Media and human capital development: Can video game playing make you smarter?*

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Abstract

According to the literature, video game playing can improve such cognitive skills as problem solving, abstract reasoning, and spatial logic. I test this hypothesis using The Child Development Supplement to the Panel Study of Income Dynamics. The endogeneity of video game playing is addressed by using panel data methods and controlling for an extensive list of child and family characteristics. To address the measurement error in video game playing, I instrument children's weekday time use with their weekend time use. After taking into account the endogeneity and measurement error, video game playing is found to positively affect children's problem solving ability. The effect of video game playing on problem solving ability is comparable to the effect of educational activities.

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1 Introduction

An individual's cognitive skills are linked to a number of important outcomes. Individuals with higher cognitive abilities have higher educational attainment. Controlling for education, cognitive skills are positively related to an individual's success in the labor market, as measured by occupational choice, employment, work experience, and wages (Currie and Thomas, 2001; Heckman et al., 2006; Fletcher, 2013). Additionally, cognitive skills reduce the likelihood of engaging in such risky behaviors as teenage pregnancy, smoking, use of marijuana, and engaging in illegal activities (Heckman et al. 2006).

Because cognitive skills affect many economic and health-related outcomes, it is important to understand how they can be fostered. It is known that cognitive skills are most malleable in early years of life (Byron 2008). It is also known that practicing improves cognitive skills (Byron 2008). For example, reading or being read to develops language skills. Attending a math club is useful for improving mathematics skills. Children can, however, improve cognitive skills in other less obvious ways. For example, some media activities may contribute to the development of cognitive skills. Fiorini and Keane (2014) find that time spent on media is as important input in cognitive skill production as after-school care. According to the findings of Fiorini (2010), Malamud and Pop-Eleches (2011), and Beuermann et al. (2013), computer use fosters verbal and non-verbal intelligence. Gentzkow and Shapiro (2008) and Huang and Lee (2010) conclude that moderate television watching improves children's reading ability.

This study is the first to focus on the effect of video game playing on cognitive skills. Video game playing is one of the most popular leisure activities among children. The majority of U.S. children have access either to a video game console or a computer (which can be used to play video games) (Roberts and Foehr 2008). According to the data used for this analysis, almost 90 percent of 10-18 year old children play video games at least once or twice a month, and 43 percent play video games everyday or almost everyday.

These figures are consistent with the statistics reported in the other studies (Gentile et al. 2007).

A video game is essentially a problem solving task that requires certain cognitive skills. In order to win a video game, players need to plan their actions, find relevant and discard irrelevant information among all information given to them, and remember their previous actions. Thus, video game playing is most likely to improve such skills as problem solving, abstract reasoning, pattern recognition, and spatial logic, which are part of fluid, or general, intelligence (Johnson 2005). Because video game playing is a more cognitively challenging and interactive activity than television watching and most computer activities (Johnson 2005), video game playing is expected to be a more important input in cognitive skill production than computer use and television watching.

In order to answer the question of how video game playing affects cognitive skills, one needs to deal with three important issues. The first issue is related to the interpretation of the estimated coefficients. If children spend an additional one hour playing video games, they spend one hour less doing something else. The effect of video game playing on cognitive skills depends on what activity video game playing replaces. If children play video games instead of doing homework, their cognitive skills are likely to decrease. If children play video games instead of watching television, their cognitive skills may improve. To take this substitution effect into account, all other children's activities are included in the estimated regressions, although one activity group needs to be omitted to avoid perfect collinearity. I omit the "non-productive" activities, which include shopping, household chores, talking and visiting with people, resting, traveling, sleeping, and attending to personal needs. Thus, the coefficient on video game playing is interpreted as the effect of video game playing relative to the effect of these "non-productive" activities.

The endogeneity of video game playing is another issue that needs to be addressed. The time spent playing video games may be correlated with other unobserved determinants of cognitive skills. For example, innate abilities are likely to be an important source of the endogeneity. Children who like playing video games may have innate abilities that make them good at both video game playing and cognitive skill tests. Because of the potential correlation between video game playing and the unobservables, the estimates of standard models are likely to be biased. To address the endogeneity of video game playing, I use panel data methods, including the child fixed-effects model. The child fixed-effects model controls for any child-specific time-invariant variables including innate abilities. In addition to the child fixed-effects model, I estimate the sibling fixed-effects and value added models. All models control for an extensive list of observed variables that may be correlated with both video game playing and cognitive skills.

The final issue is related to measurement error. Video game playing is measured using time diary data in this analysis. Time diaries provide a more reliable measure of children's time use than survey recall questions (Stafford and Yeung 2004). However, a time diary is usually completed on one randomly selected day of the week. The time a child spent playing video games on that day may be different from the child's average daily video game time, which is the relevant variable in this analysis. The measurement error in children's video game time will bias the estimated effects of video game playing on cognitive skills, most likely downwards. To take the measurement error into account, I use two measures of children's video game time, one from a weekday time diary and another from a weekend time diary. The time spent playing video games on weekends is used as an instrument for the time spent playing video games on weekdays.

The data comes from the Child Development Supplement to the Panel Study of Income Dynamics (PSID-CDS). The PSID-CDS is a particularly suitable dataset for this analysis, because it is designed to collect information on the determinants of child development. The cognitive skills are measured by the achievement test scores. I examine how video game playing affects two skills, the ability to solve practical mathematics problems (mathematics reasoning) and the ability to correctly read English words (reading recognition). The main hypothesis tested in this paper is that video game playing has a positive effect on problem solving ability. Holding other activity time fixed, video game playing is not expected to affect reading ability. Thus, the regression of reading ability on video game playing may be viewed as a placebo test.

The results show that video game playing positively affects children's problem solving ability. After addressing the endogeneity and measurement error in video game playing, an additional hour of play per day is found to increase the mathematics reasoning test score by 9.3 percent of a standard deviation, holding the other activity time fixed. This effect is comparable to the effect of an additional hour spent on educational activities. As expected, there is no association between video game playing and reading ability. The results based on a non-linear model show that the positive effect of video game playing on problem solving ability is largest at a moderate number of video game hours. According the the results of heterogeneity analysis, video game playing has a larger effect on problem solving ability when children do not in engage in any other activities while playing video games. Video games appear to be a complement to the other inputs in cognitive skill development, as the effect of video game playing on problem solving ability increases with the quality of a child's home environment.

To my knowledge, there is only one other study in the economics literature that provides some evidence on the relationship between video game playing and cognitive skills Fiorini (2010). The primary focus of Fiorini's study is children's computer use, not video game playing. Fiorini (2010) finds a negative effect of video game playing on young children's verbal skills and a statistically insignificant effect on their non-verbal intelligence. To the contrary, I find no effect on 3-18 year old children's verbal skills and a positive effect on their non-verbal ability. There are a few possible explanations for the differences in our results. First, Fiorini's model does not control for any other activities besides television watching and computer use, whereas I control for a full list of children's activities. I show that it is especially important to control for the time spent on educational activities. Additionally, Fiorini (2010) only provides evidence on the effects of console video games and does not analyze the effects of computer games. Computer games are considered to be more cognitively challenging than console games. Consistent with this conjecture, I find that the positive effect of video game playing on problem solving ability is driven by computer games.

2 Data

I use the Child Development Supplement (CDS) to the Panel Study of Income Dynamics (PSID) for the empirical analysis (The Survey Research Center 2012). The purpose of the PSID-CDS is to collect data on children's health, cognitive development, and behavior problems as well as factors affecting these outcomes, including family environment, neighborhood characteristics, and school environment (The Survey Research Center 2010*b*). In 1997, all PSID families with children under 13 were included in the CDS. If there were more than two children under 13 years of age in the family, two children were randomly selected into the sample. In total, 2,394 families were interviewed (88% of the selected families) and data on 3,563 children were collected. These children and their families were re-interviewed in 2002 (2,907 children) when children were 5-17 years old and in 2007 (1,506 children) when children were 10-18 years old.[1] The PSID-CDS collects data from the child, the primary caregiver of the child (usually the mother), and other people related to the child.

The analysis sample consists of children who are 3-18 year old.[2] The initial sample contained 8,277 observations in this age range. Due to non-response, 2,772 observations were not used for this analysis. Children observed only once (982 observations) were also excluded from the sample, because they do not contribute to the identification of parameters in the panel data models. Given a large number of excluded observations, there is a reason to be concerned about sample selection. I explain how I deal with this issue in Section 3. The final analysis sample consists of 4,523 observations on 2,006 children. Most of the children (75 percent) are observed two times.

Children's cognitive skills are measured by the scores of Woodcock-Johnson Revised Tests of Achievement, administered to the survey children during the interviews. These tests can be used to assess various aspects of intellectual ability of individuals from 2 to 90 years of age. The questions in each test are ordered by difficulty, starting from easy questions and progressing to more difficult ones. Each respondent is asked only a subset

[1]The sharp decline in the sample size in 2007 is due to a large number of children reaching 19 years of age, which made them no longer eligible for the CDS.

[2]In 2007, a few children are slightly over 18 years old due the delays in the interviews.

of questions. The starting point for asking questions depends on the respondent's age. If the respondent answers the six first questions in a row incorrectly, the interviewer asks the respondent to start at an easier point. The respondent answers all the questions until six consecutive mistakes are made or the end of the test is reached. The raw scores of a test are calculated by adding the correct responses. The answers to the questions that are below the starting point are counted as correct (The Survey Research Center 2010*a*). For the empirical analysis, the achievement test scores are standardized by wave with respect to the weighted sample mean and standard deviation.

I analyze how video game playing affects children's performance in two tests. The Applied Problems test assesses children's ability to solve practical mathematical problems (mathematics reasoning). In this test, children need to apply their mathematics knowledge in real life situations. To successfully answer the Applied Problems test questions, a child has to plan what steps to take, identify relevant and eliminate irrelevant information, and perform relatively simple calculations. The majority of the questions (with an exception of the easiest and most difficult questions) are presented orally. Thus, children's performance in this test is independent of their reading ability. Each problem is presented as a story. Young children are given quite simple tasks (counting, solving simple one-step story problems, reading digital and analog clocks, and counting money), whereas the problems given to older children are more challenging (solving problems with fractions, making change, determining miles on the map, solving two-step story problems, measuring figures, and calculating interest rates). To give couple examples: "Sue walks 13 blocks to school, Mary walks 6 blocks, and Robert walks 8 blocks. How many more blocks does Sue walk than Robert"; "Ann lives 3 miles from school. She eats lunch at school. How many miles does she travel to and from school?" (Mather 1991). Because a video game is essentially a problem solving task (Buckingham 2007), video game playing is expected to have a positive effect on the Applied Problems test score.

The Letter-Word Identification test assesses a child's reading recognition or word decoding ability, which is a crucial aspect of reading. The first questions, asked to youngest children, require them to identify letters. The following questions, aimed at older children, require them to correctly read words. A child does not necessarily need to understand the meaning of the words. As a respondent progresses through the questions, the words become more difficult to read. The last questions consist of words that are rarely used in written English (Mather 1991). Historically, video games used to be accompanied by written manuals, but many of the modern games come with in-build tutorials that are interactive and require little reading (Andersen et al. 2012). Instead of reading the manual, players can learn the rules of the game by experimenting (Andersen et al. 2012). Since video games require limited amount of reading, video game playing is expected to have no effect on reading recognition ability when other activities are held constant. The regression of reading recognition ability on video game playing can, therefore, be viewed as a placebo test.

The time spent playing video games is measured using the CDS time diary data. The availability of time diary data is an advantage of the PSID-CDS compared to other surveys. Time diaries provide more reliable measures of time use variables than recall questions (Stafford and Yeung 2004). A child (or the parent if the child is too young) is asked to list all his/her activities in the 24 hour time diary. For each activity, the time the activity started and the time the activity ended is recorded. If a child is doing more than one activity at the same time, both the primary activity and the secondary activities is recorded. Each child is asked to complete two diaries - one on a weekday and one on Saturday or Sunday. Specific weekday and weekend days are randomly assigned.

A child's video game time is calculated by adding the time the child spent playing games on different platforms - a video game console, hand-held device, computer, Internet, and mobile phone. Children's other activities are grouped as follows: (1) educational activities, including the time at school/daycare center, private tutoring, and homework; (2) reading; (3) computer use for recreational activities and communication with others, for example, web surfing, emailing, and instant messaging; (4) television watching; (5) active leisure, including sports, other physical activities, games, hobbies, crafts, arts, attending events, visiting places, and participating in organizational activities; (6) shopping, obtaining services, doing household chores, and caregiving; (7) talking and visiting with other people; (8) resting, listening to music, and traveling; (9) sleeping, eating, and other personal needs; and (10) missing time. Educational activities are expected to positively affect both mathematics reasoning and reading skills. Reading should improve children's reading recognition skills. Computer use may have positive affect both types of cognitive skills and television may improve reading skills (Fiorini, 2010; Malamud and Pop-Eleches, 2011; Beuermann et al., 2013; Gentzkow and Shapiro, 2008; Huang and Lee, 2010). Some active leisure activities, for example, team sports and educational games, may also positively affect cognitive skills. Shopping, doing chores, socializing, resting, sleeping and attending to other personal needs are likely to have little effect on cognitive skills. In most of the analyses, I group these "non-productive" activities together.

All time use variables are measured in hours per day. The weighted means of the time use variables are reported in Table 1. Columns (1) and (3) provide information about children's primary activities on weekdays and weekends, respectively. On average, children spent 23 minutes per day playing video games on weekdays and twice as much time (44 minutes) on weekends. Console video games were more popular than computer games. Video game players spent close to 1.5 hours per day on average playing video games both on weekdays and weekends. Comparing to the other media activities, children spent more time on video game playing than on computer activities, but television time exceeded both video game time and computer time. Around 40 percent of the time, children engaged in other activities, mainly talking to other people, listening to music, eating, watching television and emailing, while playing video games. Columns (2) and (4) of Table 1 present information on children's secondary activities on weekdays and weekends, respectively. The most common secondary activity was talking with other people either face-to-face or over the phone. Video game playing was very rarely reported as a secondary activity. For this reason, I only use the primary activity data for the empirical analyses.

3 Identification strategy

To answer the question of how video game playing affects cognitive skill development, I estimate the following linear approximations of the cognitive skill production functions:

$$s_{k,t} = \beta_{0,k} + \beta_{vg,k} vg_t + OTI_t' \beta_{OTI,k} + G_t' \beta_{G,k} + \mu_k + e_{k,t}, \quad (1)$$

where $k = (MR, RR)$ denotes a particular skill (mathematics reasoning and reading recognition, respectively), $t = 1, \ldots, T$ denotes a time period, and child subscript is suppressed. Cognitive skills are produced using time inputs t_{vg} (the time spent playing video games) and OTI_t (the time spent on other activities) and "goods" inputs G_t that include educational resources, quality of home environment, and nutrition (Todd and Wolpin 2003). Children's cognitive skills also depend on their unobserved ability endowment μ_k. Random shocks to a child's cognitive development and any other unobserved variables are denoted by $e_{k,t}$.

If the time spent playing video games were uncorrelated with the unobserved variables μ_k and $e_{k,t}$, equation (1) could be estimated by the ordinary least squares (OLS) or random effects (RE). Because it is unlikely that video game time is exogenous, OLS and RE estimators are likely to be biased and inconsistent. There are a number of reasons to be concerned about the endogeneity of video game time. Below, I explain how I deal with each of these concerns.

One of the main concerns is that the time children spend playing video games may be correlated with their unobserved ability endowment μ_k. If children who like playing video games were innately better in problem solving and reading, the effect of video game playing on these skills would be overestimated. To take this possibility into account, I estimate equation (1) using the child fixed-effects (FE) model. This model eliminates any time-invariant child-specific unobservables, including innate ability μ_k. Children's video game time varies substantially over time, which helps to identify the effects video game playing on the cognitive skills. In order to obtain consistent coefficient estimates in the child FE model, the strict exogeneity assumption needs to hold:

$$E(e_{k,m}|vg_n, OTI_n, G_n) = 0, \forall m, n = 1, \ldots, T. \tag{2}$$

Strict exogeneity is a stronger assumption than contemporaneous or sequential exogeneity. The strict exogeneity assumption would be violated if children's cognitive skills in the current period would affect their video game time in the future period. Because the PSID-CDS data is collected every five years, this is quite unlikely in this analysis.

The second concern is that not all inputs in the cognitive skill production functions can be observed and some of these omitted inputs may be correlated with video game playing. Shocks to children's cognitive development $e_{k,t}$ may also affect their video game time. To account for the possible correlation between video game playing and time-varying inputs in the child cognitive skill production function, I include an extensive list of control variables available in the data. The CDS data contain a long list of variables describing a child's family environment as well as neighborhood and school characteristics (The Survey Research Center 1997). Additional variables, such as family income and parental education and employment, are available in the PSID questionnaire.

The first group of controls consists of variables that directly enter the cognitive skill production function. The Home Observation for Measurement of the Environment - Short Form (HOME-SF) index measures cognitive stimulation and emotional support provided to children by their parents. The HOME-SF index is based on the questions on the educational resources available to children, time spent on their cognitive development, disciplinary practices, and attitudes to parenting in the family. Since these questions vary by age and year, the HOME-SF index is standardized by age group and year (using weights). Additionally, I control for the parental warmth variables that measure how often the primary caregiver expresses positive feelings towards the child and shows interest in the child.[3] As proxies for nutrition, I use household food expenditure (adjusted for

[3] Specifically, the primary caregiver is asked: "How often you told the child that you love him/her; spent time with the child doing one of his/her favorite activities; talked with him/her about things he/she is especially interested in; and told the child you appreciated something he/she did?" For each parental warmth question, I create an indicator variable for whether or not the primary caregiver expressed parental warmth at least several times a week.

the household size and structure and measured in 1997 dollars) and a binary variable indicating whether or not a child usually has breakfast.

The second group of controls includes proxies for any other unobserved inputs in the cognitive skill production function. Specifically, the regressions control for household income (adjusted for household size and composition and measured in 1996 dollars); the number of adults and children in the household; whether or not a child has a second caregiver; whether or not a child lives with both parents; age, education, and employment status of the primary caregiver; and whether or not the family lives in a Standard Metropolitan Statistical Area (SMSA).

The third group of controls consists of the following variables that can be interpreted as shocks to a child's cognitive development: whether or not a child changed schools since the beginning of school; whether or not the family moved since the last PSID interview; neighborhood quality; whether or not the family had any financial hardships in the past 12 months; whether or not a child is negatively affected by anyone in the household's alcohol consumption; the primary caregiver's self-esteem, self-efficacy, and psychological distress scales; whether or not a child has been diagnosed with a long term health condition; a child's number of doctor visits in the past 12 months (for illness or injury); whether or not a child has any physical or mental disability; and primary caregiver-assessed health status of a child.

All regressions include a quadratic function in age, year effects, and the indicator for who completed the time diary (an adult, the child together with an adult, or the child alone). I dealt with missing values of the control variables in two ways. If a variable had less than 5 percent of values missing, the observations with missing values for this variable were omitted from the sample. If a variable had more than 5 percent of values missing[4], I created a binary variable for missing values and kept the observations with missing values in the sample.

[4]These variables are household income, primary caregiver education, alcohol problems indicator, primary caregiver's self-esteem, self-efficacy and distress scales, financial hardship indicator, and neighborhood rating.

As a sensitivity check, I estimate the sibling FE model. Compared to the child FE model, the sibling FE model has an advantage because it controls for the unobserved time-varying characteristics common to the siblings. The disadvantage of the sibling FE model is that it does not fully control for child-specific ability endowments. Siblings' innate abilities are expected to be correlated, but not perfectly. Because innate ability is an important source of endogeneity bias, the child FE model is arguably preferred to the sibling FE model in this analysis.

Another limitation of the baseline model (1) is its static nature: it is based on the assumption that only inputs in the current period matter for children's cognitive development. If cognitive skills were affected not only by video game playing in the current period, but also by video game playing in the past, this assumption would be violated. In turn, the coefficient on video game playing in the baseline model would capture not only the effect of video game playing in the current period but also the effects of video game playing in the past. To relax the assumption that only current period inputs matter, I estimate the following value added model:

$$s_{k,t} = \delta_k s_{k,t-1} + \beta_{0,k} + \beta_{vg,k} vg_t + OTI_t' \beta_{OTI,k} + G_t' \beta_{G,k} + \mu_k + e_{k,t}, \tag{3}$$

In the value added model, the time spent playing video games in the past enters the cognitive skill production function via the past period cognitive skills $s_{k,t-1}$. The consistency of the value added model estimates relies on a quite restrictive assumption that, over time, the effects of the observed and unobserved variables decline at the same rate, equal to the coefficient on the past period cognitive skills δ_k (in addition to contemporaneous exogeneity). Under these assumptions, the coefficient on video game playing $\beta_{vg,k}$ is interpreted as the short-term effect of video game playing on cognitive skills. The long-term effect of video game playing on a cognitive skill k can be calculated as:

$$\beta_{vg,k}(1-\delta_k^t)/(1-\delta_k), \ -1 < \delta_k < 1, \ t = 1, \ldots, T. \tag{4}$$

We may also be concerned that children's cognitive skills directly affect the time they spend playing video games. On the one hand, it is unlikely that children's achievement test scores directly affect their video game time. The achievement tests are administered during the main interview, whereas the time diaries are completed before the main interview. On the other hand, parents may restrict children's video game time, if their academic performance worsens. Poor academic performance, in turn, could be reflected in lower cognitive achievement test scores. To address this possibility, I check the robustness of the results to controlling for whether a child has ever repeated a grade.[5]

In addition to the potential endogeneity of video game playing, there are two more issues that need to be addressed. The first issue is that children's average daily time spent on video game playing and other activities may be measured with error. The time children spend playing video games on the day they complete the diary may differ from their actual average daily video game time. Under the classical measurement error assumption, this may bias the estimated effects of video game playing and other activities towards zero. To address the measurement error issue, I use a strategy similar to the multiple indicator solution (Wooldridge 2010, pp.112-114). More specifically, I use two measures of children's video game time. One measure comes from the weekday diary ($vg_{t,wd}$) and another measure comes from the weekend diary ($vg_{t,we}$).[6] Each diary measures children's average daily (weekday or weekend) video game hours with error:

$$vg_{t,wd} = \overline{vg}_{t,wd} + a_{t,wd}, \tag{5}$$

$$vg_{t,we} = \overline{vg}_{t,we} + a_{t,we}, \tag{6}$$

where subscripts wd and we denote weekday and weekend, respectively. This error is assumed to be uncorrelated with average daily video game hours and other inputs in the

[5]Although academic grades are a better measure of academic performance than grade repetition, the data on academic grades is not available. Even if the data on children's academic grades were available, including them in the regression would be problematic. If video game playing affects cognitive skills, academic grades are also likely to be affected. It is less likely that video game playing (except for perhaps extremely long hours of play) affects grade repetition.

[6]I am grateful to the referee for this suggestion.

cognitive skill production function:

$$
\begin{aligned}
&Cov(\overline{vg}_{t,j}, a_{t,j}) = 0, \\
&Cov(Z_t, a_{t,j}) = 0, \\
&Z_t = (OTI_t, G_t), \quad j = (wd, we).
\end{aligned}
\tag{7}
$$

Because children's weekday and weekend video game hours are correlated, one variable can be used as an instrument for the other to remove the attenuation bias.[7] The validity of this strategy relies, however, on two important additional assumptions. First, weekend video game hours are assumed to have no independent effect on cognitive skills conditional on weekday video game hours. Second, it is assumed that there is no correlation in the two errors: $Cov(a_{t,wd}, a_{t,we}) = 0$. These assumptions may not necessarily hold. Video game playing on weekends may affect cognitive skills differently than video game playing on weekdays. Children may also be systematically over- or under-reporting video game hours in both diaries. Violation of either of the two assumptions would bias the FE-IV estimates (more likely upwards). Therefore, the estimates of the FE-IV model estimates should be interpreted with caution.

The final issue relates to sample selection. The consistency of the presented estimates relies on the assumption that selection in the analysis sample is not correlated with the unobserved variables. Importantly, in the child fixed-effects model, selection is allowed to be correlated with both observed variables and time-invariant unobservables, which makes the assumption of random selection more convincing. To provide additional support for this assumption, the model is re-estimated using a balanced sample. If the non-response were indeed random, restricting the sample this way should not affect the results (Wooldridge 2010).

[7] In the main specification, weekend video game hours are used as an instrument for weekday video game hours. I also present the estimates of a specification in which weekday video game hours are used as an instrument for weekend video game hours.

4 Results

4.1 Correlation between video game playing and other variables

Before presenting the main results, I analyze how daily (weekday) video game hours are correlated with child and family characteristics. The first two columns of Table 2 present the ordinary least squares (OLS) estimates. These results show that boys spend more time playing video games than girls. Black and Hispanic children play less video games than white children. Video game hours increase non-linearly with a child's age. From the extensive list of child, primary caregiver and family characteristics, the only variables that are significantly correlated with video game playing are moving, having financial problems, the primary caregiver's psychological distress, and a child's number of doctor visits. The results show that it is important to control for who completed the time diary. If the child participated in completing the time diary, the recorded number of hours spent on video game playing is larger.

It is more important to investigate whether video game playing is correlated with the time-varying variables controlling for the child fixed-effects (FE). If video game hours varied systematically with a large number of time-varying variables, the exogeneity of video game playing would be threatened. The results presented in the last two columns of Table 2 show that it is not the case. Besides the indicator for who completed the diary, the only two variables that are significantly correlated with video game hours in the child FE model are the primary caregiver's psychological distress and a child's number of doctor visits. I do not reject the null hypothesis that all child, primary care giver and family characteristics are jointly statistically insignificant. These findings increase confidence in the assumption that, controlling for the child FE, the within-variation in video game hours is not correlated with the within-variation in the time-varying unobservables.

In Figure 1, I explore the question of how the time spent on the other activities changes when the time spent playing video games increases. The graph in Figure 1 is based on a set of child FE regressions. The dependent variable in each of the regressions is the number of hours spent on a given activity on a weekday. The explanatory variables include weekday video game hours and the controls described in Section 3. The horizontal bars in the graph represent the coefficients on weekday video game hours and the horizontal lines represent the 95 percent confidence intervals. Figure 1 shows that an increase in children's video game time mainly comes from a decrease in their time spent on educational activities. When the time spent on video games increases by one hour per day, the time spent on educational activities decreases by approximately 45 minutes. Children also spend less time on the non-productive activities, whereas the time spent on the other activities does not change significantly.

The observed substitution pattern between video game playing and the other activities explains why it is important to control for the other activities, especially educational activities, in the regressions of cognitive skills on video game playing. If the time spent on the other activities is not included in the regression and the coefficient on video game hours is found to be negative, this does not necessarily imply that video game playing is bad for cognitive skill development. In this specification, the negative coefficient on video game hours is consistent with video game playing having a non-negative effect on cognitive skills, which is larger than the effect of non-productive activities and smaller than the effect of educational activities.

To separate the effect of video game playing from the effect of the other activities, I control for the time spent on the other activities in all regressions. Since the time spent on all activities adds up to 168 hours per week, one activity needs to be omitted from the regression to avoid perfect collinearity. The effects of the other activities can only be estimated relative to this omitted activity. I omit the "non-productive" activities, which include shopping, household chores, talking and visiting with people, resting, traveling, sleeping, and attending to personal needs. Because the unproductive activities are expected to have no or little effect on cognitive skills, the coefficients on the other activities can be interpreted not only as relative but also as approximate absolute effects of these activities on cognitive skills.[8] Thus, a positive coefficient on a given activity suggests that

[8]The relative effect of an activity j (β_{jnp}) is equal to a difference between the absolute effect of this activity (β_j) and the absolute effect of the nonproductive activities (β_{np}): $\beta_{jnp} = \beta_j - \beta_{np}$. If $\beta_{np} = 0$, $\beta_{jnp} = \beta_j$.

this activity is beneficial for cognitive skill development and a statistically insignificant coefficient suggests that there is no or little effect.

4.2 Effects of video game playing on cognitive skills

This sub-section presents the estimated effects of video game playing and other activities on the mathematics reasoning and reading recognition test scores. In all estimations, the time use variables are measured in the number of hours per day using the weekday time diary data. The child fixed-effects (FE) model controls for the time-varying child and family characteristics described in Section 3. The ordinary least squares (OLS) and value added (VA) models additionally control for a child's gender and race. The sibling FE model controls for gender, but the effects of the variables that do not vary across siblings cannot be estimated in this model. Since the cognitive achievement test scores are standardized, the presented coefficients are interpreted as standard deviation unit changes in the cognitive achievement test scores.

Table 3 presents the estimated effects of video game playing on the standardized mathematics reasoning test score. The OLS estimates with and without controls are reported in columns (1) and (2), respectively. Not controlling for the observed child and family characteristics, a one hour per day increase in video game time on weekdays is found to increase the mathematics reasoning test score by 8.9 percent of a standard deviation. Controlling for the observed variables reduces the estimated effect to 3.8 percent, implying that selection on the observables is positive.

The models in columns (3) to (6) take into account the unobserved heterogeneity. According to the VA model estimates, the short-term effect of video game playing on the mathematics reasoning test score is small (1 percent of a standard deviation) and not statistically significant. The long-term effect of video game playing is estimated to be 2.8 percent of a standard deviation[9] (also statistically insignificant). In the sibling FE model, video game playing is found to increase the mathematics reasoning test score by

[9]The long-term effect is estimated according to equation (4) using the coefficient on the lagged test score (0.951): $0.010 * (1 - 0.951^3)/(1 - 0.951) = 0.028$

2.2 percent of a standard deviation. In the child FE model, the coefficient on video game playing is similar in magnitude (2.1 percent of a standard deviation), but more precisely estimated and statistically significant at the 10 percent level. The child and sibling FE estimates are more similar to the long-term effect estimate than to the short-term effect estimate in the VA model. Thus, the coefficients in the child and sibling FE models may capture the effects of both current and past video game playing. The differences between the OLS and FE model estimates suggest that the OLS estimates are biased upwards. Children who spend more time on video game playing appear to be innately better at problem solving, as expected.

Column (6) presents the estimates of the child FE-IV model, in which children's weekday time use is instrumented with their weekend time use to address the potential measurement error in the time use variables. According to the first-stage results (not shown), children's weekday and weekend video game hours are positively and significantly correlated. A one hour per day increase in children's weekend video game time is associated with a 12 minute per day increase in their weekday video game time (t-statistic = 16.59). In the FE-IV model, a one hour per day increase in video game time on weekdays is found to increase the mathematics reasoning test score by 9.3 percent of a standard deviation. The effect of video game playing is statistically significant the the 5 percent level. The difference between the child FE and FE-IV estimates suggests that children's video game time is indeed measured with error. Failing to account for this measurement error biases the estimated effect of video game playing (and the effects of most of the other activities) towards zero. We cannot rule out, however, that the FE-IV estimates are upward biased for the reasons discussed in Section 3. Therefore, it is better to think about the FE-IV estimate as an upper-bound of the causal effect of weekday video game hours on mathematics reasoning ability.

Most of the other activities do not have any statistically significant effects on children's mathematics reasoning ability. In the child FE-IV model, the effect of reading is large in magnitude, but not statistically significant. The effects of the other media activities, computer use, and television watching, are also not significantly different from zero.

Educational activities are found to significantly increase the mathematics reasoning test score, as expected. A one hour per day increase in the time spent studying either at or outside school is found to increase the mathematics reasoning test score by 9.1 percent of a standard deviation. The effect of educational activities is similar in magnitude to the effect of video game playing. Although both video game playing and educational activities are found to positively affect the mathematics reasoning test score, these effects are likely to work through different pathways. Video game playing is likely to improve children's problem solving ability, whereas educational activities are likely to improve their mathematics knowledge as well as problem solving skills. Both problem solving ability and mathematics knowledge are necessary to do well in the test. Because an increase in children's video game time is associated with a decrease in their educational activity time (as shown in Figure 1), failing to control for educational activity time underestimates the effect video game playing. In the model with no other time use variables, the estimated effect of daily video game hours is only 5.4 percent of a standard deviation ($S.E. = 2.95$).

Table 4 presents the estimated effects of video game playing and other activities on the reading recognition test score. Video game playing is found to be positively correlated with the reading recognition test score, but this correlation is driven by the observed and unobserved confounders. As expected, the effect of video game playing on reading recognition ability is statistically insignificant in the models that control for the observed and unobserved heterogeneity (columns 3 to 6), including the child FE-IV model. The latter result lessens the concern that the finding of a positive effect of video game playing on mathematics reasoning ability is driven by omitted time-varying variables or violation of the FE-IV model assumptions. Another expected finding is that reading has a large effect on the reading recognition ability, although it is imprecisely estimated due to little variation in reading time. The time spent on educational activities is also found to have a positive (and statistically significant) effect on the reading recognition test score. Thus, children's reading skills are negatively affected if they play video games instead of reading or studying.

To conclude this subsection, I check whether the finding of a positive effect of video game playing on mathematics reasoning ability is robust to other potential threats to the internal validity. Column (1) of Table 5 presents the estimates of the model that controls for whether or not a child has repeated a grade in addition to the other controls. Having repeated a grade has a large negative effect on the mathematics reasoning test score, but the estimated effect of daily video game hours is not affected by the inclusion of this variable. Thus, children's video game time does not appear to be affected by their poor academic performance.

Columns (2) and (3) of Table 5 show that non-random sample selection is unlikely to explain the finding of a positive effect of video game playing on mathematics reasoning ability. Column (2) presents the estimates based on the unbalanced panel. Column (3) shows how the estimates change when the sample is restricted to a balanced panel, that is, children observed in all three waves of the CDS. Both samples are further restricted to children who were 3-8 years old in the first wave, because only children of this age can be potentially observed in all three waves. Restricting the sample to the balanced panel increases the coefficient on video game playing from 11.8 to 14.3 percentage points, although the latter coefficient is imprecisely estimated because of a substantial decrease in the sample size.

Columns (4) and (5) of Table 5 show that the baseline results are robust to the exclusion of atypical observations. In column (4), outliers are excluded from the analysis sample. An observation is considered to be an outlier if the time spent on any of the activities exceeds the 99th percentile of the corresponding distribution. In column (5), I exclude observations for which either weekday or weekend diary was completed on a day that was very atypical for the child. Excluding outliers and atypical observations increases the estimated effect of video game playing on mathematics reasoning ability to 12.3 and 15.1 percentage points, respectively. Overall, the results presented in Table 5 support the hypothesis that there is a positive relationship between video game playing and problems solving skills.

4.3 Non-linearity and heterogeneity in the effects of video game time

The effect of video game playing on cognitive skills may decrease or increase with the number of hours played. To allow for a non-linear effect of video game time, I include a quadratic function of daily weekday video game hours in the model. The results, presented in panel A of Table 6, show that the relationship between video game time and cognitive skills is indeed non-linear. The estimated effect of an additional hour of video game playing on mathematics reasoning ability is largest (21.7 percent of a standard deviation) when a child does not play any video games. The effect of video game time decreases, as the number of hours played increases, as shown by the negative coefficient on the quadratic term (-2.0 percent of a standard deviation). At the mean (0.74 hours per day), an additional hour of play is estimated to increase the mathematics reasoning test score by 20.3 percent of a standard deviation ($S.E. = 7.4$). Video game time is found to no longer affect mathematics reasoning ability, when the number of hours played reaches 5.5 hours per day. If children spend more than 5.5 hours per day playing video games, their mathematics reasoning ability may be affected negatively. Only a small proportion of the sample (0.5 percent) spend 5.5 or more hours per day playing video games.

The results presented so far show how video game playing on weekdays affects children's cognitive skills. Panel B of Table 6 reports the estimated effect of daily weekend video game hours on mathematics reasoning ability. Weekday video game hours are used as an instrument for weekend video game hours in this model. For comparison, the first row presents the estimated effect of weekday video game time. A one hour per day increase in weekend video game time is found to have a positive effect on mathematics reasoning ability, although this effect is smaller (5.9 percent of a standard deviation) and less statistically significant than the effect of weekday video game time (9.3 percent of a standard deviation).

Around 40 percent of the time, children engage in some other activity while playing video games. When children multitask, the positive effect of video game playing on cognitive skills may be smaller than when they focus all their attention on a video game.

I test this hypothesis by separating video game time by whether or not another activity was performed while playing video games. As shown in Panel C of Table 6, video game playing indeed has a larger positive effect (11.5 percent of a standard deviation) when no other activity is performed while playing video games. When children multitask, the effect of video game playing is estimated to be 5.7 percent of a standard deviation and is not statistically significant. The difference in the two coefficients is not, however, statistically significant.

The effect of video game playing on cognitive skills is likely to vary depending on what video games children play. Certain types of video games, such as strategy, role playing and simulation, are more cognitively challenging and may have larger effects on cognitive skills. These types of games are more suitable for playing on a computer than on a video game console. Computer games also have more complex control systems[10]. Therefore, computer games are expected to have a larger effect on children's problem solving ability than console games. I can test this hypothesis using the PSID-CDS time diary data, because the time spent playing video games on a console is recorded separately from the time spent playing video games on a computer. Panel D of Table 6 shows that the positive effect of video game playing on mathematics reasoning ability is indeed driven by computer games. The effect of computer game playing is estimated to be 6.2 percent of a standard deviation (significant at the one percent level), whereas the effect of console game playing is smaller (1.1 percent of a standard deviation) and not significantly different from zero. The difference between the two effects is significantly significant at the five percent level.

Finally, the effect of video game playing on cognitive skills may vary by child and family characteristics. Girls may be more likely than boys to prefer video games that are more cognitively challenging. There are also gender differences in cognitive skill development. The effect of video game playing on mathematics reasoning ability may be larger at younger ages, when cognitive skills are more malleable (Byron 2008). If video games were substitutes or complements the other inputs in the cognitive skill production

[10] I am grateful to James Murchison and Robert Bird for these insights.

function, the effect of video game playing would vary with the goods and time investments in children. To test these hypotheses, I investigate whether there is heterogeneity in the effect of video game playing on mathematics reasoning by gender, age, HOME-SF scale, and single-parent status. The HOME-SF scale is a proxy for the quantity and quality of the goods and time inputs in a child's cognitive development. Single-parent status may also be correlated with the goods and time investments.

The results of this regression are reported in panel E of Table 6. The coefficient presented in the first row is interpreted as the effect of daily weekday video game hours on mathematics reasoning ability for older girls from single-parent families with the average HOME-SF scale score. This effect is positive and of similar magnitude as in the baseline model, but not statistically significant. The remaining rows present the coefficients on the interactions of daily video game hours with the child and family characteristics. The effect of video game playing on mathematics reasoning ability is found to be larger for girls and younger children as expected, although the differences by gender and age are not statistically significant. The estimated effect of video game playing significantly increases with the quality of home environment. A one standard deviation increase in the HOME-SF scale increases the effect of daily video game hours on mathematics reasoning ability by 8.0 percent of a standard deviation. The interaction between video game time and two-parent family dummy is also positive, but not statistically significant. The latter two findings suggest that video game playing is a complement to the other inputs in the cognitive skill production function. Children from families with more goods and time resources appear to benefit from video game playing most.

5 Conclusions

To conclude, the presented results show that there is a plausibly causal relationship between video game playing and children's ability to solve practical mathematics problems. Because video game playing does not directly improve mathematics knowledge, this finding can be explained by a positive effect of video game playing on children's problem solving ability, a skill that is useful in many life and work situations. The positive effect of video game playing on problem solving ability decreases with the number of hours played and is larger in families that invest more goods and time resources in children. The latter result suggests complementarity between video games and other investments. I also find suggestive evidence that certain types of video games may have larger effects on cognitive skill development than others. This analysis could be extended by investigating this question further.

Video game playing is not expected to affect children's reading ability, and no statistically significant effect of video game playing on reading ability is found. The latter finding provides more confidence that the results on problem solving skills are not driven by time-varying omitted variables. I show that it is important to account for both endogeneity and measurement error issues. Failing to control for the observed and unobserved heterogeneity over-estimates the effect of video game playing on problem solving skills. Measurement error leads to downward biased estimates.

The magnitude of the estimated effect of video game playing on problem solving ability varies across different models, from 1 percent of a standard deviation in the value added model to 9.3 percent of a standard deviation in the child FE-IV model. In most of the estimated models, the effect of video game playing is found to be comparable to the effect of educational activities, suggesting that some video games may have as much potential to improve children's problem solving skills as more traditional educational tools. Irrespective of the preferred identification strategy and model specification, video game playing is never found to negatively affect children's problem solving skills. In the case of reading skills, however, it matters what activities are being displaced by video game playing. If children played video games instead of studying or reading, their reading ability would be negatively affected. On the other hand, substituting television watching with video game playing would not affect children's reading ability.

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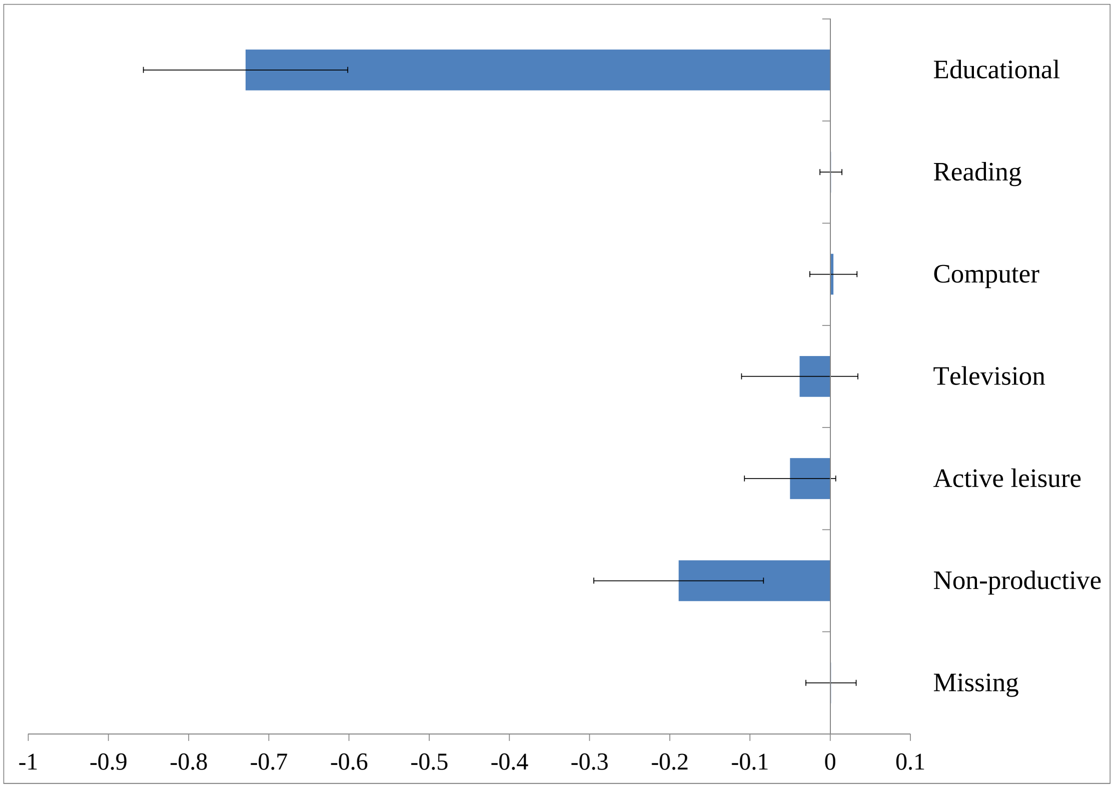
Figure 1: Variation in children's time use associated with a one hour per day increase in video game time, child FE model estimates.



Notes: Sample size is 4,523. The graph is based on a set of child FE regressions. The dependent variable in each of the regressions is the number of daily hours spent on a given activity on weekdays. The horizontal bars represent the coefficients on weekday video game hours and the horizontal lines represent the 95 percent confidence intervals. All regressions include the control variables described in Section 3.

Table 1: Weighted means of time use variables, hours per day

	Weekday		Weekend	
	Primary activity	Secondary activity	Primary activity	Secondary activity
	(1)	(2)	(3)	(4)
Video games:	0.39	0.02	0.74	0.05
Computer	0.12	0.01	0.21	0.01
Console	0.27	0.01	0.53	0.04
Educational	6.37	0.07	0.34	0.02
Reading	0.17	0.04	0.21	0.07
Computer	0.20	0.07	0.29	0.11
Television	1.70	0.35	2.67	0.45
Active leisure	1.49	0.38	3.15	0.64
Non-productive:	13.57	3.07	16.42	4.87
Shopping/chores	0.63	0.06	1.42	0.11
Talking/visiting	0.38	2.13	0.83	3.36
Rest/travel	1.19	0.50	1.28	0.72
Personal needs	11.37	0.38	12.89	0.68
Missing	0.11	0.01	0.17	0.00
Total	24.00	4.01	24.00	6.20
Sample size	4,523	4,523	4,523	4,523

Table 2: Variation in daily weekday video game hours by child and family characteristics

	OLS		Child FE	
	Coef.	S.E.	Coef.	S.E.
Male	0.428***	(0.029)		
Black non-Hispanic[a]	−0.089**	(0.043)		
Hispanic[a]	−0.236***	(0.060)		
Other race[a]	−0.007	(0.068)		
Age	0.075***	(0.018)	−0.004	(0.101)
Age^2	−0.003***	(0.001)	−0.002**	(0.001)
HOME-SF score	−0.023	(0.019)	−0.028	(0.031)
Has breakfast	−0.038	(0.059)	−0.074	(0.078)
Food expenditure	−0.000	(0.000)	0.000	(0.001)
Warmth (love)	−0.049	(0.067)	−0.060	(0.078)
Warmth (participation)	0.050	(0.038)	0.060	(0.049)
Warmth (talking)	−0.075	(0.047)	−0.004	(0.063)
Warmth (appreciation)	−0.017	(0.044)	0.033	(0.061)
HH income	−0.000	(0.000)	−0.000	(0.001)
Number of adults in HH	0.005	(0.030)	−0.000	(0.042)
Number of children in HH	−0.012	(0.013)	−0.003	(0.027)
Has secondary caregiver	−0.038	(0.051)	−0.057	(0.065)
Both parents live at home	0.002	(0.040)	0.016	(0.088)
Age of PCG	0.001	(0.002)	0.004	(0.009)
PCG's education, years	−0.011	(0.008)	0.060	(0.039)
PCG employed	−0.022	(0.035)	−0.002	(0.048)
SMSA	0.039	(0.033)	0.068	(0.116)
Changed school	0.080	(0.082)	0.045	(0.109)
Moved	−0.064*	(0.039)	−0.071	(0.049)
Poor quality neighborhood	0.058	(0.058)	0.008	(0.082)
Financial problems in HH	0.078**	(0.032)	0.040	(0.049)
Alcohol problems in HH	0.039	(0.064)	−0.061	(0.079)
PCG's self-esteem	−0.015	(0.048)	−0.101	(0.068)
PCG's self-efficacy	−0.003	(0.038)	−0.042	(0.052)
PCG's psychological distress	−0.011**	(0.005)	−0.017**	(0.008)
Has health condition	0.032	(0.033)	0.033	(0.044)
Number of doctor visits	−0.010***	(0.003)	−0.008**	(0.004)
Physical or mental disability	0.010	(0.066)	−0.074	(0.109)
Poor health	−0.034	(0.112)	−0.069	(0.173)
Diary completed by child & adult[b]	0.127**	(0.052)	0.126*	(0.069)
Diary completed by child[b]	0.119***	(0.041)	0.163***	(0.059)
2002	0.112***	(0.040)	0.506	(0.546)
2007	0.075	(0.051)	0.757	(1.008)
R-squared	0.081		0.047	
F-stat(joint significance test)	8.405		1.195	
F-stat p-value	0.000		0.216	

Notes: Sample size is 4,523. Standard errors are clustered at the family level. [a]Omitted category is white non-Hispanic. [b] Omitted category is diary completed by an adult. The descriptions of the variables are provided in Section 3. *denotes statistical significance at the 10% level, **denotes statistical significance at the 5% level, and ***denotes statistical significance at the 1% level.

Table 3: Effects of children's weekday time use on standardized mathematics reasoning test score

	OLS	OLS	VA	Sibling FE	Child FE	Child FE-IV
Hours/day spent on:	(1)	(2)	(3)	(4)	(5)	(6)
Video games	0.089***	0.038***	0.010	0.022	0.021*	0.093**
	(0.018)	(0.013)	(0.011)	(0.024)	(0.010)	(0.037)
Educational	0.065***	0.023***	0.021***	0.013	0.023***	0.091***
	(0.007)	(0.004)	(0.004)	(0.009)	(0.004)	(0.033)
Reading	0.066*	0.055**	0.001	−0.027	0.014	0.113
	(0.038)	(0.023)	(0.028)	(0.042)	(0.024)	(0.123)
Computer	0.208***	0.050***	0.025*	−0.019	0.022	0.009
	(0.027)	(0.018)	(0.014)	(0.031)	(0.014)	(0.038)
Television	0.014	0.004	0.012*	0.022*	0.018***	−0.021
	(0.011)	(0.006)	(0.007)	(0.012)	(0.006)	(0.030)
Active leisure	0.013	0.026***	0.012*	−0.003	0.006	0.055
	(0.011)	(0.006)	(0.007)	(0.013)	(0.007)	(0.040)
Missing	0.009	−0.002	−0.000	0.010	0.017	0.095
	(0.021)	(0.013)	(0.015)	(0.030)	(0.013)	(0.100)
Control variables	No	Yes	Yes	Yes	Yes	Yes
R-squared	0.051	0.662	0.678	0.656	0.589	-
Sample size	4,523	4,523	2,442	2,212	4,523	4,523

Notes: In column (6), daily weekday hours are instrumented using daily weekend hours. Standard errors in parentheses. All regressions control for the variables described in Section 3. *denotes statistical significance at the 10% level, **denotes statistical significance at the 5% level, and ***denotes statistical significance at the 1% level.

Table 4: Effects of children's weekday time use on standardized reading recognition test score

	OLS	OLS	VA	Sibling FE	Child FE	Child FE-IV
Hours/day spent on:	(1)	(2)	(3)	(4)	(5)	(6)
Video games	0.070***	0.014	0.008	0.010	0.008	−0.005
	(0.015)	(0.010)	(0.009)	(0.020)	(0.009)	(0.038)
Educational	0.052***	0.008**	0.006	0.005	0.011***	0.072**
	(0.007)	(0.004)	(0.004)	(0.011)	(0.004)	(0.035)
Reading	0.101***	0.099***	0.026	0.017	0.036	0.171
	(0.036)	(0.024)	(0.025)	(0.040)	(0.027)	(0.128)
Computer	0.221***	0.068***	0.006	0.002	0.008	0.035
	(0.024)	(0.016)	(0.013)	(0.027)	(0.014)	(0.040)
Television	0.008	−0.006	0.003	0.019	0.008	−0.012
	(0.012)	(0.007)	(0.007)	(0.015)	(0.006)	(0.031)
Active leisure	−0.014	0.002	−0.002	−0.008	−0.011	−0.043
	(0.012)	(0.007)	(0.008)	(0.017)	(0.007)	(0.042)
Missing	0.021	0.007	−0.001	−0.055**	0.002	0.122
	(0.020)	(0.013)	(0.013)	(0.025)	(0.011)	(0.105)
Control variables	No	Yes	Yes	Yes	Yes	Yes
Within R-squared	0.047	0.633	0.647	0.646	0.578	-
Sample size	4,523	4,523	2,442	2,212	4,523	4,523

Notes: In column (6), daily weekday hours are instrumented using daily weekend hours. Standard errors in parentheses. All regressions control for the variables described in Section 3. **denotes statistical significance at the 5% level, and ***denotes statistical significance at the 1% level.

Table 5: Sensitivity analysis, child FE-IV estimates, dependent variable: standardized mathematics reasoning test score

		3-8 year old in 1997		Outliers	Atypical days
	All	Unbalanced	Balanced	excluded	excluded
Hours/day spent on:	(1)	(2)	(3)	(4)	(5)
Video games	0.090**	0.118**	0.143	0.123*	0.151***
	(0.037)	(0.058)	(0.092)	(0.073)	(0.055)
Educational	0.071**	0.141**	0.171**	0.107**	0.112**
	(0.034)	(0.065)	(0.085)	(0.045)	(0.048)
Reading	0.126	−0.027	−0.476	0.055	0.071
	(0.124)	(0.290)	(0.482)	(0.226)	(0.152)
Computer	0.005	0.024	0.008	0.013	0.029
	(0.037)	(0.063)	(0.079)	(0.081)	(0.046)
Television	−0.027	−0.050	−0.042	−0.022	0.002
	(0.029)	(0.053)	(0.094)	(0.036)	(0.042)
Active leisure	0.044	0.106	0.138	0.051	0.056
	(0.040)	(0.074)	(0.101)	(0.045)	(0.053)
Missing	0.095	0.227	0.106	−0.028	0.230
	(0.100)	(0.389)	(0.484)	(0.394)	(0.206)
Repeated grade	−0.270***				
	(0.048)				
Sample size	4,371	2,635	1,533	4,048	3,169

Notes: The time use variables are measured daily weekday hours and instrumented with daily weekend hours. Standard errors in parentheses. All regressions control for the variables described in Section 3. *denotes statistical significance at the 10% level, **denotes statistical significance at the 5% level, and ***denotes statistical significance at the 1% level.

Table 6: Nonlinearity and heterogeneity in the effect of daily video game hours on standardized mathematics reasoning test score, child FE-IV estimates

	Coeff.	S.E.
A.		
Video games	0.217***	(0.080)
Video games^2	−0.020**	(0.010)
B.		
Video games, weekday	0.093**	(0.037)
Video games, weekend	0.059*	(0.030)
C.		
Video games, no multitasking	0.115**	(0.051)
Video games, multitasking	0.057	(0.073)
D.		
Computer games	0.062***	(0.021)
Console games	0.011	(0.011)
E.		
Video games	0.092	(0.118)
Video games*		
Male	−0.005	(0.107)
Under 11 years	0.067	(0.090)
HOME-SF scale	0.080**	(0.034)
Two-parent family	0.116	(0.083)

Notes: Sample size is 4,523. Except for the second row of panel C, video game time is measured in daily weekday hours. In the second row of panel C, video game time is measured in daily weekend hours. All regressions control for the other activities and variables described in Section 3. *denotes statistical significance at the 10% level, **denotes statistical significance at the 5% level, and ***denotes statistical significance at the 1% level.