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Attentional biases and daily game craving dynamics: An ecological momentary assessment study

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FULL-LENGTH REPORT

ABSTRACT

Background and aims: Theories posit that the combination of external (e.g. cue exposure) and internal (e.g. attention biases) factors contributes to the development of game craving. Nevertheless, whether different components of attentional biases (namely, engagement bias and disengagement bias) play separate roles on game craving has not been fully elucidated. We aimed to examine the associations between two facets of attentional biases and game craving dynamics under a daily life setting. *Methods:* Participants (110 regular internet game players) accomplished the modified attentional assessment task in the laboratory, after which they entered a 10-day ecological momentary assessment (EMA) to collect data on their momentary game craving and occurrence of game-related events at five different time points per day. *Results:* We found that occurrence of game-related events was significantly associated with increased game craving. Moreover, attentional disengagement bias, instead of engagement bias, bore on the occasional level variations of game craving as moderating variables. Specifically, attentional disengagement bias, not engagement bias, was associated with a greater increase in game craving immediately after encountering a game-related event; however, neither attentional engagement bias nor disengagement bias was associated with the craving maintenance after a relatively long period. *Discussion and conclusions:* The present study highlights the specific attentional processes involved in game craving dynamics, which could be crucial for designing interventions for attentional bias modification (ABM) in Internet Gaming Disorder (IGD) populations.

KEYWORDS

game craving, game-related events, attentional disengagement, attentional engagement, ecological momentary assessment

Online games have become popular, especially since online multiplayer games that serve social and recreational purposes emerged (Nuyens et al., 2016). They have become an indispensable part of many people's lives as a popular pastime. However, overindulgence could lead to players developing Internet gaming disorder (IGD), "characterized by persistent gaming and functional impairment in multiple areas of life" (King & Delfabbro, 2018, p. 17). Several researchers have recently advocated IGD as an essential public health issue worthy of attention (King, Koster, & Billieux, 2019; Stein et al., 2018). In line with this, the Diagnostic and Statistical Manual for Mental Disorders, Fifth Edition (DSM-5; APA, 2013), includes IGD as a condition for further study in Section 3. Furthermore, in 2018, the World Health Organization officially recognized IGD as an addictive disorder in the International Classification of Diseases, 11th Revision (ICD-11; WHO, 2018). Identifying potential psychological mechanisms underlining IGD development is of great significance theoretically and practically.

Dual process model of addiction (Brand, 2022; Wiers, Gladwin, Hofmann, Salemink, & Ridderinkhof, 2013) highlights the combination of strengthened cravings to cues and weakened reflective processes as the defining feature in addiction. Craving, often defined as the subjective, intense desire or urge to initiate addictive behaviors (Giuliani & Berkman,

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2015; Lavallee, 2020), serve a crucial role in drug addictions (APA, 2013), as well as behavioral addictions (Dong et al., 2018; Potenza et al., 2003; Wegmann, Muller, Trotzke, & Brand, 2021). For instance, previous studies have consistently found heightened game craving in individuals with IGD exposed to game-related cues (Bargeron & Hormes, 2017; Dong, Dong, et al., 2021; Shin et al., 2018). Additionally, game craving was positively correlated with problematic game playing (Moretta & Buodo, 2018), general psychopathology (i.e., depression, anxiety, and stress), decreased life satisfaction, and impulsivity (Bargeron & Hormes, 2017). In a recent international Delphi study, game craving, though not included in the ICD-11 and DSM-5 definitions, was considered an additional relevant diagnostic criterion with sufficient prognostic value (Castro-Calvo et al., 2021).

Diverse paradigms have been developed in laboratory settings to explore game craving. The most widely used ones usually involve cue exposure procedures (e.g., presenting participants with game-related pictures and sounds; Dong, Dong, et al., 2021; Niu et al., 2016). However, artificial stimuli and strict laboratory settings far from real-life contexts did not fully reveal the ephemeral and fluctuant nature of craving dynamics (Enkema, Hallgren, Bowen, Lee, & Larimer, 2021). Fortunately, mobile technologies, such as ecological momentary assessment (EMA; Stone & Shiffman, 1994), have permitted real-time data collection in natural contexts and therefore offer a solution to numerous methodological barriers to emotion and addiction research (Mun et al., 2021). The feasibility and validity of the EMA have been repeatedly established in individuals with different addiction syndromes (see review from Serre, Fatseas, Swendsen, & Auriacombe, 2015). Further, they are well suited to explore the craving state as a function of various determinants. Repeated within-day assessments capture fluctuations in craving dynamics and inform researchers about prospective relationships (Shiyko & Ram, 2011).

Theories posit that a combination of external and internal factors contributes to game craving and addiction development (Brand, Young, Laier, Wölfling, & Potenza, 2016, 2019). Game craving has been conceptualized as an outcome of classical conditioning (Heuer, Mennig, Schubö, & Barke, 2021). Specifically, when environmental cues (e.g., the sight of game advertisements and the sound of game characters) have been repeatedly associated with playing games, they become conditioned stimuli that elicit gaming urges. This explanation is supported by Dong et al. (2021) and Shin et al. (2018). They found that exposure to both real and virtual gaming environments increased subjective craving among problematic Internet game players. Recent neurocognitive studies have also investigated potential behavioral and neural mechanisms of cue reactivity and craving in IGD populations (see review from Fauth-Bühler & Mann, 2017). The up-to-date findings demonstrated the involvement of both the ventral and dorsal striatum (Dong, Dong, et al., 2021), which give preliminary support for parallels among IGD, pathological gambling (Crockford, Goodyear, Edwards, Quickfall, & el-Guebaly, 2005) and substance-use disorders (Skinner & Aubin, 2010).

Additionally, theories postulate that internal factors, such as attentional bias, are closely associated with the development of craving (Brand et al., 2016, 2019). Attentional bias is the preferential attention of addiction-related stimuli, making it difficult to deal with the current task (Field & Cox, 2008) and having a common neural mechanism with craving (Hester & Luijten, 2014). The celebrated incentive sensitization theory of addiction (Robinson & Berridge, 2008) purports that persistent addictive behaviors can cause "sensitization" or hypersensitivity to addiction-related stimuli. This incentive-sensitization produces attentional bias toward those stimuli, leading to enhanced craving and addiction motivation. Although theoretically crucial in addiction, investigation of attentional bias in individuals with IGD has been scarce, producing mixed evidence: some have found evidence of attentional bias toward gaming-related stimuli using classical paradigms, such as Stroop or dot-probe tasks (Jeromin, Nyenhuis, & Barke, 2016; Lorenz et al., 2013; Metcalf & Pammer, 2011), whereas others have not (Van Holst et al., 2012; Zhang et al., 2016). This may be because of the conceptual distinction between facilitated attentional engagement with gaming-related stimuli (reflecting a disproportionate tendency for attention to be *captured* by gaming-related stimuli), and impaired attentional disengagement from gaming-related stimuli (reflecting an excessive predilection for attention to be *held* by gaming-related stimuli). Specifically, Heuer et al. (2021) found that IGD gamers demonstrated longer reaction times than casual gamers. Further, they demonstrated increased sustained posterior contralateral negativity (SPCN) amplitude to computer-related stimuli in a visual search task, indicating that the disengagement of attention from addiction-related stimuli was impaired in IGD individuals. Contrastingly, the initial deployment of attention to addiction-relevant stimuli was relatively intact.

Based on the aforementioned findings and related theories, we tentatively propose two possible pathways through which external cues and internal attentional biases contributes to game craving development: the reactivity model (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002) and the perseverance model (Joormann, Yoon, & Zetsche, 2007). Attentional biases to game-related information (especially for impaired attentional disengagement) contribute to prolonged and perseverative game-related information processing (Koster, De Lissnyder, Derakshan, & De Raedt, 2011). These, in turn, may amplify the emotional impact of game cue exposure regarding acute craving change (reactivity model) and/or persistent high craving maintenance (perseverance model).

In sum, the present study aimed to examine the factors contributing to daily game craving dynamics and test specific models in a college sample who regularly played Internet games. First, we compared general game craving, attentional biases, and gaming behaviors among Internet gamers with different levels of IGD tendencies. We hypothesized that Internet gamers with higher levels of IGD would have higher levels of game craving, demonstrate altered attentional biases (especially in attentional disengagement), and spend more time playing Internet games compared with lower IGD tendency gamers. Subsequently, multilevel modeling was used to examine the specific role of attentional biases and everyday game cues in developing game cravings. We hypothesized that both the reactivity and perseverance model were valid in the current study.

METHOD

Participants and procedures

Participants were 110 (39 female and 71 male; $M_{age} = 19.05$ years; $SD = 0.93$ years) undergraduate students who played the game of Glory of Kings[1] (Tencent Company) at the Zhejiang University, China.

First every participant provided a signed informed consent after being briefed of the purpose of the study. Later, they completed the dichotomous 9-Item Internet Gaming Disorder Scale (Lemmens, Valkenburg, & Gentile, 2015), the Internet Gaming Addiction Scale (revised from the Internet Addiction Scale; Young, 1999), the Craving Questionnaire (Weiss, Griffin, & Hufford, 1995), and the modified attentional assessment task (Rudaizky, Basanovic, & MacLeod, 2014). Beginning on the following day, participants took part in 10 days of EMA sampling (Including 6 working days and 4 weekends). After completing all the sessions, participants were debriefed and were given monetary compensation based on their EMA compliance. The sample size meets the guideline of 30 individuals for 30 observations (the 30/30 rule; e.g., Hox, 2010). Other studies indicated that the 30/30 rule can achieve a statistical power greater than 0.80 to detect a medium-to-large fixed effect (Mathieu, Aguinis, Culpepper, & Chen, 2012).

Measures

Questionnaires

9-Item Internet Gaming Disorder Scale (IGD-9). IGD-9 (Lemmens et al., 2015) is an 9-item online gaming disorder tendency scale developed based on the 9 diagnostic criteria (including preoccupation, withdrawal, tolerance, unsuccessful attempts to control, loss of other interests, continued excessive use despite psychosocial problems, deceiving regarding online gaming, escape, and functional impairment) formulated in DSM-5 (APA, 2013). Respondents need to rate all items with either NO (0) or YES (1). The item scores are summed to arrive at a total score, with higher scores indicating higher online gaming disorder tendency (range 0–9). If the total score is 5 points or above, the respondent is believed to meet the diagnostic criteria of IGD (APA, 2013). The internal consistency of the IGD-9 in the present study was acceptable ($\alpha = 0.65$).

Internet Gaming Addiction Scale (IGA). The Internet Gaming Addiction Scale (IGA) is revised from the Internet Addiction Scale developed by Young (1999). The original scale provides a framework for assessment of specific situations or problems that have been caused by computer overuse to facilitate subsequent treatment planning. This scale consists of 20 items and respondents need to rate all items on a 5-point scale, ranging from 1 (never) to 5 (always). The item scores are summed to arrive at a total score (range 20–100), with higher scores indicating higher Internet Addiction tendency. We replace the word “Internet” for the phrase “Internet gaming” to measure the level of Internet Gaming Addiction in this study. If the total score is 50 points or above, the respondent is believed to meet the moderate to severe level of IGD (Young, 1999). The internal consistency of the IGA in the present study was good ($\alpha = 0.90$).

Craving Questionnaire (CQ). The Craving Questionnaire is revised from the Cocaine Craving Scale developed by Weiss et al. (1995), which is designed to assess five dimensions of craving: 1) immediate intensity, 2) intensity during the previous 24 h, 3) frequency, 4) reactivity of craving to game-related cues, and 5) likelihood of playing if in an environment with high online game availability. This scale consists of 5 items, and each item is rated on a 10-point scale, ranging from 1 (not at all) to 10 (very much so). The item scores are summed to arrive at a total score, with higher scores indicating higher craving trait. The internal consistency of the CQ in the present study was good ($\alpha = 0.88$).

Modified attentional assessment task. We adapted attentional engagement bias and disengagement bias assessment task, developed by Rudaizky et al. (2014), to enable the independent assessment of each facet of selective attention. In this task, each trial begins with the displaying of two 200×150 pixels white rectangle outlines, on both sides of the screen. An 80×60 pixels red square outline appears in one of these white rectangles with equal frequency, signaling the location where the cue probe will briefly appear. Meanwhile, participants are required to fixate their attention at the red square. After 1,000 ms, a 20 pixels red line will appear within the red square outline, with equal probability of being horizontal or vertical. The cue probe will remain for only 200 ms, therefore its orientation can only be perceived if participants have already attended to the cued location. Immediately thereafter an image pair appears, with one image filling each of the two white rectangles. One image is abstract and the other representational.[2] The representational image appears

[1]Glory of Kings is one of the most popular multiplayer online battle arena (MOBA) game in the world whose average daily active users in 2020 was 100 million (You, 2022).

[2]The modified attentional assessment task contained 256 pictures, including abstract images, game-related images and neutral images. Half of the images (128) were “non-representational” images of an abstract nature. The other half images were “representational”. Among them, half of the images (64) were game-related while the other half (64) were neutral images. See more details in Supplementary materials.

with equal frequency either in the distal location from that where the participant is already attending (attentional engagement bias assessment trials) or in the same location as the participant is already attending to (attentional disengagement bias assessment trials). This image display lasts for either 500 ms or 1,000 ms, with equal probability to prevent participants from fixed response tendency. But in the present study, we emphasized on the trials with a duration of 500 ms only because they can better reflect the automatic attentional bias mode (Grafton & MacLeod, 2016). The screen then clears, and a target probe immediately appears in either one of these two screen regions, with equal probability. Again this is a 20 pixels red line, either horizontally or vertically. Participants are required to indicate whether the orientation of this target probe matched that of the cue probe, which was the case on 50% of trials. Participants respond by pressing "j" or "f" key on the keyboard to respectively indicate that the probes match or mismatch. Reaction times (RTs) to make this probe discrimination decision are recorded and used to calculate the relevant indices of attentional bias (see below). After a 1,000 ms interval, the next trial begins. An example trial is presented in Fig. 1.

Engagement bias index = (Cue probe distal to game-related image in game-related/abstract image pair: RT for target probe distal to game-related image minus RT for target probe proximal to game-related image) minus (Cue probe distal to neutral image in neutral/abstract image pair: RT for target probe distal to neutral image minus RT for target probe proximal to neutral image). A higher score on this engagement bias index will represent selectively enhanced shifting of attention towards initially unattended distal images when these are game-related rather than neutral.

Disengagement bias index = (Cue probe proximal to game-related image in game-related/abstract image pair: RT for target probe distal to game-related image minus RT for target probe proximal to game-related image) minus (Cue probe proximal to neutral image in neutral/abstract image pair: RT for target probe distal to neutral image minus RT for target probe proximal to neutral image). A higher score on this disengagement bias index will represent a heightened tendency for attention to be held in the locus of initially attended proximal images when these are game-related rather than neutral.

In the present study, the task contained a total of 256 trials. In the task, each image pair was presented twice, left or right position was counterbalanced across participants, and the order of presentation of the images was randomized. Participants were instructed to respond as quickly as possible while maintaining accuracy. After every 64 trials participants were instructed to take a self-timed break. Before the formal experiment, participants performed 10 practice trials, including 10 pairs of neutral images (different from the neutral images in the formal experiment). Participants entered the formal experiment after the correct rate of practice trials reached 75%.

Ecological Momentary Assessment (EMA). We used a mobile phone-based EMA to collect data on participants' momentary internal and external experiences (Takano & Tanno, 2011). Participants received 5 messages on their own mobile phones between 9:40 and 22:30 each day (the five time points are 9:40, 13:00, 16:30, 19:10, 22:30, to stagger the participants' class schedule). Each message contained a URL for an online questionnaire (see Table 1). When participants received the e-mail, they were required to access and

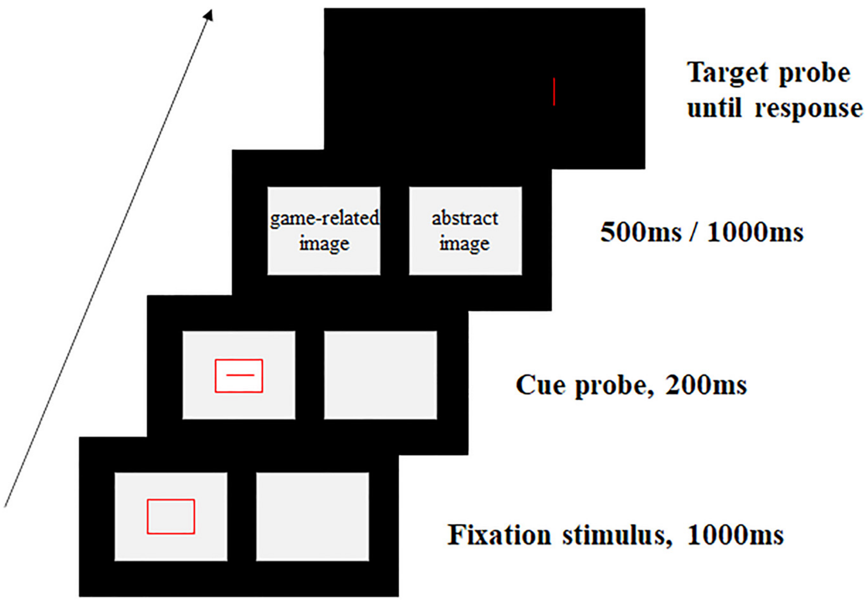

Fig. 1. Example of a trial on the modified attentional assessment task. Trial displayed is a disengagement bias assessment trial. Attentional focus is initially anchored proximally to the game-related image

Table 1. Test items included in Ecological Momentary Assessment (EMA)

EMA items	Response options
Craving intensity: How strong do you want to play online games now?	Rating 0–100
Anxiety intensity: How anxious you are now?	Rating 0–100
Game thoughts episode: Since last questionnaire, how many times did you experience urges to play online games?	( ) Times
Have you played any online games?	Yes(1)/No(0)
How long did you play?	( ) Minutes
What online game did you play	(The name of online games)
Game-related event occurrence: Since last questionnaire, did something happen that remind you of online games?	Yes(1)/No(0)
[a] Gaming duration: How much time did you spend playing online games, in total today?	( )hours

Note. [a]Game duration was assessed in the last questionnaire (22:30) in each day.

complete the questionnaire within 15 min. The EMA sampling continued over 10 consecutive days, including 4 weekend days.

Statistical analyses

Attentional biases indices. For attentional bias indices, the mean response latencies observed under the different task conditions were used to calculate the engagement bias and disengagement bias indices of attentional preference for game-related information for each participant. In computing these indices, response latencies from incorrect trials were excluded. In addition, outliers were identified using a 99% confidence level meaning scores that were greater than 2.58 standard deviations from the participant's mean latency for that experimental condition were excluded (in total 7% of trials were excluded from the analysis).

EMA data preparation. During the 10-day EMA sampling, we excluded data from five participants: one made errors on more than 30% of the trials in the attentional assessment task, and 4 participants did not complete EMA seriously whose responses were all 0.

Multilevel modeling. To test the association between attentional biases and craving reactivity and perseverance, we estimated two multilevel models, wherein game craving intensity at time *t* was predicted a) by game-related event at time *t* and attentional biases (i.e., the reactivity model; cf. Bylsma, Taylor-Clift, & Rottenberg, 2011; Peeters, Berkhof, Rottenberg, & Nicolson, 2010), and b) by game-related event at time *t*-1 and attentional biases (i.e., the perseverance model; cf. Iijima, Takano, & Tanno, 2018). Note that game-related event at time *t* refers to an event that happened in the interval between the last (time *t*-1) and current (time *t*) occasions.

In **the reactivity model**, *the occasion level* equation was given as:

$$CRA_{tdj} = \pi_{0dj} + \pi_{1dj}\, CRA_{t-1\,dj} + \pi_{2dj}\, GAM_{tdj} + \pi_{3dj}\, ANX_{tdj} + e_{tdj}$$

where CRA_{tdj} is the level of game craving intensity at the *t*-th measurement in the *d*-th day of the *j*-th participant, and GAM_{tdj} is the game-related event occurrence in the interval between time *t*-1 and *t*. We controlled for the effects of game craving at the previous measurement in the same day ($CRA_{t-1\ dj}$) and the level of anxious mood (ANX_{tdj}). That the current level of anxious mood was controlled was based on the assumption that online gaming may be a coping strategy for individuals with psychological stress (Chang, Chang, Hou, Lin, & Griffiths, 2021), and thereby confound the influence of game-related events on game craving. No extra variable at *the day level* was included:

$$\pi_{0dj} = \beta_{00j} + r_{0dj}$$

$$\pi_{1dj} = \beta_{10j} + r_{1dj}$$

$$\pi_{2dj} = \beta_{20j} + r_{2dj}$$

$$\pi_{3dj} = \beta_{30j} + r_{3dj}$$

At *the person level*, effects of gender differences (*GEN*) and severity of Internet Gaming Disorder diagnosis (*IGD*; IGD-9 scores were used) were included:

$$\beta_{00j} = \gamma_{000} + \gamma_{001}\, GEN_j + \gamma_{002}\, IGD_j + u_{00j}$$

Moreover, the influence of game-related event occurrence was hypothesized to vary according to the level of attentional biases (*BIAS*). Therefore, the slope (β_{20j}) was described as follows:

$$\beta_{20j} = \gamma_{200} + \gamma_{201}\, BIAS_j + u_{20j}$$

The γ_{200} coefficient indicates the main effect of the game-related event occurrence, and γ_{201} reflects the cross-level interaction effect between attentional biases and game-related event occurrence.

The perseverance model was the same as the reactivity model, except for the timing of game-related event: the model included negative event at time *t*-1 instead of at time *t* as a predictor.

Therefore, the reactivity model tested an immediate craving change in response to a game-related event that occurred in the interval between time *t*-1 and *t*, whereas the perseverance model captured a persistent process following a game-related event that occurred during the interval from time *t*-2 to *t*-1. This conceptualization of the craving perseverance drew on emotion dynamic research by Koval et al. (2015), wherein perseverance was operationally defined as the difference in effect between time *t* and *t*-1, when an event was reported at time *t*-1 (i.e., occurring since the previous occasion). All multilevel modeling analyses were conducted using HLM Version 6.08.

Ethics

This study was approved by the Ethics Committee of the department of psychology and behavioral science of the Zhejiang University.

RESULTS

Group differences in attentional bias indices and EMA summary

Descriptive statistics are presented in Table 2. Generally, the current sample did not meet the diagnostic criteria in IGD-9 scale ($M = 3.41$, $SD = 1.93$), whereas they reach the moderate level of IGD in IGA scale ($M = 52.41$, $SD = 11.99$). In order to determine whether high and low disorder tendency online gaming participants differed in terms of sample characteristics, attentional bias indices, and EMA descriptive statistics, participants first were divided into different IGD tendency groups based on their IGD-9 and IGA scores (high IGD tendency: 50 and above in IGD-9, as well as 50 and above in IGA, $n = 30$; low IGD tendency: below 5 in IGD-9, as well as below 50 in IGA, $n = 32$; APA, 2013; Young, 1999). Results demonstrated that two groups did not differ in terms of age ($P > 0.050$) and gender ($P > 0.050$). High IGD tendency group showed significantly higher scores on IGD-9, IGA, and CQ (all $P < 0.001$) compared with low IGD tendency group (see Table 2).

For attentional bias indices, the independent-samples *t* test showed significant higher attentional disengagement bias scores in the high IGD tendency group compared to the low IGD tendency group ($M = 25.35$, $SD = 75.96$ vs. $M = -37.61$, $SD = 99.78$, $P = 0.007$, *Cohen's d* $= 0.71$). However, two groups did not differ in terms of attentional engagement bias ($M = 1.30$, $SD = 126.33$ vs. $M = 19.01$, $SD = 73.25$, $P > 0.050$, *Cohen's d* $= 0.17$). In addition, low and high disorder tendency online gaming participants did not differ in terms of accuracy ($M = 0.93$, $SD = 0.04$ vs. $M = 0.94$, $SD = 0.04$, $P > 0.050$, *Cohen's d* $= 0.25$). This possibly suggested that the higher disorder tendency online gaming participants displayed difficulty in disengaging from initially proximal game-related images.

For EMA descriptive statistics, we computed person-mean game craving, anxiety, number of thoughts to play games, and time on playing games, and made comparisons between two groups. High IGD tendency group generally demonstrated higher levels of game craving ($M = 27.21$, $SD = 18.42$ vs. $M = 18.22$, $SD = 15.31$, $P = 0.040$, *Cohen's d* $= 0.53$), had more thoughts to play online games between two occasions ($M = 1.11$, $SD = 1.12$ vs. $M = 0.54$, $SD = 0.35$, $P = 0.012$, *Cohen's d* $= 0.69$), and spent more time on playing online games each day ($M = 2.44$, $SD = 1.95$ vs. $M = 1.18$, $SD = 0.96$, $P = 0.003$, *Cohen's*

Table 2. Main sample characteristics, attentional bias indices, and EMA summary

Variable	Group				
	[d] Low disorder tendency ($n = 32$) M ([e] SD)	[f] High disorder tendency ($n = 30$) M (SD)	t (p)	95% CI	All ($N = 105$) M (SD)
Main Sample Characteristics					
Age	19.03 (0.86)	19.17 (1.26)	0.49 (0.621)	[−0.41, 0.68]	19.08 (0.94)
Gender (male)	12	21			69
[a] IGD-9	1.88 (1.07)	5.83 (0.95)	15.36 (0.000)	[3.44, 4.47]	3.41 (1.93)
[b] IGA	38.44 (7.53)	63.70 (8.42)	12.47 (0.000)	[21.21, 29.31]	52.41 (11.99)
[c] CQ	20.59 (6.14)	29.50 (7.61)	5.09 (0.000)	[5.40, 12.41]	25.36 (7.99)
Attentional Bias Indices					
Engagement bias index	19.01 (73.25)	1.30 (126.33)	−0.67 (0.506)	[-70.97, 35.53]	18.07 (108.79)
Disengagement bias index	−37.61 (99.78)	25.35 (75.96)	2.78 (0.007)	[17.68, 108.23]	2.28 (108.93)
EMA Summary					
Game Craving - Person Mean	18.22 (15.31)	27.21 (18.42)	2.10 (0.040)	[0.41, 17.58]	24.70 (17.10)
Anxiety–Person Mean	26.25 (19.70)	31.80 (16.20)	1.21 (0.232)	[-3.64, 14.75]	28.02 (16.95)
Thoughts to play games between two occasions	0.54 (0.35)	1.11 (1.12)	2.66 (0.012)	[0.13, 0.99]	0.82 (0.74)
Time on playing games between two occasions/min	12.28 (10.51)	18.12 (13.22)	1.93 (0.058)	[-0.21, 11.89]	15.32 (12.44)
Time on playing games a day h^{-1}	1.18 (0.96)	2.44 (1.95)	−3.19 (0.003)	[-2.47, −0.62]	1.65 (1.44)

Note. [a]IGD-9 = 9-Item Internet Gaming Disorder Scale; [b] IGA = Internet Gaming Addiction Scale; [c] CQ = Craving Questionnaire; [d] Low disorder tendency: below 5 in IGD-9, as well as below 50 in IGA; [e] *SD* = standard deviation; [f] High disorder tendency: 50 and above in IGD-9, as well as 50 and above in IGA.

Table 3. Estimated fixed effects of the multilevel model predicting momentary game craving (at Time *t*) for Reactivity and Perseverance models

Variables	Reactivity model			Perseverance model		
	Coefficient ([b] *SE*)	*t*	*P*	Coefficient (*SE*)	*t*	*P*
Person-level predictors						
Intercept	13.54 (1.85)	7.34	0.000	17.64 (1.89)	9.35	0.000
Gender	3.34 (2.56)	1.31	0.195	5.70 (2.62)	2.17	0.032
[a] IGD-9	0.76 (0.78)	0.97	0.334	0.88 (0.76)	1.16	0.251
Occasion-level predictors						
Game craving (*t*-1)	0.07 (0.03)	2.68	0.007	0.09 (0.03)	3.05	0.002
Game-related events (*t*-1 to *t*)	13.83 (1.30)	10.61	0.000	—	—	—
Game-related events (*t*-2 to *t*-1)	—	—	—	−0.33 (0.72)	−0.46	0.648
Current anxious mood	0.14 (0.03)	4.26	0.000	0.16 (0.03)	4.72	0.000
Cross-level interaction						
Disengage × Game-related events (*t*-1 to *t*)	0.03 (0.01)	2.91	0.004	—	—	—
Engage × Game-related events (*t*-1 to *t*)	0.01 (0.01)	0.40	0.690	—	—	—
Disengage × Game-related events (*t*-2 to *t*-1)	—	—	—	0.00 (0.01)	0.04	0.967
Engage × Game-related events (*t*-2 to *t*-1)	—	—	—	0.00 (0.01)	0.27	0.786

Note. 4,981 observations across 105 participants were used for model estimation.
[a] IGD-9 = 9-Item Internet Gaming Disorder Scale;
[b] *SE* = standard error.

d = 0.82). Two groups did not differ in terms of general anxiety (*M* = 31.80, *SD* = 16.20 vs. *M* = 26.25, *SD* = 19.70, $P > 0.050$, *Cohen's d* = 0.31). Correlations between attentional bias and craving dynamics[3] parameters can be found in Supplementary materials.

Attentional disengagement bias moderates craving reactivity but not perseverance

Next, we examined the specific associations between attentional biases (engagement and disengagement respectively) and craving reactivity and perseverance. To test the enhanced reactivity hypothesis, we estimated a multilevel model wherein temporary game craving at time *t* was predicted by occurrence of a game-related event (from time *t*-1 to *t*), attentional biases, and their interaction, while controlling for game craving at the previous assessment occasion (time *t*-1) and current anxious level (time *t*). The estimated fixed effects are presented in Table 3. Game-related event occurrence (from time *t*-1 to *t*) was significantly associated with increased game craving at time *t*, as a main effect. Furthermore, this main effect was qualified by the interaction with attentional disengagement bias ($t = 2.91$, $P = 0.004$), but not engagement bias ($t = 0.40$, $P > 0.050$). To further illustrate the pattern of this interaction, a post hoc analysis was used to test the simple slopes of game-related event for individuals with relatively higher and lower levels of attentional disengagement bias ($M \pm 1SD$; Preacher, Curran, & Bauer, 2006). The conditional effect of game-related event occurrence on game craving was greater for individuals with higher levels of attentional disengagement bias ($B = 16.58$, $SE = 1.65$, $t = 10.04$, $P < 0.001$) than for those with lower levels of bias ($B = 8.48$, $SE = 1.70$, $t = 4.99$, $P < 0.001$). These findings suggest that attentional disengagement bias, not engagement bias, serves as a moderator that amplifies immediate craving elevation in response to a game-related event, which supports the hypothesis that attentional disengagement bias is associated with increased game craving reactivity to game-related cues.

To test the enhanced perseverance hypothesis, we estimated a similar multilevel model, in which game craving at time *t* was predicted by the occurrence of a game-related event (time *t*-2 to time *t*-1), attentional biases, and their interaction. Table 3 also illustrates the estimated results of this perseverance model, which showed non-significant interaction between attentional biases (both engagement and disengagement) and game-related events (all $P > 0.050$). These null interactions suggest that both attentional engagement and disengagement bias may bear no influence on the maintenance of craving for a delayed time point.

DISCUSSION

Although theoretically important, game craving has been investigated in a few studies on Internet game players. The present study examined the external and internal factors that contributed to daily game craving dynamics using EMA in a college sample who regularly played Internet games. Our main results illustrate that the occurrence of game-related events[4] was significantly associated with increased game craving. More importantly, we explored the moderating function of attentional biases as an internal factor bore on occasional level variations in game craving.

[3]Based on previous study (Iijima et al., 2018), we calculated three dynamics parameters from the EMA assessment of game craving. See more details in Supplementary materials.

[4]Here, game-related events occurred in the interval between time *t*-1 and *t*.

Specifically, attentional disengagement bias (not engagement bias) was associated with a more significant increase in game craving immediately after encountering a game-related event (i.e., the reactivity model). However, neither attentional engagement nor disengagement biases were associated with craving maintenance after a relatively long period (i.e., the perseverance model).

Researchers have claimed that attentional disengagement probably distinguishes individuals with an addiction history from those without and can contribute to the maintenance of addictive behaviors (e.g., problematic gambling and substance abuse; Heuer et al., 2021; Hudson, Olatunji, Gough, Yi, & Stewart, 2016). Consistently, we found that individuals with relatively high IGD tendencies had more impaired disengagement of attention from addiction-related stimuli than individuals with low IGD tendencies. This result indicated that attentional disengagement may be a potential vulnerability factor helping to differentiate between different patterns of Internet game use (Brand, 2022). Based on multilevel model analyses, this study also demonstrated that although encountering game-related events amplified momentary craving in all game players, individuals with higher levels of attentional disengagement bias exhibited more significant instant changes. This result supports the distinctive role of attentional disengagement toward addiction-related information on craving, which has not been investigated in regular Internet game players. According to the cognitive processing model (Franken, Stam, Heniks, & van den Brink, 2003), continued attentional processing of addiction-related stimuli may contribute to explicit desire thinking (see review from Brandtner, Antons, Cornil, & Brand, 2021), which is believed to be an essential part of the craving experience that leads to excessive memory bias and fuels the strength of the craving experience. In support of this potential mechanism, we found a significant positive correlation between attentional disengagement bias indices and the number of thoughts about playing online games (person mean) during EMA sampling ($r = 0.265$, $P = 0.006$; see Supplementary materials). Conversely, it is also possible that prolonged attentional processing of addiction-related stimuli contributes to the impairment of cognitive control (Dong, Dong, et al., 2021), which may explain the difficulties in controlling gaming cue-elicited cravings. Actually, intensive investigations have demonstrated deficits of self-control in problematic internet gaming use (Brand, 2022). However, the exact mechanism warrants further study.

The present study highlights the specific attentional processes involved in game craving dynamics, which could be crucial for designing interventions for attentional bias modification (ABM, Chia & Zhang, 2020) in IGD populations. We suggest that future studies design effective intervention strategies targeting the components of disengagement. Nevertheless, several limitations should be considered when interpreting the results of this study. First, the present study only focused on two driving factors (namely external cues and internal attentional biases) contributing to game craving. It would be more theoretically-elaborated to consider the self-control process as counterpart, as illustrated in the dual process model of addiction (Brand, 2022; Wiers et al., 2013). Investigations into the dynamic interplays of driving and control processes will produce a more comprehensive understanding of craving development. Second, the definition of reactivity and perseverance depends mainly on the assessment interval of the EMA paradigm. Replications using different timeframes are warranted before coming to a consensus. Third, a single-item visual analogue scale was used to assess the momentary craving. Therefore, we were unable to explicitly distinguish between reward and relief cravings which were motivationally different. Actually, several integrative models have posit craving to have different (sub)dimensions associated with corresponding subtypes of addictive behaviors (Glöckner-Rist, Lémenager, Mann, & PREDICT Study Research Group, 2013; Heinz et al., 2003). Further studies are encouraged to resolve this issue. Forth, the multilevel model analyses included all participants with varying levels of IGD tendency (although IGD-9 scores were controlled for in the model). Future studies should investigate whether Internet game players with or without IGD diagnoses demonstrate different patterns of results.

CONCLUSION

The present study demonstrated that though encountering game-related events amplified momentary game craving for all internet game players, individuals with higher levels of attentional disengagement bias exhibit more intense elevations in game craving. The component of attentional disengagement distinctively contributes to game craving dynamics, which could be crucial for designing interventions for attentional bias modification in IGD populations.

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Authors' contribution: Yucheng Zhou, Yanling Zhou, Jifan Zhou, Mowei Shen, and Meng Zhang designed the study and wrote the protocol as a team. Yucheng Zhou, Yanling Zhou, Jifan Zhou, and Meng Zhang conducted literature searches and wrote reviews of prior researches. Yucheng Zhou, Yanling Zhou, and Meng Zhang collected data. Yucheng Zhou, Yanling Zhou, and Jifan Zhou conducted the statistical analysis. Yucheng Zhou and Yanling Zhou wrote the first draft of the manuscript and all authors conducted to and have approved the final manuscript.

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SUPPLEMENTARY MATERIALS

Supplementary data to this article can be found online at https://doi.org/10.1556/2006.2022.00085.

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