The associations among type D personality and nomophobia, metacognitions about smartphone use, smartphone addiction in Chinese university freshmen: a two-wave study

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Abstract

Objective This study aimed to examine longitudinal associations of Type D personality and smartphone addiction, while also exploring the mediating roles of nomophobia and metacognitions about smartphone use.

Methods Type D Personality Scale-14 (T1), Nomophobia Questionnaire (T2), Metacognitions about Smartphone Use Questionnaire (T2) and Smartphone Addiction Scale Short Version (T2) were applied at two time points. 653 university freshmen (M_{age} = 18.56, SD = 0.65) from a university in China were surveyed.

Results (1) Type D personality was significantly and positively correlated with nomophobia, negative metacognition, and smartphone addiction. In contrast, the correlation between Type D personality and positive metacognition did not reach the significant level. (2) Compared with individuals with non-Type D personality, those with Type D personality scored significantly higher on nomophobia, negative metacognition, and smartphone addiction. However, the difference was not significant for positive metacognition. (3) Nomophobia and metacognitions about smartphone use fully mediated the relationship between Type D personality and smartphone addiction. While the mediating effects of nomophobia and negative metacognition were significant, the mediating effect of positive metacognition was not significant.

Conclusions Type D personality can not only affect smartphone addiction directly but also indirectly through nomophobia and negative metacognition. Therefore, to prevent and intervene in smartphone addiction, we can start from both affect (nomophobia) and metacognition (negative metacognitions about smartphone use).

Keywords Type D personality, Nomophobia, Metacognitions about smartphone use, Smartphone addiction

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Introduction

Nowadays, smartphones are inseparable from people's personal and professional lives [1–3]. The recent development of the multifunctional smartphone and its subsequent global popularity has changed the communication and information landscape; remolded the interests, values, and desires of many users; and triggered concerns around the world about overuse and addiction [4]. Smartphone addiction, characterized as a form of behavioral addiction [5, 6], is typified by excessive and uncontrollable engagement with smartphone technology [7]. The problem is particularly acute among college students. It can cause serious damage in all areas of an individual's life, including physical health, mental health, and social functioning [8–10].

Type D personality and smartphone addiction

Several studies have explored the relationship between personality and smartphone addiction [11–13]. Carvalho et al. (2018) [14] argued that problematic smartphone use is associated with pathological personality. A meta-analysis that included 33 studies revealed that smartphone addiction was significantly and positively correlated with psychoticism and neuroticism in Eysenck's personality traits [15]. Neuroticism and extroversion exert an influence on the development of smartphone addiction [16, 17]. Another meta-analysis of 26 studies found robust associations between higher neuroticism and lower conscientiousness and higher propensity for smartphone use disorder [18].

Type D personality also known as distressed personality [19, 20], has been identified as a risk factor for addictive behavior [21, 22]. Denollet (2000) [23] defined Type D personality by the combination of two personality traits (negative affectivity and social inhibition). Negative affectivity (NA) refers to discomfort in social interactions (For example, anxiety, anger, hostile feelings, irritability, and dysphoria) [24, 25], and social inhibition (SI) refers to difficulties in the expression of emotions and to a discomfort in social interactions [22]. If an individual scores high on both negative affectivity and social inhibition, they may have Type D personality [26]. In one study, among 3,813 participants, 1,027 individuals (28%) met the classification criteria for Type D personality [25] One study revealed robust positive associations between neuroticism and negative affectivity, as well as substantial negative associations between extraversion and social inhibition, and the overall Type D construct being well represented by the Big 5 [27]. In addition, owing to their higher levels of stress and negative emotions, individuals with Type D personalities may be more inclined to use smartphones to alleviate negative emotions and have positive affective experiences. They may be more prone to addictive behaviors as well [28, 29].

The interaction of person–affect–cognition–execution (I-PACE) model can be used to explain the relationship between Type D personality and smartphone addiction. The I-PACE model is a theoretical framework for the processes underlying the development and maintenance of an addictive use of certain Internet applications or sites promoting gaming, gambling, pornography viewing, shopping, or communication [30]. First, according to the I-PACE model, personality traits are important factors in the development of addictive behaviors [31]. Thus, as an important personality type, the relationship between Type D personality and addictive behavior cannot be overlooked. Second, emotional factors are likewise crucial in this context. According to the self-regulation theory, people maintain or restore psychological balance in a wide variety of ways [32], and people who have more negative emotions have a greater need for self-regulation [33]. Smartphones act as daily emotion regulation tools [34], that help people to get their needs met [35], thus helping Type D personalities to cope with stress and relieve their emotions. This over-reliance on smartphones for self-regulation may eventually lead to the development of smartphone addiction. Finally, the impact of cognition is also of significant importance. According to the Cognitive Dissonance Theory, people make themselves have consistent cognitive attitudes and behaviors and experience discomfort when their behaviors are inconsistent with their cognitions [36, 37]. Individuals with Type D personality are often in a negative emotional state and have a more negative view of themselves, their environment, and others [38]. Type D personality types will seek out negative content to reaffirm their worldview. Smartphones serve as platforms that can reinforce these negative perceptions by providing information and social interactions that align with their existing beliefs, thereby alleviating cognitive dissonance. In addition, people could use smartphones to socially disengage [39].Thus, individuals with Type D personalities may be more likely to become addicted to smartphone use and develop addictive behavior.

In light of the above, the following hypothesis was formulated.

Hypothesis 1 Type D personality influences smartphone addiction.

Mediation of nomophobia

Constant mobile phone use has resulted in the concept of Nomophobia, in other words, the fear of being out of mobile phone contact [40]. The term nomophobia refers to the worry or fear that individuals experience when they do not have a mobile phone or are unable to use it

[41]. More generally, it is the pathological fear of being out of touch with technology [42].

Established studies have highlighted the relationship between nomophobia and addictive behaviors [43–45]. Bhattacharya et al. (2019) [46] stated that young people are more likely to have more addictive behaviors due to nomophobia. According to the fear avoidance model, people avoid contact with stimuli that they feel fearful and anxious about [47]. In a mobile phone-free scenario, many people experience unbearable anxiety and restlessness [48]. This anxiety may lead them to avoid this anxiety by constantly using their mobile phones. Therefore, nomophobia could be a trigger for smartphone addiction.

According to the social support theory, social support is a crucial factor for individuals to feel fulfilled and happy [49, 50]. Individuals with Type D personality exhibit avoidant behaviors when it comes to social interaction [19]. If they do not have access to a smartphone, they may feel a lack of connection to social support and social interaction, which in turn exacerbates their anxiety about being without a mobile phone. To allay their anxiety, they may become more dependent on and use their smartphones, ultimately leading to the development of smartphone addiction. Furthermore, according to the I-PACE model, addiction is generally ascribable to individual susceptibility (genetic and personality), psychopathological factors (negative emotions), and the interaction of cognitive and affective factors [31, 51], and personality traits may influence addictive behavior through emotions, among others [30]. Based on this, the present study suggests that fear of being without a mobile phone may be a mediating variable between Type D personality and smartphone addiction. With this background, the following hypothesis was formulated.

Hypothesis 2 Nomophobia mediates the relationship between Type D personality and smartphone addiction.

Mediation of metacognitions about smartphone use
Metacognition can be defined as a person's awareness of their cognitive processes and outcomes [52]. It has been extensively studied not only in the fields of learning and education [53, 54], but also in domains such as psychopathology [55, 56]. According to the metacognitive model of psychopathology, metacognition plays a critical role in all psychological disorders [57] and is closely associated with addictive behaviors [58–60].

Hamonniere and Varescon (2018) [61] divided metacognition in the field of addiction into two types, namely, general metacognition of cognitive–emotional experiences and specific metacognition of addictive behaviors. The latter is further divided into positive metacognition and negative metacognition [62]. Positive metacognition plays a role in motivating individuals to engage in addictive behaviors, whereas negative metacognition contributes to the maintenance of addictive behaviors [63]. Research has demonstrated that metacognition about smartphone use is strongly associated with smartphone addiction [64]. Furthermore, negative metacognitions about the uncontrollability and perceived harm of smartphone use are more salient dimensions that predict the maintenance and perpetuation of problematic smartphone use [65].

In addition to the above aspects, existing studies have explored the relationship between personality and metacognitions about smartphone use. For example, Xie et al. (2022) [66] observed that among the Big Five personality traits, neuroticism was significantly positively correlated with positive metacognition, while conscientiousness, extraversion, and agreeableness were negatively correlated with negative metacognition, and neuroticism was positively correlated with negative metacognition. According to the personality typology theory, different people may exhibit different personality types [67, 68]. Each personality type may differ in regard to information processing and cognitive orientation [69], and such differences in cognition may influence an individual's behavior [70], which includes addictive behaviors [71]. Furthermore, according to the I-PACE model, personality traits may influence addictive behaviors not only through emotions but also through cognition [30, 31]. Furthermore, metacognition is the "cognition of cognition" [72]. Therefore, the present study suggests that metacognition of smartphone use may also be a mediating variable between Type D personality and smartphone addiction. In light of the above points, the following hypothesis was formulated.

Hypothesis 3 Metacognitions about smartphone use mediates the relationship between Type D personality and smartphone addiction.

The current study
Most of the existing studies have used cross-sectional studies to investigate the relationship between Type D personality and smartphone addiction, which makes it difficult to identify the causal relationship. Furthermore, China boasts the highest number of smartphone users globally, with the issue of problematic smartphone usage among university students becoming increasingly pronounced [73, 74]. Besides, college freshmen have just arrived at the college campus and have not yet adapted to the new environment [75]. They are thus prone to depression and anxiety [76] as well as addictive behaviors [77]. Given the potential relevance of both the time of first contact with mobile phone use (years), time spent on mobile phone per day (hours) duration to smartphone addiction [40, 78], this study intends to include them as

control variables when investigating the relationship between Type D personality and smartphone addiction. Therefore, based on the I-PACE model, this study included college freshmen as subjects and involved a longitudinal research design to explore the longitudinal associations of Type D personality with nomophobia, metacognitions about smartphone use, and smartphone addiction to reveal the mechanism of action of Type D personality and to provide a reference for prevention and intervention of smartphone addiction among individuals with Type D personality.

Methods
Participants
Convenience sampling was used to select freshmen from a university in Hunan Province, China.

The participants were drawn from diverse academic disciplines (e.g., e-commerce, preschool education, arts and sciences). At the first measurement, 739 students participated. After an interval of six months, 653 students participated in the second measurement. The attrition rate of the sample was 11.64%. The results of the two independent samples t-test showed that the attrition sample ($M \pm SD = 2.54 \pm 0.62$) and the follow-up sample ($M \pm SD = 2.50 \pm 0.67$) did not differ significantly on Type D personality, $t_{(737)} = -0.53$, $p = 0.59$. It indicated that there was no structural attrition in this study. In the follow-up sample, 171 (26.19%) were male and 482 (73.81%) were female. The mean age was 18.56 years ($SD = 0.65$ years). The mean time of their first exposure to cell phone was 8.82 years ($SD = 3.16$), and the mean time of daily cell phone use was 7.03 h ($SD = 3.13$ h).

Measures
Type D personality.
Type D Personality Scale-14 [25, 79] was utilized to measure the participants' level of distress, i.e., detect Type D personality. This scale consists of 14 items and includes two dimensions, i.e., negative affectivity (NA) and social inhibition (SI). A 5-point Likert scale was utilized for the corresponding measurements. The criteria for determining Type D personality were NA≥10 and SI≥10. The alpha coefficients for the two dimensions, NA and SI, in this study were 0.86 and 0.71, respectively. Scores on the dimensions of social inhibition and negative affectivity were combined to derive a Type D personality score.

Nomophobia
Nomophobia Questionnaire (NMP-Q; [41, 80]) was used to identify nomophobia among participants. It consists of a total of 20 items and includes four dimensions, i.e., not being able to communicate, losing connectedness, not being able to access information, and giving up convenience. A 7-point Likert scale was used for the related

measurements. For the purposes of this study, a single score was calculated by aggregating responses across all dimensions to represent an overall nomophobia score. Higher scores indicate higher levels of nomophobia. In this study, the alpha coefficients of the four dimensions ranged from 0.80 to 0.94.

Metacognitions about smartphone use
The Metacognitions about Smartphone Use Questionnaire (MSUQ; [63, 64]) was utilized to measure positive and negative metacognitions related to smartphone use. It consists of a total of 24 items and includes two dimensions, i.e., positive metacognition (PM) and negative metacognition (NM). A 4-point Likert scale was used for making measurements. In this study, the alpha coefficients of the two dimensions, namely, PM and NM, were 0.89 and 0.84, respectively.

Smartphone addiction
The Smartphone Addiction Scale Short Version (SAS-SV; [81]), was utilized to measure problematic smartphone use. This scale consists of a total of 10 items and is considered to be unidimensional. A 6-point Likert scale was employed, with higher scores indicating a greater tendency for smartphone addiction. The alpha coefficient for the scale in this study was found to be 0.87.

Procedure
The study was conducted in a classroom setting, with the consent of the university students, using paper and pencil responses during the time when the students were concentrating on their evening studies. Measurements were performed at two separate time points (six months apart). At time point 1 (T1, October 2022), Type D personality was primarily measured. At time point 2 (T2, April 2023), nomophobia, metacognitions about smartphone use, and smartphone addiction were measured. Subjects participated voluntarily during both measures and were free to withdraw at any time.

Data analysis
Frequency analyses, descriptive statistics, correlation analyses, two independent samples t-tests, and ANOVA were conducted using JASP 0.17.2.1, and raincloud plot was plotted. The mediating effect was analyzed using Model 4 in the PROCESS 4.2 macro program. Because all data collected in this study came from subjects' self-reports, the results may have been affected by common method bias. Therefore, this study involved measures such as organizing different questionnaires separately, reverse-scoring some entries, and emphasizing data confidentiality in the research design and data collection process. In addition, Harman's one-way ANOVA was used in this study to test for common method bias. The results

Table 1 Descriptive statistics and correlation matrix of key variables

	M ± SD	1	2	3	4	5	6	7	8	9
1. Gender	—	1								
2. Type D personality (T1)	21.53 ± 8.62	0.07	1							
3. Age (T2)	18.56 ± 0.65	0.09*	−0.03	1						
4. Time of first contact with mobile phone (T2)	8.82 ± 3.16	0.09*	−0.07	0.05	1					
5. Time spent on mobile phone per day (T2)	7.03 ± 3.13	−0.08*	0.09*	−0.04	0.15***	1				
6. Nomophobia (T2)	3.94 ± 1.31	−0.22***	0.18***	−0.04	−0.01	0.22***	1			
7. PM (T2)	2.51 ± 0.64	−0.01	0.08	−0.03	0.04	0.12*	0.34***	1		
8. NM(T2)	1.89 ± 0.68	0.14***	0.23***	−0.01	−0.03	0.07	0.28***	0.31***	1	
9. SA (T2)	3.20 ± 0.84	−0.08*	0.20***	0.03	0.01	0.16***	0.50***	0.28***	0.44***	1

Gender: 0 = Female, 1 = Male; $^*p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$; PM = Positive metacognition, NM = Negative metacognition; SA = Smartphone addiction

Table 2 Comparison of differences ($M \pm SD$)

	Type D personality (n = 287)	Non-Type D personality (n = 366)	t	Cohen's d
1. Time of first contact with mobile phone	8.58 ± 3.14	9.01 ± 3.17	−1.64	−0.14
2. Time spent on mobile phone per day	7.56 ± 3.38	6.59 ± 2.85	3.71***	0.31
3. Nomophobia	4.17 ± 1.24	3.75 ± 1.33	3.85***	0.32
4. PM	2.54 ± 0.64	2.49 ± 0.63	0.99	0.08
5. NM	2.00 ± 0.69	1.81 ± 0.65	3.43***	0.29
6. SA	3.37 ± 0.84	3.05 ± 0.81	4.64***	0.39

$^{***}p<0.001$; PM = Positive metacognition, NM = Negative metacognition; SA = Smartphone addiction
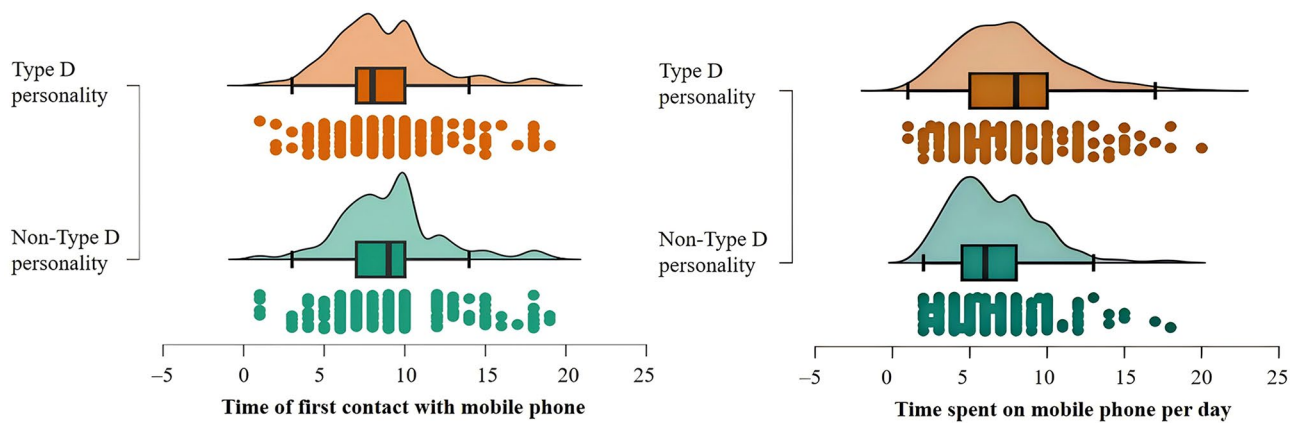

Fig. 1 Differences of time

identified 11 factors with eigenvalues greater than 1. The explained variance of the first factor was 22.86%, which was less than 40%. This indicates that this study had no major common method bias.

Results

Descriptive statistics and correlation matrix of key variables

The results of Pearson product-difference correlation analysis (Table 1) revealed that Type D personality showed significant positive correlation with nomophobia, negative metacognition, and smartphone addiction ($p<0.001$). The correlation between Type D personality

and positive metacognition did not reach the significant level ($p=0.07$). In addition, nomophobia, negative metacognition, and smartphone addiction showed significant positive correlation between the two, $p<0.001$.

Comparison of different groups of type D personality

A total of 287 participants (43.95%) satisfied Denollet's (2005) [25] criterion for determining Type D personality (NA≥10 and S1≥10). The results of the two independent samples *t*-test (Table 2) showed that the Type D personality group scored significantly higher on the time spent on mobile phone per day (Fig. 1), nomophobia (Fig. 2), smartphone addiction (Fig. 3) and negative
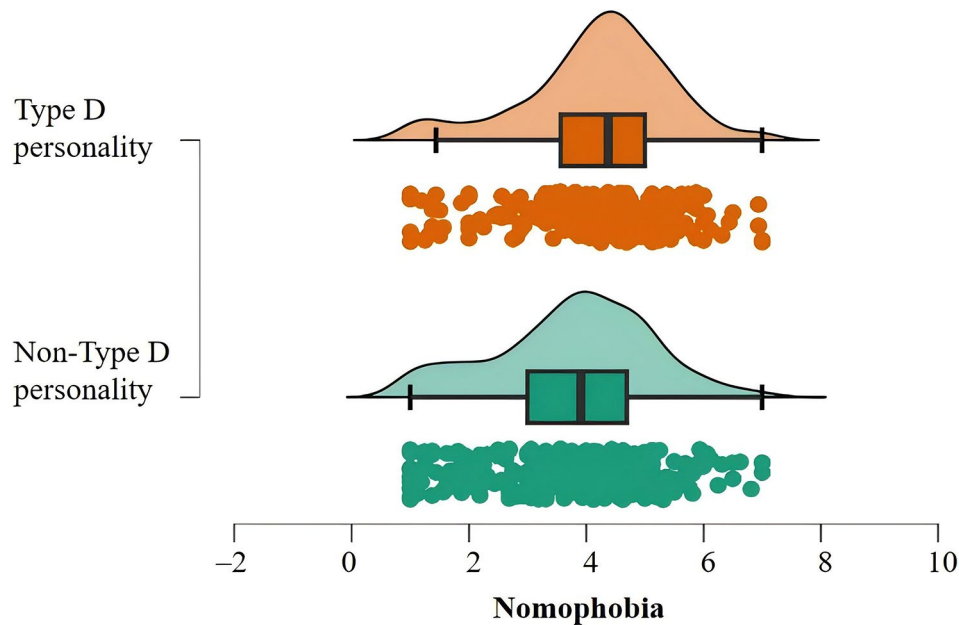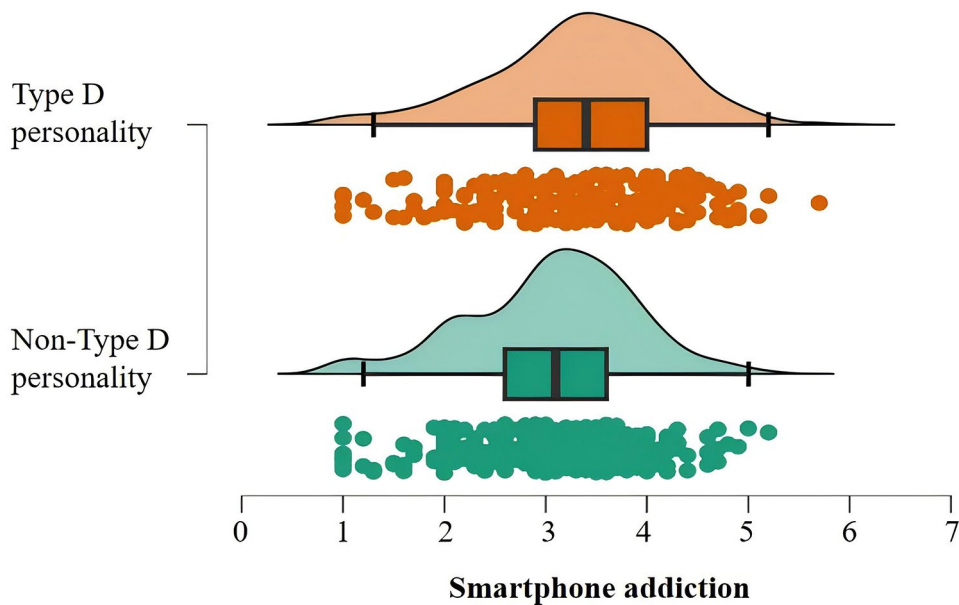
Fig. 2 Differences of nomophobia

Fig. 3 Differences of smartphone addiction

metacognition (Fig. 4) compared with the non-Type D personality group. However, the difference was not significant at the time of first contact with mobile phone ($p = 0.10$) (Fig. 1) and positive metacognition ($p = 0.32$) (Fig. 4).

Tests for mediating effects of nomophobia and metacognitions about smartphone use

Model 4 in the PROCESS macro program was used to test the mediating effects of nomophobia and metacognitions

about smartphone use between Type D personality and smartphone addiction.

The results (Table 3; Fig. 5) revealed that in Eq. 4, after controlling for gender, age, time of first contact with mobile phone, and time spent on mobile phone per day after controlling for the effects of gender, age, time of first contact with mobile phone, and time spent on mobile phone per day, both nomophobia and negative metacognition significantly and positively predicted smartphone addiction ($p < 0.001$), and positive metacognition's effect on smartphone addiction did not reach a significant
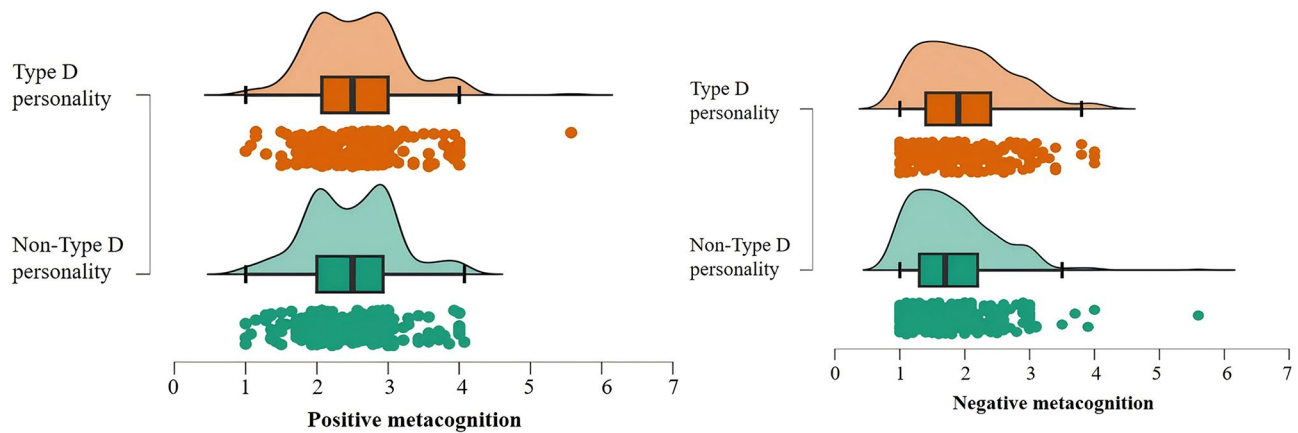
Fig. 4 Differences of metacognitions about smartphone use

Table 3 Tests for mediating effects of nomophobia and metacognitions about smartphone use

Predictor variable	Equation 1 (Outcome variable: Nomophobia)		Equation 2 (Outcome variable: PM)		Equation 3 (Outcome variable: NM)		Equation 4 (Outcome variable: SA)	
	B	95% CI	B	95% CI	B	95% CI	B	95% CI
1. Gender	−0.63***	[−0.87,−0.40]	−0.01	[−0.13,0.14]	0.21**	[0.07,0.35]	−0.09	[−0.23,0.05]
2. Age (T2)	−0.02	[−0.17,0.13]	−0.04	[−0.12,0.05]	−0.01	[−0.09,0.08]	0.06	[−0.03,0.14]
3. Time of first contact with mobile phone (T2)	−0.01	[−0.03,0.04]	0.01	[−0.01,0.03]	−0.01	[−0.02,0.01]	0.01	[−0.02,0.02]
4. Time spent on mobile phone per day (T2)	0.07***	[0.04,0.10]	0.02*	[0.01,0.04]	0.01	[−0.01,0.03]	0.03**	[0.01,0.05]
5. Type D personality (T1)	0.03***	[0.01,0.04]	0.01	[−0.01,0.01]	0.02***	[0.01,0.02]	0.01	[0.00,0.01]
6. Nomophobia (T2)							0.23***	[0.17,0.29]
7. PM (T2)							0.09	[−0.02,0.20]
8. NM (T2)							0.42***	[0.30,0.54]
R^2	0.113		0.020		0.069		0.378	
F	14.28***		2.30*		8.39**		40.85***	

*$p<0.05$, **$p<0.01$, ***$p<0.001$; 95% confidence intervals with predictors were obtained by Bootstrap method; PM = Positive metacognition, NM = Negative metacognition; SA = Smartphone addiction

level ($p=0.08$). At this point, the effect of Type D personality on smartphone addiction became rather insignificant ($p=0.28$). Furthermore, the total mediating effect reached a significant level (bootstrap 95% CI = [0.008, 0.018]). This suggests that nomophobia and metacognitions about smartphone use fully mediated the relationship between nomophobia and smartphone addiction.

Though the mediating effects of nomophobia and negative metacognition reached a significant level, the mediating effect of positive metacognition was not significant (Table 3). The two-by-two comparison of the mediating effect values showed that the mediating effect value of nomophobia significantly greater than that of positive metacognition (bootstrap 95% CI = [0.002, 0.009]), and the mediating effect value of positive metacognition was significantly smaller than that of negative metacognition (bootstrap 95% CI = [−0.010, −0.003]). In contrast, the difference between nomophobia and negative metacognition was not significant (bootstrap 95% CI =

[−0.006, 0.003]). In addition, the total mediating effect value (0.013) accounted for 81.25% of the total effect value (0.016), and the mediating effect values of nomophobia, positive metacognition, and negative metacognition accounted for 37.50%, 0.00%, and 43.75% of the total effect value, respectively (Table 4).

Discussion

Using a two-wave study design, this study was the first to examine the relationship of Type D personality with nomophobia, metacognition of smartphone use, and smartphone addiction. The results not only confirmed the negative effects of Type D personality but also revealed the mechanism of action of Type D personality and further validated the I-PACE model from an empirical perspective.
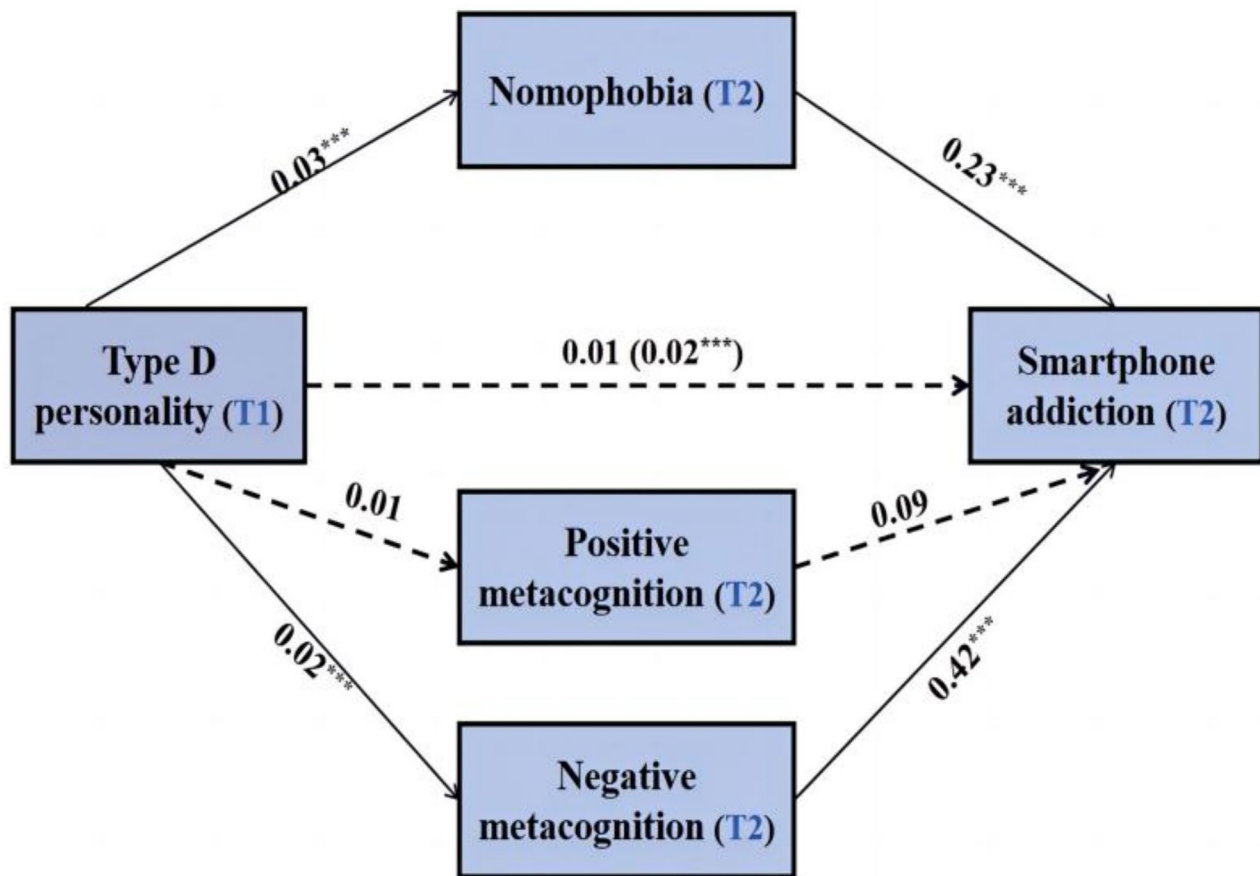
Fig. 5 Mediating role of nomophobia and metacognitions about smartphone use

Table 4 Comparison of indirect effect values for different variables

	Effect	Boot SE	95% CI	Proportion of indirect effect to total effect (%)
1. Total indirect effect	0.013	0.003	[0.008,0.018]	81.25
2. Nomophobia (T2)	0.006	0.002	[0.002,0.009]	37.50
3. Positive metacognition (T2)	0.000	0.001	[−0.001,0.001]	0.00
4. Negative metacognition (T2)	0.007	0.002	[0.004,0.010]	43.75

The relationship among type D personality, nomophobia, metacognitions about smartphone use and smartphone addiction

The present study demonstrates a significant positive relationship between Type D personality and smartphone addiction among Chinese college freshmen. This finding supports Hypothesis 1 and aligns with the component of the I-PACE model that suggests personality factors play a role in the development of addictive behaviors. While our results do not provide a comprehensive validation of the I-PACE model, they do substantiate the model's proposition regarding the influence of personality on addictive behaviors. This is congruent with the findings of existing studies on the relationship between Type D personality and addiction [21, 82]. Our results further demonstrated

that individuals with Type D personality spent significantly more time per day on their smartphones and had significantly higher levels of smartphone addiction than those with non-Type D personality. Although smartphone addiction cannot be understood merely as spending copious amounts of time using smartphones [83], the amount of time spent using a smartphone tends to be closely related to smartphone addiction [84]. Nevertheless, some studies indicate that the correlation between screen time and smartphone addiction may not be as robust as initially presumed [85, 86]. Consequently, it is imperative to exercise caution when inferring a direct relationship between the two variables. According to the cognitive escape theory, some people tend to escape from reality when confronted with challenging and stressful

situations [87]. Individuals with Type D personality, who often experience negative emotions, are more likely to divert their attention to smartphone use and become addicted to smartphones.

This study also found that Type D personality can not only directly influence smartphone addiction but also indirectly influence ground smartphone addiction through nomophobia. Hypothesis 2 and the argument of the I-PACE model that affect factors influence addictive behavior were thus validated. We further found significantly higher levels of nomophobia in individuals with Type D personality compared with individuals with non-Type D personality. Type D personality has also been found to be prone to fear and anxiety, among other such emotions [88, 89]. According to the self-concept theory, an individual's self-concept influences behavioral performance [90]. With a Type D personality, individuals may have a negative view of their social skills and emotional states [23]. However, smartphones can go some way to satisfying the need for social interaction [91]. If such individuals are unable to use a smartphone, they may feel unable to satisfy their need for social interaction and emotional regulation, increasing their anxiety about being phone-free. To compensate for this disturbance in self-concept, they may attempt to change their self-perception by overusing their smartphone, ultimately leading to smartphone addiction.

While nomophobia is closely associated with smartphone addiction, it is essential to acknowledge that nomophobia may manifest as mild anxiety in response to mobile phone separation, whereas smartphone addiction represents a more severe dependency characterized by withdrawal symptoms and persistent urges for mobile phone use.

Furthermore, we found that metacognitions about smartphone use mediated the relationship between Type D personality and smartphone addiction, confirming Hypothesis 3 and substantiating the argument of I-PACE model. This model suggests that cognitive factors influence addictive behavior, and metacognition plays a role in addictive behavior [58], providing further support for metacognitive models of psychopathology [57]. As previously mentioned, metacognition of smartphone use includes positive and negative metacognition. Our study revealed that negative metacognition played a more significant role in mediating the relationship between Type D personality and smartphone addiction, while positive metacognition did not have a significant mediating effect. Additionally, we found that individuals with Type D personality had significantly higher levels of negative metacognition of smartphone use compared with individuals with non-Type D personality. However, no significant difference was found in positive metacognition. Considering the inclination of individuals with Type D personalities

to exhibit pessimistic tendencies and negative emotional states, coupled with a pervasively negative worldview [23, 92], it is imperative to delineate the roles of positive and negative metacognition. Positive metacognition is characterized by the cognitive and emotional self-regulatory advantages that accrue from engaging in a particular behavior, whereas negative metacognition encompasses the perception of uncontrollability and the potential risks linked to addictive behaviors and their repercussions [58]. In this context, it is noteworthy that the association between Type D personality and positive metacognition is markedly weaker than the association between Type D personality and negative metacognition. This disparity may underlie the observed lack of significant mediating effects attributed to positive metacognition. These findings align with the cognitive–behavioral model of pathological Internet use, which posits that maladaptive cognition contributes to Internet use disorders [93]. It is worth noting that metacognition can activate maladaptive coping strategies [61], and negative metacognition, in turn, manifests itself as an individual's awareness of the uncontrollability and dangers posed by smartphone use [63]. Therefore, it is extraordinarily important to pay attention to the impact of negative metacognition.

Practical significance
The present study provides a new potential perspective for screening for smartphone addiction in individuals with high levels of Type D personality traits. The findings have important practical implications for managing the effects of Type D personality and for prevention and intervention in smartphone addiction.

First and foremost, it is essential to cultivate the skill of emotional regulation. This involves developing a conscious awareness of our emotional states and learning strategies to manage and express them in a healthy and constructive manner. By doing so, we can enhance our emotional intelligence, which in turn fosters greater psychological resilience and overall well-being. For example, mindfulness meditation. Practicing mindfulness involves non-judgmental awareness of present experiences. It has been shown to enhance emotion regulation by promoting acceptance and reducing emotional reactivity [94].

Our second recommendation is to eliminate or attenuate nomophobia. To this end, specific situations can be created to provide guidance on time management and encourage individuals to rationalize the time spent on different activities. For example, gradual exposure therapy, which involves incrementally increasing an individual's contact with the feared situation, could be used to intervene on nomophobia by helping individuals to confront their anxiety in a controlled and supportive manner. Over time, individuals can build tolerance and reduce anxiety levels [41].

Finally, metacognition of smartphone use should be actively managed. Identifying specific metacognitive characteristics associated with smartphone use may be helpful in developing intervention strategies [64]. Furthermore, given the positive effects of metacognitive therapy in addressing addictive behaviors [95], metacognitive therapy should continue to be deepened in interventions for smartphone addiction by guiding individuals to adjust their metacognition. For example, attentional control training: Practice exercises to enhance focus and attention, reducing the tendency to multitask with smartphones [96].

Limitations

This study has a few shortcomings. First, we collected data on nomophobia, metacognitions about smartphone use, and smartphone addiction at the same time, making it difficult to infer a causal relationship between them. Future studies can design more time points to explore the mechanism of smartphone addiction in more depth. Second, this study only involved college students from a specific province in China, without accounting for more regions and cultures. Future studies can include subjects from a wider range of geographical and cultural backgrounds to further validate the findings. Third, the data in this study were all self-reported by the subjects, which may be difficult to reflect the effects of Type D personality on smartphone addiction in a comprehensive and in-depth manner. Future studies could collect data through others' reports, observations, and other methods in addition to subjects' self-reported data.

Conclusion

The results of this study suggest that Type D personality can not only affect smartphone addiction directly but also indirectly through nomophobia and negative metacognition. Taking into account the mediating influences of nomophobia and negative metacognitions in the relationship between Type D personality and smartphone addiction, to prevent and intervene in smartphone addiction, we can start from both affect (nomophobia) and metacognition (negative metacognitions about smartphone use).

Data availability
The data underlying this article cannot be publicly shared at this time due to privacy and confidentiality concerns, as well as legal and ethical restrictions. However, the data may be available from the corresponding author on reasonable request, subject to the necessary agreements and conditions to ensure the protection of personal information and compliance with legal and ethical standards.

Declarations

Ethics approval and consent to participate
Ethical approval was granted by the Research Department of Changsha Normal University. Written informed consent was obtained from all participants. All participants were informed of voluntarily participating and could withdraw from the study at any time. All methods were performed following the Declarations of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

References
1. Derks D, van Duin D, Tims M, Bakker AB. Smartphone use and work–home interference: the moderating role of social norms and employee work engagement. J Occup Organ Psychol. 2015;88:155–77.
2. Ramanujam E, Perumal T, Padmavathi S. Human activity recognition with smartphone and wearable sensors using deep learning techniques: a review. IEEE Sens J. 2021;21:13029–40.
3. Vaterlaus JM, Aylward A, Tarabochia D, Martin JD. A smartphone made my life easier: an exploratory study on age of adolescent smartphone acquisition and well-being. Comput Hum Behav. 2021;114:106563.
4. Panova T, Carbonell X. Is smartphone addiction really an addiction? J Behav Addict. 2018;7:252.
5. Lin YH, Chiang CL, Lin P-H, Chang L-R, Ko C-H, Lee Y-H, Lin S-H. (2016). Proposed Diagnostic Criteria for Smartphone Addiction. Plos One. 2016; 11: e0163010.
6. Yu S, Sussman S. Does smartphone addiction fall on a continuum of addictive behaviors? Int J Env Res Pub He. 2020;17:422.
7. Kwon M, Lee JY, Won WY, Park JW, Min JA, Hahn C, et al. Development and validation of a smartphone addiction scale (SAS). PLoS ONE. 2013;8:e56936.
8. Amez S, Baert S. Smartphone use and academic performance: a literature revie. Int J Educ Res. 2020;103:101618.
9. Hartanto A, Chua YJ, Quek FY, Wong J, Ooi WM, Majeed NM. Problematic smartphone usage, objective smartphone engagement, and executive functions: a latent variable analysis. Atten Percept Psycho. 2023;85:2610.
10. Ratan ZA, Parrish AM, Zaman SB, Alotaibi MS, Hosseinzadeh H. (2021). Smartphone addiction and associated health outcomes in adult populations: a systematic review. Int J Env Res Pub He. 2021; 18: 12257.
11. Arpaci I, Kocadag Unver T. Moderating role of gender in the relationship between big five personality traits and smartphone addiction. Psychiatr Q. 2020;91:577–85.
12. Cocoradă E, Maican CI, Cazan AM, Maican MA. Assessing the smartphone addiction risk and its associations with personality traits among adolescents. Child Youth Serv Rev. 2018;93:345–54.
13. Kim Y, Jeong JE, Cho H, Jung DJ, Kwak M, Rho MJ, et al. Personality factors predicting smartphone addiction predisposition: behavioral inhibition and activation systems, impulsivity, and self-control. PLoS ONE. 2016;11:e0159788.
14. Carvalho LF, Sette CP, Ferrari BL. Problematic smartphone use relationship with pathological personality traits: systematic review and meta-analysis. Cyberpsych: J Psycho Res Cyberspace. 2018;12:1–20.

15. Xiong S, Xu Y, Zhang B, Zhu L, Xie J. Smartphone addiction and Eysenck's personality traits among Chinese adolescents: a meta-analysis. Front Psychol. 2022;12:794112.
16. Cho HY, Kim DJ, Park JW. Stress and adult smartphone addiction: mediation by self-control, neuroticism, and extraversion. Stress Health. 2017;33:624–30.
17. Gao T, Xiang YT, Zhang H, Zhang Z, Mei S. Neuroticism and quality of life: Multiple mediating effects of smartphone addiction and depression. Psychiat Res. 2017; 258: 457–461.
18. Marengo D, Sindermann C, Häckel D, Settanni M, Elhai JD, Montag C. The association between the big five personality traits and smartphone use disorder: a meta-analysis. J Behav Addict. 2020;9:534–50.
19. Allen MT, Shields MM, Myers CE. Distressed (type D) personality is predicted by avoidance: evidence from a computer-based avatar task. PeerJ. 2022;10:e14302.
20. Denollet J, Schiffer AA, Spek V. A general propensity to psychological distress affects cardiovascular outcomes: evidence from research on the type D (distressed) personality profile. Circ Cardiovasc Qual Outcomes. 2010;3:546–57.
21. Błachnio A, Przepiorka A, Czuczwar SJ. Type D personality, stress coping strategies and self-efficacy as predictors of Facebook intrusion. Psychiatry Res. 2017;253:33–7.
22. Holdoš J. Type D personality in the prediction of internet addiction in the young adult population of Slovak Internet users. Curr Psychol. 2017;36:861–8.
23. Denollet J. (2000). Type D personality: A potential risk factor refined. J Psychosom Res. 2000; 49: 255–266.
24. Asendorpf JB. Social inhibition: a general–developmental perspective. In: Traue HC, Pennebaker JW, editors. Emotion, inhibition, and Health. Seattle: Hogrefe & Huber; 1993. pp. 80–99.
25. Denollet J. (2005). DS14: standard assessment of negative affectivity, social inhibition, and Type D personality. Psychosom Med. 2005; 67: 89–97.
26. Lodder P. Modeling synergy: how to assess a type D personality effect. J Psychosom Res. 2020;132:109990.
27. Horwood S, Anglim J, Tooley G. Type D personality and the five-factor model: a facet-level analysis. Pers Indiv Differ. 2015;83:50–4.
28. Qiu H, Lu H, Pei J, Zhang Y, Ma Y, Xing C, et al. Effects of chronic stress on smartphone addiction: a moderated mediation model. Front Public Health. 2023;11:1048210.
29. Yue H, Zhang X, Sun J, Liu M, Li C, Bao H. The relationships between negative emotions and latent classes of smartphone addiction. PLoS ONE. 2021;16:e0248555.
30. Brand M, Young KS, Laier C, Wölfling K, Potenza MN. Integrating psychological and neurobiological considerations regarding the development and maintenance of specific internet-use disorders: an Interaction of person-affect-cognition-execution (I-PACE) model. Neurosci Biobehav Rev. 2016;71:252–66.
31. Brand M, Wegmann E, Stark R, Müller A, Wölfling K, Robbins TW, et al. The Interaction of person-affect-cognition-execution (I-PACE) model for addictive behaviors: Update, generalization to addictive behaviors beyond internet-use disorders, and specification of the process character of addictive behaviors. Neurosci Biobehav Rev. 2019;104:1–10.
32. Kuhl J, Kazén M, Koole SL. Putting self-regulation theory into practice: a user's manual. Appl Psychol. 2006;55:408–18.
33. Ode S, Robinson MD. (2007). Agreeableness and the self-regulation of negative affect: Findings involving the neuroticism/somatic distress relationship. Pers Individ Dif. 2007; 43: 2137–2148.
34. Shi Y, Koval P, Kostakos V, Goncalves J, Wadley G. Instant happiness: smartphones as tools for everyday emotion regulation. Int J Hum Comput Stud. 2023;170:102958.
35. Kang S, Jung J. Mobile communication for human needs: a comparison of smartphone use between the US and Korea. Comput Hum Behav. 2014;35:376–87.
36. Stone J, Cooper J. A self-standards model of cognitive dissonance. J Exp Soc Psychol. 2001;37:228–43.
37. McGrath A. Dealing with dissonance: a review of cognitive dissonance reduction. Soc Personal Psychol Compass. 2017;11:e12362.
38. Domagalska J, Rusin M, Razzaghi M, Nowak P. Personality type D, level of perceived stress, insomnia, and depression among high school teachers in Poland. Front Psychol. 2021;12:626945.
39. Chotpitayasunondh V, Douglas KM. How phubbing becomes the norm: the antecedents and consequences of snubbing via smartphone. Comput Hum Behav. 2016;63:9.
40. Sahin S, Ozdemir K, Unsal A, Temiz N. Evaluation of mobile phone addiction level and sleep quality in university students. Pak J Med Sci. 2013;29:913–8.
41. Yildirim C, Correia AP. Exploring the dimensions of nomophobia: development and validation of a self reported questionnaire. Comput Hum Behav. 2015;49:130–7.
42. Bragazzi NL, Del Puente G. A proposal for including nomophobia in the new DSM-V. Psychol Res Behav Manag. 2014; 155–60.
43. Anshari M, Alas Y, Sulaiman E. Smartphone addictions and nomophobia among youth. Vulnerable Child Youth Stud. 2019;14:242–7.
44. Çobanoğlu A, Bahadir-Yilmaz E, Kiziltan B. The relationship between nursing students' digital and smartphone addiction levels and nomophobia: a descriptive, correlational study. Perspect Psychiatr Care. 2021;57:1727–34.
45. Lin CY, Potenza MN, Ulander M, Broström A, Ohayon MM, Chattu VK, et al. Longitudinal relationships between nomophobia, addictive use of social media, and insomnia in adolescents. Healthc. 2021;9:1201.
46. Bhattacharya S, Bashar MA, Srivastava A, Singh A, Nomophobia. No mobile phone phobia. J Family Med Prim Care. 2019;8:1297.
47. Peeters G, Bennett M, Donoghue OA, Kennelly S, Kenny RA. Understanding the aetiology of fear of falling from the perspective of a fear-avoidance model–A narrative review. Clin Psychol Rev. 2020;79:101862.
48. León-Mejía AC, Gutiérrez-Ortega M, Serrano-Pintado I, González-Cabrera J. A systematic review on nomophobia prevalence: surfacing results and standard guidelines for future research. PLoS ONE. 2021;16:e0250509.
49. Lane JA, Fink RS. Attachment, social support satisfaction, and well-being during life transition in emerging adulthood. J Couns Psychol. 2015;43:1034–16.
50. Tan CS, Low SK, Viapude GN. Extraversion and happiness: the mediating role of social support and hope. Psych J. 2018;7:133–43.
51. Mehmood A, Bu T, Zhao E, Zelenina V, Alexander N, Wang W, et al. Exploration of psychological mechanism of smartphone addiction among international students of China by selecting the framework of the I-PACE model. Front Psychol. 2021;12:758610.
52. Flavell JH. Metacognitive aspects of problem solving. In: Resnick LB, editor. The nature of intelligence. Hillsdale, NJ: Erlbaum; 1976. pp. 231–6.
53. Hamzah H, Hamzah MI, Zulkifli H. Systematic literature review on the elements of metacognition-based higher Order thinking skills (HOTS) teaching and learning modules. Sustainability. 2022;14:813.
54. Veenman MV, Van Hout-Wolters BH, Afflerbach P. Metacognition and learning: conceptual and methodological considerations. Metacogn Learn. 2006;1:3–14.
55. Butzbach M, Fuermaier AB, Aschenbrenner S, Weisbrod M, Tucha L, Tucha O. Metacognition, psychopathology and daily functioning in adult ADHD. J Clin Exp Neuropsychol. 2021;43:384–98.
56. Rees CS, Anderson RA. (2013). A review of metacognition in psychological models of obsessive–compulsive disorder. Clinic Psychol. 2013; 17: 1–8.
57. Wells A. Advances in metacognitive therapy. Int J Cogn Ther. 2013;6:186–201.
58. Casale S, Musicò A, Spada MM. A systematic review of metacognitions in internet gaming disorder and problematic internet, smartphone and social networking sites use. Clin Psychol Psychoth. 2021;28:1494–508.
59. Rogier G, Zobel SB, Morganti W, Ponzoni S, Velotti P. Metacognition in gambling disorder: a systematic review and meta-analysis. Addict Behav. 2021;112:106600.
60. Toneatto T. Metacognition and substance use. Addict Behav. 1999;24:167–74.
61. Hamonniere T, Varescon I. Metacognitive beliefs in addictive behaviours: a systematic review. Addict Behav. 2018;85:51–63.
62. Spada MM, Caselli G, Nikčević AV, Wells A. Metacognition in addictive behaviors. Addict Behav. 2015;44:9–15.
63. Casale S, Caponi L, Fioravanti G. Metacognitions about problematic smartphone use: development of a self-report measure. Addict Behav. 2020;109:106484.
64. Shi Z, Chen H, Guan J, Xie Y, Huang S, Chen X, et al. Psychometric properties of the metacognitions about smartphone use questionnaire (MSUQ) in Chinese college students. Addict Behav. 2021;123:107041.
65. Akbari M, Zamani E, Fioravanti G, Casale S. Psychometric properties of the metacognitions about smartphone use questionnaire (MSUQ) in a sample of iranians. Addict Behav. 2021;114:106722.
66. Xie Y, Lei Q, Xie R, Yang Y. The role of family functioning: how the big five affect metacognitions about smartphone use. Front Psychol. 2022;13:991315.
67. Bohane L, Maguire N, Richardson T. Resilients, overcontrollers and undercontrollers: a systematic review of the utility of a personality typology method in understanding adult mental health problems. Clin Psychol Rev. 2017;57:75–92.
68. Tokar DM, Vaux A, Swanson JL. Dimensions relating Holland's vocational personality typology and the five-factor model. J Career Assess. 1995;3:57–74.

69. Baumert A, Schmitt M. Personality and information processing. Eur J Pers. 2012;26:87–9.
70. Armitage CJ, Conner M. Social cognition models and health behaviour: a structured review. Psychol Health. 2000;15:173–89.
71. Verdejo-Garcia A, Garcia-Fernandez G, Dom G. Cognition and addiction. Dialogues Clin Neurosci. 2022;21:281–90.
72. Flavell JH, Miller PH, Miller SA. Cognitive development. 4th eds. ed. Upper Saddle River, NJ: Prentice-Hall; 2002.
73. Wang A, Wang Z, Zhu Y, Shi X. The prevalence and psychosocial factors of problematic smartphone use among Chinese college students: a three-wave longitudinal study. Front Psychol. 2022;13:877277.
74. Long J, Liu TQ, Liao YH, Qi C, He HY, Chen SB, Billieux J. Prevalence and correlates of problematic smartphone use in a large random sample of Chinese undergraduates. BMC Psychiatry. 2016;16:408.
75. Guo T, Bai X, Zhen S, Abid S, Xia F. Lost at starting line: Predicting maladaptation of university freshmen based on educational big data. J Assoc Inf Sci Technol. 2023;74:17–32.
76. Brailovskaia J, Margraf J. Decrease of well-being and increase of online media use: cohort trends in German university freshmen between 2016 and 2019. Psychiatry Res. 2020;290:113110.
77. Liu H, Zhou Z, Zhu E, Huang L, Zhang M. (2022). Smartphone addiction and its associated factors among freshmen medical students in China: A cross-sectional study. BMC Psychiatry. 2022; 22: 308.
78. Parasuraman, S., Sam, A. T., Yee, S. W. K., Chuon, B. L. C., & Ren, L. Y. (2017). Smartphone usage and increased risk of mobile phone addiction: A concurrent study. Int J Pharm Investig. 2017; 7: 125–131.
79. Yu X-N, Zhang J-X. Application of type D personality scale (DS14) in Chinese college students. Chin Mental Health J. 2006; 313–6.
80. Ren S-X, Guli G-N, Liu T. Revisement of Nomophobia Scale for Chinese. Pychol Explor. 2020;40:300–11.
81. Kwon M, Kim DJ, Cho H, Yang S. The smartphone addiction scale: development and validation of a short version for adolescents. PLoS ONE. 2013;8:e83558.
82. Nie J, Li W, Wang P, Wang X, Wang Y, Lei L. Adolescent type D personality and social networking sites addiction: a moderated mediation model of restorative outcomes and affective relationships. Psychiatry Res. 2019;271:96–104.
83. Montag C, Błaszkiewicz K, Lachmann B, Sariyska R, Andone I, Trendafilov B, et al. Recorded behavior as a valuable resource for diagnostics in mobile phone addiction: evidence from psychoinformatics. Behav Sci. 2015;5:434–42.
84. Kuss DJ, Kanjo E, Crook-Rumsey M, Kibowski F, Wang GY, Sumich A. Problematic mobile phone use and addiction across generations: the roles of
85. psychopathological symptoms and smartphone use. J Technol Behav Sci. 2018;3:141–9.
85. Hitcham L, Jackson H, James RJ. The relationship between smartphone use and smartphone addiction: an examination of logged and self-reported behavior in a pre-registered, two-wave sample. Comput Hum Behav. 2023;146:107822.
86. Parry DA, Davidson BI, Sewall CJ, Fisher JT, Mieczkowski H, Quintana DS. A systematic review and meta-analysis of discrepancies between logged and self-reported digital media use. Nat Hum Behav. 2021;5:1535–47.
87. Thomas AC, Sullivan GB, Allen FCL. A theoretical model of EGM problem gambling: more than a cognitive escape. Int J Ment Health Addict. 2009;7:97–107.
88. Kupper N, Denollet J. Type D personality is associated with social anxiety in the general population. Int J Behav Med. 2014;21:496–505.
89. Sher L. Type D personality: the heart, stress, and cortisol. QJM. Int J Med. 2005;98:323–9.
90. González-Valero G, Zurita-Ortega F, Lindell-Postigo D, Conde-Pipó J, Grosz WR, Badicu G. Analysis of self-concept in adolescents before and during COVID-19 lockdown: differences by gender and sports activity. Sustainability. 2020;12:7792.
91. Humphreys L, Hardeman H. Mobiles in public: Social interaction in a smartphone era. Mob Media Commun. 2021;9:103–27.
92. van den Tooren M, Rutte C. Explaining emotional exhaustion and work engagement: the role of job demands-resources and type D personality. Int J Stress Manage. 2016;23:147–66.
93. Davis RA. A cognitive-behavioral model of pathological internet use. Comput Hum Behav. 2001;17:187–95.
94. Goldin PR, Gross JJ. Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. Emotion. 2010;10:83.
95. Caselli G, Spada MM. Desire thinking: a new target for treatment of addictive behaviors? Int J Cogn Ther. 2016;9:344–55.
96. Turel O, Serenko A. The benefits and dangers of enjoyment with social networking websites. Eur J Inf Syst. 2012;21:512–28.

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