

# Grit Perseverance, Not Passion, Moderates the Association Between Behavioral Inhibition/Approach System and Internet Addiction in Adolescents

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**Background:** Research on the links between the behavioral inhibition and approach systems (BIS/BAS), and internet addiction (IA) in adolescents has been inconclusive. BIS/BAS may interact with adolescent trait characteristics, resulting in different outcomes. Grit may alter adolescents' motivations, which can even be based on biological systems such as BIS/BAS. However, the impact of BIS/BAS and potential moderating factors on adolescents' internet use remains unclear. This study aimed to examine the association between BIS/BAS and IA in adolescents and explore the potential moderating roles of the two facets of grit, passion and perseverance, on the association between BIS/BAS and IA.

**Methods:** A total of 1,881 junior and senior high school students ( $M_{\text{age}} = 14.65$ , standard deviation  $_{\text{age}} = 1.81$ , ranging from 11 to 20 years) completed a self-reported measure of BIS/BAS, IA, and grit. Independent t-tests and chi-square tests were used to evaluate the differences between adolescents with IA and those with normal internet use. Pearson correlation and regression model analyses, including moderating model analysis, were used to qualify the associations between IA and BIS/BAS, as well as the potential moderating role of grit passion and perseverance.

**Results:** The results showed that 19.1% of the participants met the criteria for IA. Both BIS ( $\beta = 0.085$ ,  $t = 3.650$ ,  $p < 0.001$ ) and BAS ( $\beta = 0.06$ ,  $t = 2.552$ ,  $p < 0.05$ ) were positively associated with IA risk, and grit-perseverance moderated the association between BIS and IA ( $\beta = -0.230$ , bootstrap 95% confidence interval:  $-0.450$  to  $-0.012$ ) and BAS with IA ( $\beta = -0.187$ , bootstrap 95% confidence interval:  $-0.299$  to  $-0.076$ ).

**Conclusion:** These findings extend the current knowledge on the associations between BIS/BAS and IA. Moreover, the findings suggest that enhancing grit-perseverance may improve prevention and intervention of IA risk in adolescents who are sensitive to BIS and BAS.

**Keywords:** internet addiction, reinforcement sensitivity, grit, perseverance, passion

## Introduction

The internet has penetrated every aspect of people's daily experiences, including school, work, and entertainment. For modern adolescents, who are growing up in a time of rapid development of digital and information technology, the internet is considered an integral part of their day-to-day lives.<sup>1</sup> Because of its convenience and efficiency, adolescents worldwide also spend a large amount of time on the internet,<sup>2</sup> especially during the coronavirus disease pandemic.<sup>3</sup> Internet addiction (IA), also known as internet dependence or problematic internet use, is a growing concern.<sup>4</sup> IA, which is a behavioral addiction, can be defined as excessive or impulse-controlled preoccupation behaviors regarding internet use, such as playing internet games and social media, which leads to impairment or distress.<sup>5,6</sup> The prevalence rates of

worldwide adolescents' IA vary widely (eg, 0.8% in Italy and 36.1% in China).<sup>7,8</sup> Both addictive and excessive use of the internet have been extensively reported to be associated with negative consequences,<sup>9</sup> including risk of substance use experience,<sup>10</sup> sleep problems, depression, anxiety, and even suicidality in adolescents.<sup>11,12</sup> Because of adolescents' specific neuro-developmental plasticity,<sup>13</sup> it is crucial to explore the impact factor of IA in order to shed light on more effective prevention and intervention targets regarding IA risk in adolescents. Gray's neuropsychological reinforcement sensitivity theory (RST),<sup>14,15</sup> which suggests that behavior originates from at least two basic systems of motivation, a reward system and a punishment system, to govern approach and avoidance behavior based on biological systems, has been applied extensively in the research on high-risk behaviors in adolescents. Emerging studies have revealed that these two systems may be the critical factors accounting for high-risk behaviors in adolescents, including substance use disorder, problematic gambling,<sup>16,17</sup> and IA.<sup>18,19</sup> However, the findings concerning the effect of the two systems on IA are still inconsistent.<sup>18,20–22</sup> Therefore, the present study aimed to examine the associations of the two systems with IA and extend previous studies by exploring possible moderators in their associations.

The Behavioral Inhibition System (BIS), including the original BIS and the Fight-Flight-Freeze System,<sup>19,23</sup> is associated with punishment sensitivity, which mediates responses to conditioned signals of punishment (resulting in avoidance of negative or harmful consequences and frustrative non-reward or retarded response to reward), reflecting anxiety.<sup>14,24</sup> The Behavioral Approach System (or Behavioral Activation System, BAS) is associated with reward sensitivity, which is responsible for mediating reactions to conditioned signals of reward (result in approach behavior, and stimuli of decreasing punishment), reflecting impulsivity.<sup>23,24</sup> In line with the view that certain personality traits are prominent vulnerability factors for addiction,<sup>25–28</sup> BAS-sensitive adolescents may be more prone to engage in approaching behavior for stimuli with reward, including substance and behavioral addictions.<sup>29–31</sup> Of note, the current findings regarding the association between BIS/BAS and IA in adolescents are inconsistent. One empirical study revealed that a higher score on the overall BAS and its subscale, fun seeking, was positively associated with the occurrence of IA.<sup>20</sup> Conversely, another study suggested that BIS-sensitivity, not BAS-sensitivity, could predict IA levels.<sup>19</sup> It has also been found that both BIS and BAS are positively associated with IA.<sup>22</sup> A Recent study highlighted the moderating role of gender in the association between BIS/BAS and IA, suggesting that BIS was directly and indirectly mediated by emotion-focused coping associated with IA in girls, whereas BAS was directly and indirectly mediated by problem-focused coping associated with IA in boys.<sup>18</sup> In view of the above discrepant findings, it is possible that there are certain moderators such as gender that influence the association between BIS/BAS and IA in adolescents. For example, adolescents who are sensitive to BIS or BAS with certain personality traits may not be addicted to the internet. Based on the literature, we suggest that grit may be an important moderator that amplifies or diminishes the strength of the link.

Grit is defined as a combination of two facets: consistency or sustained interests and persistent efforts (hereafter referred to as passion and perseverance) for long-term goals despite setbacks.<sup>32</sup> Mounting studies have revealed that grit is negatively associated with addictive behaviors in students (mainly college students), including mobile phone addiction,<sup>33,34</sup> social media addiction,<sup>35</sup> and IA.<sup>36,37</sup> Several recent studies have indicated that grit is negatively associated with media device addiction,<sup>38</sup> smartphone addiction,<sup>39</sup> and IA in adolescents.<sup>40</sup> Moreover, a higher level of grit as a moderator could buffer the negative effects of paternal attachment insecurity on adolescents' IA.<sup>40</sup> In another recent study, grit moderated the correlation between school disengagement and victimization in internet game addiction.<sup>41</sup> Therefore, grit may be an important factor influencing adolescents' internet usage. On the other hand, research has found that high BAS for reward or fun seeking is linked to increased externalizing behaviors if directed toward high-reward pursuits.<sup>42</sup> However, self-control and grit are required to be adjunct to these reward drives for final achievement.<sup>32,43,44</sup> BAS sensitivity is supposed to make people prone to impulsivity and respond to short-term rewards, which may increase the risk of substance or behavioral addiction.<sup>30</sup> In addition, grit is supposed to entail dedication to long-term rewarding goals.<sup>32</sup> Accordingly, we hypothesized that grit may moderate the correlation between BIS/BAS and IA in adolescents. Although most studies reported findings at the level of an overall grit score and Duckworth et al also suggested that the two facets (passion and perseverance) together were more predictive than either alone in most cases,<sup>32</sup> other research has shown that a combination of the two facets may result in a significant loss in the ability to predict behaviors or performance.<sup>45,46</sup> Perseverance has been shown to be significantly more strongly associated with

performance than passion or overall grit.<sup>45</sup> Therefore, we considered passion and perseverance as two moderators and included both in a moderating model.

The aim of the current study was twofold: (1) to examine the association between BIS/BAS and IA risk in adolescents and (2) to explore whether grit passion and perseverance moderate these associations. Specifically, we established and tested moderating models to answer the following questions: (1) whether BIS-sensitivity and BAS-sensitivity had the same effect on IA; and (2) whether and how grit perseverance and passion play distinct roles in the association between BIS/BAS and IA.

## Material and Methods

### Participants and Procedure

Participants in the study were recruited from seven schools in Hunan Province, in central China. A total of 1,881 middle and high school students completed the questionnaires. The mean age of the participants was 14.65 years (standard deviation [SD] = 1.81; range from 11 to 20 years), with 915 girls (49%). A packet of questionnaires, including basic demographic information (gender, age, educational grades, body mass index, parents' marital stability, parents' education, socioeconomic status, etc.) with anonymized name, was administered to participants in their normal classes. All participants and their guardians were informed of the purpose of the study and provided written informed consent. This study was approved by the Ethics Committee of the Hunan University of Science and Technology in China.

### Instruments

IA risk was assessed using the Revised Chinese Chen Internet Addiction Scale,<sup>47,48</sup> which has been extensively applied in research on adolescents. The validity and reliability of the Revised Chinese Chen Internet Addiction Scale were confirmed, and Cronbach's alpha coefficient was 0.94 in the present study. The scale is a self-reported screening tool to investigate IA levels and comprises 26 items in four dimensions: compulsive use and withdrawal, interpersonal and health-related problems, time management problems, and tolerance. Each item has four response options, ranging from 1 ("does not match") to 4 ("totally matches"). The scores for the four dimensions were summed to calculate the total IA levels. Based on the recommended cutoffs for adolescents,<sup>48</sup> participants with a total score of 64 or above were categorized as having potential IA.

We measured participant's sensitivity to the behavioral inhibition and activation systems using a validated Chinese version of the BIS/BAS scales,<sup>49</sup> which was based on Carver and White's BIS/BAS scales.<sup>29</sup> This scale includes two subscales, the BIS and BAS, in addition to the four disturbance items. The BIS scale is a single dimension, and the BAS comprises three dimensions: drive, reward responsiveness, and fun seeking. The total BAS score, which is the sum of the scores of the three dimensions, was used for analysis in the present study. Each item was evaluated on a 4-point Likert scale, ranging from 1 ("does not match") to 4 ("totally matches"). The Cronbach's alpha values of the BAS and the BIS in the present study were 0.80 and 0.69, respectively.

A validated Chinese version of the Short Grit Scale<sup>50</sup> was used to assess the participant's grit. The scale comprises two dimensions: perseverance of effort (perseverance) and consistency of interest (passion). Each dimension consists of four items with responses based on a 5-point Likert scales ranging from 1 ("does not match") to 5 ("totally matches"). For the present study, the total grit scores were used in descriptive statistics, and then perseverance and passion were separately analyzed in the regression models. The Cronbach's alpha values of the scale in the present study were 0.77 for grit-perseverance, and 0.65 for grit-passion.

### Data Analysis

Descriptive statistics, *t*-test, variance analyses, Chi-square test, and correlation analyses were performed using SPSS 26.0 (IBM Corp). For continuous variables, means with SDs were used. The number of participants (*n*) and percentage rates (%) were used for discrete variables. Further regression models included two steps: (1) simple regression analyses predicting IA from BIS and BAS, respectively; (2) moderating model analyses to examine grit's moderating effects using the Version 3.5 of the PROCESS macro for SPSS developed by Hayes<sup>51</sup> (Model 2). All continuous variables were

centered. Post hoc simple effects were tested at one standard deviation above and below the means of grit perseverance and passion, respectively, if the moderation effect was significant. We used the bootstrapping method with 5,000 estimates, which provides a strong possible 95% bias-corrected confidence interval without the need for an assumption of normal distribution for the sampling,<sup>52</sup> to examine the interactive effects. Conditional effects in moderating analyses were considered statistically significant when zero was not included between the lower and upper bounds of 95% confidence intervals (CIs). For all t-tests, chi-square tests, and variance analyses, a two-tailed p-value < 0.05 was considered statistically significant. To test whether there was common method variance for single-time behavioral research, we performed Harman's one-factor analysis.<sup>53</sup> The results showed that the first common factor in our study explained 18.68% of the variance, indicating that common method variance in the present study was not a severe problem.

## Results

### Descriptive Statistics

Among the 1,881 participants included in the analysis, 359 (19.1%) met the criteria for IA. Table 1 presents the different characteristics of participants with and without IA. Participants with IA were more likely to be older ( $p < 0.05$ ) and in a family in which the parents' marriage was unstable ( $p < 0.05$ ) and had lower maternal education ( $p < 0.05$ ), lower socioeconomic status ( $p < 0.001$ ), and lower self-reported school social status ( $p < 0.001$ ). With regard to both low- and moderate-to-high-intensity physical activity, adolescents with potential IA exhibited significantly lower levels in comparison to those in the non-IA group ( $ps < 0.01$ ).

### Correlation Analysis

The correlations between the study variables are listed in Table 2. IA was positively associated with BIS and BAS ( $ps < 0.01$ ) but negatively correlated with total grit, grit passion, and perseverance ( $ps < 0.001$ ). Both BIS

**Table 1** Different Characteristics of the Participants with IA and Non-IA

		IA (N = 359)	Non-IA (N = 1,522)	Effect size Cohen's d	Chi/t-test	p
Gender, n (%)	Male	183 (19.2)	770 (80.8)		0.002	0.966
	Female	175 (19.1)	740 (80.9)			
Age, M (SD)		14.82 (1.64)	14.60 (1.85)	0.121	-2.172	0.030
BMI, M (SD)		18.82 (3.29)	18.92 (3.09)	0.031	0.563	0.574
One-child, n (%)	Yes	99 (21.1)	371 (78.9)		1.610	0.205
	No	250 (18.4)	1,109 (81.6)			
Parents' marriage, n (%)	Stable	289 (18.1)	1,310 (81.9)		5.453	0.020
	Instable	59 (24.4)	183 (75.6)			
Paternal education, n (%)	University	44 (18.2)	198 (81.8)		4.021	0.259
	High school	102 (18.8)	440 (81.2)			
	Middle school	161 (18.4)	712 (81.6)			
	Primary or below	42 (24.9)	127 (75.1)			
Maternal education, n (%)	University	33 (16.7)	165 (83.3)		8.922	0.030
	High school	78 (16.4)	398 (83.6)			
	Middle school	179 (19.4)	746 (80.6)			
	Primary or below	57 (25.4)	167 (74.6)			
SES, M (SD)		5.86 (1.64)	6.33 (1.69)	0.280	4.741	<0.001
SSS, M (SD)		6.37 (1.84)	6.84 (1.78)	0.262	4.482	<0.001
Low intensity PA, M (SD)		2.64 (2.24)	3.05 (2.04)	0.191	3.127	0.002
Moderate to high intensity PA, M (SD)		1.62 (1.89)	2.11 (1.84)	0.263	4.493	<0.001

**Abbreviations:** IA, internet addiction; BMI, body mass index; SES, social economic status; SSS, school social status; PA, physical activity.

**Table 2** The Associations of the Study Variables

	<b>M</b>	<b>SD</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
1 Internet addiction	51.01	14.42	1					
2 BIS	15.46	2.82	0.075**	1				
3 BAS	38.87	6.09	0.062**	0.532***	1			
4 Grit	3.06	0.58	-0.424***	-0.044	-0.037	1		
5 Grit-passion	2.98	0.81	-0.308***	-0.179***	-0.181***	0.684***	1	
6 Grit-perseverance	3.13	0.84	-0.280***	0.111***	0.125***	0.709***	-0.029	1

**Notes:** \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

**Abbreviations:** BIS, behavioral inhibition system; BAS, behavioral approach system.

and BAS were negatively associated with grit-passion ( $ps < 0.001$ ) and positively associated with grit-perseverance ( $ps < 0.001$ ).

## Hypothesis Testing

All the regression analyses were controlled for age and gender. For BIS and IA (see Table 3), BIS significantly predicted IA ( $\beta = 0.085$ ,  $t = 3.650$ ,  $p < 0.001$ ) in the simple regression model ( $R^2 = 0.027$ ). The moderating model test ( $R^2 = 0.203$ ) indicated that the main effect of BIS on IA remained significant ( $\beta = 0.313$ ,  $t = 2.766$ ,  $p < 0.01$ ). Moreover, the grit-perseverance  $\times$  BIS interaction ( $\beta = -0.230$ ,  $t = -2.102$ ,  $p < 0.05$ ; bootstrap 95% CI:  $-0.450$  to  $-0.012$ ) but not the grit-passion  $\times$  BIS interaction, significantly predicted IA. For BAS and IA (see Table 4), BAS significantly predicted IA ( $\beta = 0.060$ ,  $t = 2.552$ ,  $p < 0.05$ ) in the simple regression model ( $R^2 = 0.023$ ). However, the moderating model ( $R^2 = 0.203$ ) indicated that the main effect of BAS on IA was not significant, but its interaction with grit-perseverance ( $\beta = -0.187$ ,  $t = -3.532$ ,  $p < 0.001$ ; bootstrap 95% CI:  $-0.299$  to  $-0.076$ ) was negatively related to IA. There was no significant interactive effect of grit passion with BAS was found.

The simple slope tests demonstrated significant regression slopes of BIS and BAS on IA when grit-perseverance was low (see Figure 1), but not when grit-perseverance was high. Table 5 presents the conditional effects of BIS and BAS at low ( $-1$  SD) and high ( $+1$  SD) values of grit-perseverance. When grit-perseverance was low, BIS significantly positively predicted IA, regardless of high ( $\beta = 0.530$ ,  $t = 3.258$ ,  $p < 0.01$ ; 95% CI:  $0.211$  to  $0.848$ ) or low ( $\beta = 0.486$ ,  $t = 2.555$ ,  $p < 0.05$ ; 95% CI:  $0.113$  to  $0.858$ ) grit-passion. BAS could also significantly predict IA when grit-perseverance was low,

**Table 3** Moderating Effects of Grit-Perseverance and Grit-Passion on BIS and Internet Addiction ( $n = 1,785$ )

Predictors	Step 1		Step 2			
	$\beta$	t	$\beta$	t	Bootstrap 95% CI	
					LL	UL
Age	0.153	6.556***	0.916	5.328***	0.602	1.241
Gender	0.013	0.574	-0.813	-1.311	-1.998	0.406
BIS	0.085	3.650***	0.313	2.766**	0.079	0.536
Grit-passion			-5.376	-13.908***	-6.153	-4.579
BIS $\times$ Grit-passion			0.027	0.215	-0.214	0.270
Grit-perseverance			-5.090	-13.911***	-5.845	-4.343
BIS $\times$ Grit-perseverance			-0.230	-2.102*	-0.450	-0.012
$R^2$	0.027		0.203			
F	17.744***		64.640***			

**Notes:** \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

**Abbreviations:** BIS, Behavioral inhibition system; CI, confidence interval; LL, lower confidence limits; UL, upper confidence limits.

**Table 4** Moderating Effects of Grit-Perseverance and Grit-Passion on BAS and Internet Addiction (N = 1,759)

Predictor	Step 1		Step 2			
	$\beta$	t	$\beta$	t	Bootstrap 95% CI	
					LL	UL
Age	0.144	6.126***	0.887	5.116***	0.561	1.207
Gender	0.018	0.781	-0.645	-1.036	-1.875	0.560
BAS	0.060	2.552*	0.094	1.776	-0.013	0.207
Grit-passion			-5.467	-14.055***	-6.266	-4.694
BAS $\times$ Grit-passion			-0.102	-1.820	-0.217	0.009
Grit-perseverance			-4.948	-13.321***	-5.704	-4.182
BAS $\times$ Grit-perseverance			-0.187	-3.532***	-0.299	-0.076
R <sup>2</sup>	0.023		0.203			
F	14.746***		63.568***			

Notes: \* $p < 0.05$ ; \*\*\* $p < 0.001$ .

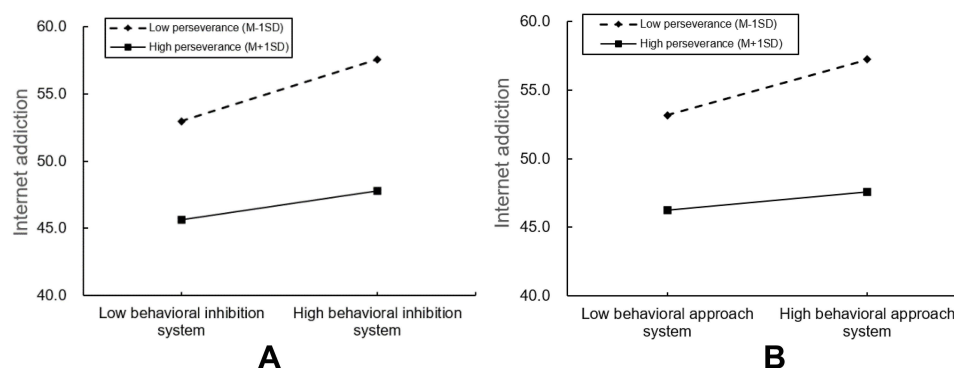
Abbreviations: BAS, behavioral approach system; CI, confidence interval; LL, lower confidence limits; UL, upper confidence limits.

regardless of high ( $\beta = 0.168$ ,  $t = 2.313$ ,  $p < 0.05$ ; 95% CI: 0.026 to 0.311) or low ( $\beta = 0.335$ ,  $t = 3.797$ ,  $p < 0.001$ ; 95% CI: 0.162 to 0.507) grit-passion.

## Discussion

The present study aimed to explore the associations between BIS/BAS and IA and to determine whether and how grit moderates these associations. Our findings demonstrated that BIS and BAS were both positively associated with IA risk and highlighted the moderating roles of grit-perseverance on BIS/BAS and IA.

Notably, our findings suggested that both BIS ( $\beta = 0.085$ ,  $t = 3.650$ ,  $p < 0.001$ ) and BAS ( $\beta = 0.060$ ,  $t = 2.552$ ,  $p < 0.05$ ) positively predicted IA after controlling for age and gender. This seems to be in line with the results of previous studies.<sup>22,54</sup> It has been suggested that BAS can positively predict IA because the dual-system neurobiological model of BAS proposes that reward-seeking is a risk factor for addictive behaviors in adolescents.<sup>29,30</sup> According to evolutionary theory, risk taking and novelty seeking are the markers of adolescence, which may lead to risky behaviors.<sup>55</sup> The internet provides extensive stimuli that make it easier and more convenient to seek rewards and take risks online. Adolescents with higher sensitivity to BAS may overuse the internet and are more likely to become addicted to it. However, given the anonymity, invisibility and fantasy of the internet, adolescents with high levels of BIS may also be prone to spending



**Figure 1** (A) Interaction effects between behavioral inhibition system (x axis) and low (-1 SD) and high (+1 SD) levels of grit-perseverance on internet addiction (y axis). (B) Interaction effects between behavioral approach system (x axis) and low (-1 SD) and high (+1 SD) levels of grit-perseverance on internet addiction (y axis).

**Table 5** Conditional Interaction Effects Between Grit Perseverance and Passion and BIS/BAS on Internet Addiction

	Grit-perseverance	Grit-passion	Effect sizes	SE	t	LLCI	ULCI
BIS	High	High	0.140	0.171	0.822	-0.195	0.476
		Low	0.097	0.188	0.513	-0.273	0.466
	Low	High	0.530	0.163	3.258**	0.211	0.848
		Low	0.486	0.190	2.555*	0.113	0.858
BAS	High	High	-0.147	0.083	-1.771	-0.310	0.016
		Low	0.019	0.087	0.223	-0.151	0.190
	Low	High	0.168	0.073	2.313*	0.026	0.311
		Low	0.335	0.088	3.797***	0.162	0.507

**Notes:** \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ .

**Abbreviations:** BIS, behavioral inhibition system; BAS, behavioral approach system; LLCI, lower limits confidence interval; ULCI, upper limits confidence interval.

more time on the internet to avoid real-world face-to-face social activities.<sup>18,19</sup> They may face scolding, criticism, and even punishment from parents, teachers, classmates, or friends and may be able to avoid these experiences by spending more time on the internet. Adolescents who are BIS- or BAS- sensitive are prone to addiction to the internet because it offers the ability to avoid real-world punishment or to seek rewards. Some previous studies have found that only BAS or only BIS<sup>56,57</sup> can predict IA. One possible reason for this inconsistency may be the different measurements used in the different studies. For BIS/BAS, the present study used a revised version of the BIS/BAS scale validated specifically for adolescents,<sup>49</sup> which excluded two items (“Even if something bad is about to happen to me, I rarely experience fear or nervousness” and “I have very few fears compared to my friends.”) from the original scale that were determined to be unfit in the item analysis. Other studies have used the original scale, which has been version validated in college students.<sup>29,58</sup> This makes it difficult to compare those studies with our own. Further studies with the same measurements and a thorough comparison of the associations between BIS and BAS and IA are required to clarify this issue.

Moreover, the present study first examined the moderating effects of grit-perseverance and grit-passion on the correlation between BIS/BAS and IA. Our findings revealed that grit-perseverance moderated the associations of BIS and BAS with IA. Specifically, only for adolescents with low levels of grit-perseverance were BIS and BAS both positively associated with IA, regardless of the levels of grit-passion. Although perseverance and passion were considered as two separate constructs, most previous studies reported grit at the level of the overall score<sup>45</sup> because they believed that the two facets together were more predictive than either alone.<sup>32</sup> However, from a meta-analytic synthesis of grit, grit-perseverance had stronger criterion validities of general GPA than grit-passion and only perseverance predicted academic performance,<sup>45</sup> suggesting that the perseverance facet may be the primary utility of the grit construct. For the effort-related nervous system hypothesis, individuals with high grit-perseverance showed a series of autonomic coactivations, in which the pre-ejection period and respiratory sinus arrhythmia became stronger during tasks, indicating that they considered tasks more serious and dedicated greater efforts to it, while people with high grit-passion did not.<sup>46</sup> For today’s adolescents who grew up during the rapid development of the internet, controlling themselves from overusing the internet is an unignorable and even difficult task. It is especially difficult for adolescents with high BIS or BAS because they are more likely to seek abundant rewards<sup>20,22</sup> or avoid punishments<sup>19,57</sup> from the real world through the convenience of the internet. However, for individuals sensitive to BIS or BAS with strong grit-perseverance, their effort-related nervous system guarantees that they take the task more seriously and make more effort to resist temptation from the internet. Thus, it is highly important to assist adolescents with lower levels of grit-perseverance to decrease IA risk, such as carrying out grit interventions via deliberate practices.<sup>59</sup> Generally, our findings highlight the importance of grit-perseverance in the educational domain<sup>60</sup> and further extend its key role in the area of behavioral addiction.

## Limitations and Future Research

The present study highlights the interactive role of personality factors in adolescents' IA, adding to existing research on adolescent samples that has thus far focused on a single BIS/BAS role<sup>19,20</sup> or moderator effects of gender.<sup>18</sup> Despite its insightful findings, the present study had several limitations that should be addressed. First, the cross-sectional design did not allow for causal inference on the effect of BIS/BAS on IA. Moreover, internet use, especially overuse and IA, may create differences in the development of adolescents' sensitivity to punishment (BIS) and reward (BAS).<sup>20</sup> Additional longitudinal studies are required to clarify the associations demonstrated in the study over time. Second, the measures involving retrospective self-reporting are vulnerable to bias. Replications applying other types of measures (eg, reports from parents and teachers, or objective measurements) are needed. Cronbach's alphas for BIS (0.69) and grit-passion (0.65) in the present study were consistent with the previous studies in this samples<sup>17,18</sup> but slightly deviated from the benchmark of 0.70, indicating that the results regarding these tests should be interpreted with caution. Third, the nature of observational studies makes it difficult to exclude potential biases induced by other factors. Although we controlled for age and gender for all model analyses, other potential factors (eg, type of internet application,<sup>61</sup> and physical activity<sup>62,63</sup>) may also influence the results. Finally, the present study did not recruit adolescents who were homeschooled or truant from school; thus, the findings of the present study may not apply to off-school adolescents. Future studies with a broader population could provide stronger evidence for this issue.

## Conclusion

For adolescents, high BIS and BAS scores were both positively associated with IA risk, and grit-perseverance could moderate these associations. Higher grit-perseverance may be a protective factor in preventing adolescents with high BIS/BAS from developing IA. Our findings provide insights into how to effectively prevent and intervene in adolescent IA. However, due to the cross-sectional design of our study, the findings should be interpreted with caution.

## Abbreviations

IA, Internet Addiction; BIS, Behavioral Inhibition System; BAS, Behavioral Approach System.

## Data Availability Statement

The data presented in this study are available on request from the corresponding author.

## Ethics Statement

The ethics of this study was reviewed and approved by the Ethics Committee of the Hunan University of Science and Technology. We confirm that the guidelines outlined in the Declaration of Helsinki were followed.

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## Disclosure

The authors report no conflicts of interest in relation to this work.

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