Received: 17 September 2024 | Accepted: 31 March 2025

DOI: 10.1111/add.70088

RESEARCH REPORT

ADDICTION SSA

Associations of emotional experience with gaming duration and risk of gaming disorder among adolescent gamers: An ecological momentary assessment study

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Funding information
The work described in this paper was fully supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (PolyU 15601422). The funding provider had no role in the study design, collection, analysis or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Abstract

Background and aims: Affect has been shown to be associated with gaming disorder (GD), but little is known about how its temporal tendency may predict excessive gaming. We aimed to evaluate how affect intensity and fluctuations may predict gaming duration and risk of GD among adolescent gamers.

Design: A longitudinal study with ecological momentary assessment (EMA) to collect participants' data at four time points throughout the day during a 14-day observation period.

Setting: July and August 2023 in Hong Kong SAR, China.

Participants: A total of 317 adolescents (37.2% female; M_{age} = 15.5) who self-identified as regular gamers.

Measurements: The major measures were daily game time, GD (Internet Gaming Disorder Scale; IGDS9-SF) and affect intensity (the Positive and Negative Affect Schedule; PANAS), while affect fluctuations were captured by obtaining the root mean squared of successive differences of the PANAS scores.

Findings: Both overall negative affect intensity [β = 0.3816, 95% confidence interval (CI) = 0.0941–0.6691, *P* = 0.0095] and fluctuations (β = 0.5123, 95% CI = 0.0567–0.9679, *P* = 0.0277) were statistically significantly associated with the follow-up IGDS9-SF score. In terms of positive affect, only affect fluctuations were statistically significantly associated with IGDS9-SF score (β = 0.4457, 95% CI = 0.0279–0.8636, *P* = 0.0367). At within-person level, both daily negative affect intensity (exponentiated β = 1.0159, 95% CI = 1.0018–1.0302, *P* = 0.0265) and fluctuations (exponentiated β = 1.0144, 95% CI = 1.0030–1.0258, *P* = 0.0130) were statistically significantly associated with daily game time. Daily positive affect intensity (exponentiated β = 1.0136, 95% CI = 1.0025–1.0248, *P* = 0.0166) was statistically significantly associated with increased daily game time at within-person level. The association between daily positive affect fluctuations and game time was statistically non-significant.

Conclusions: Both intensity and fluctuations of negative affect may predict gaming duration and risk of gaming disorder among Hong Kong adolescents. For positive affect, emotion intensity may be more related to gaming duration, and emotion fluctuations may be more related to adolescents' risk of gaming disorder.

KEYWORDS
adolescent health, affect, behavioral health, ecological momentary assessment, gaming, gaming disorder

INTRODUCTION

Video gaming is a popular leisure activity among adolescents, and studies have reported potential benefits of video gaming on adolescents' problem solving, physical activity and well-being [1]. However, a minority of gamers may develop gaming disorder (GD), a diagnosable behavioral addiction characterized by a persistent pattern of impaired control over gaming, and continuation or escalation of gaming despite negative consequences [2]. Globally, 3.3% to 6.6% of children and adolescents suffer from GD [3]. To better inform preventive strategies, researchers continue to investigate factors that elevate the risk of GD, especially in children and adolescents.

Systematic reviews show that among a wide range of biopsychosocial predictors, emotional health problems such as depression and anxiety are consistently associated with GD [4, 5]. However, previous research investigating the association between emotions and GD tends to view emotions as a static construct, such as asking research participants to report average levels of emotions [6], failing to take into consideration emotions as dynamic, state-like experiences that vary across daily situations. State-like emotional experience or mood can be categorized into negative affect and positive affect. Negative affect refers to the degree to which an individual experiences negative mood (such as feeling nervous, ashamed and upset); and positive affect refers to the extent to which an individual experiences positive mood (such as feeling alert, enthusiastic and happy) [7]. A cross-sectional study provided preliminary evidence on the link between affective states and symptoms of GD, revealing a significant relationship between higher levels of negative affect and GD, but not positive affect [6]. Furthermore, it is not only the levels of affect that matter. Increasing evidence has shown that fluctuations in emotional states, also referred to as affect instability in the literature, are a key element of mental health [8–10]. Affect fluctuations may reflect deficits in emotion regulation, which has been viewed as a transdiagnostic construct that is linked with psychopathology [11] as well as addictive behaviors including problematic gambling and gaming [12]. Additionally, adolescence is a time when individuals often experience changes in emotions [13], underscoring the importance of assessing affect fluctuations for this age group. Surprisingly, no studies to date have examined how emotion fluctuations influence adolescents' and risk of GD. Besides assessing GD, gaming duration is a crucial outcome closely linked to GD [14]. While prior research has indicated that heightened trait-like negative emotions are associated with increased gaming duration [15], the link between state-like emotions and gaming duration in adolescents' daily lives remains largely unexplored.

Apart from the limitation of over-emphasis on static, trait-like emotions in previous GD studies, there is also strong reliance on the use of retrospective assessment [16], which will likely result in participants' recall bias, especially when respondents are asked to recall the occurrence of behaviors and experience for a specific reference period. One way to address this methodological challenge is to use an ecological momentary assessment (EMA) approach to collect self-reported momentary experience on multiple occasions in participants' real-life settings [17]. Assessments can be conducted via written diaries, phone calls or smartphone apps and can enhance ecological validity and minimize recall bias because the assessments are conducted at, or very close to, the time and place the experience or behavior occurred. EMA is suitable for capturing transient experience like affective states, which are likely to occur at different times and contexts throughout a day. In addition, EMA is suggested to be a promising approach to capture symptoms of mental health, including addictive behaviors [18]. The application of EMA has been reported in addressing emotions and affect in other addiction problems, such as substance use disorder [19]. However, EMA research examining momentary affect in relation to gaming and GD is lacking.

Building on the foundations laid by prior research on the relationships of emotions with gaming and GD, in the current study we sought to estimate the strength between:

1. 14-day average affect intensity and risk of GD;
2. affect fluctuations across the 14-day EMA and risk of GD;
3. daily affect intensity and daily gaming time; and
4. daily affect fluctuations and daily gaming time.

We hypothesized that negative affect (but not positive affect) intensity and fluctuations would be positively associated with risk of GD and gaming time.

METHODS

Study design

This was an intensive longitudinal study delivered via a smartphone application. The study consisted of a pre-EMA survey, a 14-day EMA and a post-EMA survey. The 14-day EMA period involved having participants answered a short survey with their mobile phone at four prescheduled times a day (on notification from the app), which allowed us to capture the within-person affect fluctuations. This study was reported based on an adapted strengthening the reporting of observational studies in epidemiology (STROBE) checklist for reporting EMA studies (CREMAS) (Table S1) [20].

Participant eligibility criteria

Using purposive sampling, Chinese adolescents age between 12 and 18 years at the time of enrollment were considered eligible for the study if they: (1) self-reported as regular gamers; (2) owned a smartphone with access to the internet; (3) did not have any condition that would affect their completion of the scheduled surveys of the study; and (4) provided written consent (or parental written consent and adolescent assent for those younger than 18 years old). There is no consensus regarding the definition of regular gamers. In this study, regular gamers were those who play video games (on-line, off-line or both) at least 7 hours per week [21].

Sample size and recruitment

Based on the estimates from a previous study on associations between affect and risk of gaming disorder [6], a sample of 214 was sufficient to detect an association with 80% statistical power at a significance level of 0.05. Former EMA studies of adolescent samples showed retention rates between 83.4% [22] and 95.2% [23]. We assumed a retention rate of 80% for the current study, from which we anticipated a sample size of no less than 268 would be needed. However, we deliberately oversampled to increase the diversity of the participant pool for analysis purposes.

Invitation letters detailing the study purpose were sent to 447 secondary schools. Twenty-five schools responded to the letter, of which eight schools enrolled in the study and 17 schools declined participation. We also sent posters to 161 non-governmental organizations serving youth to advertise our study. Adolescents who self-identified as regular gamers were asked to indicate their intention to participate in the study by completing an on-line screening questionnaire. Interest was expressed by 605 adolescents who responded to the screening questionnaire, of whom 495 met the eligibility criteria. A total of 319 adolescents participated in and completed the study; 317 were included for analyses after removing the data of two unmatched participants. Major reasons for non-participation included busy schedule (required to attend supplementary classes in school during the summer, part-time job engagement), traveling outside Hong Kong and lack of parental consent.

Study procedures

Data collection took place between July and August 2023. Data were collected during school summer holidays such that participants' compliance to the study protocol would not be deterred by restrictions on smartphone use in schools. An EMA smartphone app called 'Assessify' was developed by the research team to collect momentary data. Before the 14-day EMA, eligible participants were asked to complete the pre-EMA survey on-line and underwent training for the EMA app at a briefing session either on-line or in person. Participants were reassured that the research team would not reveal any of the information they provided, such as their gaming time and their reported experiences, to anyone, including their parents and teachers, to minimize potential social desirability responses. After the briefing session, participants were given 1 day to trial run the app before the commencement of the 14-day EMA.

The current study adopted the interval-based EMA approach. During the EMA period, the app sent push notifications to participants daily at four randomized times during four pre-determined periods (11 AM–12 PM, 2 PM–3 PM, 5 PM–6 PM and 8 PM–9 PM) for a total of 14 consecutive days (56 surveys in total). Participants were required to complete the survey within 20 minutes of the first notification. After the last day of EMA, participants were asked to complete the post-EMA survey on-line within 7 days. Participants received a base amount of HK$50 (~US$6.41) in cash after completion of the pre-EMA survey, and an additional amount of cash incentive based on the number of surveys completed. A progressive incentive strategy was used to maximize participation rates (see Table S2 for details). The maximum amount of cash incentive a participant could receive was HK$500 (US$64.1). Additional details of the study procedures are reported in Appendix S1.

Ethics

Ethical approval for the study was obtained from the first author's affiliated institution (reference number: HSEARS20220124002-01).

Measurements

We measured the between-person constructs (GD, gaming motives and difficulties in emotion regulation) at the pre-EMA survey/pre- and post-EMA surveys, while the within-person measures (positive and negative affect, and gaming duration), were captured at the 14-day EMA entry. Participants' demographic information, including family socio-economic status (SES), parental education level, parental age, parental marital status and participants' age, sex and chronic illness status were also collected at the pre-EMA survey.

Pre-EMA and post-EMA surveys

Gaming disorder

The Chinese version of the Internet Gaming Disorder Scale-Short Form (IGDS9-SF), which had been validated previously using a sample from the same population [24], was used to measure GD. Each item of IGDS9-SF is rated on a five-point Likert scale from 1 = never to 5 = very often, with higher scores indicating a higher level of severity of GD [25]. The IGDS9-SF captures symptoms of GD from a static perspective (in the past 12 months), and hence it was only used in the pre- and post-EMA surveys, not the 14-day EMA. The baseline Cronbach's α was 0.782 (95% CI = 0.742–0.813) in the current study.

Gaming motives (pre-EMA only)

The Chinese version of the Motives for On-line Gaming Questionnaire (MOGQ) [26] was administered to assess seven gaming motives (social, escape, competition, coping, skill development, fantasy and recreation). All items are answered with a five-point Likert scale ranging from 1 = almost never/never to 5 = almost always/always, with higher scores indicating greater expressions of gaming motive. The overall Cronbach's α was 0.926 (95% CI = 0.913–0.937). See Table S3 for details of subscales.

Difficulties in emotion regulation (pre-EMA only)

The 16-item Difficulties in Emotion Regulation Scale (DERS-16) [27] is a five-point Likert type self-report scale that assesses emotion dysregulation. Participants responded to each item using a five-point Likert scale (1 = almost never to 5 = almost always). A higher total score represents greater overall difficulty in regulating emotions. We obtained an excellent overall internal consistency for the scale in the current study (α = 0.938; 95% CI = 0.926–0.947). The αs of subscales are presented in Table S3.

Gaming genres (pre-EMA only)

Information on gaming genres was collected by asking participants to rate the frequency of playing in different game categories proposed by Männikkö [28] on a five-point scale ranging from 1 = never to 5 = every day. The types of genres and examples of games were slightly modified according to the popular games played by local adolescents, including multiplayer on-line role-playing game (MMORPG), first-person shooter (FPS), sports simulation games (SSG), multiplayer on-line battle arena (MOBA), real-time strategy (RTS), asymmetrical multiplayer games (AMG) and role-playing games (RPG).

14-day EMA surveys

Positive and negative affect

Participants were asked to report their affect using the Chinese version of the International Positive and Negative Affect Schedule Short Form (10 items; PANAS) [29] 4 times a day × 14 days = 56 times total. To capture participants' in-the-moment affectivity (their feeling right now), we modified the original five-point scale (1 = not at all to 5 = always) to 1 = very slightly or not at all to 5 = very much or always. The sum of scores of each subscale ranged from 10 to 50, with higher scores indicating greater affectivity. In the current study, the positive PANAS scale had a pooled Cronbach's α of 0.735 (95% CI = 0.724–0.747), while that of the negative PANAS was α = 0.738 (95% CI = 0.726–0.749). See Table S4 for details.

An aggregated variable, root mean squared of successive differences (RMSSD), was calculated to capture the variability and temporal dependency of positive affect fluctuations and negative affect fluctuations by using all four daily PANAS score entries, as recommended by previous studies [8, 9]. It is obtained by squaring the successive interval differences (e.g. T2 minus T1, T3 minus T2, *etc.*) of each affect measure entry, then square-rooting the mean value of those squared differences. This measure allowed us to capture both variability and temporal tendency in EMA data [10].

Gaming duration

Time spent on gaming was collected by having participants report how much time (minutes) they spent on gaming for that day at their final daily EMA entry.

Statistical analysis

Both uni- and multi-level regression models were constructed to examine the stated hypotheses (see details below). Demographic data were measured at baseline and adjusted as covariates at the between-person level, along with their IGDS9-SF, MOGQ and DERS scores. These covariates were selected because they might influence the exposures and outcomes measured in the study. All analyses were conducted with R version 4.3.1. We used the lme4 package (version 1.1–34) to perform multi-level linear regressions. α Level was set at 0.05 for all tests of statistical significance in all analyses. The analysis plan was not preregistered and the results should be regarded as exploratory.

Affect intensity over 14 days predicting gaming disorder

To examine the first objective, we performed a multi-variable linear regression model. Overall affect intensity was operationalized as the mean of PANAS scores for each participant using all 56 EMA entries (positive and negative, respectively), whereas the follow-up IGDS9-SF score was treated as the outcome. Baseline IGDS9-SF score was included in the model as a covariate to account for potential reverse causality. Histogram and normality test indicate the skewness of model outcome = 0.65 was within acceptable range.

Affect fluctuations over 14 days predicting gaming disorder

Similarly, for the second objective, multi-variable linear regression model was performed to examine the captioned association. All

56 entries of PANAS scores (positive and negative, respectively) were used to calculate the RMSSDs of affect fluctuations as the exposures.

Daily affect intensity predicting game time

To examine the third objective, multi-level mixed-effect models were used to account for within-person (level 1) and between-person (level 2) variances with full maximum likelihood estimations. The daily means of positive and negative PANAS scores (computed by averaging the four score entries per day) were used to predict the daily game time. These level-1 predictors were person–mean centered (i.e. daily means of PANAS scores minus person–mean) to test the within-person association and the person–mean scores were then centered by the grand mean (i.e. person–mean minus grand mean) to test the between-person association. The centering methods were adopted such that not only between-person variance was estimated (i.e. the quantification of each individual's affective state was compared with the average affective score in the sample), but within-person variance of PANAS could also be obtained (i.e. the affective state for a given individual in our sample at any given time point was compared with their own average state across measurements). To control for any time-related spurious effects, 'day' was included as a fixed effect covariate.

Daily affect fluctuations predicting game time

To capture the daily affect fluctuations in the mixed-effect models (the fourth objective), a total of 14 positive and negative RMSSDs were clustered within each participant. Day was included as a fixed effect covariate along with other demographics and confounding variables. The bilevel mean-centering approach was also adopted to examine the two-level variances. Multi-level linear regression models were performed to account for within-person and between-person variations. For the two daily game time models, logarithmic transformation was applied on the outcome variable because of its severe distribution skewness based on visual assessment on a histogram. All results presented thereafter have been back transformed for easier interpretation.

RESULTS

Sample descriptive statistics

In our sample, 62.8% were boys and the mean age was 15.5 (SD = 1.49) (Table 1). A total of 40 (12.6%) adolescents had one or more chronic conditions. Over half of the sampled households (56.8%) had a monthly household income between HK$20 000 (∼US$2 564) and HK$39 999 (∼US$5 128), with 73 (23%) receiving social security (Comprehensive Social Security Assistance). Table 1 shows the descriptive statistics of PANAS, RMSSD and daily game time of participants. The mean score of IGDS was 20.4 (SD = 5.65). The participants had a mean daily game time of 160 minutes (SD = 128.23). The overall mean scores of MOGQ and DERS were 81.3 (SD = 20.1) and 36.3 (SD = 14.1), respectively. Participants' game genre preferences are tabulated in Table S5. Over half of the participants reported that they played MOBA at least weekly (51.1%), followed by RPG (48.6%) and FPS (46.7%).

EMA data

Before establishing the adjusted multilevel models, null models (i.e. intercept only) were used to determine the variability in the study outcomes at within- and between-person levels based on the intraclass correlation coefficient (ICC) calculation. For the two daily game time models, 50.9% of the variability occurred at the between-person level, and 49.1% occurred at the within-person level.

A total of 13 392 observations were obtained from the participants, which account for 75.4% of the complete EMA data set (317 × 14 × 4 = 17 752). In other words, 4360 rows of data were missing of all EMA data. Since the nature of missingness was reckoned to be missing not at random, multiple imputation was not adopted. Each momentarily measured variable with missing data was imputed with random values within possible range (with replacement), which could increase non-differential misclassification and, therefore, have more conservative findings. Results from autoregression and partial autoregression functions on data missingness are listed in Table S6.

Affect intensity/fluctuations over 14-days and gaming disorder

Table 2 tabulates the coefficients of the multi-variable linear regression models. Results indicated that overall negative affect intensity was significantly associated with IGDS9-SF score (β = 0.3816, 95% CI = 0.0941–0.6691, *P* = 0.0095). But such association was nonsignificant when predicted by overall positive affect intensity (*P* = 0.4080).

Moreover, both overall positive affect fluctuations (β = 0.4457, 95% CI = 0.0279–0.8636, *P* = 0.0367) and negative affect fluctuations (β = 0.5123, 95% CI = 0.0567–0.9679, *P* = 0.0277) predicted the follow-up IGDS9-SF score.

Daily affect intensity/fluctuations and game time

Table 3 illustrates the coefficients of models relating PANAS scores and log-transformed game time. For daily means of positive PANAS, the within-person association was found to be statistically significant (exponentiated β = 1.0136, 95% CI = 1.0025–1.0248, *P* = 0.0166), but not between-person association. Similarly, negative PANAS was significantly associated with daily game time at the within-person level (β = 1.0159, 95% CI = 1.0018–1.0302, *P* = 0.0265); no significant result was found for the between-person association.

Table 3 also summarizes the results of the daily affect fluctuations models. When predicting daily game time by daily positive affect

TABLE 1 Descriptive statistics of participants.

	Overall (n = 317)
Household demographics	
Sex (n, %)	
Male	199 (62.8)
Female	118 (37.2)
Age (n, %)	
Mean (SD)	15.5 (1.49)
Chronic conditions (n, %)	
Any	40 (12.6)
Restriction in body movement	1 (0.3)
Seeing difficulty	8 (2.5)
Hearing difficulty	2 (0.6)
Speech difficulty	5 (1.6)
Mental illness/mood disorder	10 (3.2)
Autism	6 (1.9)
Specific learning difficulty	7 (2.2)
Attention deficit/hyperactive disorder	16 (5.0)
Parents' marital status (n, %)	
Never married	6 (1.9)
Cohabitant	61 (19.2)
Married	196 (61.8)
Divorced/separated	42 (13.2)
Deceased	12 (3.8)
Mother's age (n, %)	
18–24	13 (4.1)
25–34	134 (42.3)
35–44	153 (48.3)
45–54	15 (4.7)
55–64	2 (0.6)
65 or above	0 (0)
Father's age (n, %)	
18–24	2 (0.6)
25–34	6 (1.9)
35–44	71 (22.4)
45–54	146 (46.1)
55–64	74 (23.3)
65 or above	18 (5.7)
Mother's education (n, %)	
Elementary or below	41 (12.9)
Middle school	95 (30.0)
High school	136 (42.9)
College or above	45 (14.2)
Father's education (n, %)	
Elementary or below	24 (7.6)
Middle school	89 (28.1)
High school	128 (40.4)

(Continues)

TABLE 1 (Continued)

	Overall (n = 317)
College or above	76 (24.0)
Monthly household income (n, %)	
HK$4 999 or below	26 (8.2)
HK$5 000–HK$9 999	14 (4.4)
HK$10 000–HK$14 999	27 (8.5)
HK$15 000–HK$19 999	23 (7.3)
HK$20 000–HK$29 999	85 (26.8)
HK$30 000–HK$39 999	95 (30.0)
HK$40 000–HK$49 999	14 (4.4)
HK$50 000 or above	33 (10.4)
CSSA (n, %)	
Recipient	73 (23.0)
Personal measures	M (SD)
IGDS9-SF score	20.4 (5.65)
MOGQ score	81.3 (20.1)
DERS score	36.3 (14.1)
PANAS score	
Positive	10.20 (4.28)
Negative	7.23 (3.12)
RMSSD	
Positive	3.18 (2.18)
Negative	2.13 (1.95)
Daily game time[a]	160.53 (128.23)

Notes: US$1 = ∼HK$ 7.8.
Abbreviations: CSSA, Comprehensive Social Security Assistance; DERS, Difficulties in Emotion Regulation Scale; HK, Hong Kong; IGDS9-SF, Internet Gaming Disorder Scale-Short Form; M, mean (grand mean for PANAS related scores); MOGQ, Motives for On-line Gaming Questionnaire; PANAS, Positive and Negative Affect Schedule; RMSSD, root mean squared of successive differences of PANAS; US, United States.
[a]Daily game time was measured in minutes.

fluctuations, no statistically significant results were observed for within-person or between-person associations. When regressing game time on daily negative affect fluctuations, only the within-person association was found to be significant (exponentiated β = 1.0144, 95% CI = 1.0030–1.0258, P = 0.0130).

DISCUSSION

In accordance with our prediction (hypotheses 1 and 2) and previous research [30, 31], greater intensity of negative affect, but not positive affect, over the 14-day assessment period was significantly associated with higher risk of GD. Extending the current literature, this study reveals that not only the levels of negative affective states matter, but negative affect fluctuations also appear to be an important factor that may contribute to the development and maintenance of symptoms of GD. Taken together, the findings on negative affect intensity and

TABLE 2 Multi-variable linear regression models predicting IGDS9-SF score by 14-day average affect intensities and fluctuations.

	Estimate	SE	95% CI	*P*-value
Intensity[a]				
Positive affect	0.0817	0.0986	−0.1125 to 0.2758	0.4080
Negative affect	0.3816	0.1460	0.0941–0.6691	0.0095
Fluctuations[a]				
Positive affect	0.4457	0.2121	0.0279–0.8636	0.0367
Negative affect	0.5123	0.2313	0.0567–0.9679	0.0277

Abbreviations: IGDS9-SF, Internet Gaming Disorder Scale-Short Form; PANAS, Positive and Negative Affect Schedule; RMSSD, root mean squared of successive differences of PANAS.
[a]Both affect intensities and fluctuations (RMSSDs) were calculated as grand means using 56 time points of PANAS scores over a 14-day observation period.

TABLE 3 Multi-level linear regression models predicting daily game time by daily affect intensities and fluctuations over a 14-day period.

	Exponentiated estimate	SE	95% CI	*P*-value
Intensity[a]				
Daily mean of positive PANAS				
Within-person	1.0136	1.0056	1.0025–1.0248	0.0166
Between-person	1.0150	1.0120	0.9916–1.0391	0.2100
Daily mean of negative PANAS				
Within-person	1.0159	1.0071	1.0018–1.0302	0.0265
Between-person	1.0113	1.0177	0.9770–1.0468	0.5218
Fluctuations[a]				
RMSSD of positive PANAS				
Within-person	1.0054	1.0051	0.9955–1.0155	0.2850
Between-person	1.0274	1.0287	0.9717–1.0864	0.3400
RMSSD of negative PANAS				
Within-person	1.0144	1.0058	1.0030–1.0258	0.0130
Between-person	1.0046	1.0320	0.9441–1.0690	0.8841

Abbreviations: PANAS, Positive and Negative Affect Schedule; RMSSD, root mean squared of successive differences of PANAS.
[a]All output statistics were exponentiated given that logarithmic transformation was operated on the dependent variable. Coefficients are to be interpreted as factors, in which effect size is estimated by multiplying the intercept by the predictor's coefficient.

fluctuations are consistent with the longstanding self-medication hypothesis to explain addiction [32, 33]. The experience of high levels of negative affect intensity and fluctuations can be emotionally exhausting for adolescents [34], which in turn may trigger them to engage in gaming as a coping strategy. Contrary to our hypothesis, greater emotion fluctuations in positive affect were also significantly associated with increased risk of GD in our study sample. A possible explanation for this finding is that positive emotion variability may be linked to certain personality states such as extraversion [35], which is associated with risk of GD [36]. Nevertheless, from a perspective of emotion regulation, fluctuations in both positive and negative affect might reflect failure in emotion regulation [37]. It is noteworthy that participants in our study were on average 15.5 years old. Adolescents of this age may not yet fully develop their emotion regulation capacities [38], making them more prone to mental health symptoms, including addictive behaviors [39]. Hence, the link between emotion fluctuations and risk of GD may be of special relevance to this age group.

The use of the ambulatory assessment approach allowed for the examination of within-person changes of emotional experiences with gaming duration in adolescents' daily contexts. Consistent with our prediction (hypotheses 3 and 4), adolescents reported more gaming time when they experienced higher than usual daily negative affect intensity and fluctuations. Interestingly, greater intensity of positive affect than usual was associated with increased gaming duration on a given day. Several models of addiction offer plausible explanations for the finding on positive affect and gaming duration. According to the syndrome model of addiction, individuals develop addiction from repeated interactions with activities that reliably produce their desired emotional states, which can be experience of positive emotions associated with sensation seeking (feeling good) or mitigation of negative feelings (feeling less bad) [40]. The experience of elevated positive emotions may cause adolescents to want to maintain their positive emotional states by engaging in gaming. Feeling positive is also associated with broadened cognitions and tendency to perceive problems as solvable [41, 42], which may make adolescents believe that they will perform better in gameplay and be more able to win a game, thereby extending their gaming duration or facilitating their motivation to replay on that day, resulting in increased gaming time. Moreover, the interaction of person-affect-cognition-execution model states that disordered gaming may be developed through the gratification and compensation pathways [43], highlighting the importance of both positive and negative reinforcement and associated positive and negative emotions in addiction. However, existing research on GD has placed strong emphasis on the self-medication hypothesis and negative emotions. More research to explore the role of positive emotions in gaming and the function of sensation seeking in disordered gaming is needed.

Implications for research and practice

This study demonstrates the advantage of using EMA in capturing adolescents' change in affective states in daily contexts at the individual level, adding value to the study of gaming and GD. Although EMA requires intense monitoring, this study achieved an acceptable compliance rate of 75.4%, which is comparable to the pooled compliance rate of 78.3% reported in a meta-analysis on EMA studies involving children and adolescents [44], giving confidence in the use of EMA in similar samples for future studies. As this study is the first to examine the relationships of affect intensity and fluctuations with gaming and GD in adolescents, additional studies to replicate the findings are needed. In particular, more research to clarify the association between positive affect and GD is warranted. In addition, the study took place during summer holidays when students tend to have an unstructured timetable and parents tend to impose less stringent monitoring of adolescents' gameplay. Future researchers may consider replicating the study during school days. Furthermore, the current study focuses on emotional experience of adolescents, lacking understanding of potential influence of cognitions, which is another crucial factor contributing to GD [43, 45]. Future research adopting EMA methods to examine the dynamics and processes of cognitions and emotions involved in the development of GD will shed light on the topic.

Regarding practice, emotion-focused intervention approaches may be helpful in reducing adolescents' gaming time and symptoms of GD. Professionals may consider preventive strategies that support adolescents to become aware of their emotions and to be able to regulate their emotions or to achieve their desired emotional states using adaptive strategies. When working with adolescents who are highly involved in video gaming, professionals' assessment should go beyond assessing adolescents' time spent gaming and toward understanding the dynamics of emotions in their daily life and how such emotion dynamics may be related to gaming time and symptoms of GD.

Limitations

There are several important strengths of this study, including the use of EMA to measure adolescents' affect in their daily life, and an acceptable compliance of the EMA surveys by participants. Despite these strengths, the findings of the study should be interpreted with consideration of the study limitations. First, the external validity of the study is in question because of the low response rate in schools and participant eligibility. Second, the short form of PANAS used in this study was unable to capture a wider spectrum of emotional states that may be experienced by adolescents. It also relied on adolescents' awareness of their own emotions, and such capacity may be weaker for some adolescents, such as those with higher levels of GD [46]. Hence, underreporting of emotional states is possible. Third, while the longitudinal design of this study is a strength, it is not possible to rule out time varying confounders that could change affect and gaming behavior simultaneously. Fourth, to minimize burden on participants and for practical reasons, we only asked participants to report affective states four times a day and gaming time at the end of the day. This method may not accurately capture affect fluctuations, and gaming time could be influenced by recall bias. We recommend future EMA studies to identify or develop better approaches to capture data (e.g. passive data collection), to reduce participants' burden and recall bias. Last, the results of this study came from a sample of Chinese adolescents from Hong Kong, and the extent to which the findings can be generalized to adolescents in different cultural contexts remains uncertain.

CONCLUSION

This study contributes to the limited literature on the associations of emotional states in terms of affect intensity and fluctuations with gaming duration and risk of GD in the daily contexts of adolescents' lives. For negative affect, both intensity and fluctuations may predict gaming duration and risk of GD. For positive affect, emotion intensity may be more related to gaming duration, and emotion fluctuations may be more related to adolescents' risk of GD. Further studies are needed to expand our understanding of how positive emotions and gaming and GD are related, which is largely missing in the current literature.

AUTHOR CONTRIBUTIONS

Camilla K.M. Lo: Conceptualization; methodology; writing—original draft; funding acquisition. **Edward W.W. Chan**: Formal analysis; writing—original draft. **Frederick K. Ho**: Methodology; Writing—review and editing. **Lu Yu**: Writing—review and editing. **William W.H. Chui**: Writing—review and editing. **Ko Ling Chan**: Writing—review and editing.

ACKNOWLEDGEMENTS

The work described in this paper was fully supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (PolyU 15601422).

DECLARATION OF INTERESTS

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Lo CKM, Chan EWW, Ho FK, Yu L, Chui WWH, Chan KL. Associations of emotional experience with gaming duration and risk of gaming disorder among adolescent gamers: An ecological momentary assessment study. Addiction. 2025;120(9):1853–62. https://doi.org/10.1111/add.70088