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ORIGINAL ARTICLE

Cross-Lagged Analysis of Gender Differences in the Motivation-Cognition-Behavior Model of Gaming Disorder in Primary School Students

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Abstract
The motivation-cognition-behavior model elucidates the intricate psychological mechanisms that contribute to gaming disorder (GD). To test this new model, the present study employed cross-lagged analysis to investigate the reciprocal relationships among academic stress, gaming flow, maladaptive gaming cognition (MGC), and GD symptoms at two time points, 3 months apart. The participants were 600 Chinese students (52% male; $M_{age}=9.95$) from four primary schools in Hong Kong. The multi-group analysis showed significant gender differences. For girls, there were one linear relationship (MGC to academic stress) and two reciprocal relationships (MGC and GD symptoms, MGC and gaming flow). For boys, there were four linear relationships (MGC to gaming flow, GD symptoms to MGC, gaming flow to academic stress, and academic stress to MGC) but no reciprocal relationships. These findings highlight the complex mechanisms underlying GD development among children, and the importance of considering gender-specific factors in intervention design for this age group.

Keywords Gaming addiction · Problematic gaming · Sex difference · Stress · Cross-lagged model · Children

Introduction

Video gaming (hereafter gaming) has been a popular form of leisure play for decades. Gaming can yield benefits such as enhancing health and prosocial behaviors (e.g., Shoshani, 2023; Sung et al., 2017). However, excessive and maladaptive engagement can lead to hazardous outcomes such as decreased attentional span, increased difficulty in emotion regulation, depression, sleep problems, and deteriorated quality of life (e.g., Billieux et al., 2020; C. Cheng et al., 2018; Király et al., 2023; Wang et al., 2022).

Gaming habits have been found to develop from a young age, and underdevelopment in cognitive control increases children's vulnerability to gaming disorder (GD; e.g., Qi et al.,

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2024). A meta-analysis of 29 countries worldwide documents that the highest incidence of GD, at 7%, was observed among the pediatric population across various age groups (Kim et al., 2022). Studies have shown that the prevalence rates of GD among Chinese children and adolescents well exceeded the world average, ranging from 13 to 16% (Tsui & Cheng, 2021; Wang & Cheng, 2022; Yang et al., 2023a, b). Investigating the psychological mechanisms underlying the development and maintenance of GD symptoms in Chinese pediatric samples can facilitate early identification and intervention, thus addressing GD-related issues before they evolve into entrenched behaviors that are more challenging to modify (C. Cheng et al., 2024a, b). However, research on these prevalent issues among children, particularly in Chinese contexts, has been scant. The present study sought to uncover the underlying mechanisms of GD among primary school students in Hong Kong.

In the literature, several theoretical frameworks have been formulated to elucidate the psychological mechanisms underlying GD. Cognitive-behavioral theories (e.g., King & Delfabbro, 2014, 2020) emphasize the pivotal role of gaming-related thoughts in driving problematic gaming behaviors. On the other hand, motivation theories such as self-determination theory have been adopted to investigate the underlying needs and motives that propel individuals toward engaging in such behaviors (e.g., Mills & Allen, 2020; Ryan & Deci, 2017). Given that GD is a complex clinical condition (e.g., Cho et al., 2024; Larche & Dixon, 2020), both perspectives exhibit limitations when considered in isolation: Cognitive-behavioral theories may overlook the motivational factors that exacerbate GD symptoms, while motivation theories often fail to explicate the maladaptive thoughts that should be restructured for symptom relief.

Motivation-Cognition-Behavior Model on GD

To bridge this knowledge gap, we expanded the literature by investigating a new model—the motivation-cognition-behavior model on GD—that integrates both theoretical perspectives, thereby enhancing our understanding of the complexities of GD and ultimately improving the efficacy and adaptability of interventions targeted at this disorder. This model is specifically formulated to unveil the intricate interplay of motivational, cognitive, and environmental factors in the development and maintenance of GD symptoms (Ji et al., 2022). These model elements are derived from a meta-analysis that synthesizes an array of studies conducted in Chinese populations, thus providing a conceptually, empirically, and culturally sound framework for GD research in Chinese settings. This study thus represents a pioneering effort to test a new model that is both theory- and data-driven, aimed at elucidating the mechanisms underlying GD. By integrating theoretical frameworks with empirical evidence, our study offers a unique contribution to the field, advancing our understanding of the complexities associated with GD.

According to this model, a key motivational factor is gaming flow, which refers to an intrinsic motivation that drives problematic gaming behavior (e.g., Kiatsakared & Chen, 2022; Stavropoulos et al., 2022). Flow is conceptualized as a state of deep engagement that fosters immersive and pleasurable experiences (Csikszentmihalhi, 2020). Nevertheless, this pleasant experience can also drive excessive gaming (Dixon et al., 2018; Footitt et al., 2024), with studies linking gaming flow to the development of GD symptoms in Chinese settings (e.g., Hu et al., 2019; Li et al., 2021). Increased video game consumption is positively associated with online flow, which reinforces compulsive behaviors (Lee & Jeong, 2024). Notably, males tend to experience more gaming flow than females (Li et al., 2021; Stavropoulos et al., 2013).

A key cognitive factor contributing to GD is maladaptive gaming cognition (MGC), which refers to the perceived rewards of gaming, urges to gameplay, and unwillingness to stop without task completion (Yu et al., 2019, 2021a). In the literature, MGC has been widely recognized as a significant risk factor associated with GD symptoms (e.g., Bodi et al., 2021; Tang et al., 2023; Yang et al., 2023a, b; Yu et al., 2021a). Specifically, distorted beliefs about gaming value, rigid gaming rules, reliance on gaming for self-esteem, and the pursuit of social acceptance contribute to the emergence of GD symptoms (Billieux et al., 2020; Yu et al., 2021a). Similar to the aforementioned findings of gaming flow, studies showed that males (vs. females) tend to exhibit higher MGC levels (Yu et al., 2021b).

As this study is conducted in the Chinese context, the influential impact of the sociocultural environment should also be considered. A key environmental contributing factor of GD is academic stress, which is particularly prevalent among East Asian students, including those in Chinese societies (Sun et al., 2011). Academic stress refers to a subjective reaction that arises from the multitude of demands students encounter in their academic pursuits (e.g., Wahid et al., 2023; Wang et al., 2024). This type of stress is linked to GD symptoms indirectly through psychological distress, unpleasant emotions, negative mood reduction, and avoidant coping (e.g., Y. Cheng et al., 2024a, b; Gu & Mao, 2023; Mun & Lee, 2024; Yang et al., 2023a, b). Moreover, intense academic demands often drive children to cope with such stress through gaming, which can exacerbate GD symptoms due to diminished behavioral regulation under heightened stress (Chyu & Chen, 2022; Jeon et al., 2022; Lee & Jeong, 2024).

Reciprocal Relationships among Multiple Risk Factors of GD

In addition to its complexity, the development and persistence of GD symptoms exhibit reciprocal effects, wherein GD can serve as both antecedent and outcome to motivational, cognitive, and environmental factors (C. Cheng & Li, 2022). This interplay can create a feedback loop that amplifies the overall impact of all of these factors. Specifically, MGC may contribute to the development of GD symptoms by intensifying gaming behavior, fostering children to rely on gaming as a primary source of validation and fulfillment (e.g., Dong & Potenza, 2014; Moudiab & Spada, 2019). In turn, GD symptoms may amplify MGC as children increasingly turn to gaming to meet emotional needs, deepening maladaptive gaming-related beliefs and behaviors (Billieux et al., 2020). Taken together, these findings imply reciprocal relationships between MGC and GD symptoms.

MGC may also influence children's experience of gaming flow, distorting healthy engagement and making it harder to regulate problematic gaming behaviors. Children with maladaptive beliefs about gaming may experience heightened flow not just from enjoyment but from a perceived need to game excessively, viewing it as a key source of validation (Yu et al., 2021a). This reliance creates a feedback loop where distorted beliefs fuel deeper immersion. Conversely, experiencing gaming flow may reinforce MGC, as children justify excessive play as essential, thus deepening their cognitive dependence on gaming (Gentile et al., 2011). In this light, reciprocal relationships between MGC and gaming flow may also exist.

Despite these established connections identified separately in individual studies, no empirical effort has fully examined these reciprocal relationships in a systematic manner, particularly concerning how each factor may act as both an antecedent and outcome of others. Addressing these nuances is critical for understanding the dynamic interplay among

diverse factors. The present longitudinal study aims to address these gaps by employing a cross-lagged analysis to investigate the bidirectional influences among the multiple elements of the motivation-cognition-behavior model on GD over time, providing a comprehensive framework for understanding GD's contributing factors and informing targeted, empirical-based interventions for children.

Cross-lagged analysis offers unique advantages for testing reciprocal relationships. Unlike cross-sectional analyses that capture bidirectional associations at one point in time, cross-lagged models examine temporal precedence, thus identifying specific directions between the study variables. These models also account for autoregressive effects, controlling for prior levels and reducing the risk of yielding spurious findings. More importantly, cross-lagged analysis allows for multi-group comparisons, such as gender differences (Park & Lee, 2022; Wang & Cheng, 2022; Yang et al., 2023a, b), providing nuanced insights into how hypothesized relationships may vary across groups, thereby enhancing the interpretability and generalizability of findings.

Gender Differences

When conducting cross-lagged analyses in pediatric samples, it is essential to consider potential gender differences in these dynamics. While these factors interact complexly with GD, research shows that boys and girls may experience and respond to gaming in diverse manners (Dong & Potenza, 2022; Kim et al., 2022), leading to distinct bidirectional pathways related to GD.

In the literature, findings consistently reveal a higher prevalence of GD in boys than girls. A multinational meta-analysis found GD rates of 9% for boys and 4% for girls (Kim et al., 2022). This gender difference is evident across cultural regions, indicating a universal trend in boys' heightened vulnerability to GD (Borgonovi, 2016). Boys also report higher cravings in response to gaming-related cues, which may explain in part their greater susceptibility to GD compared to girls (Dong et al., 2018).

Boys are found to generally spend more time gaming than girls, leading to higher levels of engagement that can contribute to more severe GD symptoms (Wichstrøm et al., 2019). The extended gaming time may correlate with greater immersion and gaming flow experiences, intensifying the potential for maladaptive gaming behaviors. It interferes with daily functioning and elicits more psychological distress in boys (van den Eijnden et al., 2018). Furthermore, societal perceptions that portray boys as more achievement-oriented may influence their gaming motives, thus reinforcing MGC (Yang & Quadir, 2018). Boys with GD often demonstrate higher impulsivity and sensitivity to gaming rewards, while girls may experience gaming more as a coping mechanism for mitigating loneliness and unpleasant emotions, highlighting differences in maladaptive cognition to gaming contexts (Dong & Potenza, 2022).

Overall, the two gender groups may experience and respond to gaming differently over time (Borgonovi, 2016; Yu et al., 2019). The pathways leading to GD may thus vary between boys and girls. The present study is the first to employ cross-lagged analysis to investigate the reciprocal associations among the factors of the motivation-cognition-behavior model on GD, with the analysis conducted by gender group. Contributing valuable insights into the dynamics of GD, the study may also have practical implications for guiding the design of gender-specific preventive programs and interventions for GD.

Method

Participants

To obtain a diverse and representative sample, we randomly selected four schools across different districts in Hong Kong, encompassing a range of socioeconomic statuses. This sampling method seeks to provide a sample that more closely reflects the population of senior primary school students in the region. Invitation letters were sent to the administrators of the selected schools to take part in this study.

The initial sample comprised 679 students. Out of these, 79 participants were excluded due to substantial data loss (i.e., > 50% of their data; $n = 32$) or absence during the follow-up session ($n = 47$). The final sample included 600 participants, with 314 (52%) male students and an average age of 9.95 years ($SD = 0.97$, range = 8–15). A post hoc power analysis showed a statistical power of 0.80, indicating that the final sample size has a robust capacity to detect true effects.

Measures

All of the Chinese measures employed in this study were selected for their widespread use, robust psychometric properties, and established validation in Chinese student samples. In the present study, all of these measures were reliable at both time points (see Table 1).

Academic Stress

Academic stress was tested by the seven-item Educational Stress Scale for Adolescents (Sun et al., 2011), rated on a five-point Likert scale (1 = "strongly disagree," 5 = "strongly agree"). The composite score ranges from 7 to 35. Higher scores indicate the perception of more academic pressure and workload.

Table 1 Descriptive statistics of the study variables by gender

Study variable	Male ($n = 314$)		Female ($n = 286$)		t	Cronbach's α
	M	SD	M	SD		
Academic stress—T1	23.06	5.79	23.00	5.90	0.127	.84
Gaming flow—T1	22.55	4.04	20.84	4.49	4.923***	.74
Maladaptive gaming cognition—T1	28.11	7.37	21.31	12.20	6.966***	.90
Gaming disorder symptoms—T1	32.98	7.42	29.33	6.79	6.287***	.82
Academic stress—T2	23.17	6.64	22.52	6.52	1.198	.89
Gaming flow—T2	21.96	4.36	20.58	4.81	3.687***	.77
Maladaptive gaming cognition—T2	25.96	12.21	19.64	12.23	6.334***	.91
Gaming disorder symptoms—T2	31.59	7.34	27.64	6.94	6.750***	.82

T1 time 1, *T2* time 2

***$p < .001$

Gaming Flow

Gaming flow was assessed using a six-item Gaming Flow Scale (Wan & Chiou, 2006) that measures intrinsic interest, curiosity, control, and attention focus. The items were rated on a five-point Likert scale (1 = "strongly disagree," 5 = "strongly agree"). The aggregated gaming flow score ranges from 6 to 30, with higher scores reflecting a greater flow experience while gaming.

Maladaptive Gaming Cognition

MGC was assessed using the 15-item Chinese version of the Revised Internet Gaming Cognition Scale (C-RIGCS; Yu et al., 2021b), rated on a five-point Likert scale (0 = "never," 4 = "always"). The total MGC score ranges from 0 to 60, with higher scores showing a greater level of MGC.

Gaming Disorder Symptoms

GD symptoms were measured by the 15-item Korean Internet Addiction Proneness Scale for Youth (Koh et al., 2015), whose items and classification scheme of GD have been validated among Hong Kong primary school students (e.g., Chau et al., 2019). The items were rated on a 4-point Likert scale (1 = "strongly disagree," 4 = "strongly agree"). The composite GD score ranges from 15 to 60. Higher scores indicate the experience of more severe GD symptoms. Following the established classification scheme for Hong Kong students (e.g., Tsui & Cheng, 2021), respondents scoring 40 or below are categorized as "average gamers," those scoring between 41 and 43 inclusively are categorized as "at-risk gamers," and those scoring 44 or above are categorized as "high-risk gamers."

Compliance with Ethical Standards

Ethical approval was obtained from the Research Ethics Committee of the Department of Psychology at the authors' institution before data collection began in May 2023. Consent was secured from the principals of all partner schools and from participants' parents prior to distributing questionnaires. An invitation letter outlining the study's purpose, assuring data confidentiality, and detailing the disposal procedures for completed questionnaires was sent to parents. Both parents and students were informed that participation was entirely voluntary and that they could withdraw at any time without any adverse consequences.

Procedures

The data were collected from June 2023 to June 2024, with participants completing a self-reported questionnaire at two time points, 3 months apart, on a rolling basis. To minimize the impact on academic stress, examination and testing periods were deliberately avoided. Students with parental consent completed the questionnaires in class under the supervision of a trained research assistant. All measures were administered at both time points, and

participants' names, classes, and class numbers were collected for data matching. All such personal information was discarded after data matching.

At the outset of the session, participants received a standardized briefing outlining the study's objectives and instructions, and they were invited to give informed consent. Participants were encouraged to respond to all items without skipping any. Most of them completed the questionnaires within 30 min.

Data Analyses

R Studio version 4.2–764 (RStudio, 2024) was employed to perform all statistical analyses. For preliminary analyses, descriptive statistics were conducted, and gender differences in the study variables were tested using independent-samples t-tests and chi-square tests. The hypothesized bivariate relationships among the study variables at the two time points were examined using Pearson zero-order correlation. The Bonferroni correction was employed to minimize type I error, resulting in an adjusted critical p level of 0.0014 (calculated as $0.05/36 = 0.0014$).

For cross-lagged analysis, the R package *lavaan* (Rosseel, 2012) was employed to conduct multi-group path analyses, examining the proposed cross-lagged model of the study variables by gender across time 1 and time 2. The cross-lagged analytical framework was chosen due to its unique capacity to disentangle reciprocal, directional relationships over time, which is particularly valuable for understanding dynamic processes such as gaming behavior. The validity of cross-lagged models was evaluated by testing three key assumptions: stationarity, linearity, and synchronicity (Hamaker et al., 2015). First, the stationarity of the model was tested by examining the auto-regression coefficient (i.e., the bivariate correlation between the same study variable across the two time points), and these coefficients were positive for all study variables. Second, the scatterplots of the auto-regression coefficients were checked with *ggplot2* in R (Wickham, 2016), and the results showed satisfactory linearity in all the variables. Third, the synchronicity of the model was supported by observing all the variables at a single time point. Collectively, these results supported the validity of the model's assumptions, facilitating a more reliable interpretation of the associations among the study variables.

To assess the adequacy of the proposed cross-lagged model, several model fit indices were examined (Hu & Bentler, 1999): the chi-square statistic ($p > 0.05$), the root mean square error of approximation (RMSEA) and the standardized root mean squared residual (SRMR; both ≤ 0.08), and the comparative fit index (CFI) and the Tucker-Lewis Index (TLI; both ≥ 0.90). These criteria provided a comprehensive evaluation of the model's fit and its ability to adequately represent the observed data.

Results

Preliminary Analyses

Table 2 displays the classification of GD by gender at time 1 and time 2, respectively. Significant gender differences were observed in the distribution of GD classifications at both time points. Fisher's exact test for post hoc analyses indicated that boys were more likely to be classified as "at-risk gamers" compared to "average gamers" than their girls at both time points.

Table 2 Classification of gaming disorder groups by gender at time 1 and time 2

Gender	Average	At-risk	High-risk	χ^2	*p*
GD classification at time 1					
Male	267	27	20	9.876	.007
Female	266	13	7		
GD classification at time 2					
Male	280	15	19	9.396	.009
Female	274	6	6		

GD gaming disorder

Given the identified gender differences, Table 1 summarizes the descriptive statistics for the study variables, disaggregated by gender. Significant gender differences were identified in the levels of gaming flow, MGC, and GD symptoms at both time points.

Table 3 presents the correlations among the study variables by gender. The results showed significant gender differences in the relationships of the variables with GD symptoms. Specifically, the bivariate correlations showed that gaming flow, MGC, and academic stress were all positively associated with GD symptoms among females across time points. However, only MGC was positively associated with GD symptoms among males across time points.

Multi-group Path Analysis

Table 4 summarizes the model fit statistics for all models. The results showed that the cross-lagged model (model 1) exhibited a satisfactory fit to the data. The fully unconstrained model (model 2) was compared with the fully constrained model (model 3), in which all parameters were held constant across male and female participants. All models

Table 3 Pearson zero-order correlations among the study variables by gender

Study variable	1	2	3	4	5	6	7	8	9
1. Academic stress—T1	–	.161	.317**	.219**	.482**	.161	.296**	.161	.039
2. Gaming flow—T1	.219**	–	.458**	.162	.240**	.434**	.237**	.133	.015
3. Maladaptive gaming cognition—T1	.280**	.550**	–	.588**	.313**	.350**	.562**	.393**	-.057
4. Gaming disorder symptoms—T1	.308**	.298**	.674**	–	.214**	.151	.417**	.558**	-.025
5. Academic stress—T2	.514**	.133	.297**	.257**	–	.221**	.407**	.299**	.106
6. Gaming flow—T2	.156	.559**	.496**	.290**	.250**	–	.404**	.166	.062
7. Maladaptive gaming cognition—T2	.287**	.483**	.685**	.535**	.383**	.637**	–	.658**	.016
8. Gaming disorder symptoms—T2	.259**	.272**	.552**	.637**	.316**	.387**	.677**	–	.000
9. Age	.024	.038	.027	-.082	.136	.036	-.035	-.060	–

The correlation coefficients are presented with male data in the upper diagonal and female data in the lower diagonal

T1 time 1, *T2* time 2

** $p < .0014$ (critical *p* value after Bonferroni correction: .05/36 = .0014)

Table 4 Model fit of the cross-lagged models

Model	χ^2	*df*	*p*	CFI	TLI	RMSEA [90% CI]	SRMR
Model 1. Cross-lagged model	1.710	4	.788	1.000	1.012	.000 [.000, .040]	.006
Model 2. Fully unconstrained	3.840	6	.698	1.000	1.014	.000 [.000, .057]	.009
Model 3. Fully constrained	82.049	48	.002	.982	.973	.049 [.030, .066]	.059

CFI comparative fit index, *RMSEA* root mean square error of approximation, *SRMR* standardized root mean squared residual, *TLI* Tucker-Lewis Index

exhibited adequate fit to the data. In addition, the results revealed a significant change in the chi-square value between model 2 and model 3 ($\Delta\chi^2/\Delta df = 78.209/42$, $p < 0.001$). This finding indicated that cross-group invariance could not be assumed, underscoring gender differences in some of the paths.

Figure 1a and b present the standardized estimates of the paths in the multi-group analyses for male and female participants, respectively. All autoregressive paths were significant, indicating that each study variable at time 1 reliably predicted its corresponding value at time 2 in both genders.

The multi-group path analysis showed two reciprocal relationships in girls, namely MGC with GD symptoms and MGC with gaming flow. MGC was positively associated with academic stress across time in girls. No reciprocal relationship was found in boys. Instead, four linear associations were discovered from the two time points, namely MGC to gaming flow, GD symptoms to MGC, gaming flow to academic stress, and academic stress to MGC.

Discussion

In the present study, the prevalence of GD within the sample and the classification of GD were consistent with those reported in previous Chinese research (Chau et al., 2019). Boys are more likely to be classified as having at-risk GD symptoms compared to girls, aligning with existing literature indicating that boys are generally more susceptible to GD than are girls (Yu et al., 2021b; Zhu et al., 2021). However, the absence of significant differences in the classifications of high-risk gamers between genders suggests that the severity of GD symptoms may be comparable across genders once symptom intensity has surpassed a certain threshold.

Importantly, the new findings lend support to the applicability of the motivation-cognition-behavior model in explaining and predicting the complexities associated with GD. The results reveal a reciprocal association between MGC and GD symptoms, reconciling the body of prior inconsistent findings that show their influences in either direction (e.g., Forrest et al., 2017; Moudiab & Spada, 2019; Yu et al., 2021a, b). To the best of our knowledge, this is among the first longitudinal studies to provide evidence for this reciprocal relationship among children.

Besides, the present findings provide evidence that motivational factors such as gaming flow can influence the cognitive process involved in gaming. The reinforcing nature of gaming flow facilitates the development of MGC in terms of the sense of rewards, urge and unwillingness to stop gaming without completing the gaming tasks (Yu et al., 2019). In particular, the urge to play may be more intricately associated with the experience of

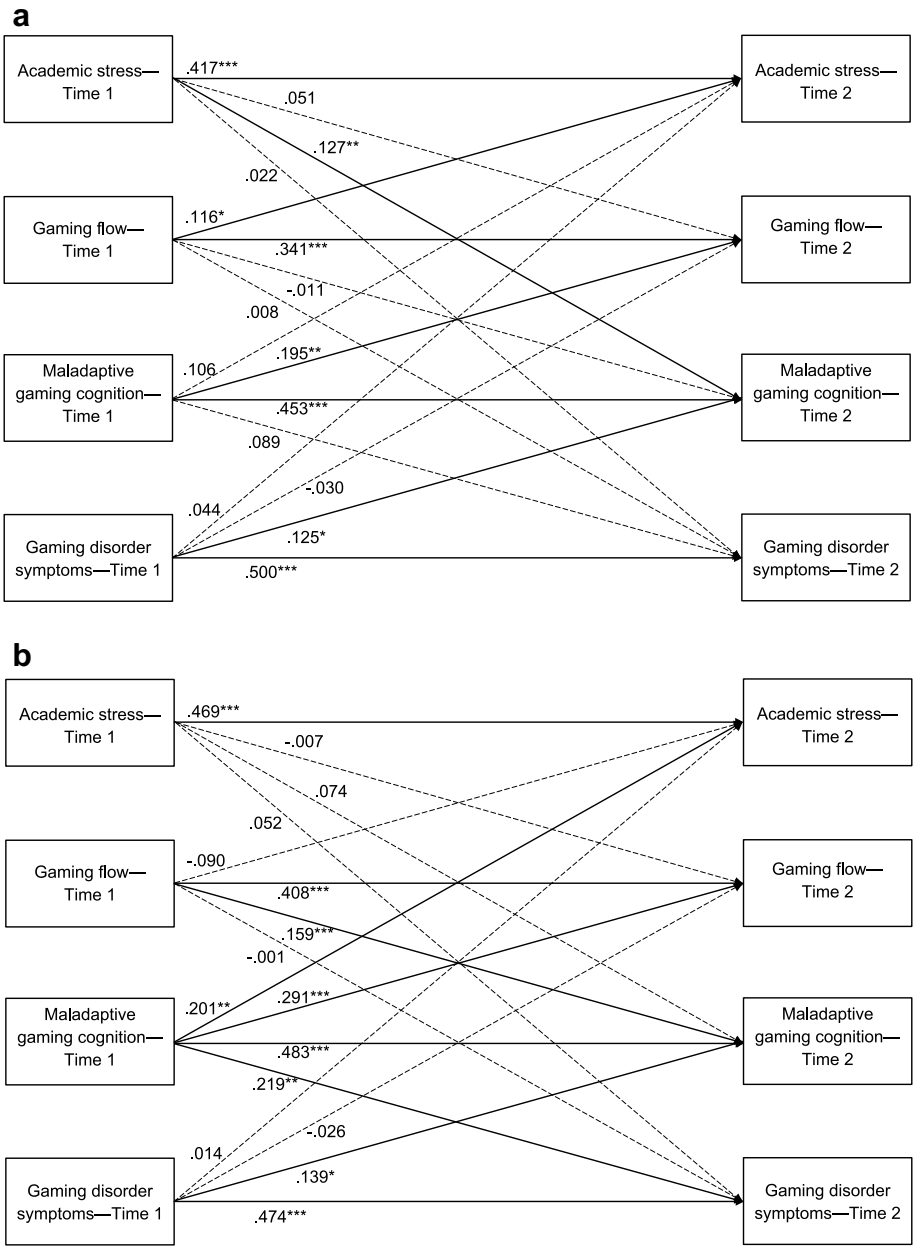

Fig. 1 **a** Cross-lagged model with standardized beta coefficients for male student participants. **b** Cross-lagged model with standardized beta coefficients for female student participants. Significant paths ($p < 0.05$) are shown in solid black arrows while non-significant paths are shown in dashed arrows. *$p < .05$; **$p < .01$; ***$p < .001$

gaming flow, as heightened levels of flow can reinforce the craving to gameplay (Larche & Dixon, 2020, 2021), generating a cycle that perpetuates engagement in gaming.

The present study extended the work of Chong et al. (2014) by documenting that academic stress, as an environmental factor, predicts MGC. Gaming is strongly associated with the motivation of escapism (Gu & Mao, 2023; Wang & Cheng, 2022). Children with a high level of academic stress may seek instant gratification from gaming, so as to alleviate their academic stress and fulfil a sense of achievement (Lee & Jeong, 2024). These findings advance our understanding by demonstrating academic stress exerts its influence indirectly on GD symptoms. Taken together, the motivation-cognition-behavior model provides a theoretically and culturally sound framework for a systematic examination of GD among Chinese primary school students.

Gender differences in the relationships of GD symptoms with multiple risk factors (i.e., gaming flow, MGC, and academic stress) are also found in the present study. According to social-cognitive theories (e.g., Bandura et al., 2001; Leaper & Friedman, 2007; Schunk & DiBenedetto, 2020), children are motivated to observe and interact to establish gender-specific interests and meet social expectations. Such cognitive-motivational processes are believed to be associated with the gender-differences in the deployment of emotion regulation strategies and the choice of game genres, thus accounting for the observed gender differences in the present study.

The new findings regarding the gender-specific reciprocal relationship between MGC and GD symptoms may be explained by the observed gender differences in emotion regulation (Gross, 2015). Females are more likely to use maladaptive cognition strategies such as rumination and pessimistic thinking to respond to unpleasant emotions than their male counterparts (Sanchis-Sanchis et al., 2020; Zhou et al., 2020). Therefore, girls may be more susceptible to MGC in the long run and develop GD symptoms than boys. This finding aligns with prior research, which has indicated that girls (vs. boys) may be more susceptible to cognitive risk factors associated with gaming (Yang et al., 2023a, b).

The gender differences in emotion regulation may further explain the association between gaming flow and academic stress among only boys in the present study. Previous studies have shown that males tend to deploy less adaptive coping strategies than their female counterparts (Graves et al., 2021; Sanchis-Sanchis et al., 2020). Further aggravating the condition, excessive engagement in gaming associated with gaming flow may additionally diminish the capacity of boys to use appropriate coping strategies, leading to mental health issues, as proposed by the time-displacement hypothesis (C. Cheng et al., 2020). As a result, boys with high levels of gaming flow are more vulnerable to experiencing academic stress due to their deployment of ineffective coping strategies.

Gender differences in game genre preferences may influence the nuanced relationship between MGC and gaming flow among boys and girls due to distinct socialization processes. It was reported that girls prefer simulation, virtual life, puzzles, and party games more than boys, while boys prefer game genres such as first-person shooter and fighting games (Hamlen, 2011; Homer et al., 2012). Among these genres, social-oriented games, such as simulation and virtual life games, typically emphasize social experience that is associated closely with gaming flow (Hu et al., 2019). In these respects, girls may be more inclined to experience prolonged pleasure (i.e., gaming flow) from social games, leading to MGC-related thoughts such as an inflated perception of rewards from gaming and an excessive urge to play (Larche & Dixon, 2020). In contrast, first-person shooting and fighting games may provide a burst of gaming flow that is more readily interrupted with the completion of the predetermined goals (Yang et al., 2023a, b). Therefore, such gaming flow may not sustain long enough to elicit MGC-related cognition, as revealed in the present

findings. Our new findings imply the importance of examining potential effects of game genres on gaming flow and MGC across genders.

It is noteworthy that the relationship between academic stress and MGC may also vary by gender. Among boys, findings show that initial levels of academic stress predict subsequent levels of MGC, indicating that boys may cope with academic stress through maladaptive gaming, leading to cognitive distortions around gaming behavior (Ju & Lim, 2016; Yang et al., 2023a, b). In contrast, girls tend to exhibit an inverse relationship, suggesting that girl's MGC tends to exacerbate academic stress over time, potentially due to the impact of gaming on their academic performance. Girls often seek support and employ problem-solving strategies when facing academic difficulties (Skinner & Saxton, 2019), implying that gaming serves as an alternative coping strategy that is used only if the deployed strategies become ineffective, resulting in a delayed emergence of MGC.

Overall, the gender differences observed in this study indicate that the pathways related to GD may vary between boys and girls. This finding aligns with previous research indicating that the two gender groups may experience and respond to gaming differently (Borgonovi, 2016; Yu et al., 2019). Such gender-specific differences highlight the practical utility of incorporating gender-differentiated pathways in design of GD interventions.

Research and Practical Implications

Given the increasing prevalence of GD and its gender-specific dynamics identified in the present study, both schools and parents play critical roles in prevention and mitigation (Su et al., 2020). To facilitate early intervention of the development of GD symptoms, AI-driven platforms enable early identification and personalized interventions by utilizing machine learning algorithms to analyze individual differences, including gender differences, in gaming behaviors and their associated risk factors (Amiri et al., 2024a, b; Heidari, Amiri, et al., 2024a, b). Schools could incorporate these gender-specific assessment to the existing screening scales, such as the 13-item KS-II scale on GD symptoms and the 15-item Revised Internet Gaming Cognition Scale on MGC, to early identify at-risk students (Amiri et al., 2024a, b; Chau et al., 2019; Heidari, Navimipour, et al., 2024a, b). Schools should also design psycho-educational programs based on these screening results to increase students' awareness of the risk factors most relevant to their profiles (Li et al., 2021; Zhou et al., 2020).

In light of the present new findings, for boys, interventions focusing on reward sensitivity and achievement-driven behaviors can mitigate GD risk by alleviating MGC and maladaptive gaming behavior. School-based programs using gamified cognitive-behavioral therapy techniques have demonstrated effectiveness in promoting goal-setting and self-control (Stevens et al., 2019; Wölfling & Dominick, 2022). For girls, emphasizing the deployment of adaptive coping mechanisms to handle academic stress and emotional escapism is crucial for reducing MGC and gaming flow to break the vicious cycle. Mindfulness-based programs tailored for girls have been shown to reduce stress-driven gaming behaviors and improve psychological resilience (Chen et al., 2023; Sharma et al., 2021; Zajac et al., 2020).

Parents should also engage in gender-specific discussions about gaming motivations and risks (King et al., 2020). Parent-led interventions combining psychoeducation and cognitive restructuring have been shown to mitigate GD symptoms effectively (King & Delfabbro, 2020; King et al., 2020; Nielsen et al., 2020). AI-driven parental control apps can support parents in supervising gaming activities and help identify problematic gaming behaviors (e.g., Răzvan et al., 2024; Woodcock et al., 2021). Parents can also promote

resilience-building activities to mitigate the impact of stress on GD (Sharma et al., 2021; Tharumiya et al., 2024; Yang et al., 2024). Family-based interventions incorporating stress inoculation training and mindfulness practices have demonstrated efficacy in helping children manage academic pressures and reduce excessive gaming (Nielsen et al., 2020).

Limitations and Directions for Future Research

While this study offers new insights into the relationships among gaming flow, MGC, academic stress, and GD symptoms, some limitations should be acknowledged. Specifically, data were collected at two time points, 3 months apart, providing only short-term longitudinal data. Collecting data at three or more time points over a longer period may further strengthen our understanding of long-term effects.

To expand the scope of research, future studies may consider a wider range of game-related and demographic variables, including pre-existing health conditions, gaming duration, preferences for specific game genres, socioeconomic status, and family-related factors. These elements may serve as either target or confounding variables related to GD symptoms and merit further investigation.

Finally, the reliance on self-reported measures may introduce bias, as respondents may underreport or overreport their gaming behaviors and cognitive experiences. If researchers have adequate resources, future research should consider incorporating qualitative methods, such as interviews, focus groups, or observations, to complement self-reported data and obtain a more comprehensive understanding of the GD symptoms being studied.

Conclusions

In conclusion, the present study enhances our understanding of the longitudinal dynamics among motivational, cognitive, and environmental factors related to GD. Specifically, the present findings lay an empirical ground for understanding the development of GD among Chinese primary school students through the lens of the newly proposed motivation-cognition-behavior model. MGC emerges as a cognitive factor interconnected with GD, while gaming flow as a motivational factor and academic stress as an environmental factor exert their reciprocal influences differently across genders. Furthermore, this study contributes to a more nuanced understanding of GD and offers insights into gender-specific interventions for addressing GD.

Author contributions All authors contributed to the study conception and design. Material preparation and data collection were performed by Cheuk Him Chow. Data analysis was conducted by Cheuk Him Chow and Hao Zhang. The first draft of the manuscript was written by Cheuk Him Chow, Hao Zhang, and Cecilia Cheng, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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

Declarations

Ethics Approval and Informed Consent All procedures followed were in accordance with the ethical standards of the Research Ethics Committee of the Department of Psychology of the University of Hong Kong, and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all student participants and their parents for being included in the study.

Conflict of Interest The authors declare no competing interests.

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