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Cross-lagged panel analysis of the relationship between social networking sites use (SNSU) and sleep problems among university students

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Abstract

Background Sleep remains a cornerstone for sociopsychological well-being, but it is in decline, especially among today's youth. Simultaneously, engagement with social media is escalating. Research has identified a link between social networking sites use and sleep problems; however, the nature and direction of the relations remain obscure. Therefore, it is imperative to pursue longitudinal research to elucidate this correlation and guide suitable intervention practices. The present study aimed to examine the reciprocal relationship between social networking sites use and sleep problems.

Methods By adopting a three-stage cross-lagged design across four time points, assessment results from 194 university students were gathered at four-week intervals.

Results The findings indicate that (1) Social networking sites use was significantly greater in females than in males at all four time points, while sleep problems were significantly greater in females than in males at Time 3 and Time 4. (2) Sleep problems at the second time point serve as a positive predictor of subsequent social networking sites use at the third time point. (3) Social networking sites use at the initial time point could marginally significantly predict sleep problems at the fourth time point.

Conclusions This study elucidates the dynamic relationship between social networking sites use and sleep problems across an academic term, suggesting the need for temporally tailored interventions.

Keywords Social networking sites use, Sleep problems, Cross-lagged panel design, University students

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Introduction

Throughout the course of an individual's life, sleep is an essential determinant of their sociopsychological well-being [1]. A lack of adequate sleep has been implicated in propelling adolescents toward heightened levels of anxiety, depression, emotional instability, suicidal thoughts, and substance misuse [2–4]. Furthermore, it is correlated with compromised judgment, diminished motivation, and a reduction in overall quality of life [5, 6].

In the context of contemporary societal trends, there has been a notable decline in sleep duration among young people, a phenomenon that has unfolded alongside the surge in social media engagement [7]. Research has found that adolescents using social media within 30 min before bed is independently associated with disturbed sleep [8]. Nighttime-specific social media use and emotional investment in social media are significantly predictive of poorer sleep quality [9]. Frequent social media interaction via email and instant messaging within one hour before bed is significantly correlated with perceived sleep insufficiency [10]. Adolescents with prolonged social media use are more likely to go to bed late, wake up late, and experience difficulty falling back asleep after waking during the night [11]. Many studies have found that women engage in SNSU more frequently than men [12, 13] and experience more sleep problems than men [14–16]. Therefore, this study hypothesizes that females are more likely to have higher SNSU and more sleep problems compared to males.

Social networking sites provide rich social content that is easily accessible to young people at any hour, day or night, in contrast to other forms of media. The following discussion outlines multiple mechanisms through which SNSU may be associated with poorer sleep. This accessibility may lead to a decrease in sleep time due to the Time Displacement Hypothesis [17], potentially intensifying the adverse effects of social networking sites on sleep [18]. Additionally, missing out on online interactions may negatively impact adolescents' online relationships and social status [19, 20]. As a result, if adolescents have not engaged with social networking sites for an extended period, they may frequently feel threatened or anxious, which increases their physiological arousal and makes it harder for them to fall asleep. However, even when adolescents are actively using social networking sites and not missing any social interaction, the resulting high arousal state can still affect their sleep. For example, Mauri et al. found that using Facebook can induce a psychophysiological state characterized by high valence and high arousal [21], which may make it more difficult for adolescents to fall asleep. Furthermore, the accessibility of social networking sites makes it easier for young people to use them in bed and more difficult to disconnect at night, exposing them to bright screen light that disrupts the secretion of melatonin [22, 23], thereby adversely affecting their quality of sleep [19, 24]. Research has established that the light from iPads, when utilized for social networking sites at night, can deteriorate the quality of sleep [25]. In conclusion, an amalgamation of theoretical perspectives and empirical findings support the assertion that SNSU is a significant agent contributing to sleep-related difficulties.

An interventional experiment revealed that stopping the use of electronic devices 1 h before bed can improve sleep outcomes [26]. Therefore, it is plausible that if pre-sleep SNSU habits change, sleep problems may also improve. This experimental research suggests that SNSU could be a contributing factor to sleep problems. However, there is currently a lack of longitudinal evidence to support this explanation. Thus, it is essential to further investigate the relationship between pre-sleep SNSU habits and sleep problems through longitudinal studies, although it is important to note that such studies do not establish causality but can provide valuable insights into the temporal associations between the two.

Moreover, is poor sleep a consequence of SNSU, or does it precede it? In reality, many people with sleep problems resort to social networking sites as a coping strategy or aid. This means that sleep problems may lead to increased SNSU. According to the Uses and Gratifications Theory (UGT), people adopt new technologies to fulfill particular needs [27]. Social networking sites can satisfy human needs for knowledge, relaxation, social interaction, companionship, leisure, and/or escapism [28]. Research has found that using Facebook can evoke a psychophysiological state characterized by high positive valence and high arousal, indicating that users experience a positive emotional state when engaging with social networking sites [21]. Therefore, when individuals experience sleep problems, they may turn to social networking sites to find pleasure and pass the time, which increases the likelihood of SNSU. In fact, Eggermont and Van den Bulck reported that 36.7% of respondents reported using television as a means to help them fall asleep [29]; hence, social networking sites may play a similar role. A longitudinal study indicated that the more severe the insomnia, the more time college students spent on social networking sites, but a reverse prediction has not been established [30]. This finding suggests that sleep problems may be a potential predictor of social networking site use. However, this study measured social networking sites use in terms of time spent. Would the same results hold if social networking site use were measured in terms of intensity? Furthermore, as most current research is cross-sectional and the few existing longitudinal studies contain contradictory forecast directions, it is crucial to further explore whether the relationship between SNSU and sleep problems is unidirectional or bidirectional.

Multiple-timepoint longitudinal studies can reveal the relationships in more detail.

The purpose of this longitudinal study was to further investigate the relationship between SNSU and sleep problems, thus providing useful insights for practical intervention work. We hypothesize that there is a bidirectional predictive relationship between SNSU and sleep problems. This study provides important insights for future research on the interaction between SNSU and sleep problems, as well as on the time span used in longitudinal study designs.

Methods

Participants

Participants for this study were recruited from three general elective courses at a university in Shandong Province. Those who completed all the measurements received bonus course credits. Participants were required to complete four questionnaires, each approximately one month (4 weeks) apart. The initial measurement involved 198 participants, with a few students dropping out during the following three measurements. Ultimately, only data from participants who completed all four measurements were retained, resulting in a total of 194 participants. There were 69 males (35.6%), and 125 females (64.4%). The average age of the participants was 21.80 ± 1.20 years.

Measurement tools

SNSU

The Intensity of SNS use Scale [31], which was modified from The Facebook Intensity Scale [32], was used. The questionnaire consists of eight items, with the first two measuring the number of friends and average daily usage time on social networking sites, while the remaining six items measure the emotional bond with the social networking sites and the degree to which it is integrated into an individual's life. Due to varying scales between the initial two items and the remaining six items, for the sake of computational convenience, only the latter six items were utilized. These items were assessed using a 5-point Likert scale, where 1 indicates "strongly disagree" and 5 indicates "strongly agree." Example items include "I would feel very upset if the social network site was shut down" and "Logging into social network sites has become a daily habit for me." The scores from these six items were summed to yield a total score, with higher scores indicating a greater intensity of SNSU. The internal consistency reliability (Cronbach's alpha) of the questionnaire at the four time points ranged from 0.89 to 0.91.

Sleep problems

The Chinese version of the Pittsburgh Sleep Quality Index (PSQI) [33] was used to measure sleep problems. The original English version was developed by Buysse et al. [34] and assessed subjective sleep quality during the preceding month. The questionnaire consisted of 19 self-reported items and 5 other-rated items, with the 19th item and the 5 other-rated items not included in the scoring. Thus, only 18 items were utilized in this study. These 18 items comprised seven components: sleep quality, sleep latency, sleep duration, sleep efficiency, sleep problems, hypnotic drug usage, and daytime dysfunction. Each component was scored on a scale of 0 to 3, with the total PSQI score being the sum of the component scores, ranging from 0 to 21. Higher scores indicate more serious sleep problems. In this study, the internal consistency reliability (Cronbach's alpha) of the PSQI at the four time points ranged from 0.70 to 0.81.

Procedure and data analysis

There were four measurement time points in total. The first measurement was conducted in the third week after the beginning of the school term in September 2022, with subsequent measurements taken every four weeks thereafter, continuing through January 2023. Each measurement was carried out as an in-class online test using smartphones, with participants scanning QR codes displayed on the multimedia system of the class to access the test. Before commencing the test, uniform instructions were provided, and any uncompleted items were flagged by the system before questionnaire submission to avoid missing values. Descriptive statistics were computed using SPSS 18.0, while cross-lagged model analysis was performed using Amos 24.0.

Results

Descriptive statistics and correlation analysis on SNSU and sleep problems

Pearson product-moment correlation analysis (Table 1) indicated that SNSU exhibited significant correlations across all time points ($0.66 \le r \le 0.77$, $ps < 0.01$), as did sleep problems ($0.49 \le r \le 0.66$, $ps < 0.01$), suggesting high across-time stability for both variables. Furthermore, the correlations between SNSU at Time 1 (t1) and sleep problems at Time 4 (t4) reached a marginally significant level ($p < 0.1$).

Independent sample t tests (Table 2) revealed that SNSU was significantly greater in females than in males at all 4 time points ($ps < 0.01$), while sleep problems, except for at Time 1 and Time 2, were significantly greater in females than in males at Time 3 ($p < 0.01$) and Time 4 ($p < 0.01$).

Cross-lagged model analysis

To explore the longitudinal relationship between SNSU and sleep problems, structural equation modeling (SEM) was used to analyze six competing cross-lagged models, and the results are shown in Table 3.

Table 1 Descriptive statistics and correlation analysis of SNSU and sleep problems

	1	2	3	4	5	6	7	8
1. SNSU (t1)	—							
2. SP (t1)	-0.03	—						
3. SNSU (t2)	0.74**	-0.10	—					
4. SP (t2)	0.03	0.56**	-0.04	—				
5. SNSU (t3)	0.66**	-0.03	0.71**	0.11	—			
6. SP (t3)	0.09	0.58**	-0.07	0.65**	0.08	—		
7. SNSU (t4)	0.66**	-0.07	0.72**	0.08	0.77**	0.02	—	
8. SP (t4)	0.14†	0.49**	0.02	0.60**	0.09	0.65**	0.07	—
M ± *SD*	19.35 ± 5.08	5.65 ± 2.47	19.60 ± 4.74	4.97 ± 2.63	19.39 ± 4.64	4.99 ± 2.82	19.34 ± 4.77	4.89 ± 2.83

Note: SNSU = Social Networking Sites Use; SP = Sleep Problems. t1, t2, t3, and t4 represent different time points. $^{\dagger}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$

Table 2 Gender differences in SNSU and sleep problems at four time points

	Gender	*N*	M	SD	Sig.
SNSU (t1)	Male	69	17.75	5.38	0.001
	female	125	20.22	4.70	
SP (t1)	Male	69	5.32	2.90	0.168
	female	125	5.83	2.21	
SNSU (t2)	Male	69	18.36	5.39	0.007
	female	125	20.28	4.22	
SP (t2)	Male	69	4.72	2.76	0.338
	female	125	5.10	2.56	
SNSU (t3)	Male	69	17.70	4.71	0.000
	female	125	20.32	4.34	
SP (t3)	Male	69	4.13	2.83	0.001
	female	125	5.47	2.71	
SNSU (t4)	Male	69	17.17	4.99	0.000
	female	125	20.53	4.21	
SP (t4)	Male	69	4.04	2.86	0.002
	female	125	5.35	2.72	

Note: SNSU = Social Networking Sites Use; SP = Sleep Problems. t1, t2, t3, and t4 represent different time points

Model 1 (M1) is a baseline model without any cross-lagged paths, containing only autoregressive paths for SNSU and sleep problems (including across-time autoregressive paths to increase model fit) [35], correlations between variables at Time 1 (t1), and residual correlations for the subsequent three time points (t2, t3, t4). Model 2 (M2) adds paths from SNSU to sleep problems to Model 1. Model 3 (M3) adds paths from sleep problems to SNSU to Model 1. Model 4 (M4) is a full model that includes all paths from the aforementioned models. Model 5 (M5) adds the path from SNSU at Time 1 (t1) to sleep problems at Time 4 (t4) to Model 4. Model 6 (M6) adds the path from SNSU at Time 1 (t1) to sleep problems at Time 4 (t4) to Model 3.

A comparison of the models is shown in Table 3. Non-significant disparities were observed when contrasting M2 with M1, M4 with M1, M4 with M3, and M5 with M3. However, M3 demonstrated a superior fit over M1, M4 outperformed M2, M5 outperformed M4, and M6 was superior to M3 (reaching marginal significance). Consequently, Model 6 (M6) has been shown to have the most robust fit among the six models evaluated and was subsequently utilized to examine the longitudinal association between SNSU and sleep problems.

The specific results for Model 6 are provided in Fig. 1. To maintain clarity, only significant cross-lagged paths are presented in Fig. 1. The results showed that the positive predictive effect of SNSU at time point 1 on sleep problems at time point 4 reached a marginally significant level, and the positive predictive effect of sleep problems at time point 2 on SNSU at time point 3 reached a significant level.

Discussion

Gender differences in SNSU and sleep problems

This study revealed significant gender disparities in SNSU and sleep problems at various time points, with

Table 3 Comparison of the fit indices of each model

	Fit index of each model							Model comparison		
	χ^2	*df*	CFI	TLI	SRMR	RMSEA		$\Delta\chi^2$	Δdf	*p*
M1	27.58	12	0.98	0.96	0.05	0.08	M2 vs. M1	0.97	3	0.81
M2	26.61	9	0.98	0.94	0.04	0.10	M3 vs. M1	9.46	3	0.02
M3	18.12	9	0.99	0.97	0.04	0.07	M4 vs. M1	10.43	6	0.11
M4	17.15	6	0.99	0.94	0.03	0.10	M4 vs. M2	9.46	3	0.02
M5	13.31	5	0.99	0.95	0.02	0.09	M4 vs. M3	0.97	3	0.81
M6	14.65	8	0.99	0.97	0.03	0.07	M5 vs. M4	3.84	1	0.05
							M5 vs. M3	4.81	4	0.31
							M6 vs. M3	3.47	1	0.06

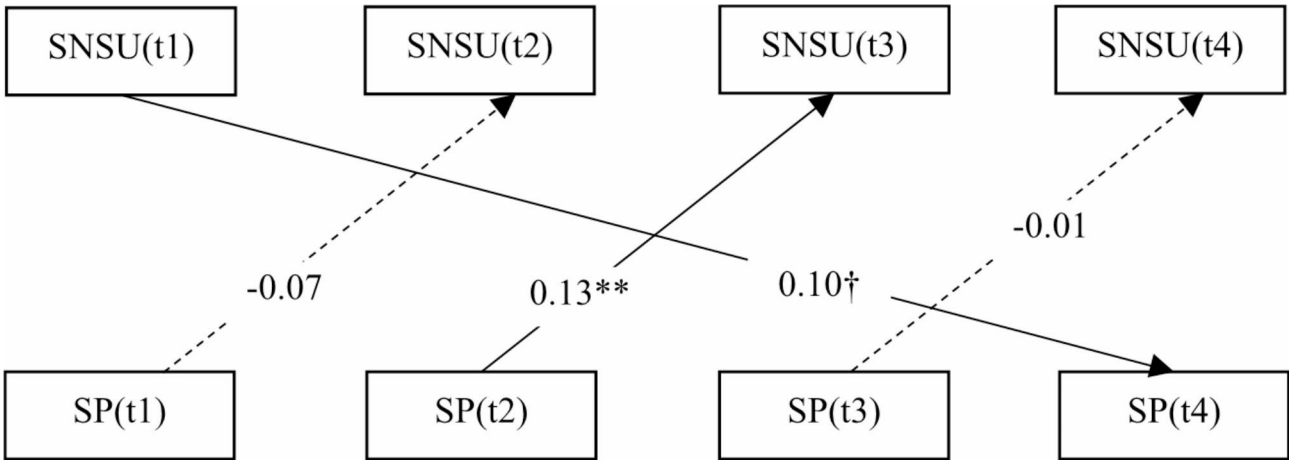

Fig. 1 Cross-lagged model of SNSU and sleep problems. Note: For simplicity of the graph, only cross-lagged path coefficients are shown in Fig. 1. The solid line indicates that the path coefficient has reached a significant level, and the dashed line indicates that the path coefficient has not reached a significant level. SNSU = Social Networking Sites Use; SP = Sleep Problems. t1, t2, t3, and t4 indicate different time points. ** $p < 0.01$; * $p < 0.05$; $^{\dagger}p < 0.06$

women exhibiting significantly higher on these indicators than men. The patterns observed in SNSU align with the extant literature [12, 13], where female internet usage tends to be predominantly relational, thereby precipitating more frequent engagement with social networking sites. In contrast, male internet activities are often oriented toward instrumental or "tool-related" functions [36]. Regarding sleep problems, our findings are consistent with some international studies [14–16], indicating that women experience more sleep problems than men. However, our results differ from existing research in China. Specifically, a meta-analysis by Li et al. [37] reported an absence of gender-based disparities in sleep problems among Chinese college students. This discrepancy may be intricately linked to the evolving dynamics of the internet in China over the past decade, which may engender differential online behaviors among men and women, thereby influencing their sleep problems.

Cross-lagged relationships between SNSU and sleep problems

Our cross-lagged model analyses revealed that sleep problems at Time 2 herald SNSU at Time 3, supporting the findings of Tavernier and Willoughby [30], which suggest that sleep problems precede and inform SNSU among college students. This aligns with the Uses and Gratifications Theory (UGT), which posits that individuals adopt new technologies to fulfill specific needs, such as relaxation, social interaction, or escapism [27, 28]. Given that social networking sites can evoke positive emotional states and high arousal, they serve as appealing tools for those experiencing sleep disturbances [21].

Nevertheless, it is important to note that the influence of sleep problems on SNSU among university students is not constant throughout the academic term. Initially, this effect is negligible, gains a positive correlation in the semester's intermediate stages, and eventually diminishes once again. This pattern underscores the dynamic and context-dependent nature of this relation, suggesting links to varied campus life and academic environments. Studies have found that perceived stress among college students increases from the beginning to the middle and peaks at the end of the semester, only easing after final exams [38, 39]. Consequently, the relationship between sleep problems and SNSU also changes with the varying situational stress. Future research should incorporate stress as a significant variable to explore the interplay between sleep problems and SNSU. According to the transactional model of stress and coping [40], there may not be a direct relationship between sleep problems and SNSU. Instead, both may be influenced by external stressors. Therefore, future research should investigate whether stress is a common underlying cause of both sleep problems and SNSU. These observations reveal that the impact of sleep problems on SNSU is fluid and likely subject to moderation by various factors.

The cross-lagged analysis model shows that SNSU at Time 1 has a marginally significant positive predictive effect on sleep problems at Time 4, which is consistent with the positive predictive results of numerous cross-sectional studies [8, 9]. It is important to note that SNSU at Time 1 does not predict sleep problems in the short term but does so over a longer period. This may reflect the cumulative effects of SNSU on sleep problems over time. Initially high levels of SNSU can establish a pattern of behavior that gradually disrupts sleep habits. While this disruption might not be immediately apparent, it becomes evident after an extended period, as observed from the initial to the fourth time point. These delayed consequences suggest that the habit of late-night SNSU can eventually lead to disruptions in circadian rhythms and sleep hygiene. Over time, these

disruptions accumulate and become significant enough to cause noticeable sleep problems. This time-specific predictive relationship underscores the complexity of SNSU's impact on sleep, highlighting that while immediate effects might not be evident, long-term consequences can emerge significantly after a delay. Understanding these patterns is crucial for designing interventions that address the cumulative and delayed impacts of SNSU on sleep health.

However, it should be noted that the prediction of sleep problems at Time 4 by SNSU at Time 1 is not statistically significant but marginally significant ($p=0.06$). This could be due to the small sample size. With a larger sample size and increased statistical power, the significance level might change. This warrants further investigation in future research. Additionally, the longitudinal study by Tavernier & Willoughby did not find a predictive effect of SNSU on sleep problems [30], which is inconsistent with our findings. This discrepancy may be due to differences in the measurement of SNSU; Tavernier & Willoughby measured SNSU in terms of time spent, whereas we measured the intensity of SNSU. This inconsistency suggests that future research should consider measuring SNSU from multiple dimensions.

Drawing upon the aforementioned findings, it appears that a bidirectional prediction exists between SNSU and sleep problems, albeit with disparate temporal effects. The influence of SNSU on sleep problems exhibits greater longevity and less fluctuation, in contrast to the effect of sleep problems on SNSU, which manifests over a briefer span and demonstrates increased variability. Previous research, such as the study by Doane et al. [41], supports the hypothesis that SNSU may impair sleep problems by exacerbating anxiety. Subsequent investigations into this relationship would benefit from the inclusion of additional mediating variables for a more nuanced understanding. Conversely, the exploration of further moderating variables could shed light on the impact of sleep problems on SNSU. This interplay suggests that the duration of observation in longitudinal studies is pivotal to the derived conclusions on the nexus between SNSU and sleep problems. Hence, whether to adopt a brief ecological momentary assessment or an extensive year-long observation, both approaches warrant rigorous empirical inquiries. Indubitably, the present study has contributed valuable preliminary insights into this domain.

Clinical and real-world implications

Gender-Specific Interventions. Given that women are more prone to both higher SNSU and sleep problems, tailored interventions are necessary. Healthcare providers should consider gender-specific strategies when addressing sleep disorders. For women, reducing SNSU, particularly in the hours leading up to bedtime, may help mitigate sleep problems. Counseling sessions could focus on managing social media habits and promoting healthier digital consumption patterns.

Long-Term Monitoring. The study's longitudinal analysis reveals that high levels of SNSU at an initial time point can predict sleep problems over an extended period, although this effect is marginally significant. This finding underscores the importance of long-term monitoring of SNSU behaviors and their impact on sleep. Clinicians should be aware of the delayed effects of SNSU on sleep and consider long-term behavioral tracking and interventions to address sleep disturbances effectively.

Preventive Measures for Digital Consumption. The study suggests that high levels of SNSU can establish a behavioral pattern that disrupts sleep over time. Preventive measures should be implemented to address late-night SNSU, which can interfere with circadian rhythms and sleep hygiene. Public health campaigns and educational programs could emphasize the importance of limiting social media use before bedtime and encourage practices that promote better sleep hygiene.

Limitations and future research

This study has made notable contributions to the field, yet it is not without its limitations. A primary limitation is the reliance on self-reported data for both SNSU and sleep problems, thereby potentially introducing response bias. Future research would be enhanced by the inclusion of objective measures, such as usage statistics from digital devices and actigraphy, to validate self-reported information.

Moreover, while the proposed model (M6) exhibited robustness in terms of fit, it failed to account for the potential moderating or mediating influence of external variables such as stress levels, social support networks, or individual personality traits. Subsequent research endeavors could refine and extend our model by assimilating these elements, thereby providing a more comprehensive framework to interpret the dynamics at play.

Lastly, this study did not differentiate between various types of social networking sites in our measurements. It is possible that the relationship between SNSU and sleep problems varies depending on the type of social networking sites used. Future research should categorize social networking sites and investigate how different types relate to sleep problems.

Conclusions

Our study found evidence of a vicious cycle, where sleep problems lead to increased SNSU as a coping mechanism, and this increased usage, in turn, predicts further sleep problems. In summation, by illuminating the temporal intricacies within the relationship between SNSU and sleep problems, this research bridges a gap in existing

scholarship. The insights presented herein not only compel a reevaluation of previous assumptions regarding the SNSU-sleep connection but also bolster the case for adopting a more nuanced and multifaceted methodological approach in forthcoming scholarly inquiries.

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Author contributions
X.L.: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. H.L.: Conceptualization, Formal analysis, Funding acquisition, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing. J.L.: Investigation, Resources, Validation, Writing – original draft, Writing – review & editing. All authors read and approved the final manuscript.

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Data availability
The datasets generated by the survey research during and/or analyzed during the current study are available in the Science DB repository.https://www.scidb.cn/en/anonymous/cUlKdllu.

Declarations

Ethics approval and consent to participate
The studies involving humans were approved by Institutional Review Board of School of Psychology, SDNU (IRB number: SDNU2022036). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because in conducting the questionnaire-based research with college student participants, written informed consent was deemed not required due to the minimal risk nature of the study and the non-sensitive content of the questions. Participants were provided with detailed information about the study, including its purpose, procedures, potential risks, benefits, and the confidentiality measures in place to protect their privacy. This information was presented to participants prior to the commencement of the questionnaire, ensuring they were fully informed about the study. Furthermore, it was explicitly stated that participation was completely voluntary and that participants could withdraw at any time without consequence. In light of these considerations, and in compliance with institutional ethical guidelines, verbal informed consent was deemed adequate, as it sufficiently protected student participants' autonomy while allowing for the efficient administration of the survey. This approach is consistent with prevailing ethical standards for low-risk educational research and was approved by our Institutional Review Board (IRB).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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