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Effects of Digital Media Use on Academic Achievement: A Three-Wave Longitudinal Study

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We analyzed data from a three-wave longitudinal survey of elementary, junior high, and high school students in Japan to determine the effects of digital media use on academic achievement. The time spent on digital media use increased at each developmental stage. A cross-lagged panel model was used to identify the causal relationship between digital media use and reading, study time, and academic achievement. No direct impact was found for digital media use on academic achievement at any developmental stage. Various influence relationships were found in high school students. The results suggest that digital media use does not replace reading time, but it does replace study time and has a negative impact on academic achievement.

Keywords: Academic achievement, Cross-lagged panel model, Digital media, Longitudinal study, Secondary data analysis

Introduction

Digital media is an integral part of modern life. A survey by the Institute for Information and Communications Policy (2021) found that Japanese children (aged 13–19 years) spent 309.5 min watching television and using the Internet per weekday and 414.5 min per free day.1 A survey of children aged 10–17 years found that elementary school students, junior high school students, and high school students used the Internet for 146.4 min, 199.7 min, and 267.4 min per weekday, respectively (Cabinet Office, Director-General for Policy Coordination, 2021). The time a child spends on digital media increases with school type. According to Programme for International Student Assessment (PISA) conducted by Organisation for Economic Co-operation and Development (OECD) in 2018 (PISA 2018), Japan recorded the shortest frequency of using digital devices in school lessons (language-of-instruction, mathematics, and science) compared with other OECD member countries. The frequency of using digital devices for learning outside school on weekdays was also very low. However, the frequency of playing one-player games and chatting online was the highest among OECD member countries (National Instutute for Esucation Policy Research, 2019). These results suggest that Japanese children's media use is largely for entertainment.

Numerous studies have been conducted on the effects of digital media use on children's academic achievement and intellectual performance. In a meta-analysis of 30 cross-sectional studies conducted in 23 countries between 1958 and 2018, Adelantado-Renau et al. (2019) examined the association between time or frequency of screen media use, including television, video games, computers, and cell phones and academic achievement. Time spent on overall screen media use was not associated with academic achievement, but television viewing was inversely associated with composite performance scores, language, and mathematics. Video game playing was inversely associated with composite scores. These negative associations were larger for older children, suggesting differences by developmental stage.

In a longitudinal study examining causality, Koolstra et al., (1997) conducted a three-year panel study of elementary school children and found that television viewing suppressed reading comprehension. A two-year longitudinal study of elementary school students (Mundy et al., 2020) showed that watching more than 2 hours of television per day lowered reading and numeracy scores and that using a computer for more than 1 hour per day lowered numeracy. There was no association between video game use and academic achievement. Aksoy and Link (2000) showed that watching television had a negative effect on math test scores in high schoolers. These studies indicate the negative effects of digital media use. However, Gaddy (1986) found no clear evidence of the negative effects of television viewing on high school students' vocabulary, reading comprehension, or math achievement. Further Zavodny's (2006) analysis of data from three surveys showed that television viewing did not negatively affect performance on standardized exams. Additionally, Hofferth (2010) showed that the impact of television and video games on academic achievement varies by gender and race. Although several studies have examined the causal relationship between digital media use and academic achievement, the findings are mixed and inconsistent. While some previous Japanese studies have examined correlations (e.g., Morita et al., 2016), studies of causal relationships are lacking. As shown by international comparative surveys, such as PISA 2018, there are cultural differences in children's media use. Therefor e, it is necessary to present findings that consider the situation of Japanese children. This can contribute to existing knowledge in this area.

This study attempts to fill this gap and examine the causal relationship between digital media use and academic achievement among Japanese elementary, junior high, and high school students in a secondary data analysis of the Japanese Longitudinal Study of Children and Parents (JLSCP) by the Center for Social Research and Data Archives, Institute of Social Science, The University of Tokyo and Benesse Education Research and Development Institute. JLSCP has conducted an annual survey of elementary through high school children and their parents since 2015. By analyzing this large panel dataset in Japan, we can clarify the actual condition of media use and examine its impact at different developmental stages. The survey measures time spent watching television and DVDs, playing video games and portable game consoles, using cell phones and smartphones, and using PCs and tablets. We define digital media use time as the sum of these time values.

This study sought to answer the following research questions (RQ):
RQ1: What are the characteristics of digital media use among elementary, junior high, and high school students in Japan?
RQ2: What is the causal relationship between digital media use and academic achievement?

Time displacement theory, a leading theory that explains the negative impacts of digital media use on academic achievement (e.g., Perse, 2001; Shin, 2004), is applied to examine RQ2. It suggests that time spent using digital media could reduce time spent on other activities such as doing homework, reading, or sleeping, which could affect academic achievement (e.g., Sharif et al., 2010). Thus, we examine both the direct effects of digital media use on academic achievement and its relationship to reading and study time.

Methods

Data and Participants

Parent and child data from the 2016 (Wave 1), 2017 (Wave 2), and 2018 (Wave 3) JLSCP were used. We analyzed data from children who were in the fourth year of elementary school, first year of junior high school, and first year of high school in Wave 1 and were followed for 3 years. In other words, we captured changes from fourth to sixth years in elementary school, first to third years in junior high school, and high school.

In the three surveys, the analysis included data from the four types of media use, reading, time spent studying, and academic achievement, with no missing data. A total of 755 elementary school students (349 males and 406 females), 714 middle school students (329 males and 385 females), and 673 high school students (324 males and 349 females) were included.

Questionnaire

Digital media usage time. The respondents provided their average daily usage time for the four categories of watching television or DVDs, playing video games or portable game consoles, using cell phones or smartphones, and using PCs or tablets (e.g., iPads) during a typical day (i.e., school days). Responses were given on a 10-point scale (1 = never to 10 = more than 4 h) were converted into hours (min), and the four types of media use times were summed (e.g., 1 h was converted to 60 min and more than 4 h to 300 min).

Reading time. Similarly, the results for reading a book and reading a newspaper were converted into minutes and totaled.

Study time. The two items doing school homework and studying other than school homework (excluding tutoring school time) were converted into hours (minutes) in the same way. Taking the number of times that students attended tutoring sessions per week and the number of hours of study per session, the average daily hours of study at tutoring sessions were calculated, and all were then added together.

Academic achievement. The children self-reported their academic achievement. Elementary school students' relative-to-peer performance in their classes for Japanese, mathematics, science, and social studies were obtained on a five-point scale from 1 = lower to 5 = higher and then averaged. Junior high and high school students reported their relative performance for Japanese, math, science, social studies (for high school students in Wave 3, geography, history, and civics were used), and English (foreign language) at their respective grade levels on a five-point scale, and the scores were averaged. Subjects that consisted of multiple subjects, such as science and social studies, were annotated to be answered approximately on average. For high school students, "not taken" was an option in Wave 1 and Wave 2, and if the option was used, averages were calculated for all other subjects.

Gender. We used responses that matched two or more times out of three surveys. If there was no match, the data were considered missing.

Educational expenses. The average monthly educational expenses (total expenses for lessons, tutoring school, and educational materials) were obtained from the parents of each child on a 10-point scale ranging from 1 = less than 1,000 yen to 10 = 50,000 yen or more. Data from Wave 1 were used in the analysis.

Data analysis

To examine RQ1, we analyzed differences in media use by gender and grade using two-way, repeated-measures ANOVA. RQ2 was analyzed using a three-wave, cross-lagged panel model. Specific analysis methods and model comparisons are detailed below.

Results

Table 1 shows the means and standard deviations for the four types of media usage time, and Table 2 shows those for the other variables.

Table 1
Means and standard deviations of time spent using the four types of media

		Elementary school		Junior high school		High school	
		M	*SD*	*M*	*SD*	*M*	*SD*
TV/DVDs	w1	83.68	59.61	84.81	69.35	69.71	59.88
	w2	92.90	70.61	84.24	67.92	64.99	52.86
	w3	94.42	71.17	78.00	65.06	57.82	54.95
Game	w1	33.75	41.57	42.86	58.77	49.77	69.44
	w2	43.70	55.34	52.02	71.54	48.08	68.28
	w3	49.70	63.02	48.10	69.38	42.08	66.86
Phone	w1	7.62	22.05	34.91	58.84	97.03	79.43
	w2	14.44	35.90	54.01	71.68	112.15	82.19
	w3	25.01	53.24	68.33	76.28	101.14	81.60
PC/tablet	w1	12.91	30.31	29.02	49.67	21.98	47.30
	w2	20.28	41.33	31.93	53.27	20.16	48.41
	w3	26.17	48.21	36.66	63.21	19.15	49.34

※w1, w2, and w3 denote Waves 1, 2, and 3, respectively, for all tables.

RQ1: What are the characteristics of digital media use among elementary, junior high, and high school students in Japan?

The time spent using digital media increases by school tier (Table 2). Time spent using media was examined using year and gender.

Television/DVDs. For elementary students, the main effect of year level was significant ($F(2, 1506) = 11.39$, $p < .001$, $\eta_p^2 = .01$): fifth- and sixth-year students watched significantly longer than fourth-year students ($p < .001$). No significant main effect or interaction for gender was identified (in order, $F(1, 753) = .001$, $p = .98$, $\eta_p^2 < .001$; $F(2, 1506) = 1.48$, p = .23). In junior high students, the main effects of year and gender were significant (in order, $F(2, 1424) = 5.94$, $p = .003$, $\eta_p^2 = .01$; $F(1, 712) = 7.55$, $p = .006$, $\eta_p^2 = .01$). Third-year students had significantly shorter viewing times than first- and second-year students ($p = .01$). Females had more watch time ($p < .01$). The interaction was nonsignificant (F(2, 1424) = 2.30, p = .10, η_p^2 = .003). For high school students, the main effect of year was significant (F(2, 1342) = 19.76, p < .001, η_p^2 = .03). Viewing time decreased with increasing year (p < .05 between years 1 and 2, p < .001 between years 2 and 3). The main effect and interaction for gender were nonsignificant (in order, F(1, 671) = 1.20, p = .27, η_p^2 = .002; F(2, 1342) = 1.56, p = .21, η_p^2 = .003).

Table 2
Means and standard deviations for time spent using digital media, reading, studying, academic achievement, and educational expenses

		Elementary school		Junior high school		High school	
		M	*SD*	*M*	*SD*	*M*	*SD*
Digital media usage	w1	137.95	104.95	191.60	154.89	238.49	178.99
	w2	171.32	138.16	222.21	171.97	245.39	164.00
	w3	195.30	154.94	231.10	179.79	220.19	173.19
Reading	w1	21.74	32.97	24.13	42.21	15.56	32.90
	w2	25.89	40.38	22.18	41.96	14.02	24.95
	w3	25.56	38.67	20.18	35.68	12.50	21.63
Studying	w1	70.16	55.59	103.03	67.22	98.00	88.52
	w2	86.68	65.99	101.20	71.56	93.47	84.56
	w3	101.84	89.14	132.15	92.07	172.56	150.61
Academic achievement	w1	3.71	0.92	3.59	1.06	3.23	0.97
	w2	3.64	0.97	3.51	1.08	3.20	0.99
	w3	3.70	1.00	3.48	1.11	3.32	0.97
Educational expenses	w1	4.75	2.10	4.61	2.30	3.68	2.68

Games. The main effects of year and gender were significant for elementary students (in order, F(2, 1506) = 31.60, p < .001, η_p^2 = .04; F(1, 753) = 67.48, p < .001, η_p^2 = .08). Time increased as year increased (p < .001 for years 4 and 5, 6; p < .05 for years 5 and 6). Time was also longer for males (p < .001). The interaction was nonsignificant (F(2, 1506) = 1.75, p = .17, η_p^2 = .002). For junior high school students, the main effects of year and gender and interactions were significant (in order, F(2, 1424) = 8.06, p < .001, η_p^2 = .01; F(1, 712) = 58.47, p < .001, η_p^2 = .08; F(2, 1424) = 4.86, p = .01, η_p^2 = .01). First-year students spent more time playing games than second-year students (p < .001); there were no significant differences between first- and third-year students or between second- and third-year students (p = .09, p = .25, in that order). Males played longer (p < .001). For high school students, the main effects of year and gender were significant (in order, F(2, 1342) = 5.41, p = .005, η_p^2 = .01; F(1, 671) = 76.48, p < .001, η_p^2 = .10). Third-year students played significantly shorter than first- and second-year students (p < .01 for first and third-year students and (p < .05 between second and third year). Males played longer (p < .001). The interaction was nonsignificant (F(2, 1342) = .80, p = .45, η_p^2 = .001).

Phones. The main effect of year and interaction were significant for elementary school students (in order, F(2, 1506) = 60.68, p < .001, η_p^2 = .07; F(2, 1506) = 4.46, p = .01, η_p^2 = .01). The use duration increased with increasing year (p < .001). The main effect of gender was nonsignificant (F(1, 753) = 3.56, p = .06, η_p^2 = .005). For junior high school students, the main effects of year and gender were significant (in order, F(2, 1424) = 91.17, p < .001, η_p^2 = .11; F(1, 712) = 15.04, p < .001, η_p^2 = .02). The higher the year and for females, the longer the time of use (both p < .001). The interaction was nonsignificant (F(2, 1424) = 1.39, p = .25, η_p^2 = .002). For high school students, the main effect for year and interaction were significant (in order, F(2, 1342) = 15.17, p < .001, η_p^2 = .02; F(2, 1342) = 4.31, p = .01, η_p^2 = .01). Second-year students spent significantly longer than first- and third-year students (both p < .001). The main effect of gender was nonsignificant F(1, 671) = .15, p = .70, η_p^2 < .001).

PC/Tablet. For elementary school students, the main effect of year was significant (F(2, 1506) = 33.15, p < .001, η_p^2 = .04). The higher the year, the longer the time of use (p < .01). The main effects of gender and interaction was nonsignificant (in order, F(1, 753) = 1.07, p = .30, η_p^2 = .001; F(2, 1506) = .05, p = .95, η_p^2<.001). For junior high school students, the main effects and interactions for year and gender were significant (in order, F(2, 1424) = 6.72, p = .001, η_p^2 = .01; F(1, 712) = 8.38, p = .004, η_p^2 = .01; F(2, 1424) = 4.39, p = .01, η_p^2 = .01). Third-year students spent more time using PCs/tablets than first- and second-year students, and males spent more time (p < .01 for both). For high school students, the main effect of gender was significant (F(1, 671) = 10.48, p = .001, η_p^2 = .02), and males spent more time (p = .001). The main effects for year and interaction were nonsignificant (in order, F(2, 1342) = 1.18, p

= .31, η_p^2 = .002; $F(2, 1342) = 1.25$, $p = .29$, η_p^2 = .002).

Digital media use. The main effects of year and gender were significant for elementary school students (in order, $F(2, 1506) = 72.24$, $p < .001$, $\eta_p^2 = .09$; $F(1, 753) = 8.01$, $p = .005$, $\eta_p^2 = .01$). Greater school years and males showed more time using digital media ($p < .001$, $p < .01$, in that order). No interaction was found ($F(2, 1506) = .30$, $p = .74$, η_p^2<.001). For junior high school students, the main effect of year was significant ($F(2, 1424) = 27.06$, $p < .001$, η_p^2 = .04), with third-year students spending more time using digital media ($p < .001$). No main effect was seen for gender or interaction (in order, $F(1, 712) = 1.10$, $p = .30$, $\eta_p^2 = .002$; $F(2, 1424) = .46$, $p = .63$, η_p^2<.001). For high school students, the main effects of year and gender were significant (in that order, $F(2, 1342) = 11.31$, $p < .001$, $\eta_p^2 = .02$; $F(1, 671) = 14.71$, $p < .001$, $\eta_p^2 = .02$); third-year students used significantly less time than first- and second-year students ($p < .01$). Males used more ($p < .001$) than females. The interaction was also significant ($F(2, 1342) = 5.05$, p = .01, η_p^2 = .01).

RQ2: What is the causal relationship between digital media use and academic achievement?

A cross-lagged panel model was used to examine the causal relationship between digital media use, reading and study time, and academic achievement. A cross-lagged panel model is expressed within the framework of structural equation modeling and is used to describe reciprocal relationships, or directional influences, between variables over time (Allen, 2017). The use of longitudinal data clarifies temporal ordinal relationships among variables, thereby allowing the estimation of causal relationships that is difficult to achieve with cross-sectional data. Figure 1 shows the model for estimating causality between two variables collected at three time points. In this model, when path a from variable X_1 in Wave 1 to variable Y_2 in Wave 2 or path b from X_2 in Wave 2 to Y_3 in Wave 3 has a significant positive effect, a causal relationship wherein an increase in X increases Y (decrease in X decrease Y) is estimated. If it has a significant negative effect, the causal relationship is inferred to be such that an increase in X decreases Y (decrease in X increase Y). If path c from Y_1 to X_2 or path d from Y_2 to X_3 has a significant positive effect, the causal relationship is estimated such that an increase in Y increases X (decrease in Y decrease X). If it has a significant negative effect, the causal relationship is estimated to be such that an increase in Y decreases X (decrease in Y increase X). Therefore, the paths from Wave 1 to Wave 2 and Wave 2 to Wave 3 estimate the short-term causality, and the path from Wave 1 to Wave 3 estimate the longer-term causality. e is the error variable, and σ is the error covariance. To control for the influence of the third variable (control variable Z), a path is drawn from Z to X and Y. In this study, we extended the model to include four kinds of variables (digital media use, reading time, studying time, and academic achievement). Additionally, the student's gender and educational expenses were used as control variables. The former was used because the results of RQ1 suggest that there are significant gender differences in elementary school and high school students. The latter was selected as a variable reflecting parents' attitudes toward the four kinds of variables used in this analysis. Figure 2 shows a schematic of the model where the paths from the two control variables to each variable and the error variable and error covariance are omitted.

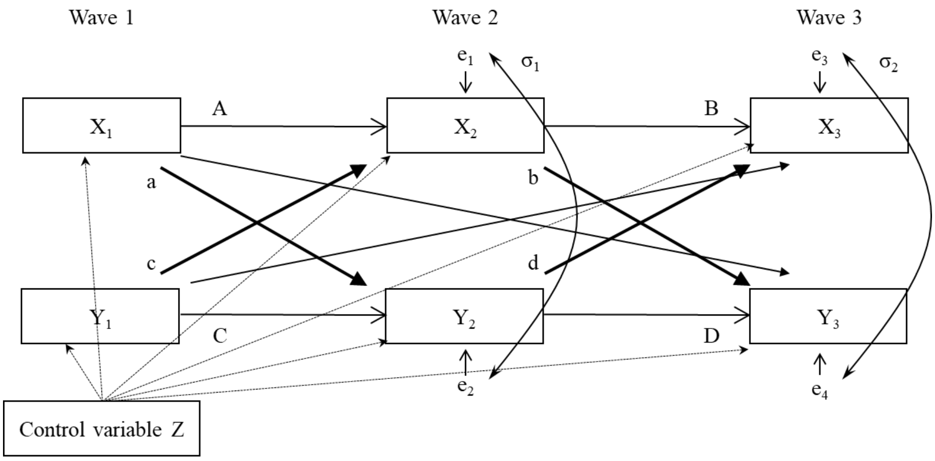
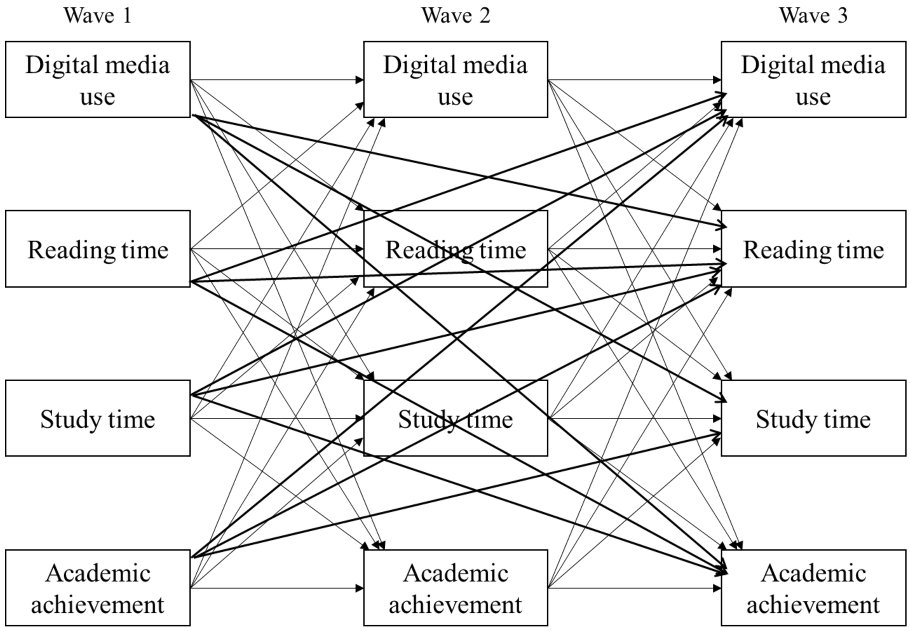


Figure 1. The example of three-wave, cross-lagged effects model



※Control variables (gender and educational expenses) and paths to each variable; error variables and error covariance omitted.

Figure 2. Schematic of the analytical model

In general, when conducting structural equation model analysis, the fewer the number of estimated paths, the more stable the solution. Therefore, the model constraints were examined with reference to Tajima et al. (2012). In the three-wave, cross-lagged panel model, the autoregressive coefficients from Wave 1 to Wave 2 (path A or path C in Figure 1) are of the same magnitude as the autoregressive coefficients from Wave 2 to Wave 3 (path B or D). Similarly, we can impose an equality constraint that the cross-lagged coefficients from Wave 1 to Wave 2 (path a or path c) and the cross-lagged coefficients from Wave 2 to Wave 3 (path b or path d) are of the same magnitude. In this study, four models were compared. Model 1 had no restrictions on paths. Model 2 applied equality constraints to the four autoregressive coefficients. Model 3 placed equality constraints on the cross-lagged coefficients for the same variable combination. Model 4 applied equality constraints to the autoregressive and cross-lagged coefficients. After selecting the best-fitting model with reference to the goodness-of-fit indices (e.g., Hooper et al., 2008), the nonsignificant paths of error covariance between variables in each survey year were removed and analyzed again. Model 3 was used for elementary, junior high, and high school students.

Tables 3–5 present the standardized coefficients of autoregressive coefficients and cross-lagged coefficients for elementary, junior high, and high school students. The data for elementary school students show no significant paths for digital media usage time on other variables. A significant negative effect was seen on time spent using digital media from academic achievement. The path from reading time to study time was significantly positive, and the path from study time to reading time was significantly negative. The 1-and 2-year interval paths from academic achievement to study time were significantly positive. There was no effect of digital media use on other variables among junior high school students. The path from study time and academic achievement to time spent using digital media was significantly negative.

High school students had more significant paths than elementary and middle school students. The path from digital media use to reading was significantly positive. The path from media use to study time was significantly negative, and the path at 2-year interval was also significant. The path from reading time to digital media use was significantly positive. The path from study time to digital media use was significantly negative. Two-way positive influence relationships were found between reading time and study time and between study time and year. The path from academic achievement to reading time was significantly positive.

Table 3
Standardized coefficients of autoregressive coefficients and cross-lagged coefficients for elementary school students

	w1 → w2		w2 → w3		w1 → w3	
Autoregressive coefficients						
Digital media	.48	†	.47			
Reading	.51	**	.69	***		
Studying	−1.26	†	−1.08	†		
Academic achievement	.81		−4.80			
Cross-lagged coefficients						
Digital media → Reading	−.01		−.01		.03	
Digital media → Studying	.01		.01		.05	
Digital media →Academic achievement	−.01		−.01		−.20	
Reading → Digital media	−.04	†	−.04	†	−.01	
Reading → Studying	.30	*	.27	*	−.04	
Reading → Academic achievement	.06		.07		.91	
Studying → Digital media	−.02		−.02		−.03	
Studying → Reading	−.10	***	−.12	***	.07	†
Studying → Academic achievement	−.02		−.03		.14	
Academic achievement →Digital media	−.06	*	−.06	*	−.04	
Academic achievement →Reading	.06	†	.07	†	−.01	
Academic achievement →Studying	.14	**	.11	**	.14	*

$\chi^2(16) = 24.72, p = .075$, CFI = 1.00, RMSEA = .03, AIC = 230.72. $^{***}p < .001$, $^{**}p < .01$, $^{†}p < .10$

Table 4
Standardized coefficients of autoregressive coefficients and cross-lagged coefficients for junior high school students

	w1 → w2		w2 → w3		w1 → w3
Autoregressive coefficients					
Digital media	.21		.56	*	
Reading	.12		−.62		
Studying	.13		.17		
Academic achievement	.95	***	.43		
Cross-lagged coefficients					
Digital media → Reading	.03		.04		.05
Digital media → Studying	−.05	†	−.05	†	−.02
Digital media →Academic achievement	−.01		−.01		−.10
Reading → Digital media	.04		.04		.01
Reading → Studying	−.02		−.02		.07
Reading → Academic achievement	−.03		−.03		.03
Studying → Digital media	−.09	***	−.09	***	.06
Studying → Reading	.08		.10		.12
Studying → Academic achievement	.03		.03		−.01
Academic achievement →Digital media	−.14	*	−.14	*	.02
Academic achievement →Reading	−.02		−.03		.04
Academic achievement →Studying	.02		.01		.02

$\chi^2(15) = 15.16, p = .44$, CFI = 1.00, RMSEA = .004, AIC = 223.16. $^{***}p < .001$, $^{*}p < .05$, $^{†}p < .10$

Table 5
Standardized coefficients of autoregressive coefficients and cross-lagged coefficients for high school students

	w1 → w2		w2 → w3		w1 → w3	
Autoregressive coefficients						
Digital media	.27	*	2.12	*		
Reading	−.40	**	−1.10	**		
Studying	−.35	†	−1.35	†		
Academic achievement	−.40		−2.46			
Cross-lagged coefficients						
Digital media → Reading	.19	***	.20	***	.12	†
Digital media → Studying	−.26	***	−.13	***	−.42	*
Digital media →Academic achievement	−.03		−.03		−.10	
Reading → Digital media	.08	*	.06	*	−.16	
Reading → Studying	.17	**	.07	**	.06	
Reading → Academic achievement	.04		.03		−.01	
Studying → Digital media	−.15	***	−.13	***	.27	
Studying → Reading	.11	*	.12	*	−.01	
Studying → Academic achievement	.12	**	.12	**	.22	
Academic achievement →Digital media	.00		.00		−.03	
Academic achievement →Reading	.07	*	.08	*	.05	
Academic achievement →Studying	.11	**	.07	**	.13	

$\chi^2(17) = 20.07$, $p = .27$, CFI = 1.00, RMSEA = .02, AIC = 224.07. ***$p < .001$, **$p < .01$, *$p < .05$, †$p < .10$

Discussion

In this study, we conducted a secondary analysis of data from a three-wave panel survey of Japanese children to determine their media use. We then examined the effects of digital media use on academic achievement. The significance of this study is that it analyzes data on Japanese children, for which there is a gap in knowledge; it examines causal relationships through a longitudinal survey; and it allows a comparison of the situation of elementary, junior high, and high school students.

Digital media use increased with developmental stage. Elementary school students spent more time using digital media with each grade level. The main effect of this grade difference was a medium effect size. Their time spent using each of the four types of media increased, thereby indicating the increasing intrusion of media into their lives. Junior high school students likewise spent more time using digital media in the third year than in the first or second year. In the third year, television viewing time decreased, and the use of phones and PCs increased. The effect size of the main effect of the grade difference in the time spent using phones was the largest. Smartphone use expands with entry into junior high school. As students progressed through school, they spend increasing time outside of school using the Internet for homework and watching Internet videos (Mobile Society Research Institute, 2018). Time spent watching television may become replaced by online videos. Third-year high school students spent less time using digital media than first- and second-year students. Particularly, time spent on television and video games was shorter. Table 2 shows that study time increased significantly in third-year students, suggesting that more time was devoted to studying for entrance examinations and other subjects. Focusing on gender differences, the results were consistent with previous studies (e.g., Hamlen, 2010), with males spending more time playing games than females across elementary, junior high, and high school students. The main effect of this gender difference was a medium effect size.

The results of the causal relationship using a cross-lagged panel model showed no direct effect of time spent using digital media on academic achievement for either elementary, junior high, or high school students. These results are consistent with previous findings of no effect of media use on academic achievement (e.g., Gaddy, 1986, Zavodny, 2006) but contradict research that found negative effects (e.g., Aksoy & Link, 2000; Koolstra et al. 1997; Mundy et al., 2020). This discrepancy may be related to differences in the definition of media, such as targeting specific media or using total media use as a measure, or to the measure of academic achievement as the dependent variable. Nevertheless, in this study, the results for elementary, junior high, and high school students consistently using the same index showed no direct effect of digital media usage time on academic achievement. This is a robust analysis using Japanese data and is the most significant result of this study.

For elementary and junior high school students, digital media use had no effect on reading or study time. Nevertheless, the path from academic achievement to digital media use was significantly negative. Although the relationship was not strong, this suggests that the lower the academic achievement, the longer the time spent using digital media. Additionally, the path from study time to digital media use was also significantly negative for junior high school students. Consequently, the shorter the studying time, the longer the media use the following year. These results suggest that digital media use does not affect the other variables and that the time displacement theory is not valid for elementary and junior high school students.

The most diverse significant paths were those among high school students. This may be because they spend more time using digital media in general. There was a bidirectional influence relationship between time spent using digital media and time spent reading or studying. The former was positive, and the latter was negative. The autoregressive coefficient of digital media use time was significantly positive, indicating that children who spent more time using digital media spent more time using media and reading the following year and less time studying. Additionally, the path connections from digital media use time to studying time and from studying time to academic achievement suggest a negative relationship: the longer the digital media use time, the shorter the studying time the following year. Additionally, the shorter the studying time, the lower the academic achievement in the following year. This mediating effect of studying time supports the time displacement theory, which suggests that digital media use reduces studying time and negatively affects academic achievement. Parental mediation may be the factor behind the causal difference between elementary/junior high school students and high school students. The percentage of children who make rules with their families regarding Internet use decreases as the school level increases (80.3% of elementary school students, 71.2% junior high school students, and 42.9% high school students, Cabinet Office, Director-General for Policy Coordination, 2021). In Japan, the most common rule made in many homes concerns the time of use, with 83.2% of elementary school students, 72.3% junior high school students, and 50.8% high school students having this rule among children with a family rule. To some extent, elementary and middle school students have the opportunity to be aware of the time they spend using media at home, whereas high school students do not. This explains the difference in the impact of media usage time.

Of the causal relationships between the variables reported, some effects were statistically significant but small. However, the negative effect on digital media use due to academic achievement was significant for elementary and junior high school students, and the negative effect on digital media use due to study time was significant for junior high and high school students. The results that are common across developmental stages suggest that the effects may well be cumulative, rather than short term over a year (e.g., Koolstra et al., 1997). Thus, even small effects would not be overlooked.

The limitations and future works of this study are noted from three perspectives. First, it calculated the time spent using digital media by summing the use of four types of media. Although we were able to identify causal relationships by viewing media use in terms of time, previous studies have indicated that the effectiveness of media use varies depending on its purpose (education or leisure) and genre (entertainment or education) (e.g., Ennemoser & Schneider, 2007; Kostyrka-Alchorne et al., 2017; Kim et al., 2017). This points to the need to consider the context in which screen media are used (Adelantado-Renau et al., 2019). As PISA 2018 indicates, most Japanese children's media use outside of school is for entertainment, so this study can be considered an examination of the effects of entertainment use. Thus, as the next step in our research, it may be possible to consider the influence of media use more diversely, using perspectives other than the temporal. The second regards indicators of academic achievement. The relative position of each respondent in the class and year level was used here. In this type of assessment, it may be that little change is seen over a three-year period. Previous studies have used various indicators, such as overall scores, GPAs, and test scores (e.g., Adelantado-Renau et al., 2019). This discussion should be advanced by examining absolute assessment-based measures. Third, this study used a cross-lagged panel model to estimate causal relationships among variables at the population level; it would also be meaningful to analyze developmental trajectories and individual differences in developmental trajectories using a latent growth model.

Conclusions

The main findings of this study can be summarized as follows: (1) Digital media use increased as school type increased. (2) The features of the type of media used varied by school type. (3) There was no direct effect of time spent using digital media on academic achievement for elementary, junior high, or high school students. (4) The time displacement theory was not supported for elementary and junior high school students. For high school students, there was a mediating effect of study time, with digital media use reducing study time, which negatively affected the students' academic achievement.

Results for elementary and junior high school students showed no negative effects caused by digital media use. However, a causal effect in the opposite direction suggested that low academic achievement and short studying time can lead to prolonged use and that the effects may be cumulative. Furthermore, for high school students, prolonged media use negatively affected their academic achievement through study time. Although this study revealed differences in the effects of media use by school stage, it is necessary to take a long-term view of children's development and consider better ways to interact with media from an earlier stage. In addition to parental mediation at home and media literacy education at school, it is necessary to encourage children's independence as good users from an early stage. For example, applications can be used to manage usage time.

This study provides Japanese findings on the actual state of children's media use and its causal relationship with academic achievement. The findings from elementary, junior high and high school students all together are valuable since they can be understood and compared in each development phase. In addition, the results of this study can integrate findings, as in a meta-analysis, and will contribute to the development of research in this area.

Footnote

1) These figures are the sum of television (real-time) viewing time, television (recorded) viewing time, and Internet usage time. The results were obtained under a state of emergency declared in 11 prefectures due to the spread of coronavirus disease 2019.

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