the period between October and November 2020. To ensure the representativeness of the sample, a randomized selection procedure was implemented, with counties, school buildings, and classes designated as the units of randomization. In the initial stage, ten urban areas and ten suburban areas were randomly chosen from Shaanxi Province. Subsequently, in the second stage, three schools (comprising two junior high schools and one senior high school) were randomly selected from each suburban area, while five schools (comprising two junior high schools, two senior high schools, and one college) were randomly chosen from each urban area. Finally, in the third stage, two classes were randomly chosen from each grade in the selected schools. All participants and their guardians provided written informed consent, and ethical approval for this study was obtained from the Medical Ethical Committee at the Shaanxi Provincial Center for Disease Control and Prevention, China. We ended up with 37,425 responses.

Following the exclusion of questionnaires that did not include information pertinent to the variables of focus in our study, the final sample comprised 22,835 students. Within this sample, 11,215 were male, and 11,620 were female. Furthermore, the distribution across educational levels revealed that 10,487 participants were junior high school students, 9858 were senior high school students, and 2490 were undergraduates.

Variables measurements

Depressive mood is measured by the 4 items from Center for Epidemiologic Studies-Depression Scale (CES-D)[25], which has excellent psychometric properties with adolescents[26]. Participants indicated the presence of four depressive mood during the past 1 week on a four-point scale: "never or occasionally (less than 1 day)" (1); "sometimes (1–2 days)" (2); "often or half of a week (3–4 days)" (3) or "most days of a week or continuously throughout (5–7 days)" (4). The Sample items are "I felt that I could not shake off the blues even with help from my family or friends", "I had crying spells". Cronbach's $\alpha = 0.74$. Items were summed together to form total scores of depressive mood. A higher score indicates more symptoms of depressive mood.

Participants indicated their learning mode preference by responding to the question, "Which learning style do you prefer? (distant learning (1), in-person learning (2), either way (3), neither way (4)."

The other variables are measured as following ways: Whether infected with COVID-19: "I was a COVID-19 patient (1), other cases (0)"; Grade: junior secondary school (1), senior secondary school (2), college (3); Gender: male (1), female (2).

Statistical analyses

In this study, we further utilized fuzzy set qualitative comparative analysis (fsQCA) to examine the moderating effect of COVID-19 infection experience. fsQCA is advantageous over traditional moderation analysis given our smaller sample size in the infected group compared to the non-infected group. fsQCA, based on set theory and Boolean algebra, investigates how interactions among causal conditions collectively lead to an outcome variable[27]. fsQCA requires calibrating raw data into membership scores ranging from 0 to 1 to explore the "degree" to which a condition is present or absent and its impact on the outcome variable. In this context, 1 indicates full membership (high level of the condition), 0 indicates full non-membership (low level of the condition), and 0.5 represents the maximum point of ambiguity (crossover point), where it is unclear whether the condition is at a high or low level. Based on previous research recommendations, values calibrated to 0.5 are converted to 0.5001 to prevent these cases from being excluded during analysis[28]. For the dependent variable, we used the direct calibration method with the 5%, 50%, and 95% benchmarks to convert raw data into fuzzy membership scores. Two concepts are crucial for understanding fsQCA results: consistency and coverage. Consistency of a configuration measures the extent to which members of a supposed subset are also members of the superset. Coverage of a configuration, on the other hand, indicates the percentage of cases in the superset that are also in the supposed subset. As described by Woodside, consistency is analogous to the correlation coefficient, and coverage is analogous to the coefficient of determination in correlation-based techniques such as regression[29,30].

We conducted statistical tests using SPSS 23.0 and fsQCA 3.0 software. In the analyses, two-tailed tests with a p-value of < 0.05 were considered statistically significant. One-way analysis of variance was used for univariate comparisons of depressive mood across gender, grade, learning mode preferences, and infection status. General linear regression was used to analyze the main and interaction effects across the four fixed factors of learning mode preference (distant learning = 1, in-person learning = 2, either way = 3, neither way = 4) and infection status before returning to in-person learning (infected = 1, non-infected = 0), while adjusting for the covariates of grade and gender. Least Significant Difference (LSD) post hoc comparisons were employed to assess variations in means.

Ethics approval and consent to participate

All participants and their guardians provided written informed consent, and ethical approval for this study was obtained from the Medical Ethical Committee at the Shaanxi Provincial Center for Disease Control and Prevention, China. All methods were performed in accordance with the relevant guidelines and regulations.

Results

Sample characteristics and the degree of depressive mood

The depressive mood levels among 22,835 young individuals over the past week ranged from 4 to 16, with a mean of 5.94 and a standard deviation of 2.42. The distribution exhibited a kurtosis of 2.57 and a skewness of 1.60. Notably, 8921 participants (39.1%) reported either never experiencing or only occasionally experiencing depressive moods during the last week, while 132 participants reported experiencing depressive moods most days of the week or continuously throughout the past week.

As illustrated in Table 1, significant variations in depressive mood levels over the past week were observed across different grades and learning mode preferences, as well as in individuals who had been infected compared to those who had not. However, no statistically significant difference was observed between individuals of different genders.

We additionally performed Least Significant Difference (LSD) post hoc comparisons to assess variations in means among the distinct categories of learning mode preferences. As indicated in Table 2, the four categories exhibit a significant difference in depressive mood upon returning to traditional, in-person learning. Notably, individuals who favor in-person learning reported the lowest levels of depressive mood (mean = 5.75, SD = 2.27), while those with a preference against both learning modalities demonstrated the highest levels of depressive mood (mean = 7.28, SD = 3.24).

The results of general liner regression

Table 3 presents the outcomes of comparisons of depressive mood scores based on learning modality preference and experiences with COVID-19 infection. The main effect for depressive mood was found to be significant ($\eta 2 = 0.001$, $p < 0.01$), signifying variations in depressive mood levels attributed to learning modality preference. Furthermore, the interaction effect for Learning Modality Preference * Ever Been Infected was also significant

Variables	Total, n	The degree of depressive mood ± SD	F	P
Gender				
Male	11,215	5.96 ± 2.43	0.93	ns
Female	11,620	5.93 ± 2.41		
Grade			117.59	
Junior high school	10,487	5.80 ± 2.47		p < 0.001
Senior high school	9858	6.20 ± 2.45		
College	2490	5.50 ± 1.90		
Learning mode preference				
Distant-learning	2899	6.37 ± 2.73		
In-person learning	9841	5.75 ± 2.27	89.07	p < 0.001
Either way	9750	5.96 ± 2.40		
Neither way	345	7.28 ± 3.24		
Ever been infected with COVID-19				
Yes	71	4.78 ± 1.91	16.24	p < 0.001
No	22,764	5.95 ± 2.42		

Table 1. Demographic characteristics of the study sample (n = 22,835). *SD* standard deviance, *ns* non-significant.

Learning mode preference		Mean difference ± SD	P value
1 6.37(2.73)	2	0.63 ± 0.05	< 0.001
	3	0.42 ± 0.05	< 0.001
	4	− 0.91 ± 0.14	< 0.001
2 5.75(2.27)	1	− 0.63 ± 0.05	< 0.001
	3	− 0.21 ± 0.03	< 0.001
	4	− 1.54 ± 0.13	< 0.001
3 5.96(2.40)	1	− 0.42 ± 0.05	< 0.001
	2	0.21 ± 0.03	< 0.001
	4	− 1.32 ± 0.13	< 0.001
4 7.28(3.24)	1	0.91 ± 0.14	< 0.001
	2	1.54 ± 0.13	< 0.001

Table 2. The result of post hoc analysis among the distinct categories of learning mode preferences. *SD* standard deviance. Distant learning = 1, in-person learning = 2, either way = 3, neither way = 4.

	Gender	Grade	Learning mode preference	Ever been infected	Learning modality preference * Ever been infected
Depressive mood	0.000, 1.041, ns	0.000, 5.060, < 0.05	0.001, 7.432, < 0.001	0.000, 2.724, ns	0.001, 6.376, < 0.001

Table 3. Effect sizes for the associations between depression, gender, comorbid problems and depression (η2, F, p). *Ns* non-significant.

(η2 = 0.001, p < 0.001), suggesting infection-specific distinctions in the dependent variables concerning learning modality preference.

As shown in Table 4, the paired comparisons revealed that within the non-infection group, the four categories displayed a significant difference in depressive mood upon transitioning back to traditional, in-person learning. Conversely, within the infection group, Significant intergroup differences were found only between students who dislike both learning modalities and the other three preference groups, while no intergroup differences were observed among the remaining three groups.

We then employed fsQCA for our analysis. First, we conducted a necessity analysis to check if any antecedent conditions were necessary for the outcome[27]. A necessary condition implies that without this condition, the outcome cannot occur. According to the QCA results, non-infection was shown to be a necessary condition for depressive mood (consistency = 0.99, coverage = 0.44), while infection was not a necessary condition for depressive mood (consistency = 0.001, coverage = 0.19) (Table 5).

Infected or not before returning to in-person learning	Learning mode preference Mean (SD)		Mean difference ± SD	P value
No	1 6.42(0.05)	2	0.67 ± 0.05	< 0.001
		3	0.46 ± 0.05	< 0.001
		4	− 0.8 ± 0.14	< 0.001
	2 5.75(0.02)	1	− 0.67 ± 0.05	< 0.001
		3	− 0.21 ± 0.03	< 0.001
		4	− 1.52 ± 0.13	< 0.001
	3 5.96(0.02)	1	− 0.46 ± 0.05	< 0.001
		2	0.21 ± 0.03	< 0.001
		4	− 1.30 ± 0.13	< 0.001
	4 7.26(0.13)	1	0.85 ± 0.14	< 0.001
		2	1.52 ± 0.13	< 0.001
		3	1.30 ± 0.13	< 0.001
Yes	1 4.45(0.33)	2	− 0.75 ± 0.80	ns
		3	− 0.69 ± 0.97	ns
		4	− 10.60 ± 2.42	< 0.001
	2 5.20(0.72)	1	0.75 ± 0.80	ns
		3	0.06 ± 1.16	ns
		4	− 9.85 ± 2.51	< 0.001
	3 5.14(0.91)	1	0.69 ± 0.97	ns
		2	− 0.06 ± 1.16	ns
		4	− 9.92 ± 2.57	< 0.001
	4 15.05(2.40)	1	10.60 ± 2.42	< 0.001
		2	9.85 ± 2.51	< 0.001
		3	9.92 ± 2.57	< 0.001

Table 4. The results of paired comparison. *SD* standard deviance, *ns* non-significant.

Conditional variables	Outcomes			
	High depressive mood		Low depressive mood	
	Consistency	Coverage	Consistency	Coverage
Distant learning	0.57	0.46	0.54	0.54
-Distant learning	0.43	0.43	0.46	0.57
In-person learning	0.84	0.43	0.87	0.57
-In-person learning	0.16	0.50	0.13	0.50
Infection	0.00	0.19	0.00	0.81
-Infection	0.99	0.44	0.99	0.56

Table 5. The necessity test results of single condition with the QCA method.

Additionally, to examine whether there are differences in the impact of the four learning modality preferences on depressive mood within the infected group, we analyzed the data using fsQCA, which can handle equifinality (the concept that multiple different configurations can lead to the same outcome). Specifically, we focused our analysis solely on the infected group to explore the variations in depressive mood associated with different learning modality preferences. The results indicated that only the group disliking both learning modalities had an impact on depressive mood (raw coverage = 0.024, unique coverage = 0.025, consistency = 1).

Therefore, the QCA results also support the moderating effect of COVID-19 infection experiences proposed in this study.

Discussion

The principal aim of this study was to understand the effect of learning modality preferences on depressive mood in children and adolescents after returning to in-person learning. Additionally, we intended to explore the moderating effects of COVID-19 infection experience prior to the return to offline learning. Results from cross-sectional data of 22,835 students revealed that students who preferred on-site learning exhibited lower levels of depression upon returning to the classroom compared to peers who preferred online formats. Additionally, those reporting no particular preference outperformed remote learning devotees on mental health metrics. However,

the highest depression occurred among individuals endorsing neither learning mode—the most maladaptive preference category. The impact of the pandemic exposure mitigated these group differences. Specifically, among infected young individuals, no intergroup differences were observed across the three learning style preferences, namely, distant learning, offline learning, and either way.

These findings carry substantive theoretical and practical implications. Foremost, they provide initial evidence that satisfying personalized learning needs promotes youth psychological wellbeing amidst educational disruptions. During the pandemic, the mental health of young people has garnered significant attention. Scholars have investigated various factors that could impact their psychological well-being, including gender, exercise, pre-pandemic depression levels, and other individual characteristics, as well as family factors such as parental work and income[1,31–38]. Witt et al.[39] pointed out that a significant change brought about by the pandemic for young individuals is the alteration in their learning modes. This type of impact brought about by the pandemic, specifically the shift to online learning, has garnered attention from various sectors[5,6]. Furthermore, comparisons have been made between online and offline learning modes[8,9]. Building upon these studies, this research, based on Chinese students as the sample, further explores the impact of learning modality preferences on mental health after they have fully resumed offline learning. Due to varying preferences for the same objective methods, the effects brought about by these objective phenomena may also differ greatly[40,41]. This study reveals that after returning to offline education, learning modality preferences influence depressive moods. Students able to resume their self-described optimal approach seemingly rebounded more positively. Those deprived of their favored methodology, however, especially those rejecting both formats, remain emotionally vulnerable. This study expands current research on the impact of learning modes on students' mental health. For practitioners and administrators, these findings highlight the potential benefits of accounting for heterogeneous learning preferences amidst post-pandemic educational transitions. Specifically, education policies emphasizing uniform standards often overlook such preference heterogeneity. Though logistically challenging, school districts could consider surveying students to gauge individualized learning style inclinations as conventional classroom formats resume. Where possible, offering temporary hybrid learning structures, with some in-person and some remote components, may help accommodate a diversity of preferences during this psychologically precarious transition period. Additionally, in everyday education, students may switch between online and offline learning due to factors such as severe weather. This study suggests that administrators should guide students in appropriately adapting to different learning methods during these temporary transitions.

Secondly, numerous scholars have delved into the inquiry of whether infected by COVID-19 or not, significantly influence individual's mental health outcomes. However, consensus remains elusive. For instance, Taquet et al.[42]identified an association between a COVID-19 diagnosis and heightened rates of mental health disorders subsequent to the diagnosis. Conversely, Sun et al.[20] posited that COVID-19 patients might exhibit enhanced resilience and a heightened appreciation for life. Our investigation contributes to this discourse by demonstrating that the presence or absence of a COVID-19 infection can moderate the impact of learning mode preferences on depressive mood. Notably, among infected youths, no statistically significant group differences emerged based on diverse learning mode preferences, aligning with the observations that experiences of infection may potentially enhance resilience. External support is an important condition for obtaining resilience when facing pressure[43]. Lee et al.[23] concluded that governments implementing strict measures to control the transmission of COVID-19, while offering aid and assistance to citizens, would positively impact their mental well-being. China provided both material and spiritual assistance and implemented rigorous epidemic prevention and control policies for its people during the pandemic, which likely facilitated the acquisition of resilience among students. This study, through findings based on student sample, once again validates the conclusions of Lee et al.[23] and the significant role of external support when facing external pressures. Synthesizing insights from preceding studies, our work extends understanding by revealing that experiences of COVID-19 patients not only exert a direct influence on individual mental health but also serve as a pivotal contextual factor. Moreover, the necessity for further exploration of COVID-19 experiences in shaping mental health outcomes, either as a direct effect or as a moderating variable, is underscored. This is also enlightening for practitioners and administrators, suggesting that in the face of stressful events, measures should be taken to support and guide adolescents, enabling them to harness positive energy.

While the influence of gender on depressive symptoms during the COVID-19 period is not the primary focus of this study, it is noteworthy that many previous researches have identified gender as a significant factor affecting mental health[44]. However, our data reveals no significant differences in depressive symptoms between genders among young individuals. We posit that this observation may be associated with the timing of data collection. The temporal dimension of data collection, in relation to the progression of the pandemic, is a crucial consideration. Mental health responses are dynamic and may evolve over time; therefore, variations in study outcomes could be attributed to the distinct phases of the pandemic during which studies were conducted. Furthermore, during the pandemic, the relationship between gender and depressive symptoms may not be straightforward, as it is likely influenced by various contextual factors. Future research endeavors should adopt a more granular approach, considering nuanced aspects and potential moderating variables that may contribute to a comprehensive understanding of the interplay between gender and depressive outcomes during the pandemic.

Strengths, limitations and future research directions

This study have some strengths. Firstly, our sample consists of over 20,000 participants, providing a substantial and representative dataset that enhances the reliability of our research findings. Furthermore, our study involved in-person data collection, contributing to the authenticity and reliability of participants' responses.

Several limitations should also be noted in this study. First, in our study, we only focused on the impact of learning modality preferences on depressive mood. Future research could examine the influence of learning

modality preferences on other aspects of mental health, such as the other three CES-D factors, the overall CES-D score, anxiety, vigor. Additionally, future studies could explore whether students' preferences for learning environments and learning media have an impact on their mental health. Second, due to the impact of China's policies, students had a low infection rate when returning to offline teaching, which may render our findings less robust. We hope that more research will be conducted to explore these issues further, leading to more robust research findings. Thirdly, this study is cross-sectional in nature, limiting the ability to establish causality between variables.

Conclusion

In conclusion, our study illuminates the nuanced relationships among learning mode preferences, COVID-19 infection experiences, and mental health outcomes in young individuals. The findings underscore the need for personalized support and targeted interventions, guiding the evolving landscape of post-pandemic education and informing strategies for enduring mental well-being. The fsQCA results indicate that non-infection is a necessary condition. This suggests that the COVID-19 infection experiences has reduced the differences of depressive mood between different learning modality preferences groups. Specifically, among the infected youth, no intergroup differences were observed among the three learning modalities (i.e., remote learning, offline learning, and either one).

Data availability

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

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References

1. Fegert, J. M., Vitiello, B., Plener, P. L. & Clemens, V. Challenges and burden of the Coronavirus 2019 (COVID-19) pandemic for child and adolescent mental health: A narrative review to highlight clinical and research needs in the acute phase and the long return to normality. *Child Adolsc. Psychiatry Mental Health* **14**, 20 (2020).
2. Bouter, D. C. *et al.* A longitudinal study of mental health in at-risk adolescents before and during the COVID-19 pandemic. *Eur. Child. Adolesc. Psychiatry.* **32**, 1109–1117 (2023).
3. Kessler, R. C. *et al.* Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Arch. Gen. Psychiatry* **62**, 593–602 (2005).
4. Mortagy, M. *et al.* Online medical education in Egypt during the COVID-19 pandemic: A nationwide assessment of medical students' usage and perceptions. *BMC Med. Educ.* **22**, 218 (2022).
5. Bird, K. A., Castleman, B. L. & Lohner, G. Negative impacts from the shift to online learning during the COVID-19 Crisis: Evidence from a Statewide Community College System. *Aera Open* **8**, 398561276 (2022).
6. Zhou, J. *et al.* Prevalence of depression and its correlative factors among female adolescents in China during the coronavirus disease 2019 outbreak. *Glob. Health* **16**, 69 (2020).
7. Bender, J. L. *et al.* Training prostate cancer survivors and caregivers to be peer navigators: A blended online/in-person competency-based training program. *Support Care Cancer* **29**, 1235–1244 (2021).
8. Vaillancourt, T. *et al.* In-person versus online learning in relation to students' perceptions of mattering during COVID-19: A brief report. *J. Psychoeduc. Assess.* **40**, 159–169 (2022).
9. Cox, C. F., Messiah, S. E. & Knell, G. Learning modality and quality of life among US school-age children during the coronavirus pandemic. *J. School Health* **93**, 441–449 (2023).
10. Basagaoglu, D. Z. & Buyukcavus, M. H. Effect of distance learning on the quality of life, anxiety and stress levels of dental students during the COVID-19 pandemic. *BMC Med. Educ.* **22**, 309 (2022).
11. Pelucio, L., Simoes, P., Dourado, M., Quagliato, L. A. & Nardi, A. E. Depression and anxiety among online learning students during the COVID-19 pandemic: A cross-sectional survey in Rio de Janeiro, Brazil. *BMC Psychol.* **10**, 192 (2022).
12. Sergi, M. R. *et al.* Psychometric properties of a new instrument for the measurement of the perceived quality of distance learning during the coronavirus disease 2019 (COVID-19) pandemic. *Front. Psychol.* **14**, 1169957 (2023).
13. Amir, L. R. *et al.* Student perspective of classroom and distance learning during COVID-19 pandemic in the undergraduate dental study program Universitas Indonesia. *BMC Med. Educ.* **20**, 392 (2020).
14. Dobson, J. L. Learning style preferences and course performance in an undergraduate physiology class. *Adv. Physiol. Educ.* **4**, 308–314 (2009).
15. Riedl, D. & Schuessler, G. Prevalence of depression and cancer: A systematic review. *Z. Psychosom. Med. Psychol.* **68**, 74–86 (2022).
16. Wang, J. *et al.* Mental health problems among school-aged children after school reopening: A cross-sectional study during the COVID-19 post-pandemic in East China. *Front. Psychol.* **12**, 773134 (2021).
17. van Winkel, M. *et al.* Daily life stress reactivity in remitted versus non-remitted depressed individuals. *Eur. Psychiatr.* **30**, 441–447 (2015).
18. Kim, S. M., Jeong, Y. M., Park, H. S. & Choi, S. Mental health of South Korean adolescents in the COVID-19 Era: Web-based survey focused on suicide-related factors. *Child Adolsc. Psychiatry Mental Health* **17**, 117 (2023).
19. Melo, G., Monteza, D., Colson, G. & Zhang, Y. Y. How to assess? Student preferences for methods to assess experiential learning: A best-worst scaling approach. *PLoS ONE* **17**, e276745 (2022).
20. Sun, N. *et al.* Qualitative study of the psychological experience of COVID-19 patients during hospitalization. *J. Affect. Disord.* **278**, 15–22 (2021).
21. Holmes, E. A. *et al.* Multidisciplinary research priorities for the COVID-19 pandemic: A call for action for mental health science. *Lancet Psychiatry* **7**, 547–560 (2020).
22. Zhang, M. *et al.* Influence of perceived stress and workload on work engagement in front-line nurses during COVID-19 pandemic. *J. Clin. Nurs.* **30**, 1584–1595 (2021).
23. Lee, Y. *et al.* Government response moderates the mental health impact of COVID-19: A systematic review and meta-analysis of depression outcomes across countries. *J. Affect. Disord.* **290**, 364–377 (2021).
24. Ozbay, F. *et al.* Social support and resilience to stress: From neurobiology to clinical practice. *Psychiatry* **4**, 35–40 (2007).
25. Yang, W. *et al.* Factor structure and criterion validity across the full scale and ten short forms of the CES-D among Chinese adolescents. *Psychol. Assess.* **30**, 1186–1198 (2018).

26. Radloff, L. S. The CES-D scale: A self-report depression scale for research in the general population. *Appl. Psychol. Meas.* **2**, 149–166 (1977).
27. Fiss, P. C. A set-theoretic approach to organizational configurations. *Acad. Manage. Rev.* **4**, 1180–1198 (2007).
28. Crilly, D., Zollo, M. & Hansen, M. T. Faking it or muddling through? Understanding decoupling in response to stakeholder pressures. *Acad. Manage J.* **55**, 1429–1448 (2012).
29. Woodside, A. G. Moving beyond multiple regression analysis to algorithms: Calling for adoption of a paradigm shift from symmetric to asymmetric thinking in data analysis and crafting theory. *J. Bus. Res.* **66**, 463–472 (2013).
30. Gao, Q., Jia, G., Fu, E., Olufadi, Y. & Huang, Y. A configurational investigation of smartphone use disorder among adolescents in three educational levels. *Addict. Behav.* **103**, 106231 (2020).
31. Taquet, M., Luciano, S., Geddes, J. R. & Harrison, P. J. Bidirectional associations between COVID-19 and psychiatric disorder: Retrospective cohort studies of 62 354 COVID-19 cases in the USA. *Lancet Psychiatry* **8**, 130–140 (2021).
32. Larsen, L., Schauber, S. K., Holt, T. & Helland, M. S. Longitudinal Covid-19 effects on child mental health: Vulnerability and age dependent trajectories. *Child Adolsc. Psychiatry Mental Health* **17**, 104 (2023).
33. Reger, M. A., Stanley, I. H. & Joiner, T. E. Suicide mortality and coronavirus disease 2019: A perfect storm?. *Jama Psychiatry* **77**, 1093–1094 (2020).
34. Brooks, S. K. *et al.* The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. *Lancet* **395**, 912–920 (2020).
35. Segovia, M. S., Huseynov, S., Palma, M. A. & Nayga, R. M. The mental burden of stay-at-home order extensions during COVID-19. *Sci. Rep.* **14**, 4293 (2024).
36. Leigh, J. P. *et al.* A muti-informant national survey on the impact of COVID-19 on mental health symptoms of parent–child dyads in Canada. *Sci. Rep.* **13**, 7972 (2023).
37. Yuan, J., Xu, F., Ren, H., Chen, M. & Feng, S. Distress and its influencing factors among Chinese patients with incidental pulmonary nodules: A cross-sectional study. *Sci. Rep.* **14**, 1189 (2024).
38. Metherell, T. E., Ghai, S., McCormick, E. M., Ford, T. J. & Orben, A. Digital access constraints predict worse mental health among adolescents during COVID-19. *Sci. Rep.* **12**, 19088 (2022).
39. Witt, A., Ordóñez, A., Martin, A., Vitiello, B. & Fegert, J. M. Child and adolescent mental health service provision and research during the Covid-19 pandemic: Challenges, opportunities, and a call for submissions. *Child Adolsc. Psychiatry Mental Health* **14**, 8 (2020).
40. Swift, J. K., Mullins, R. H., Penix, E. A., Roth, K. L. & Trusty, W. T. The importance of listening to patient preferences when making mental health care decisions. *World Psychiatry* **20**, 316–317 (2021).
41. Fahrudin, D. S. S. S. Identifying the Learning style and learning resource preferences of junior high school students after the covid-19 pandemic in Surakarta. *Paper presented at: Proceedings of the 4th International Conference Entitled Language, Literary, And Cultural Studies* (2023).
42. Kohlboeck, G., Wenter, A., Sevecke, K. & Exenberger, S. Differences in perceived threat and trauma in children during the COVID-19 pandemic. *Child Adolsc. Psychiatry Mental Health* **17**, 83 (2023).
43. Zbay, F. J. D. C. Social support and resilience to stress: From neurobiology to clinical practice. *Psychiatry* **5**, 35–40 (2007).
44. Ma, L. *et al.* Prevalence of mental health problems among children and adolescents during the COVID-19 pandemic: A systematic review and meta-analysis. *J. Affect. Disord.* **293**, 78–89 (2021).

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