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Bidirectional associations between video game playing and ADHD symptoms among school-aged children

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A R T I C L E I N F O

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A B S T R A C T

Past research has suggested associations between gaming and symptoms of attention-deficit/hyperactivity disorder (ADHD) among children and adolescents. Yet, little research has been conducted to clarify the directionality of this association during middle childhood when ADHD issues typically emerge. Clarifying directionality is key to understanding whether gaming precedes and predicts ADHD symptoms, or the opposite. To shed light on this topic, this study investigates this association longitudinally during middle childhood. We employed a Random Intercept Cross-Lagged Panel Model to estimate longitudinal bidirectional associations between child gaming and ADHD symptoms from ages 6 to 10. Variables were derived from parent-reported child weekly hours of gaming and teacher-reported child ADHD symptoms. Data are from the Quebec Longitudinal Study of Child Development, a population-based cohort of Canadian children (N = 1749). We hypothesized a bidirectional association. Our results revealed that higher levels of ADHD symptoms at age 6 predicted more time gaming at age 7. Likewise, more ADHD symptoms at age 7 predicted more gaming at age 8. However, later in development, this association reverses direction: higher levels of gaming at age 8 predicted more ADHD symptoms at age 10. Additional analyses of separated dimensions of ADHD revealed that associations with gaming were stronger for the hyperactivity/impulsivity dimension. These findings suggest that children with more ADHD symptoms tend to devote more time to gaming during the early years of middle childhood. In turn, this increase in gaming during early school years contributes to worsening ADHD symptoms later in development, particularly hyperactivity/impulsivity symptoms.

Gaming (i.e., playing video games) is a ubiquitous activity among children and adolescents. In the United States, children aged 4 to 8 typically spend 40 min per day playing video games, and the daily time devoted to this activity increases as they get older (Rideout & Robb, 2020). Between 88 % and 95 % of Canadian children aged 6 to 12 engage in gaming, with an average weekly playtime of 9 h for girls and 12 h for boys (Entertainment Software Association of Canada, 2020). However, a higher frequency of gaming may be accompanied by unwanted consequences (Alanko, 2023). Notably, increased gaming has been associated with worsened attention-deficit/hyperactivity disorder symptoms (ADHD) in children and adolescents (Masi et al., 2021; Nikkelen et al., 2014).

Associations between gaming and ADHD symptoms among young individuals are troubling, as even subclinical levels of ADHD symptoms correlate with markedly poorer physical and emotional well-being, interpersonal relationships, and academic performance (Bussing et al., 2012; Krauss & Schellenberg, 2022). Furthermore, an increase in symptom severity could heighten the risk of developing a fully-fledged ADHD disorder. In particular, gaming has been associated with a 50 %–110 % increase in the likelihood of adolescents meeting the DSM-IV criteria for ADHD (Ra et al., 2018). This association may be even more critical during childhood, a period when ADHD symptoms are more

Abbreviations: ADHD, (attention-deficit/hyperactivity disorder).

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pronounced and diagnoses are more frequent (Christakis et al., 2018; Faraone et al., 2024; Rocco et al., 2021; Wootton et al., 2022). Childhood ADHD can significantly disrupt educational, social, and emotional development, leading to a cascade of challenges later in life, including lower educational achievement, occupational and relationship difficulties, poorer health, increased risk behaviours, and higher chances of accidents and premature death (Dalsgaard et al., 2015; Dona et al., 2023; Faraone et al., 2021; Kosheleff et al., 2023).

The structural characteristics and stimulating nature of certain video games (e.g., Flayelle et al., 2023; Griffiths & Nuyens, 2017) may condition child arousal levels and attentional responses to stimuli presented in games. Consequently, children who play video games more frequently may experience decreased baseline levels of arousal and difficulties in sustaining attention during less stimulating and more effortful tasks, potentially contributing to ADHD-like behaviours (Beyens et al., 2018; Christakis et al., 2018). Conversely, the association between gaming and ADHD symptoms could also emerge in the opposite direction, with children who have higher levels of ADHD symptoms being more inclined to engage in gaming due to its stimulating nature. Children with higher levels of ADHD symptoms develop impaired inhibitory control and a preference for immediate over delayed rewards, as compared to typically developing peers (Marx et al., 2021; Mphahlele et al., 2021). As a result, the intense and immediately rewarding nature of playing certain video games may be particularly appealing to them, potentially exacerbating difficulties in regulating gaming behaviours (Paulus et al., 2018).

Longitudinal research is needed to clarify whether gaming contributes to an increase in ADHD symptoms, or whether more time spent gaming is a consequence of impaired inhibitory control and poor attention, typically observed in ADHD symptomatology (Beyens et al., 2018). One large study with American adolescents revealed that digital media use (including video games) at age 15 predicted subsequent higher levels of ADHD symptoms by age 16 (Ra et al., 2018). Another large cohort study with Canadian adolescents found that increased levels of gaming at age 12 were associated with higher levels of ADHD symptoms at age 13 (Tiraboschi et al., 2022). A more recent longitudinal study revealed between-person and within-person associations between gaming and ADHD symptoms among Canadian adolescents between the ages of 12 and 17, cross-sectionally, but not longitudinally (Wallace et al., 2023).

The association between gaming and ADHD symptoms may emerge prior to adolescence, but it is not yet clear how it unfolds during middle childhood, a critical period for the development of ADHD symptoms (Faraone et al., 2024). To our knowledge, only two studies investigated the longitudinal bidirectional associations between gaming and ADHD symptoms prior to adolescence (Gentile et al., 2012; Stenseng et al., 2020). The results from Gentile et al. (2012) suggested that this association is simultaneously bidirectional. However, because this study covers a wide range of ages within the same cohort (ages 8 to 17), it is unclear if this bidirectional effect may be driven by adolescents or may also specifically apply to school-aged children. Stenseng et al. (2020) tested bidirectional associations between ages 6 and 10, finding a unidirectional effect of ADHD symptoms preceding and predicting increased gaming but not the reverse association. However, Stenseng et al. (2020) did not differentiate between the different dimensions of ADHD symptoms in their analysis (hyperactivity/impulsivity and inattention). Furthermore, both studies did not disentangle stable between-person effects (e.g., individual differences in ADHD symptoms due to sex differences) from within-person fluctuations (e.g., differences in symptoms due to fluctuations in gaming at each year), which could result in biased estimates (Baribeau et al., 2022; Hamaker et al., 2015).

To date, few studies have examined the relationship between gaming and ADHD symptoms in middle childhood. Among them, very few have been longitudinal and explored directions of association to determine the temporal sequencing between gaming and ADHD symptoms during middle childhood. Furthermore, no study to date has differentiated between stable effects and individual variations over time. The present study addresses these gaps by testing the longitudinal directionality of associations between gaming and ADHD symptoms among school-aged children from ages 6 to 10, using a random intercept cross-lagged panel model (Hamaker et al., 2015). This statistical model isolates the influence of stable trait-like between-person effects from the analysis of longitudinal within-person associations. The key advantage of this approach is that each person at each time point is compared to their average across all time points, serving as their own control, reducing bias from cofounders that are stable over time (e.g., sex differences), and ensuring that changes in behavior reflect variations within each time point. Based on the differential susceptibility to media effects model, which posits that interactions between digital media and its effects are reciprocal (Beyens et al., 2018; Valkenburg & Peter, 2013), and on prior findings (e.g., Gentile et al., 2012), we hypothesize a bidirectional association between gaming and ADHD symptoms.

In addition, few studies have examined how distinct hyperactivity/impulsivity and inattention dimensions of ADHD symptoms are uniquely associated with gaming. To address this gap, we conducted additional separate analyses for each dimension of ADHD to identify differential associations with gaming behavior. This approach is supported by a vast literature emphasizing the distinction between these dimensions (Kuntsi et al., 2010, 2014; Milich et al., 2001), each of which may exhibit differential associations with gaming behavior (Beyens et al., 2018). However, more recent research has also provided evidence indicating a general common psychometric component and a substantial shared genetic variance between hyperactivity/impulsivity and inattention, suggesting ADHD to be one unitary component with two distinct dimensional traits (Arias et al., 2018; Bidwell et al., 2017). To account for both perspectives, we present results from three models. One model uses a composite ADHD symptom score with combined dimensions, and two additional models analyze hyperactivity/impulsivity and inattention separately. This dual approach is further supported by the DSM-5, which recognizes three ADHD presentations: predominantly hyperactive/impulsive, predominantly inattentive, and combined (American Psychiatric Association, 2013).

1. Method

1.1. Participants and setting

Data are from the Quebec longitudinal study of child development (QLSCD, 1998–2023), a representative birth cohort of children born in 1997 and 1998 of mothers residing in the province of Quebec (Canada). Children with a gestational age of less than 24 weeks or more than 42 weeks or families living in the Far North Quebec region were excluded. Participants were French or English-speaking families randomly selected from birth records. Among the participating families at study onset, 2120 of them were yearly or biennially assessed at the age of 5 months and onward. The QLSCD protocol received ethics approval from the Health Quebec. More information on the QLSCD protocol can be found elsewhere (Orri et al., 2021).

Our study draws from the elementary school follow-up stage of the QLSCD which was designed to assess academic and psychosocial adjustment during middle childhood. We use data collected at ages 6 (n = 1529), 7 (n = 1537), 8 (n = 1526) and 10 (n = 1402). Our overall cohort sample included 1749 school-aged children, 856 boys (48.9 %) and 893 girls (51.1 %). Participating children with information on video game play time and ADHD symptoms, on at least one time point were retained in the current study. All parents of the participating children provided informed consent. At age 10, children also provided assent to participate in the study in addition to their parent's consent.

1.2. Measures

Gaming. At ages 6, 7, 8, and 10, parents responded to the following item: On average, how much time does your child spend each day playing computer or video games? Options of response included "None"/"Less than 1 h"/"From 1 up to 3 h"/"From 3 up to 5 h"/"From 5 up to 7 h"/"More than 7 h". Categorical responses were converted to a continuous scale using the midpoint values of each category, as follows: None = 0, Less than 1 h = .5, From 1 up to 3 h = 2, From 3 up to 5 h = 4, From 5 up to 7 h = 6, and More than 7 h = 8.

ADHD symptoms. At the same ages (6, 7, 8, and 10), teachers reported the frequency of child symptoms of hyperactivity/impulsivity and inattention in the past 6 months. Symptoms of hyperactivity/impulsivity included: (1) Could not sit still, was restless and hyperactive; (2) Couldn't stop fidgeting; (3) Was unable to wait when someone promised him/her something; (4) Was impulsive, acted without thinking; (5) Had difficulty waiting for his/her turn in games; (6) Couldn't settle down to do anything for more than a few moments. Symptoms of inattention included: (1) Was easily distracted, had trouble sticking to any activity; (2) Was unable to concentrate, could not pay attention for long; and (3) Was inattentive. These items are from the Social Behavior Questionnaire (SBQ) created for the Canadian National Longitudinal Study of Children and Youth (Statistics Canada, 2009) and adapted to the QLSCD. The SBQ has shown excellent internal structure for the impulsive/hyperactive/inattentive subscale, excellent reliability, and good convergent and discriminant validity in the context of the QLSCD (Collet et al., 2023). In our sample, internal consistency from ages 6 to 10 ranged from α = .88–.89 for hyperactivity/impulsivity, α = .86–.91 for inattention, and α = .90–.91 for the ADHD/combined scale, all are considered good or excellent internal consistency (Cicchetti, 1994).

The items corresponding to each symptom dimension (i.e., hyperactivity/impulsivity or inattention) were summed separately to create distinct hyperactivity/impulsivity and inattention scales. A combined ADHD scale encompassing all 9 items was also computed. Each of the 9 items was rated on a 3-point Likert scale (0 = never/not true, 1 = sometimes/somewhat true, 2 = often/very true), yielding a raw total score ranging from 0 to 18 for the combined ADHD scale, 0 to 12 for the hyperactivity/impulsivity scale, and 0 to 6 for the inattention scale. To enhance interpretability and comparability across measures, the raw total was linearly rescaled to a 0–10 scale. This was done by dividing the raw score by the maximum possible raw score (i.e., 18 for the combined scale) and then multiplying it by 10. This transformation procedure was carried out by the *Institut de la statistique du Québec* (see supplemental material for a detailed explanation of this computation). A score between 7 and 10 on the combined ADHD scale suggests a diagnostic-level symptom severity (see supplemental material for additional information on the interpretability of the scale).

1.3. Statistical analysis

We estimated a Random Intercept Cross-Lagged Panel Model (RI-CLPM) to assess the bidirectional associations between gaming and ADHD symptoms at ages 6, 7, 8, and 10 (Hamaker et al., 2015). We estimated one model for the combined dimensions of ADHD symptomatology, and two other models with dimensions separated (hyperactivity/impulsivity and inattention). See Fig. 1 for a representation of our model. The RI-CLPM improves upon traditional cross-lagged models by distinguishing between-person effects (e.g., individual differences between participants), from dynamic time-dependent within-person effects (e.g., children's deviations from their own baseline over time). In a RI-CLPM, between-person effects are captured with two latent variables, while autoregressive and cross-lagged effects only reflect within-person fluctuations. Model fit was assessed according to

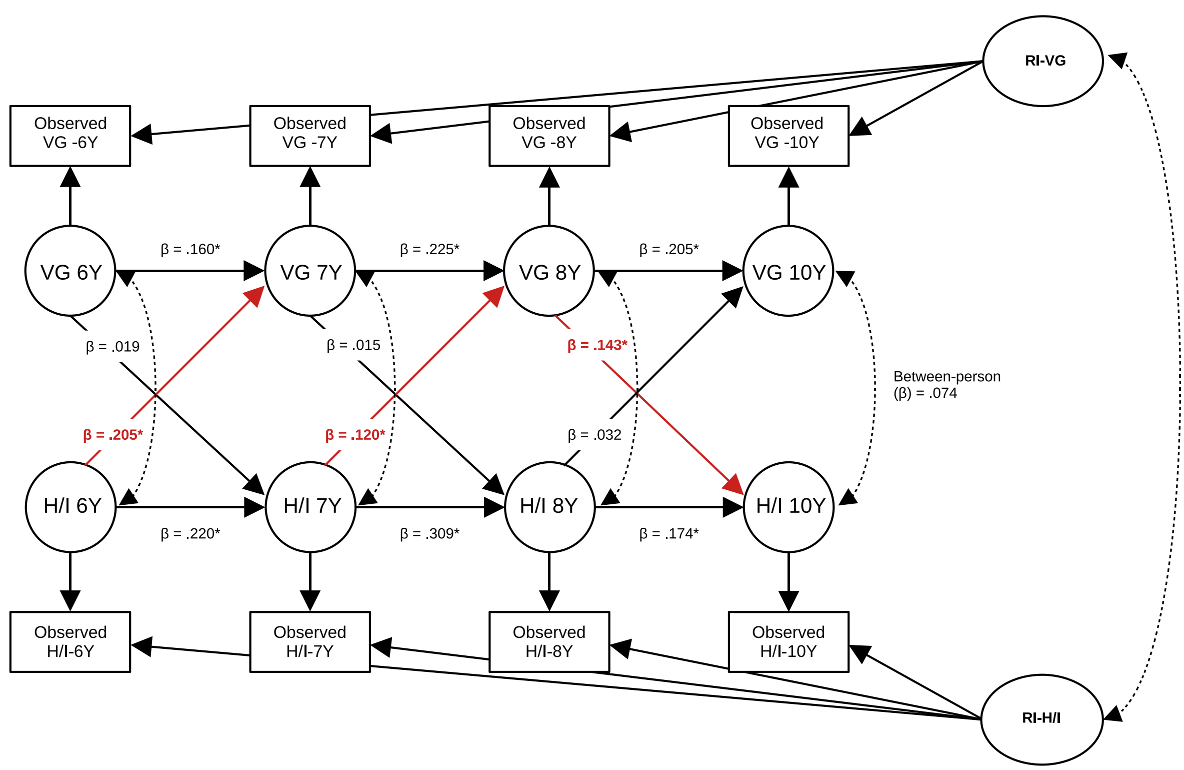

Fig. 1. Random-Intercept Cross-Lagged Panel Model of video game playing and symptoms of hyperactivity/impulsivity and inattention between the ages of 6 and 10. Each shape depicts a variable. Squares represent observable variables and circles are latent variables. Straight arrows denote regressions and curved/dashed arrows covariances. The blue dashed straight arrows represent the indirect effects analyzed post-hoc. Asterisk indicates significant associations ($p < .025$). Significant cross-lagged associations are also highlighted in bold and red. Effect sizes shown in the picture are standardized estimates of regressions within the model. H/I = hyperactivity and inattention (ADHD symptoms). VG = Video game playing time. RI = Random Intercept latent variable. Y = age in years. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

benchmarks suggested by Hu and Bentler (1999), i.e. the model is considered to have a good fit if RMSEA <.05 and CFI >.95. To estimate model parameters, we used the maximum likelihood estimator with robust standard errors (Huber-White) and a scaled test statistic that is (asymptotically) akin to the Yuan-Bentler test. Cut-off points to interpret the standardized effect sizes of cross-lagged paths were <.07 (small), .07 to .11 (medium), and ≥.12 (large) as suggested by Orth et al. (2022). Further information on RI-CLPM is available elsewhere (Hamaker et al., 2015; Mulder & Hamaker, 2021). All analyses were conducted in R-Studio (version 2022.07.1) using the Lavaan package (version .6–16). The R code for the analysis is available upon request to the authors. We report two-tailed p-values and significance levels were corrected for multiple comparisons (α = .025).

1.4. Missing data

To examine the nature of the missingness, we first conducted Little's MCAR test, which indicated the data were not MCAR, $\chi^2(678) = 891$, $p < .001$. In line with recommendations by Newman (2014), we addressed this by employing Full Information Maximum Likelihood (FIML) estimation with the *saturated correlates* approach. This method incorporates auxiliary variables into the model estimation to help satisfy the Missing at Random (MAR) assumption, thereby reducing potential bias in parameter estimates. For the saturated correlates approach to be valid, the auxiliary variable must be correlated both with the likelihood of missingness and with the variables included in the model. Socioeconomic status (SES) was selected as an auxiliary variable due to its correlation with both patterns of missingness and primary study variables. Analyses of the missing data are reported in the results.

2. Results

2.1. Descriptives statistics

Means, standard deviations, and percentiles of daily hours of gaming and symptoms of ADHD from age 6 to 10 are presented in Table 1. The amount of time children spent on video games was significantly different across all ages ($\eta^2 = .023$, $p < .001$) with a substantial increase in gaming from age 6 to age 10 (mean difference = .301 h, $p^{tuckey} < .001$). No significant difference was found across time in symptoms of ADHD ($\eta^2 = .002$, $p = .051$).

Table 1
Descriptive statistics of video game playing and ADHD symptoms.

					Percentiles		
	N	Missing	Mean	SD	25th	50th	75th
H/I age 6	964	785	2.399	2.421	.000	1.670	3.890
H/I age 7	1303	446	2.643	2.558	.560	2.220	4.290
H/I age 8	1267	482	2.547	2.426	.560	1.880	3.890
H/I age 10	986	763	2.311	2.368	.560	1.670	3.750
Hyper age 6	963	786	1.996	2.435	.000	.830	3.330
Hyper age 7	1302	447	2.053	2.524	.000	.830	3.330
Hyper age 8	1266	483	1.905	2.403	.000	.830	3.330
Hyper age 10	986	763	1.618	2.331	.000	.830	2.500
Inatt age 6	966	783	3.191	3.053	.000	3.330	5.000
Inatt age 7	1303	446	3.793	3.386	.000	3.330	6.670
Inatt age 8	1282	467	3.769	3.318	.000	3.330	5.000
Inatt age 10	987	762	3.629	3.271	.000	3.330	5.000
VG age 6	1491	258	.579	.620	.500	.500	.500
VG age 7	1317	432	.830	.946	.500	.500	.500
VG age 8	1263	486	.825	.730	.500	.571	.929
VG age 10	1329	420	.907	.767	.500	.571	.929

Note. H/I = Hyperactivity and inattention combined scale (ADHD symptoms). Hyper = Hyperactivity/Impulsivity symptoms. Inatt = Inattention symptoms. ADHD symptoms scales ranged from 0 to 10. Gaming = Video game playing time in hours per day. Data compiled from the final master file of the Québec Longitudinal Study of Child Development (1998–2023), ©Gouvernement du Québec, Institut de la statistique du Québec, Canada.

2.2. Missing data analyses

We calculated the proportions of full respondents (participants with complete data at all time points), partial respondents, and non-respondents (participants with no data available at all time points). For gaming, 4.9 % were non-respondents, 39.7 % were partial respondents, and 55.3 % were full respondents. For ADHD symptoms, 6.8 % were non-respondents, 56.8 % were partial, and 36.4 % were full respondents. Children with missing data on ADHD symptoms had significantly lower SES across all time points. For both gaming and symptoms combined, construct-level and person-level missingness ranged from 12 % to 43 % and 10 %–18 %, respectively, across time points (excluding non-respondents).

To evaluate the suitability of SES as an auxiliary variable in the saturated correlates approach, we examined its correlations with child gaming and ADHD symptoms at ages 6, 7, 8, and 10. All correlations were significant ($p < .05$), except for gaming at age 6 ($r = -.03$, $p = .25$). Furthermore, we coded binary indicators for missingness (missing = yes/no) at each time point for both gaming and ADHD symptoms, and estimated point-biserial correlations with SES. SES was significantly correlated with all missingness patterns ($p < .05$), except for gaming at age 8 ($rpb = .01$, $p = .57$). All of these results support the use of SES as an auxiliary variable with the saturated correlates approach.

2.3. Random Intercept Cross-Lagged Panel Model

All RI-CLPMs had adequate fit indices: the combined ADHD model (RMSEA = .036, Robust CFI = .989, and $\chi^2 = 28.957$, $p = .001$), the hyperactivity/impulsivity model (RMSEA = .034, Robust CFI = .989, and $\chi^2 = 27.360$, $p = .001$), and the inattention model (RMSEA = .033, Robust CFI = .989, and $\chi^2 = 26.055$, $p = .002$). For the model combining both dimensions of ADHD symptomatology, standardized and non-standardized estimates of autoregressive associations, cross-lagged

Table 2
Results from the lagged effects of the Combined RI-CLPM (Hyperactivity + Inattention).

	B	β	95 % Confidence Interval (β)		Two-tailed
			Lower	Upper	p-values
VG age 6 → H/I age 7	.065	.019	−.069	.106	.676
VG age 7 → H/I age 8	.029	.015	−.064	.094	.711
VG age 8 → H/I age 10*	.357	.143	.027	.206	.013
H/I age 6 → VG age 7*	.107	.205	.088	.322	.002
H/I age 7 → VG age 8*	.043	.120	.027	.213	.018
H/I age 8 → VG age 10	.013	.032	−.055	.118	.483
VG age 6 → VG age 7*	.270	.160	.058	.262	.003
VG age 7 → VG age 8*	.166	.225	.128	.323	<.001
VG age 8 → VG age 10*	.220	.205	.104	.306	<.001
H/I age 6 → H/I age 7*	.240	.220	.111	.330	<.001
H/I age 7 → H/I age 8*	.285	.309	.198	.420	<.001
H/I age 8 → H/I age 10*	.167	.174	.042	.307	.010
Between-person covariance (RI-VG ↔ RI-H/I)	.043	.074	−.047	.194	.236

Note. Results from the Random Intercept Cross-Lagged panel model (RI-CLPM), including cross-lagged paths, autoregressive paths, and between-person associations respectively. *B* represents the unstandardized estimate of each regression path. β represents the standardized estimate of the regression, followed by the 95 % confidence interval of β. P-values lower than .025 were considered significant and are flagged with an asterisk. RI = Random Intercept latent variable. VG = video game playing time. H/I = hyperactivity and inattention (ADHD symptoms). In the leftmost column, arrows represent the directionality of the associations at different time points. Data compiled from the final master file of the Québec Longitudinal Study of Child Development (1998–2023), ©Gouvernement du Québec, Institut de la statistique du Québec, Canada.

Table 3
Results from the lagged effects of the Hyperactivity/Impulsivity-only RI-CLPM.

	B	β	95 % Confidence Interval (β)		Two-tailed
			Lower	Upper	p-values
VG age 6 → Hyper age 7	.046	.013	−.072	.099	.763
VG age 7 → Hyper age 8	.005	.002	−.076	.081	.952
VG age 8 → Hyper age 10*	.432	.176	.047	.304	.006
Hyper age 6 → VG age 7*	.096	.190	.078	.302	.002
Hyper age 7 → VG age 8*	.045	.125	.026	.223	.020
Hyper age 8 → VG age 10	.009	.021	−.062	.105	.620
VG age 6 → VG age 7*	.266	.157	.055	.260	.004
VG age 7 → VG age 8*	.166	.226	.128	.323	<.001
VG age 8 → VG age 10*	.220	.205	.104	.307	<.001
Hyper age 6 → Hyper age 7*	.241	.232	.124	.340	<.001
Hyper age 7 → Hyper age 8*	.225	.243	.124	.340	<.001
Hyper age 8 → Hyper age 10	.037	.038	−.126	.203	.647
Between-person covariance (RI-VG ↔ RI-Hyper)	.043	.073	−.041	.188	.215

Note. Results from the Random Intercept Cross-Lagged panel model (RI-CLPM), including cross-lagged paths, autoregressive paths, and between-person associations respectively. *B* represents the unstandardized estimate of each regression path. β represents the standardized estimate of the regression, followed by the 95 % confidence interval of β. P-values lower than .025 were considered significant and are flagged with an asterisk. RI = Random Intercept latent variable. VG = video game playing time. Hyper = hyperactivity/impulsivity symptoms. In the leftmost column, arrows represent the directionality of the associations at different time points. Data compiled from the final master file of the Québec Longitudinal Study of Child Development (1998–2023), ©Gouvernement du Québec, Institut de la statistique du Québec, Canada.

associations, and between-person correlations are shown in Table 2. The results from the models with separated dimensions are shown in Table 3 (hyperactivity/impulsivity) and Table 4 (inattention). Fig. 1 illustrates the results from the combined ADHD symptoms model.

In our model combining both dimensions of ADHD symptoms, higher levels of ADHD symptoms at age 6 were associated with more time playing video games one year later (β = .205; 95 % CI [.088, .322]). In contrast, gaming at age 6 did not significantly predict ADHD symptoms at age 7 (β = .019; 95 % CI [-.069, .106]). A similar pattern emerged from age 7 to 8. Changes in the levels of ADHD symptoms at age 7 predicted increased time devoted to playing video games at age 8 (β = .120; 95 % CI [.027, .213]), but changes in gaming at age 7 were not associated with ADHD symptoms one year later (β = .015; 95 % CI [-.064, .094]). However, the directionality of this pattern of associations reversed between the ages of 8–10. More time dedicated to playing video games at age 8 predicted higher levels of ADHD symptoms at age 10 (β = .143; 95 % CI [.027, .206]). Conversely, changes in ADHD symptoms did not lead to changes in time spent playing video games at age 10 (β = .032; 95 % CI [-.055, .118]).

Results from the model using only hyperactivity/impulsivity symptoms were similar to our model with combined dimensions. Higher levels of hyperactivity/impulsivity symptoms predicted higher levels of gaming from ages 6 to 7 (β = .190; 95 % CI [.078, .302]) and ages 7 to 8 (β = .124; 95 % CI [.026, .223]). However, gaming levels did not predict changes in hyperactivity/impulsivity symptoms from ages 6 to 7 (β = .013; 95 % CI [-.072, .099]) and 7 to 8 (β = .002; 95 % CI [-.076, .081]). Similar to the model with combined symptoms, this direction of association reversed from ages 8 to 10. More time gaming at age 8 predicted higher levels of hyperactivity/impulsivity at age 10 (β = .176; 95 % CI [.047, .304]). Conversely, changes in hyperactivity/impulsivity levels did not lead to changes in time spent playing video games at age 10 (β = .021; 95 % CI [-.062, .105]).

The results from the model including only Inattention symptoms were the most different. The only significant cross-lagged effect was the association between inattention symptoms at age 6 and gaming at age 7 (β = .180; 95 % CI [.067, .292]). All other cross-lagged effects were non-significant. This suggests that more inattentive young children tend to play more video games, but gaming has little effect on inattentive symptoms.

Table 4
Results from the lagged effects of the Inattention-only RI-CLPM.

	B	β	95 % Confidence Interval (β)		Two-tailed
			Lower	Upper	p-values
VG age 6 → Inatt age 7	.113	.023	−.073	.120	.632
VG age 7 → Inatt age 8	.085	.030	−.047	.107	.453
VG age 8 → Inatt age 10	.239	.064	−.033	.161	.194
Inatt age 6 → VG age 7*	.073	.180	.067	.292	.004
Inatt age 7 → VG age 8	.023	.091	.004	.177	.051
Inatt age 8 → VG age 10	.007	.025	−.054	.104	.538
VG age 6 → VG age 7*	.276	.164	.061	.267	.003
VG age 7 → VG age 8*	.169	.230	.131	.328	<.001
VG age 8 → VG age 10*	.223	.208	.107	.309	<.001
Inatt age 6 → Inatt age 7	.094	.081	−.042	.203	.199
Inatt age 7 → Inatt age 8*	.285	.287	.193	.381	<.001
Inatt age 8 → Inatt age 10*	.218	.224	.121	.328	<.001
Between-person covariance (RI-VG ↔ RI-Inatt)	.047	.064	−.068	.197	.343

Note. Results from the Random Intercept Cross-Lagged panel model (RI-CLPM), including cross-lagged paths, autoregressive paths, and between-person associations respectively. *B* represents the unstandardized estimate of each regression path. β represents the standardized estimate of the regression, followed by the 95 % confidence interval of β. P-values lower than .025 were considered significant and are flagged with an asterisk. RI = Random Intercept latent variable. VG = video game playing time. Inatt = Inattention symptoms. In the leftmost column, arrows represent the directionality of the associations at different time points. Data compiled from the final master file of the Québec Longitudinal Study of Child Development (1998–2023), ©Gouvernement du Québec, Institut de la statistique du Québec, Canada.

3. Discussion

In this study, we estimated the longitudinal within-person associations between gaming and ADHD symptoms among Canadian children aged 6 to 10. We hypothesized bidirectional associations. In partial support of our hypothesis, we found robust, within-person associations between child ADHD symptoms and subsequent increases in gaming from ages 6 to 8. Our findings also indicate that gaming at age 8 was associated with higher levels of ADHD symptoms at age 10. Past research suggested ADHD symptoms predicts increased gaming during childhood (Stenseng et al., 2020). Other research suggest simultaneous bidirectional associations between gaming and ADHD symptoms among children and adolescents (Gentile et al., 2012), and that gaming predicts subsequent higher levels of ADHD symptoms in early adolescence (Tiraboschi et al., 2022). Our results provide novel insights by revealing non-concurrent transactional associations between gaming and ADHD symptoms during middle childhood. This suggests that the link between gaming and ADHD symptoms can emerge before adolescence. Increased symptoms of ADHD at the beginning of elementary school possibly lead to prolonged gaming, which subsequently increases the risk of worsened ADHD symptoms later on.

Our findings are consistent with the differential susceptibility to media effects model, which posits that interactions between digital media and its effects are reciprocal (Beyens et al., 2018; Valkenburg & Peter, 2013). As gaming are designed to be highly stimulating and rewarding, preferences for immediate rewards and poor inhibitory control are core elements of ADHD symptomatology that could predispose children to increased gaming (Marx et al., 2021; Mphahlele et al., 2021). Indeed, a recent study found that poor response inhibition and impulsivity trait of personality mediate cross-sectional associations between gaming and symptoms of ADHD among adolescents (Wallace et al., 2023). Conversely, children can be conditioned to the instant gratification and higher levels of arousal provided by video games, even more so if they already possess high impulsivity and low response inhibition. Spending more time partaking in such a highly gratifying and arousing activity can make children less responsive and interested in less stimulating activities, more easily distracted, and more impatient, therefore worsening ADHD-related behavior (Beyens et al., 2018; Christakis et al., 2018). This transactional mechanism may also provide a plausible explanation for why gaming was more strongly associated with hyperactivity and impulsivity than with inattention in our study, as the hyperactivity/impulsivity dimension better reflects arousal dysregulation and poor inhibitory control.

Both directions of this transactional association carry potential risks for children. Increased gaming coupled with impulsivity and poor inhibitory control can lead children to develop unhealthy gaming habits. Indeed, a recent meta-analysis found that ADHD symptom severity moderately correlated with Gaming Disorder from childhood to adulthood (Koncz et al., 2023), a condition of video game addiction with serious implications for children's well-being (Teng et al., 2020). Heightened ADHD symptoms driven by increased gaming is also problematic. It is unlikely that gaming itself causes the fully-fledged disorder, due to its strong genetic basis (Faraone & Larsson, 2019; Gidziela et al., 2023). However, higher levels of subclinical symptoms are by themselves impairing (Krauss & Schellenberg, 2022) and they could be intensified to a clinical threshold for children at higher genetic risk of ADHD. This is concerning, as childhood ADHD has long-term impacts on academic, occupational, and health outcomes in later life (Dalsgaard et al., 2015; Dona et al., 2023; Kosheleff et al., 2023; Lorenzo et al., 2021). Childhood ADHD is also persistent; at least half the children with ADHD will continue to experience impairing symptoms into adulthood (Faraone et al., 2006; Lorenzo et al., 2021).

The effect sizes of the cross-lagged associations that we found were all large (Orth et al., 2022), suggesting significant practical implications for children. In light of these findings, parents and professionals should be sensitized to the fact that young children who are more restless and easily distracted are likely to spend more time playing video games. By the end of elementary school, when the demands of school increase, gaming is likely to increase the risk of developing symptoms of ADHD, particularly hyperactivity and impulsivity. As such, parents, teachers, and healthcare professionals should monitor children's time spent gaming and encourage them to pursue other healthier leisure activities such as sports, arts, and outdoor activities. Professionals could also help parents develop personalized media use plans by providing information on healthy media use (HealthyChildren.org, 2024). In particular, such plans should emphasize avoiding excessive gaming (>2h/day, Council on Communications and Media, 2013) and video games that could overstimulate or impair children's self-control.

3.1. Limitations

Our study is not without limitations. First, data were collected from 2004 to 2008 and may not generalize to today current gaming trends. However, given that video games are now more engaging and not less (Drummond & Sauer, 2018; Zendle et al., 2020), the observed associations are likely to be stronger. Our measure of gaming does not contain information on the type of video game played. Our measure also lacks contextual media use details (Christakis, 2019), such as content and time of playing. Furthermore, although our RI-CLPM approach accounts for all stable between-person confounders, it does not control for time-varying confounders such as stress, parenting style, social acceptance, and self-perceptions of competence (Dvorsky & Langberg, 2016; Koppelmaa et al., 2024). Future research incorporating repeated measures of these variables is needed to more fully isolate potential cofounders. Finally, our study relied on teacher's reports and thus did not include a direct assessment of ADHD symptoms, which would be difficult due to the children's age.

3.2. Strengths

Our study explores prospective bidirectional links between gaming and ADHD symptoms in middle childhood, leveraging a large population-based sample of school-aged children. Our study also relied on a state-of-the-art statistical model that disentangles between-person from within-person effects. Furthermore, ADHD symptoms in our study were reported by the teacher which reduces shared measurement bias and social desirability.

4. Conclusions

Children with higher levels of ADHD symptoms tend to spend more time playing video games. In turn, increases in time spent gaming in early school years may exacerbate ADHD symptoms later in development. This is of concern as excessive gaming can lead to unhealthy gaming habits and increased ADHD symptoms can impair children's academic, social, emotional, and physical well-being. Together, excessive gaming and ADHD symptoms can reinforce each other. Our findings underscore the importance of monitoring child gaming activities, particularly that of hyperactive and inattentive children, to support healthy development.

CRediT authorship contribution statement

Gabriel A. Tiraboschi: Writing – original draft, Visualization, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Caroline Fitzpatrick:** Writing – review & editing, Supervision, Resources, Conceptualization. **Hyoun S. Kim:** Writing – review & editing. **Luísa Superbia-Guimarães:** Writing – review & editing. **Laurie-Anne Kosak:** Writing – review & editing. **Gabrielle Garon-Carrier:** Writing – review & editing, Supervision, Resources, Conceptualization.

Data access and data support

We thank our statistician and colleague Annie Lemieux for providing insights about data analysis. We thank the Institut de la statistique du Québec for access to the data used in this study that were compiled from the final master file of the Québec Longitudinal Study of Child Development (1998–2023), ©Gouvernement du Québec, Institut de la statistique du Québec. The Québec Longitudinal Study of Child Development was supported by funding from the Ministère de la Santé et des Services sociaux, le Ministère de la Famille, le Ministère de l'Éducation et de l'Enseignement supérieur, the Lucie and André Chagnon Foundation, the Institut de recherche Robert-Sauvé en santé et en sécurité du travail, the Research Centre of the Sainte-Justine University Hospital, the Ministère du Travail, de l'Emploi et de la Solidarité sociale and the Institut de la statistique du Québec. Dr. Tiraboschi, Dr. Fitzpatrick, and Dr. Garon-Carrier had full access to the data used in this study. Other authors did not have clearance to access to the data.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Gabriel A. Tiraboschi reports financial support was provided by Quebec Research Fund Society and Culture. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbr.2025.100740.

Data availability

The authors do not have permission to share data.

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