

Smartphone addiction and college students' sleep quality: Analysis of mediating and moderating effects

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Abstract: This study took college students from four universities in Zhengzhou, Henan Province as the research subjects. The research tools included the Cell Phone Addiction Scale, Self-Assessment Scale for Anxiety (SAS), Pittsburgh Sleep Quality Index Scale (PSQI) and Rumination Thinking Scale. Through online and offline questionnaires, 1053 valid questionnaires were obtained. After statistical analysis, anxiety was found to play a partial mediating role between cell phone addiction and college students' sleep quality. In addition to directly affecting the sleep quality of college students, smartphone addiction can also indirectly affect the sleep quality of college students through the mediating role of anxiety. The direct effect of rumination thinking on sleep quality and the moderating effect of the second half of the path of the mediating effect of anxiety were found to be significant through the mediation model test with moderation.

1. Introduction

In recent years, with the further popularization of the 5G network, cell phone users are increasingly showing a trend of lower age, and the number of teenage cell phone users in China has increased significantly. Cell phone addiction is a kind of addictive behavior, which refers to the addictive state in which an individual is unable to control his or her own behavior of using cell phones, thus leading to the impairment of his or her psychosocial function. Previous studies have shown that cell phone addiction has adverse effects on college students' emotions, interpersonal interactions, life satisfaction, and academic performance.

"*The Youth Sleep Quality Report 2021*" shows that the proportion of post-00s falling asleep after 12 o'clock has reached 57.1%, and the influence of playing cell phones and computers before going to bed on sleep accounts for 50.7% of the total influencing factors. Sleep quality is an important factor affecting the physical and mental health development of contemporary college students. Poor sleep quality is generally characterized by long sleep onset, low sleep efficiency, short sleep duration, the need to use drugs to hypnotize and accompanying daytime dysfunction. College students are in their youth, and good sleep quality is a physiological prerequisite for students' healthy physical development and active engagement in their studies. Currently, there is a widespread phenomenon of late sleep among college students, and the use of cell phones before going to bed is one of the major reasons for this phenomenon. The aftermath of sleeping late is mental depression and lack of vigor, which is also a manifestation of sleep deprivation and poor sleep quality.

Positive psychologist Cheksemihalyi's immersion theory suggests that when individuals are immersed in the pleasure and thrill of cell phone use, it affects their sense of time and sense of self, causing them to take time away from their own sleep for psychological satisfaction^[1]. A large number of cross-sectional empirical studies have shown that cell phone addiction is an important factor leading to lower sleep quality^[2]. Meta-analysis of the study on cell phone behavior and sleep quality among Chinese college students by Xianfeng Shi and Leilei Pei 2019 showed that cell phone addiction was highly correlated with all dimensions of sleep quality in 11 case-control studies screened^[3]. On the longitudinal follow-up study of cell phone addiction on sleep quality, the results of Thom e-Sarah's (S.) 2011 study showed that excessive cell phone use behaviors were predictive of sleep quality disorders in individuals one year later^[4]. Domestic scholar Yinzhi Kang 's 2020 tracking study of 1050 on-campus medical students showed that cell phone addictive behavior affects the sleep patterns of college students and causes them to develop sleep disorders^[5]. Therefore, from the perspective of cell phone addiction, it is important to study the internal influence mechanism that affects the sleep quality of college students.

Cell phone addiction not only affects the quality of sleep, but also easily induces negative emotions such as anxiety and depression. College students addicted to cell phones devote less time and energy to study, their academic performance decreases, and they are prone to anxiety and other negative emotions^[6]. In real life, people often have trouble falling asleep or sleeping due to anxiety. The sleep interference process theory suggests that excessive emotional arousal interferes with an individual's sleep process and affects sleep quality. Xinyu Li et al. found that negative emotions such as anxiety or depression negatively affect sleep quality^[7]. It has been shown that cell phone addiction significantly predicts anxiety^[8], while anxiety also significantly predicts cell phone addiction^[9], and the two may influence each other and be causal. In view of the fact that smartphone addiction is more common, the anxiety and other problems shown by cell phone addicts are also more common. Based on relevant theories and empirical studies, this study proposes hypothesis H1: Anxiety mediates the effect of cell phone addiction on college students' sleep quality.

Ruminate thinking refers to individuals who, when confronted with a negative event, constantly think about the negative emotion itself and its cause and effect without thinking about problem solving. Research suggests that ruminative thinking is a common form of intrusive thinking that causes individuals to worry excessively and process negative stimuli over and over again, leading to increased pre-bedtime thinking activity, heightened levels of cognitive arousal, and ultimately, difficulty falling asleep and shallow sleep, which interferes with sleep. The cognitive model of sleep suggests that ruminative thinking causes individuals to have more difficulty falling asleep or staying asleep. Rumination thinking tends to prompt individuals to focus their attention on their negative emotions and negative behaviors, reinforcing the negative effects of negative factors. Empirical studies have found that under the influence of negative emotions, individuals will repeatedly think about negative emotions and their causes, causing excessive brain activity and thus affecting sleep, and ruminative thinking can exacerbate the adverse effects of cell phone addiction on sleep quality^[10]. In view of the fact that there are fewer previous studies on the interaction between rumination and cell phone addiction and anxiety, the present study, on the basis of sorting out and integrating the existing research results, hypothesized that rumination may modulate the internal mechanism of action between negative factors (e.g., cell phone addiction and anxiety) and their adverse outcomes (poor sleep quality), and accordingly established a moderated mediator model, proposing hypothesis H2 and hypothesis H3. Hypothesis H2: The direct effect of cell phone addiction on college students' sleep quality is moderated by rumination; Hypothesis H3: The effect of anxiety on sleep quality, i.e., the second half of the path of the indirect effect of cell phone addiction and sleep quality, is moderated by rumination.

2. Objects of study and research methodology

2.1 Subject of the study

Convenience sampling method was used to conduct online and offline questionnaire surveys on college students in four colleges and universities in Zhengzhou City, Henan Province. After excluding invalid questionnaires, 1053 valid questionnaires were obtained. Among them, there were 413 male students (39.22%) and 640 female students (60.78%); 467 only children (44.35%) and 586 non-only children (55.65%); 546 liberal arts students (51.85%) and 507 science and engineering students (48.15%); 389 first-year students (36.94%), 254 second-year students (24.12%), 327 juniors (31.05%), and 83 seniors (7.89%).

2.2 Measurement tools

2.2.1 Smartphone Addiction Scale

The revised Cell Phone Addiction Scale for College Students (SAS-C) by Su Shuang et al.^[11] was used. The scale is divided into 6 dimensions, specifically composed of 22 items, including withdrawal behaviors (e.g., if my phone is not with me for a period of time, I often worry about missing calls), salient behaviors (e.g., my classmates and friends often tell me that I spend too much time on my cell phone), social appeasement (e.g., I would rather chat on my cell phone than communicate directly face-to-face), negative effects (e.g., playing on my cell phone too much time has affected my (e.g., I will unconsciously open certain cell phone applications), APP use (e.g., I will care about the recently released new applications and download them to my cell phone). The scale was scored using a Likert-5 point scale, with scores from 1 to 5 being very inconsistent, largely inconsistent, unsure, largely consistent, and very consistent. The internal consistency reliability of the scale in this study was 0.845.

2.2.2 Self-Assessment Scale for Anxiety (SAS)

The Self-Assessment Scale for Anxiety (SAS) is a 4-point scale that assesses the frequency of symptoms, with the following criteria: "1" indicating that they are not present or are present very rarely; "2" indicating that they are present sometimes; "3" indicating that they are present most of the time; and "4" indicating that they are present the vast majority or all of the time. " indicates that it is present most of the time; and "4" indicates that it is present the vast majority or all of the time. 15 of the 20 entries are stated in negative terms and are scored in the order 1-4 above. The remaining 5 items (5th, 9th, 13th, 17th, and 19th) marked with an * were stated in positive terms and were scored in reverse 4-1 order. According to the Chinese normative results, the cut-off value of the SAS standardized score is 50, where 50-59 is mild anxiety, 60-69 is moderate anxiety, and 70 or more is severe anxiety.

2.2.3 Pittsburgh Sleep Quality Index (PQI)

The Pittsburgh Sleep Quality Index (PSQI) is used for sleep disorders patients, mental disorders patients to evaluate sleep quality, but also for general population sleep quality assessment of sleep quality in the general population. The score for each component is accumulated on a four-point scale from 0-3. A total of 18 entries comprise 7 components, each component is scored on a 4-point scale from 0-3, and the cumulative score of each component is the total PSQI score, which ranges from 0-21, with the higher the score, the poorer the sleep quality. The higher the score, the poorer the sleep quality. In China, a PSQI total score of more than 7 is used as the basis for determining that

the sleep quality is problematic. The internal consistency reliability of this scale is 0.84.

2.2.4 Ruminative Thinking Scale

The Ruminative Thinking Scale was used, with 22 entries divided into three factors: symptomatic rumination, obsessive thinking, and introspective deep thinking. A four-point scale from 1-4 was used, with 1=never and 4=always, and the higher the score, the more severe the individual's ruminative thinking^[12]. The internal consistency coefficient measured in this study was 0.94.

2.3 Data processing and common method bias test

SPSS 25.0 and Hayes' macro program PROCESSv3.3 were used to statistically analyze the data. Using exploratory factor analysis, all questionnaire entries were subjected to unrotated principal component factor analysis, which revealed that there were a total of 20 factors with eigenvalues greater than 1 and that the first factor explained 21.29% of the total variance, which was below the critical criterion of 40%, indicating that there was no serious common methodological bias in the data collected for this study.

3. Results

3.1 Descriptive Statistics and Correlation Analysis

There were 14.78% of college students with poor sleep quality and sleep problems. Through Pearson correlation analysis, it was found that the four variables of cell phone addiction, anxiety, rumination thinking and sleep quality were significantly positively correlated with each other. The correlation matrix, mean, and standard deviation of each variable are shown in Table 1.

Table 1: Results of correlation analysis between variables

variant	M	SD	1	2	3	4
1.Cell phone addiction	61.63	11.46	1			
2.Anxiety	41.25	8.01	0.38***	1		
3.Ruminative thinking	43.23	11.58	0.46***	0.49***	1	
4.Quality of sleep	4.32	2.69	0.33***	0.57***	0.44***	1

Note: ***P<0.001, two-tailed.

3.2 Intermediation test

Before data analysis, each continuous variable was standardized. According to Hayes^[13], model 4 (simple mediation model) of the SPSS macro program PROCESSv3.3 was first used to test the mediating role of anxiety between cell phone addiction and sleep quality. The results showed that cell phone addiction significantly positively predicted the Pittsburgh Sleep Quality Index score (hereafter referred to as sleep quality) ($\beta = 0.35, P < 0.001$); cell phone addiction significantly positively predicted anxiety ($\beta = 0.38, P < 0.001$); and when both cell phone addiction and anxiety predicted sleep quality, the positive prediction of sleep quality by anxiety was significant ($\beta = 0.51, P < 0.001$), and the positive predictive effect of cell phone addiction on sleep quality also remained significant ($\beta = 0.15, P < 0.001$). In addition, the Bootstrap 95% confidence intervals for the total effect, the direct effect, and the anxiety-mediated effect of cell phone addiction on sleep quality did not contain 0 (see Table 2), suggesting that anxiety partially mediates the effect of cell phone

addiction on sleep quality.

Table 2: Bootstrap results for mediating effects

Type of effect	efficiency value	Boot standard error	Boot95% CI lower limit	Boot95% CI upper limit	Efficacy as a percentage of
aggregate effect	0.35	0.04	0.25	0.41	100.00%
direct effect	0.15	0.04	0.05	0.22	42.42%
intermediary effect	0.18	0.03	0.14	0.25	57.58%

3.3 Regulatory test

The PROCESS model15 (with conditioning on the direct path and the second half of the mediated path) was used to test the mediated model with conditioning, and the results are shown in Table 3. Cell phone addiction significantly and positively predicted anxiety; anxiety significantly and positively predicted sleep quality, at which point cell phone addiction also significantly and directly positively predicted sleep quality; and rumination significantly and positively predicted sleep quality. In addition, the interaction term between ruminative thinking and cell phone addiction significantly negatively predicted sleep quality; the interaction term between ruminative thinking and anxiety significantly positively predicted sleep quality. This suggests that the effects of both cell phone addiction and anxiety on sleep quality are moderated by ruminative thinking.

Simple slope analysis with ruminative thinking scores above the mean plus one standard deviation as the high grouping and below the mean minus one standard deviation as the low grouping showed that the positive effect of cell phone addiction on sleep quality was not significant ($\beta_{\text{simple}}=0.006, P>0.05$) when college students had a high level of ruminative thinking ($M+1SD$); and the positive effect of cell phone addiction on sleep quality was significant ($\beta_{\text{simple}}=0.18, P<0.001$) when college students had a low ($M-1SD$), the positive effect of cell phone addiction on sleep quality was significant ($\beta_{\text{simple}}=0.18, P<0.001$).

Table 3: Moderating effects of ruminative thinking test

outcome variable	regression equation	Overall fit index				Significance of regression coefficients		<i>t</i>
		R	R ²	<i>F</i>	β	Bootstrap lower limit	Bootstrap p cap	
apprehensive sleep quality	cell phone addiction	0.38	0.15	88.65***	0.38	0.29	0.48	9.42***
	cell phone addiction				0.09	0.02	0.17	2.32*
	apprehensive Ruminant thinking				0.41	0.32	0.49	9.49***
	Cell Phone Addiction				0.17	0.09	0.26	4.16***
	×Ruminant Thinking				-0.09	-0.15	-0.02	-2.94**
Anxiety ×Ruminant Thinking	0.11	0.03	0.16	3.34***				

Note: * $P<0.05$, ** $P<0.01$, *** $P<0.001$, two-tailed.

The positive effect of anxiety on sleep quality was significant ($\beta_{\text{simple}}=0.52, P<0.001$) when college students had a high level of ruminative thinking ($M+1SD$); when college students had a low level of ruminative thinking ($M-1SD$), the positive effect of anxiety on sleep quality, although also

significant ($\beta_{\text{simple}}=0.30$, $P<0.001$), was weaker compared to the effect of at high rumination thinking, the strength of its effect was weakened (β_{simple} reduced from 0.52 to 0.30). In addition, it can also be visualized in Table 4 that the indirect effect of cell phone addiction on sleep quality was also gradually enhanced at three different levels of rumination thinking. At this point, the significant influence of rumination thinking on the whole mediating path was 0.04.

Table 4: Direct and indirect effects when ruminative thinking levels vary

Type of effect	Ruminant thinking	efficiency value	Boot standard error	Boot 95% CI lower limit	Boot 95% CI ceiling	efficiency ratio
direct effect	M-1SD	0.18	0.05	0.08	0.28	60.00%
	M	0.09	0.04	0.01	0.18	36.00%
	M+1SD	0.006	0.05	-0.09	0.11	4.76%
	discrepancy	-0.18	0.06	-0.30	-0.05	-
indirect effect	M-1SD	0.12	0.03	0.07	0.18	40.00%
	M	0.16	0.03	0.11	0.21	64.00%
	M+1SD	0.20	0.03	0.14	0.25	95.24%
	discrepancy	0.08	0.03	0.02	0.13	-
	Index	0.04	0.01	0.01	0.07	-

Note: Differences are comparisons of differences in effects at plus or minus one standard deviation; Index is the influence of the moderator variable across the mediated path.

4. Discussion

The results of this study indicate that cell phone addiction among college students positively predicts sleep quality, i.e., the higher the level of cell phone addiction among college students, the poorer the sleep quality. This finding supports the results of previous medical and psychological related studies^[14]. The data from this study showed that 32% of college students reported using their cell phones before going to bed. In the process of using cell phones, college students can obtain social rewards and self-rewards that they may not be able to get easily in real life through social software and game software, which bring psychological pleasure to college students. However, the habit of using cell phones before going to bed and the mood swings and addictions brought by cell phone use have delayed college students' sleep onset and reduced their sleep quality. Previous studies have also shown that cell phone addiction has adverse effects on the heart, endocrine system and metabolism, and also leads to a decrease in the quality of sleep.

In addition, cell phone addiction can affect sleep quality not only directly, but also indirectly through the mediating role of anxiety. Anxiety plays a partially mediating role between cell phone addiction and college students' sleep quality. The Sleep Disturbance Process Theory suggests that excessive emotional or physiological arousal can affect sleep quality. Individuals who are cell phone addicted typically exhibit significant anxiety traits and poor sleep quality. College students addicted to cell phones are more likely to be addicted to the virtual pleasure experience of cell phones and unable to extricate themselves, which can temporarily detach themselves from the reality of worries and dilemmas, but it is easy to lead to the individual's inability to reasonably cope with the difficulties in the face of the induced anxiety, which then affects the quality of sleep. According to the resource conservation model, college students consume a large amount of physical and mental resources on cell phone use, so the resources used to cope with stress and real difficulties are relatively scarce, and are prone to anxiety. Excessive use of cell phones also tends to lead to physical problems such as sore fingers and neck, headaches, etc., increasing anxiety^[15].

The mediation model test with moderation revealed that ruminative thinking moderated the direct effect as well as the second half of the path of the mediation effect significantly. In the indirect path of cell phone addiction affecting sleep quality, when the level of rumination thinking was higher, the effect of anxiety on sleep quality was greater, and the indirect effect was enhanced, i.e., rumination thinking exacerbates the effect of anxiety on sleep quality, which supports the theory of reaction style. The present study concluded that under the blanket of anxiety, individuals are prone to fall into negative rumination about anxiety, which leads to greater difficulty in falling asleep or inability to sleep.

In the direct pathway of cell phone addiction affecting sleep quality, the effect of cell phone addiction on sleep quality was greater when college students had low levels of rumination thinking; as the level of rumination thinking increased, the effect of cell phone addiction on sleep quality was no longer significant. It seems that the moderating term of rumination thinking and cell phone addiction weakened the direct effect of cell phone addiction on sleep quality, but it is still very clear through the data that the scores of sleep quality of individuals at high rumination were all much higher than the scores of sleep quality at low rumination, indicating that the sleep quality of individuals at high rumination were all worse than at low rumination. Such results may be due to the fact that the direct effect of cell phone addiction on sleep quality is gradually replaced by the effect of increased anxiety and the influence of other possible mediating variables as the individual's level of ruminative thinking increases^[16]. Given that ruminative thinking was moderately significantly correlated with both cell phone addiction and sleep quality, and that ruminative thinking significantly and positively predicted sleep quality, the present study hypothesized that, as individuals' level of ruminative thinking increased, the adverse effects of cell phone addiction mainly affected sleep quality through the co-mediation of anxiety, ruminative thinking, and other variables; whereas, at a lower level of ruminative thinking, the effects of cell phone addiction that partly works through the mediating path of anxiety and partly works directly on sleep quality. Although the present study differs from the results of the existing study^[17] (the direct effect of cell phone addiction on sleep quality is stronger at high ruminative thinking), both ultimately point to the same goal: when individuals have the same level of cell phone addiction, the sleep quality of the individuals at high ruminative thinking is poorer than that at low ruminative thinking.

This study provides new ideas for improving college students' sleep problems. Colleges and parents should not only control the intensity of college students' cell phone use, but also cultivate a positive way of thinking, so that they can learn to seek solutions to problems when facing negative events instead of continuously immersing themselves in negative emotions. Colleges and parents should encourage college students to learn how to manage their emotions, improve their ability to manage their emotions, and strive to cultivate a positive, optimistic and stable emotional state in college students.

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