Can video games affect children's cognitive and non-cognitive skills?

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Abstract

The aim of this study is to investigate whether there is a plausibly causal relationship between video game playing and child cognitive and non-cognitive skills. One of its key findings is that video game playing has a positive statistically significant effect on children's cognitive skills. More specifically, I find that an increase in video game time improves children's ability to apply their mathematics knowledge in solving real life problems. There is no statistically significant ceteris paribus effect of video game playing on children's reading skills. Additionally, the findings of this study do not support the hypothesis that video game is detrimental to child non-cognitive development. There is no evidence that video game playing causes behavior problems in children. I also find that it is important to account for the unobserved heterogeneity of children, as it is correlated with their video game time.

1 Introduction

The aim of this paper is to determine how video game playing affects cognitive and non-cognitive skill development in childhood. To answer this question, I estimate the production functions of selected cognitive and non-cognitive skills. Video game time is included as one of the inputs in these functions. The main challenge in estimating the

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effect of video game playing on children's cognitive and non-cognitive skills is accounting for the unobserved innate ability and family environment. I address this issue by estimating child fixed effects models that eliminate any unobserved child-specific time-invariant factors.

Research shows that cognitive and non-cognitive skills affect individuals' schooling and success in labor market, as measured by wages, employment, work experience, and occupational choice (Heckman et al., 2006). Non-cognitive skills are as important as cognitive skills in determining the above mentioned outcomes. In addition, the same cognitive and non-cognitive skills are related to other behavior outcomes, such as teenage pregnancy, marital status, smoking, use of marijuana, participation in illegal activities, and engaging in activities that lead to incarceration. Therefore, it is important to understand how these skills could be improved.

I focus on children, as childhood is the period when most of the development of cognitive and non-cognitive skills takes place. Human brain mostly develops in early years, but important changes continue into adolescence, when the neural connections that are used are strengthened and those that are not used are cut off (Department of Children, Schools, and Families, 2008). Early childhood seems to be the period when the measures of intelligence (such as IQ scores) stabilize. Adolescence is the period when non-cognitive skills are most malleable (Cunha and Heckman, 2007; Cunha and Heckman, 2008). Heckman and Masterov provide evidence that early childhood intervention programs have long lasting effects on education and labor market outcomes, which is consistent with the view that investments in children accumulate and that earlier investments improve the productivity of later investments.

Next, I provide arguments for why I consider particularly the relationship between video games and cognitive and non-cognitive skills. First, video game playing is a widespread activity among children. The majority of the US children have access either to video game console or computer at home (Roberts and Foehr, 2008). In 2007, as estimated in this paper, around 50% of 10-18 year old children played video games. An average video game player spent almost nine hours per week engaging in this activity.

Second, video game playing has a potential to enhance (certain) cognitive skills. Video games incorporate a number of principles that facilitate learning (Gee, 2003). Video game playing is, in fact, a cognitively complex and challenging activity, which requires children to solve problems, plan, develop strategies, and formulate and test hypotheses (Buckingham, 2007). Therefore, it is skills such as problem solving, abstract reasoning, pattern recognition, and spatial logic that are most likely to be affected by video games

(Johnson, 2005). Third, video games could also affect non-cognitive skills of children. The literature mostly focuses on the potential effects of video games on children's aggressive behavior, as many video games involve violence. Video game playing could also potentially affect attention, hyperactivity, self-esteem, and identity development (Buckingham, 2007). According to the literature, these effects could be positive or negative.

Fourth, there is empirical evidence that other media, such as TV and computers, matter to the development of children's cognitive and non-cognitive skills (Gentzkow and Shapiro, 2008; Huang and Lee, 2010; Fiorini, 2010; Fiorini and Keane, 2011). As there are similarities between these types of media and video games, there may also be a relationship between video game playing and skill development. On the other hand, there are also differences between TV, computers, and video games. Thus, what we know about the effects of these media types may not be necessarily be extrapolated to the effects of video games. One of the main differences between TV and video games is interactivity (Buckingham, 2007). Children are part of the game. Learning by acting is central to cognitive and non-cognitive development (Department of Children, Schools, and Families, 2008). Therefore, the effects of video game playing may be stronger than those of TV. The activities that children use computers for, such as emailing, browsing the Internet, chatting, are different in nature from video game playing. Therefore, video games and computers may play different roles in child skill development.

Finally, this research potentially has policy implications. In the US, the video game industry is self-regulated. The Entertainment Software Rating Board (ESRB) applies and to some extent enforces video game rating. Statistics show that these ratings are not fully enforced. According to a survey, around 70% of the children aged 8 to 17 years report playing M-rated (mature) video games, although these games should not be sold to children under 17 years of age (Gentile et al., 2007). For this reason, some US states and cities have tried to introduce legislation banning the sale of games with violent or sexual content to children and introducing fines to retailers who sold adult video games to minors. However, these laws have been repeatedly struck down by federal courts on the basis that they are unconstitutional and violate free speech protection (Salmon and Dunn, 2008). The results of this analysis provide some evidence against the laws restricting the sale of video games.

Despite the above provided arguments, there are only a few studies in economics investigating the role of video games in the development of cognitive and non-cognitive skills. Fiorini (2010) looks at the effect of video game playing on both sets of skills, although the main focus of his analysis is on the effect of children's computer use. There are a number of differences between Fiorini's analysis and my study. Fiorini (2010) looks at young children only (6-7 years old) and my sample includes children 3-18 years of age. I use a different data set, production function specifications, identification strategy, and measures of cognitive and non-cognitive skills. Additionally, Fiorini (2010) uses a measure of video game time that only includes time spent playing games on a console and my measure includes both computer and console game time. Ward (2010) analyzes whether adolescent video game playing has a causal effect on fighting. Although tendency to engage in fights is likely to be correlated with worse non-cognitive skills, it does not capture the whole range of non-cognitive skills that could be affected by video games. I use a more comprehensive measures of non-cognitive skills commonly used in the literature[1].

To summarize my results, I find evidence of the positive effect of video game time on children's problem solving skills, which is as expected. On average, an additional hour of video game time per week increases the Applied Problems test score by 0.4% of a standard deviation. As far as non-cognitive skills are concerned, there is no evidence that video game playing contributes to behavior problems in children. To the contrary, there is some support for a positive effect of video games on non-cognitive skills. On average, a one hour per week increase in video game time, is associated with a decrease in normalized antisocial/disturbed behavior measure by 0.5% of a standard deviation. Looking at the behaviors that are most likely to be affected by violent video games, that is bullying other children, not feeling sorry after misbehaving, and being destructive, the detrimental effects of video game time can be rejected with the 95% confidence.

2 Literature review

In this section, I review relevant literature. I start with the literature on video games in and outside economics and then summarize the research on other media. The above mentioned study by Fiorini (2010) uses an Australian data set on young children to investigate whether holding other media time fixed, the time a child spends playing console video games (such as Xbox, Playstation or Nintendo) affects his/her cognitive and non-cognitive skills. The results vary by the identification strategy used. Overall, it seems that Fiorini's findings provide some evidence of a negative effect of video games on verbal skills and a positive effect on non-verbal intelligence test scores[2]. The effects of video game time on the measures of non-cognitive skills (restlessness, social skills, and emotional problems) are statistically insignificant. It should be noted that these are the

[1] I summarize the findings of Fiorini (2010) and Ward (2010) in the next section and compare my findings to the results of these papers in Section 7.

[2] More specifically, the first test evaluates a child's vocabulary knowledge and the second test measures a child's pattern recognition skills.

estimates of the effects of console video game time holding computer game time fixed, as total computer time (which includes the use of computer to play games) is included as a regressor in the model.

Ward (2010) uses the Youth Risk Behavior Survey to investigate if a positive link between video game playing and violent behavior is causal or just a correlation. He finds that as more demographic characteristics are added to the regression, the estimate of the coefficient on video game playing becomes smaller in magnitude and less statistically significant. In the model with the full set of available covariates, this estimate is of modest size and statistically insignificant. The positive association between video game playing and fighting persists only for long hours of play (4 hours per day or more). It is not clear whether the evidence against causal effect of video games on fighting would be strengthened or weakened if the unobserved heterogeneity were also taken into account.

The literature outside economics mainly focuses on the potentially detrimental effect of (violent) video game playing on non-cognitive skills. Bensley and Van Eenwyk (2001) discuss six theories in the psychology literature that relate video game playing to children's aggressive behavior. Four of these theories predict a positive relationship between video games and aggressive behavior and the other two predict the opposite. As to the empirical studies, there is a disagreement in the psychology literature on whether there is a causal link between video games and aggressive behavior.

For example, Anderson and Bushman (2001) claim that children's exposure to violent video games causes them to behave aggressively. It should be noted that these claims are partly based on experimental studies. The effects that these studies find are the short term effects and it is not clear whether these effects would persist in longer run. The other studies that supposedly find positive effects of video games on aggressive behavior are based on cross-sectional survey data. The estimates reported in these studies are just correlations, as they do not take into account the heterogeneity of children. The conclusions of an independent literature review by Bensley and Van Eenwyk (2001) are not so definite as those of Anderson and Bushman (2001). They agree that there is (experimental) evidence of short-term effects of violent video game playing on aggressive behavior of young children (4-8 years old). On the other hand, the evidence of the effects of video games on the behavior of older children appears to be inconclusive. Bensley and Van Eenwyk (2001) also raise a valid point that their literature review may be biased towards studies finding some effects of video game playing as studies finding no effects may be less likely to get published.

The science literature on the relationship between video games and cognitive skills mostly focuses on the potential of video games to enhance visual spacial skills, such as hand-eye coordination, reaction time, spatial reasoning, and spatial attention (Evans Schmidt and Vandewater, 2008) . Durkin and Barber (2002) investigate if these skills translate into better school performance by video game players using the Michigan Study of Adolescent Life transitions[3]. Their findings show that students who spent moderate time playing computer games in grade 10 had higher GPA (grade point average) in grade 11 than students who did not play computer games at all or played these games excessively.

A number of studies in the economics literature study the effects of media on cognitive and non-cognitive skills. The main focus of Fiorini (2010) is the effect of computer use[4] on the development of these skills in early childhood. Fiorini (2010) finds that at ages 4-5, computer use has positive contemporaneous effects on cognitive skills. At ages 6-7, only computer use in the last period matters. According to Fiorini (2010), these findings may indicate that either computer use in earlier childhood is more educational or that cognitive skills are malleable only at young ages or both. The results on non-cognitive skills are mixed. At ages 4-5, computer use is shown to affect some of the non-cognitive skills. At ages 6-7, none of the non-cognitive skills are significantly affected by either contemporaneous or past computer use.

A study by Fiorini and Keane (2011) investigate the trade-offs between different uses of children's time. In their analysis, media time includes time spent watching TV, using computer, and listening to music[5]. The other activities are grouped in five categories and some of them are split by whether parents participated in the activity with the child. The main findings of Fiorini and Keane (2011) are that the time allocation matters to cognitive skills, but not to cognitive skills. As to cognitive skills, media time ranks high and is more important input than pre/post-school activities. These findings do not inform, however, whether all types of media are beneficial to the cognitive development and which types of media are the most important. The educational activities, such as (being read to, talked to, educational games, being taught to do chores or read) rank as the most important time input. As to non-cognitive skills, effective parental discipline and warmth are the inputs that affect these skills positively.

Gentzkow and Shapiro (2008) study the effect of preschool television exposure on cognitive development as measured by achievement test scores in adolescence. The authors identify this effect by using the variation in timing of television introduction to different US

[3]Durkin and Barber (2002) focus only on computer game playing.

[4]Computer use may include video game playing, but not only. Children use computers for other purposes, such watching movies, listening to music, doing school work, and searching the Internet.

[5]It is not clear if media time includes video game playing on consoles.

cities as an instrument for preschool TV exposure. Gentzkow and Shapiro (2008) find that an additional year of preschool TV exposure has a small, positive, and statistically insignificant effect on average test scores in adolescence. Looking at individual test scores, their results show that TV has marginally significant positive effects on reading and general knowledge test scores. The TV effects on math, spatial reasoning, and verbal ability test scores are statistically insignificant. Huang and Lee (2010) investigate a similar question, that is, what are the effects of TV on cognitive development, but using different data and identification strategy, which may explain the differences in the findings of these two studies. Huang and Lee (2010) find that the total effect of TV viewing in the current and past period on math skills is negative. As to the reading skills, watching up to 2 hours per day of TV appears to be beneficial (comparing to no TV at all). At high levels, however, the effect of TV becomes negative.

3 Modeling framework

In this section, I describe the underlying economic model. In this model, the parents of a child make all decisions. Parents have paternalistic preferences, as in Pollak (1988), that is, they care about their children's utility, and get direct utility from the cognitive and non-cognitive skills of their children (s_c and s_n respectively), as well their own consumption c_p. Parent's utility is also increasing in the number of children N, but at a decreasing rate, which is captured by the parameter $\lambda < 1$. The utility of children depends on their skills, the time spent playing video games t_{vg}, the time spent doing other activities T, and they may also get utility or disutility from goods G_c and G_n that are used to produce cognitive and non-cognitive skills respectively[6]. Parents face a budget constraint and technological constraints given by the production functions of cognitive and non-cognitive skills. Thus, parents solve the following utility maximization problem:

$$\max \; u_p(c_p, s_c, s_n) + N^{\lambda}[u_c(s_c, s_n, t_{vg}, T, G_c, G_n)] \tag{1}$$

$$s.t. \; c_p + N(p_c G_c + p_n G_n) = M, \tag{2}$$

$$s_c = f_c(t_{vg}, T, G_c, \mu_c) + u_c, , \tag{3}$$

$$s_n = f_n(t_{vg}, T, G_n, \mu_n) + u_n, \tag{4}$$

where p_c and p_n are the vectors of good input prices and M is household income, all normalized with respect to the price of parent consumption.

[6]Note that this model is characterized by joint production: some inputs in the skill production functions may also affect the utility of children directly.

The focus of this analysis is to estimate equations (3) and (4), that is, the production functions of children's cognitive and non-cognitive skills. The stock of skills s_j depends on skill endowments or innate abilities μ_j, the time a child spends playing video games t_{vg}, a vector of other child time allocations T, and good inputs in the child ($j = c, n$). In the production function of cognitive skills, G_c refers to such inputs as nutrition and educational resources. Note that once the time inputs are held fixed, quality of educational resources is likely to matter more than their quantity. In the production function of non-cognitive skills, G_n captures less tangible inputs such as parental warmth, discipline style, and involvement in child activities, which are are not material goods.

The literature suggests that the skills of a child depend not only on current period inputs, but also on the history of inputs since the birth of the child, as skills accumulate over time (Todd and Wolpin, 2003, 2007; Cunha and Heckman, 2007, 2008). To account for these features of the skill production functions, dynamics should be introduced in the model. To estimate such model in practice, however, one needs high frequency panel data following children from their birth. As the data I use for the estimations does not have such properties, I estimate a static model. The estimates of this model are likely to capture not only the effect of contemporaneous inputs, but also the effects of the past inputs[7].

4 Identification strategy

Assuming that functions f_c and f_n are linear, equations (3) and (4) can be specified as:

$$s_{c,t} = \beta_0 + \beta_{vg} t_{vg,t} + T_t' \beta_T + G_{c,t}' \beta_G + \mu_c + u_{c,t}, \tag{5}$$

$$s_{n,t} = \gamma_0 + \gamma_{vg} t_{vg,t} + T_t' \gamma_T + G_{n,t}' \gamma_G + \mu_n + u_{n,t}. \tag{6}$$

The aim of this paper is to obtain consistent estimates of the parameters β_{vg} and γ_{vg}, which measure the causal effect of video game time on children's cognitive and non-cognitive skills respectively. The key threat to the identification of these parameters is a possible correlation between the inputs in the skill production functions and unobserved ability endowments μ_c and μ_n. For example, children who are interested in video games may be have higher innate cognitive abilities and/or lower innate non-cognitive abilities. This correlation is also implied by the model described in the previous section. Solving this model would give the reduced form demand functions for $t_{vg,t}$, T_t, $G_{c,t}$, and $G_{n,t}$ that

[7] To interpret my estimates as the effects of contemporaneous inputs, I would need to assume that past inputs do not matter, which is unlikely.

depend not only on p_c, p_n, M, but also on μ_c and μ_n. Thus, the OLS estimators of β_{vg} and γ_{vg} are likely to be inconsistent. Identification of these parameters requires an estimator that allows for the correlation between the inputs and unobserved heterogeneity μ_c and μ_n.

Therefore, I use the within-child fixed effect (FE) estimator, which eliminates any time invariant child specific unobservables, including ability endowments μ_c and μ_n. The identification of the parameters in equations (5) and (6) comes from the within-child variation in inputs over time. The identifying assumptions of this estimator are as follows (Todd and Wolpin, 2007):

1. The effects of unobserved ability endowments μ_c and μ_n are time-invariant.
2. The inputs in the skill production functions are not affected by the current and past outcomes: $E(u_{j,k}|t_{vg,l}, T_l, G_{j,l}) = 0, \forall k, l = 1, \ldots, T, j = c, n$.
3. If any of the inputs are unobserved, their effects are time-invariant or uncorrelated with the included inputs.

Implementation of this estimator requires panel data, that is, observations of the cognitive and non-cognitive skills and inputs in at least two time periods for the same children.

5 Data

Given the data requirements described in the previous section, I use the Panel Study of Income Dynamics (PSID) Child Development Supplement (CDS) data for the estimations of the production functions of cognitive and non-cognitive skills. The PSID is a panel survey of US families, which have been followed since 1968. The aim of this study is to collect data on changes in family income, wealth, welfare participation, employment, and housing. The original PSID sample consisted of a nationally representative sub-sample of around 3,000 households and an over-sample of around 2,000 low-income households. In 1997, an immigrant refresher sample was added to reflect the changes in immigration into the US since 1968. The re-interview rates of the PSID are high (96-98%). Consequently, the (weighted) sample remains nationally representative.

The aim of the 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 Institute for Social Research, 2010b). 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 was collected. These children and their families were re-interviewed in 2002 (2,907 children) and 2007 (1,506 children). The sharp decrease in the sample size in 2007 is a result of a large number of children reaching 19 years of age, which made them no longer eligible for the CDS[8]. The CDS collects data from the child, the primary caregiver of the child (usually the mother), and other people related to the child[9].

This data has a number of advantages over other alternative data sources. First, it has a time diary component, which provides a relatively reliable measure of video game time. To my knowledge, the only other survey on children that has time diary component is the Longitudinal Survey of Australian Children (LSAC) used by Fiorini and Keane (2011). Comparing to the CDS diary data, the time diaries of this survey are less informative as parents filling in the diaries can choose between 26 categories of activities rather than recording the actual activity as in the CDS. This would make using this data for my analysis problematic, as computer game time is recorded in the same category as other computer time and it is not clear in which category the console game time is likely to be recorded. In addition, the LSAC time diary is divided into 15 minute slots, so the time use is not measured as precisely as in the CDS diaries.

Second, the PSID and CDS have measures of other time and good inputs in the production of cognitive and non-cognitive skills, which I include in the regressions. Most of the studies looking at the effect of child time use on cognitive and non-cognitive skills focus on one or few time inputs, which confounds the effect of these inputs with the effects of omitted inputs (Fiorini and Keane, 2011). Third, the CDS time diaries record up to two activities for each time slot. This feature of the data allows identifying the *ceteris paribus* effect of video games and other time inputs on the cognitive and non-cognitive skills, that is, the the effect of one input holding the other time inputs fixed. This is not possible if only one activity is recorded at a time.

5.1 Variables

Children's cognitive skills are measured by the normalized achievement tests scores. These tests were administered to the survey children during the interviews. I investigate the

[8]These individuals, however, became part of another supplement to the PSID (Transition to Adulthood). Others become part of the core PSID survey once they form their own households.

[9]These people include the other caregiver of the child (usually the father, but could be a grandmother or another family member), the interviewer, the absent father, and teachers (in waves I and II).

effects of video game time on children's performance in three tests[10]. The first test (Letter-Word Identification) assesses a child's reading recognition ability. It requires children to identify pictures, name letters, and read words, but does not require them to understand the meaning of these words. I expect no effect of video game time on the score of reading test (holding other inputs, including reading time fixed). Although video games may require children to read instructions of the game, a child does not have to know how to correctly pronounce it.

The second (Applied Problems) test assesses a child's ability to solve practical math problems. Thus, this test evaluates how well a child can apply math knowledge in real life situations rather than testing their math knowledge per se. To solve these problems successfully a child has to determine the steps to be followed, identify relevant and eliminate irrelevant information, and perform relatively simple calculations. As these problems are somewhat similar to the tasks given to children in video games, my hypothesis is that video game time has a positive effect on the Applied Problem test score.

The Memory for Digit Span test assesses a child's short term memory. There are two tasks in this test. First, the interviewer says a sequence of numbers and the child is asked repeat it. Then, the child is asked to repeat a given sequence in a reverse order. Video games require children to remember information. For example, if a child makes mistake and has to start the game (or part of it) again, he/she needs to remember what she learned previously to get to the same point of the game or further. On the other hand, children are not specifically required to remember numbers. Therefore, I expect video games either to affect the score of this test either positively or have no effect.

Non-cognitive skills are measured by the behavior problem index (BPI), which is constructed based on the answers to the questions about a child's behavior and personality by the primary care giver of the child. This is a standard measure of non-cognitive skills in the literature used also by Cunha and Heckman (2008), Fiorini (2010), and Fiorini and Keane (2011). The primary care givers are given a set of statements and are asked if they "Not true", "Sometimes true" or "Often true" of the child's behavior. I recode these items to be binary, that is, each item takes the value 0 if the answer is "Not true" and takes the value 1 if the answer "Sometimes true" or "Often true". A BPI for each child is calculated by up adding these individual items. Therefore, a *higher* BPI is an indication of more behavior problems or *lower* non-cognitive skills.

[10] Letter-Word Identification and Applied Problems tests are part of the Woodcock-Johnson Revised Tests of Achievement (WJ-R). The Memory for Digit Span test is a component of the The Wechsler Intelligence Scale for Children (WISC-III) (The Institute for Social Research, 2010b).

I use two scales of the BPI for the analysis[11]. One of them measures externalizing (disturbed or antisocial) behavior problems. Examples of such behaviors are the child "cheats or tells lies", "argues too much", "bullies or is cruel or mean to others", "is disobedient", "does not seem to feel sorry after (he/she) misbehaves", "is restless or overly active, cannot sit still", and "breaks things on purpose or deliberately destroys things". Following the review of the literature, my hypothesis is that there is a nonnegative relationship between video games and externalizing behavior problems. To specifically test the hypothesis that video games cause children to behave aggressively, I construct a sub-scale of the externalizing behavior scale that includes the items describing aggressive behavior. This sub-scale consists of these items "(He/She) bullies or is cruel or mean to others", "(He/She) does not seem to feel sorry after (he/she) misbehaves", and "(He/She) breaks things on purpose or deliberately destroys things". I expect a non-negative relationship between video game time and child aggressiveness.

The second scale of the BPI measures internalizing (withdrawn/emotional) behavior problems. Examples of such behaviors are the child "feels or complains that no one loves him/her", "is too fearful or anxious", "has trouble getting along with other children", "feels worthless or inferior", "is unhappy, sad or depressed", and " worries too much". There are not much evidence about the relationship between video game playing and emotional problems in the psychology literature. Children experiencing such problems could prefer to play video games to other more social activities, because they have difficulties getting along with other children. If this is the case, there may be a correlation, but not a causal relationship between video games and emotional behavior problems. Thus, my hypothesis is that video game playing does not have any effect on internalizing behavior problems.

The scores of both cognitive and non-cognitive skills are normalized with respect to the weighted sample mean and standard deviation (by wave). Thus, the outcome variables measure how well a child performs relative to an average US child in a given year and in a given age group. For example, if a child has a positive normalized cognitive test score in wave I, that means that he/she performed better than average among 3-12 year old children in 1997. A positive score in wave II (III) is interpreted as better than average performance in the year 2002 (2007) among 5-17 (10-18) year old US children.

[11]The full list of the items of the two BPI scales can be found in The Institute for Social Research (2010a). I do not include two items that are only relevant to school age children "(He/She) is disobedient at school" and "(He/She) has trouble getting along with teachers" in any of the scales. I include the two items that are not part of any of the scale according to The Institute for Social Research (2010a) ("(He/She) is secretive, keeps things to (himself/ herself)" and "(He/She) clings to adults") to the Internalizing scale.

The time inputs t_j are measured by hours per week a child is engaged in a particular activity j ($j = 1, \ldots, J$). This measure includes the time when a child is fully focused on this activity and the time when the child is doing another activity at the same time. Most of the respondents filled in the time diaries on a randomly selected weekday and a randomly selected weekend day. I combine the data from both diaries according to this formula:

$$t_j = 5 * t_{j,wd} + 2 * t_{j,we}, \tag{7}$$

where $t_{j,wd}$ is the time spent doing activity j on the assigned weekday and $t_{j,we}$ is the time spent doing activity j on the assigned weekend day.

The video game time variable t_{vg} captures the time spent playing all types of video games (on a console, computer, Internet, and hand-held devices). I grouped the other activities as follows:

1. TV viewing;
2. computer use;
3. school/nursery/daycare, including pre/postschool, private tutoring, and homework;
4. reading;
5. attending events/venues (sports and cultural);
6. sports/physicaly active leisure;
7. creative activities/arts;
8. playing traditional children's games;
9. socializing and communicating with others;
10. participating in the activities of charity, religious, youth, and other organizations;
11. other passive leisure (listening to music, traveling)
12. work/household duties;
13. basic needs;
14. not clear what the child was doing.

Some of these activities, such as school, computer use, attending events/venues, playing games, viewing TV, may affect both cognitive and non-cognitive skills. The other activities are more likely to have an effect on cognitive skills or non-cognitive skills only.

I include all of the time inputs in both cognitive and non-cognitive skill production functions and test these hypotheses empirically.

As to the other inputs, the following variables are included in the cognitive skill production function: the number of books the child has, the frequency of museum visits, nutrition (equivalized family food expenditure[12] and an indicator whether the child has breakfast), and the child's age at the child interview (in log). The first two inputs are usually included in the cognitive skill production functions, either directly or as part of an index describing family environment (for example, Cunha and Heckman, 2008; Todd and Wolpin, 2007). Nutrition could also be potentially important for child brain development. The non-cognitive skill production function, in addition to the time inputs, includes the normalized number of activities the primary care giver and the child do together[13]; the measures of parental "warmth"; an indicator whether the child changed school since the beginning of school; an indicator whether family moved since the last PSID interview, and the child's age at the primary care giver interview (as well as the square and cube of age). The parental warmth measures indicate how often the primary care giver expresses positive feelings towards the child and interest in the child. Fiorini and Keane (2011) find that parental warmth significantly affects children's non-cognitive skills. Additionally, year fixed effects are included in all estimations[14].

My main analysis sample consists of 3,873 observations on 1,768 children. It includes children who are 3-18 years old at both primary care giver and child questionnaires[15], have non-missing values for all variables included in the baseline specification of the model, and whose missing time inputs account for less than 25% of their total weekly time. Around 80% of the sample children are observed two times and the rest are observed three times. In each wave, the weighted means of the cognitive and non-cognitive measures are all zero and their standard deviations are equal to one due to the normalization[16].

Table 1 presents the weighted means and standard deviations of the time inputs by the wave of the survey. The mean video game time across all waves is 3.43 hrs/week. It increased over time from 2.25 hrs/week in wave I to 4.19 hrs/week in wave III. This increase is due partly to the children getting older and partly to the increasing time trend in video game playing. There is a large variation in video game time across children.

[12]For more information on how this variable is constructed please see Appendix A.

[13]These activities include recreational and educational activities, as well as household chores.

[14]Note that age effect may separately identified from time fixed effects, as children's age is measured in months and the time between two waves varies across children.

[15]In wave III, a few children are slightly over 18 years old.

[16]In the analysis sample, the means and standard deviations of the normalized skill measures are slightly different from zero and one respectively, as the population statistics for the normalization are estimated using the whole sample.

Although a large proportion of children do not play video games[17], some of the children who do play them spend long hours engaged in this activity. Thus, the distribution video game time is positively skewed. The maximum number of hours recorded in the time diaries is 108 hrs/week or 16 hrs on the weekend day and 15.2 hrs on the weekday. Overall, more video games are played on weekends (mean = 0.48 hrs/day) than on weekdays (mean = 0.26 hrs/day). Most of the time, video game playing is a primary activity, that is, usually children play video games without engaging in other activities or video game playing is their primary focus.

Table 1: Weighted descriptive statistics of time inputs, hours per week

	Wave I		Wave II		Wave III		All waves	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Basic needs	91.41	13.06	85.18	11.96	81.19	11.56	85.87	12.75
School	28.14	16.29	33.76	16.14	36.05	13.19	32.80	15.76
Socializing	23.01	16.13	20.61	15.56	20.86	14.49	21.34	15.48
TV	15.63	10.55	17.09	12.12	15.89	12.21	16.37	11.75
Other passive act.	9.77	7.32	12.54	9.26	15.32	9.81	12.50	9.15
Games	14.93	12.65	6.09	8.34	2.40	5.05	7.58	10.30
Duties	5.42	5.58	6.94	9.40	7.24	9.86	6.60	8.68
Active leisure	5.34	6.84	3.93	6.03	5.04	7.40	4.61	6.66
Video games	2.25	5.63	3.72	6.53	4.19	7.48	3.43	6.60
Computer	0.17	0.98	2.02	5.63	6.23	9.76	2.60	6.70
Creative act.	2.26	3.98	1.62	3.56	1.79	4.38	1.84	3.91
Organizations	1.69	3.55	1.90	3.78	1.69	3.82	1.79	3.73
Reading	1.68	2.75	1.69	3.25	1.25	3.29	1.57	3.14
Events	0.64	2.56	0.93	3.04	1.29	3.60	0.94	3.08
Missing	1.18	3.99	0.67	2.50	0.80	2.33	0.85	2.96
Total	203.52	20.06	198.70	17.80	201.24	16.62	200.70	18.27
Observations	1227		1705		941		3873	

As expected, the largest fraction of children's time is allocated to their basic needs and educational activities. Children spend a substantial part of their time socializing and communicating with others either face-to-face or via phone. Comparing to the other media, video games is not as popular activity as TV viewing, but is more popular than computer use (for other purposes than games, mostly chatting with other people). Over time, children's exposure to TV, however, did not change much, whereas video game and computer time increased substantially[18]. Thus, it does not appear that the new media displaced the old media, rather the total media time increased. On average, children also spend more time playing traditional (card, board, social, educational, or other) games than video games. Non-electronic games, however, became less popular among children

[17]The median video game time across all waves and in each wave is zero.

[18]Roberts and Foehr (2008) find a similar trend using another source of data.

over time, most likely due to children getting older. In wave III, video game time exceeds traditional game time by 2 hours. On average, slightly more time is spent on sports and active leisure than on video games, but video game playing is more popular than creative activities (hobbies, crafts and arts) or reading. Reading time was stable in waves I and II, but decreased in wave III, more likely due to other activities crowding out reading rather than children getting older.

Table 4 in Appendix B provides the weighted means for the other inputs in the cognitive and non-cognitive skill production functions. Most of the children have access to books and visit museum at least once or twice a year. These inputs seem, however, to decrease by age. Most children usually have breakfast, either at home or at school. The mean family food expenditure is around $60 per person per week. Although the proportion of children having breakfast decreased, the family food expenditure increased over time. The number of activities that a child and his/her primary care giver do together is normalized, therefore, the mean is approximately zero. Parental warmth variables show that most parents express positive feelings towards their children (tell the child that they love him/her or that they appreciate something the child did) and talk to their children about things that interest them frequently (at least a few times a week). It is slightly less common for parents to participate in the favorite activities of children, especially as children get older. On the other hand, there are children who never or rarely receive any parental warmth, as measured by these variables, from their parents. Although the proportion of children who change schools during the school year is not high, families of around 20% of the children move between the PSID waves.

Table 5 in Appendix B reports the weighted and unweighted means of the demographic characteristics of the analysis sample. The differences between weighted and unweighted statistics indicate that black children, children with single parent, and children with less than college educated primary care giver are overrepresented in the analysis sample. The average family income in the sample is also lower compared to the national average. These differences are most likely due to the overrepresentation of the low income families in the PSID sample.

6 Results

In this section, I first present the baseline results. Then, I report the results of alternative estimation methods and address the threats to the identifying assumptions of the child FE estimator. Table 2 presents the child FE estimates of the effects of video game time on children's cognitive skills (reading recognition, problem solving, and short-term memory) and their non-cognitive skills (externalizing, internalizing, and aggressive behavior problems). These regressions are estimated separately. Standard errors in all estimations are clustered at the family level to account for the presence of siblings/cousins in the data. The reported R-squared is the within R-squared. There are differences in model fit between cognitive and non-cognitive skill regressions. The cognitive skill regressions explain a substantial part of the variation in the test scores, especially the variation in the reading recognition and problem solving test scores. Most of this variation is explained by age and time fixed effects. The tests of children's cognitive skills are not age-specific; therefore, older children do better. To the contrary, observed inputs in non-cognitive skill production function explain only a small proportion of variation in child behavior problems[19].

As all skill measures are normalized, the estimates in Table 2 measure by how many standard deviations a respective skill changes as video game time increases by an hour per week. Time trend controls for any changes over time common to all children. The within-child FE estimator eliminates any time-invariant child-specific variables. Note that a higher behavior problem index indicates lower non-cognitive skills. Therefore, the negative coefficients in Table 2 indicate positive effects on non-cognitive skills.

In panel A, the coefficient estimates measure the ceteris paribus effect of video game time. In other words, this is the effect of video game time holding all other time inputs fixed. Estimating the ceteris paribus effects is possible, because the sample children often engage in more than one activity at the same time and this is taken into account when measuring the time inputs. As a result, the total time varies across children and all time inputs can be included in the regressions. Thus, the interpretation of the coefficient on the video game time in column 2 is that a one hour increase in video game time per week increases the Applied Problems test score by 0.004 (or 0.4%) of a standard deviation, holding constant other time and good inputs and any variables that either vary only over time or only across children.

Columns 1-3 of Table 2 report the estimated effects of video game time on the cognitive skills. I find evidence of the positive effect of video game time on children's problem solving ability. Although this effect appears to be quantitatively small, it is significantly different from zero[20]. The hypothesis that video game playing does not have any effect on children's reading recognition skill cannot be rejected. Video game playing neither

[19]Fiorini and Keane (2011) also note that observed variables explain only a small fraction of the variation in child non-cognitive skills.

[20]I consider how the effect of video game time compares to the effects of other variables analyzed in the literature in Section 7.

Table 2: Baseline results, video game time, child FE estimates

	(1) Reading	(2) Probl solv	(3) ST mem	(4) Ext beh	(5) Int beh	(6) Aggr beh
A. *Ceteris paribus* effects of video game time						
Video games	0.001	0.004**	−0.002	−0.005**	−0.003	−0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
B. Effects of video game time *relative* to other time inputs						
TV	−0.000	0.002	−0.002	−0.004*	−0.001	−0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Computer	−0.005**	−0.002	−0.006**	−0.003	−0.005	−0.008*
	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
School	−0.001	0.000	−0.003*	−0.007***	−0.005**	−0.007**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Reading	−0.006*	−0.000	−0.004	0.002	0.001	−0.003
	(0.003)	(0.004)	(0.005)	(0.005)	(0.006)	(0.007)
Events	−0.004	0.002	−0.003	−0.015**	−0.006	−0.015**
	(0.003)	(0.004)	(0.005)	(0.006)	(0.006)	(0.007)
Active leisure	0.001	−0.000	−0.004	−0.003	0.001	−0.004
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)
Creative act.	−0.002	0.003	−0.000	−0.008*	−0.006	−0.007
	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.006)
Trad. games	0.003	0.005**	−0.002	−0.010***	−0.008**	−0.008**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
Socializing	0.001	0.004**	−0.003	−0.006**	−0.003	−0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Organizations	0.002	0.001	0.003	−0.005	−0.005	0.002
	(0.004)	(0.003)	(0.004)	(0.005)	(0.005)	(0.006)
Other passive act.	0.001	0.004*	−0.003	−0.004	−0.001	−0.006*
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
R-squared	0.543	0.537	0.343	0.042	0.039	0.033

Notes: Standard errors (clustered at the family level) in parentheses. 3,873 child-year observations. Regressions control for the other inputs described in Section 5.1, age, and time fixed effects. *denotes statistical significance at the 10% level; **denotes statistical significance at the 5% level; ***denotes statistical significance at the 1% level.

benefits nor harms children's ability to correctly identify letters and words. Although I expected a positive effect of video games on children's short-term memory, there is no support for this hypothesis in the data. Video game playing does not seem to improve children's ability to memorize digits.

As far as the non-cognitive skills are concerned (columns 4-6), there is no evidence that video game playing contributes to behavior problems in children. To the contrary, there is some support for a positive effect of video games on the non-cognitive skills. A one hour per week increase in video game time, causes a decrease in externalizing behavior problem scale by 0.5% of a standard deviation. Moreover, this finding is mostly driven by the negative effect of video games on aggressive behaviors. Positive effects of video games on aggressive behavior scale larger than 0.01% of a standard deviation can be rejected with the 95% confidence. The hypothesis that the video game playing has no effect on children's emotional problems cannot be rejected.

Panel B of Table 2 reports the effects of video game time on child cognitive and non-cognitive skills relative to the other time inputs. These estimates are obtained by taking the differences between the coefficient on video game time and the coefficients on the other activities. Thus, the results presented in panel B can be interpreted as the effects of video game playing displacing the other activities. For example, the estimated coefficient on video game time relative to TV time in column 4 is -0.004, which means that if children increased their video game time by an hour per week and decreased their TV exposure by an hour per week, their externalizing behavior scale would decrease by 0.4% of a standard deviation. Additionally, Table 6 of Appendix B presents the ceteris paribus effects of all time inputs.

Note that if time diaries recorded only one of the activities the child was doing at the same time, it would be possible to estimate only the relative effects of video game time. The time inputs would add up to 168 hrs/wk for all children and one activity would have to be omitted from the regressions to avoid perfect collinearity. Being able to estimate ceteris paribus effects of the time inputs provides more information. For example, if we find that the effect of video games relative to TV on externalizing behavior problem scale is negative ($\widehat{\beta_{vg}} - \widehat{\beta_{tv}} < 0$), we only know that the coefficient on video games is smaller than the coefficient on TV. Finding the negative relative effect is consistent, however, with both effects being positive, both effects being negative, the effect of video games being negative and the effect of TV being zero, and the effect of video games being zero and the effect of TV being positive. If we can estimate the ceteris paribus effects of both time inputs, it is possible to distinguish between these four scenarios. Table 6 in Appendix B shows that video game time has a negative effect on the externalizing behaviors of children, and although the effect of TV time is also negative it is smaller in magnitude and not significantly different from zero.

Looking at the cognitive skills first, video game time would be detrimental to children's reading recognition skill if video games displaced reading or computer use. This finding is driven by video game time having no effect on the reading test scores and reading and computer use having the positive effects on the scores of this test. Although the finding that reading has a positive effect on children's reading ability is hardly surprising, the positive effect of computer use is less intuitive. On the other hand, using computer to browse the Internet, email, and chat with other people does require children to read. As to children's problem solving ability, video game playing has a positive effect on this measure of cognitive skills relative to a number of other activities, but this effect is only statistically significant relative to traditional games, socializing with other people, and other passive activities, such as listening to music, relaxing, or traveling. These findings indicate that video game playing requires more cognitive involvement than non-electronic games, such as pretend, dress-up, card, board, and social games, playing with toys or dolls, and other indoor or outdoor play[21]. The other activities that have a significant positive effect on children's problem solving skills are computer use, educational activities, and sports. Computer use and formal education are the only activities that have positive effects on children's short-term memory for digits relative to video games. None of the other activities significantly affect this ability.

As to the non-cognitive skills, video games have a negative statistically significant effect on the incidence of disturbed and antisocial behaviors in children relative to a number of activities. This effect is mainly driven by the negative effect of video games on child aggressive behaviors relative to these activities. The negative effect of video games on externalizing behavior problems relative to TV, school, creative activities, and socializing can be explained by these activities not having any statistically significant effect on these particular non-cognitive skills (see Table 6 in Appendix B). On the other hand, attending events[22] and playing non-electronic games appears to increase the incidence of disturbed and antisocial behaviors in children. Although video games do not have a significant ceteris paribus effect on children's internalizing behavior problems, relative to school related activities and traditional games, the effect of video games on these behaviors is

[21] Although educational game time is included in total game time, only a small fraction of the total game time is allocated to the educational games. Thus, these results do not imply that video games are more beneficial to child cognitive development than non-electronic educational games. Most of the total game time is allocated to playing with toys/dolls and unspecified indoor and outdoor games.

[22] Note that although events do include cultural events, these activities account for less than 10% of the total event time. Most of the total event time is allocated to sports games, movies, and miscellaneous events, such as circus, fairs, and rock concerts.

negative. These findings are driven by school and non-electronic games having a positive effect on children's emotional problems, although only the latter is statistically significant.

Tables 7 and 8 in Appendix B report the coefficient estimates on the other inputs in the cognitive and non-cognitive skill production functions. The number of books appears to have a positive effect of all three measures of cognitive skills, but the effect of this input is precisely estimated only in the short-term memory equation. There is no evidence that the number of museum visits is important for the development of the cognitive skills analyzed in this study[23]. As discussed previously, it is likely that once the time inputs are held fixed, it is the quality of goods, not their quantity, that matters to the development of child cognitive skills. The nutrition variables also do not have any effects on the cognitive skills. Age is an important determinant of the normalized test scores, and the coefficients on the time dummies are negative, as expected[24]. As to the non-cognitive skills, the parental warmth measures do matter, but not all of them. It appears that expressing positive feelings (telling the child that you love him/her or appreciating something the child did) does not have any effects on either externalizing or internalizing behavior problems. On the other hand, participating in the child's favorite activities and talking to the child reduces the incidence of both disturbed/antisocial behaviors and emotional problems. Changing schools has a negative effect on non-cognitive skills. Age only explains the variation in disturbed/antisocial and aggressive behavior problems, and there is evidence of non-linear age effects.

Next, I present the results of alternative identification strategies. Panel A of Table 3 reports the estimates of OLS and random effects(RE) models. For comparison purposes, the first row of panel A replicates the child FE results. The identifying assumptions of the OLS and RE estimators are that children's innate cognitive (non-cognitive) ability (and any other unobserved heterogeneity) is uncorrelated with the inputs in the cognitive (non-cognitive) skill production function. If this assumption were true, the child FE, RE, and OLS estimators should give qualitatively similar results.

The estimates presented in the upper panel of Table 3 do not support the assumption that the unobserved heterogeneity is uncorrelated with the inputs in cognitive and non-cognitive skill production functions. The OLS and RE estimates of the effects of video game time on reading and problem solving skills are larger than the child FE estimates

[23]In fact, frequent museum visits have a negative effect on the Applied Problems test score.

[24]The latter finding is due to the varying age range across waves. Take two children with the same inputs and of the same age (say 8 years old), but one of them is observed in wave I and the other one is observed in wave II. The child from wave I is approximately of the same age as an average child in this wave, but the child from wave II is four years younger than average in this wave. Therefore, the normalized test scores of the child from wave II are expected to be lower than those of the second child (as normalization is done by wave).

of these effects, implying that the OLS and RE estimators are positively biased. Thus, it appears that video game playing is positively correlated with the innate cognitive abilities. The estimated effects of video game time on externalizing and aggressive behaviors are not significantly different from zero in the OLS and RE models. The negative and larger in absolute value child FE estimates of these effects point to the positive bias of the OLS and RE estimators. Thus, it seems that video game playing is negatively correlated with the innate non-cognitive abilities.

Panel B of Table 3 presents the estimates of the family FE regression. The implementation of this estimator is feasible due to the presence of families with two children in the data. To facilitate the comparison of the child FE and family FE estimates, I re-estimate the child FE regression using the sibling sample[25]. These estimates are presented in the first row of panel B.. The results show that family fixed effects capture most of the unobserved heterogeneity in children's innate cognitive abilities. The family FE estimator does not seem to completely eliminate unobserved child-specific non-cognitive skill endowments. Additionally, the family FE estimates are less precise. For these reasons, the child FE estimator is preferred to the family FE estimator in this analysis.

Table 3: Alternative estimators of the video game time effect

	(1) Reading	(2) Probl solv	(3) ST mem	(4) Ext beh	(5) Int beh	(6) Aggr beh
A. Child FE vs. OLS and RE estimators ($n = 3873$)						
Child FE	0.001	0.004**	−0.002	−0.005**	−0.003	−0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
OLS	0.005**	0.008***	−0.001	0.004	0.002	0.000
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Child RE	0.003*	0.006***	−0.001	−0.001	−0.001	−0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
B. Child FE vs. family FE estimator						
Child FE($n = 1606$)	0.007***	0.010***	0.005	−0.008**	−0.002	−0.010*
	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)	(0.006)
Family FE($n = 1716$)	0.004	0.011**	0.001	0.003	0.001	−0.005
	(0.004)	(0.005)	(0.005)	(0.008)	(0.007)	(0.009)

Notes: Standard errors (clustered at the family level) in parentheses. Regressions control for the time and other inputs described in Section 5.1, age, and time fixed effects. *denotes statistical significance at the 10% level; **denotes statistical significance at the 5% level; ***denotes statistical significance at the 1% level.

To conclude this section, I attempt to address the threats to the identifying assumptions of the child FE estimator. The key identifying assumption of this estimator is strict

[25] The sample size is slightly smaller in the child FE estimations than in the family FE estimations, because some of the siblings were observed only once in the data.

exogeneity, which requires no correlation between the inputs in the cognitive and non-cognitive skill production functions and the error terms in (5) and (6) in all time periods. These error terms may contain any omitted inputs, measurement errors, and random shocks to child cognitive and non-cognitive development. One way to account for a potential correlation between the inputs in the cognitive and non-cognitive skill production and the errors would be to use the instrumental variable (IV) estimator. Finding valid instruments for all the inputs is, however, hardly feasible.

Therefore, I employ another strategy to investigate if the strict exogeneity assumption is reasonable in this analysis. First, I check if including any of the additional inputs in the cognitive and non-cognitive skill production functions affects the baseline results. I include the variables used in the other studies, such as the questions about a child's home environment, which are used to compute the Home Observation Measurement of Environment - Short Form (HOME-SF), used in Todd and Wolpin (2007). I also add the inputs in the cognitive skill production to the non-cognitive skill production function, and vice versa. Additionally, I check sensitivity of the results to the inclusion of the variables that are not inputs in the production functions themselves, but may affect the demand for these inputs, such as family income, education of the primary care giver, and the number of other children in the family. Finally, I investigate the possibility of reverse causality by checking if adding variables that could disturb child cognitive and non-cognitive skill development changes the main findings[26]. I include both current and past measures of each variable[27].

Overall, the results remain robust to the inclusion of any of the above mentioned variables or their lags. The estimated effects of video game time on children's reading recognition skill and short-term memory remain statistically insignificant, and the effect of video game time on children's problem solving skill remains positive and statistically significant. There is still no evidence that video game playing increases the incidence of antisocial or disturbed behaviors in children. The effect of video game time on the externalizing behavior problem scale remains negative and statistically significant. Additionally, the results of the sensitivity analyses point to possible heterogeneity in the effects of video game time on child non-cognitive skills. For example, the effect of video game time on children's aggressive behavior becomes statistically insignificant once the sample is restricted to waves II and III so that the model with lags of the additional variables could

[26]These variables include the changes in family financial security, neighborhood safety, primary care giver emotional wellbeing, and child health.

[27]The variables are included in the regressions one at a time. I also re-estimate the baseline model each time to account for the sample selection, as most of the variables have missing values, which reduces sample size. The estimates of the model with an additional variable included are then compared to the estimates of this "new" baseline model.

be estimated. This effect is insignificant both in the model with additional variables and the (re-estimated baseline) model without these variables, suggesting that this finding is a result of sample selection. Additionally, there is some evidence that video game playing has a negative effect on the internalizing behavior problem scale in this sub-sample of children. These two observations suggest that the effect of video game time on children's non-cognitive skills may vary by age[28], as in waves II and III, the average age of children is higher than in the full analysis sample.

7 Discussion

In this section, I compare the results of this analysis to the findings of the other studies in the literature. Contrary to Fiorini (2010), I do not find any evidence of the negative effect of video game playing on verbal skills, but this is not surprising given the differences between the two studies. My specification of the cognitive skill production function controls for all other time inputs, including reading time, whereas Fiorini (2010) controls only for other media (TV and computer) time. Therefore, the interpretation of the coefficient on video game time is different in the two studies. I also find that relative to reading video games have negative effect on verbal skills. Additionally, the Letter-Word Identification test used in this analysis measures different verbal skill from the Peabody Picture Vocabulary Test used in Fiorini (2010). The first test measures a child's ability to recognize words, but does not require the child to know the meaning of a word, whereas the latter test assesses whether a child knows the meaning of different words. As to the non-verbal cognitive skills, the findings of the two studies are somewhat consistent. I find quite robust evidence that video game playing contributes to the development of child applied problem solving skills. Fiorini (2010) finds a positive marginally significant effect of video game time on child pattern recognition skills[29] in one of the specifications of the model, but this finding is not robust.

To compare my findings to those of Ward (2010), I focus on the estimated effect of video game time on children's aggressive behavior, as he looks at the relationship between video game playing and fighting. The results of my analysis are consistent with the conclusions of Ward (2010) who finds that controlling for observed heterogeneity eliminates the positive correlation between video game playing and fighting. In my analysis, video game time is also positively correlated with aggressive behavior, although this correlation is

[28]Unfortunately, the design of the CDS survey is not suitable for testing this hypothesis.

[29]The task of pattern recognition can be considered as an assessment of children's problem solving ability.

not statistically different from zero. In the OLS model that controls for other time and good inputs, the coefficient on video game time decreases. Once any child-specific time invariant variables are eliminated in the child FE model, the effect of video game time on child aggressive behavior becomes negative. Overall, my findings support the conclusion of Ward (2010) that the data does not support the hypothesis that video game playing causes children to behave aggressively.

My findings are in contrast with those of experimental studies in the psychology literature that find positive effects of exposure to violent video games on aggressive behavior of children. However, the differences in the methodologies between my analysis and these studies are likely explain the differences in the results. First, in these experiments children are exposed to violent video games, and I look at the effect of all types of video games. Second, the experimental studies measure only short-term effects, and my analysis investigates the longer term effects of video games. Finally, almost all experimental studies involve young children and my sample includes children of all ages (3-18 years old). My findings are consistent with two of the theories, discussed earlier (Bensley and Van Eenwyk, 2001). According to the catharsis theory, video games can provide a safe outlet for children's aggressive thoughts and feelings thereby reducing real-life aggressive behavior in children. According to the drive-reduction theory emotionally disturbed children may play violent video games to bring their emotions into balance. Both theories predict that children who have tendency towards aggressive thoughts and feelings are more likely to play video games and that video games may reduce actual aggressive behavior in such children. The first prediction is consistent with a positive bias in the OLS/RE estimators. The second prediction provides a potential explanation for the negative estimated effect of video games on child aggressive behavior.

To put the findings of this study in perspective, I compare the estimated effect of video games to the effects of other variables shown to be important to child cognitive development. Dahl and Lochner (forthcoming) find that a $1000 increase in family annual income increases children's (Peabody Individual Achievement Test) math score by 5.8% of a standard deviation. Given that the Applied Problems test score used in this analysis measures math related abilities, the effect of an additional video game hour per week roughly compares to the effect of a $72 increase in annual family income. Bernal and Keane (2011) find that a year of child care (or time away from the mother) decreases the cognitive skill test score of young children by 0.114 of a standard deviation[30]. The effect of an additional video game hour per week compares to the effect of two week increase in

[30]Although Bernal and Keane (2011) do not distinguish between different types of cognitive skill tests in the baseline specification, their additional estimations show that the effect of child care on math score is similar to the baseline estimate.

a child's time with the mother. Thus, the effect of video game playing on child cognitive skills appears to be not trivial.

8 Conclusion

To conclude, this paper contributes to the literature on child cognitive and non-cognitive development. I investigate the role of video game playing in the production of children's cognitive and non-cognitive skills. One of the main findings of this paper is that there is a plausibly causal relationship between video game playing and certain cognitive skills. More specifically, I find that video games increase children's ability to apply their math knowledge to solve real life problems. This finding is as expected, as a video game is in fact a problem solving task. To win the game, children are required to use their knowledge, to find the relevant information among all information given to them, and to determine the steps that need to be followed. These are the the skills that are required from children to succeed in the problem solving test. The ceteris paribus effect of video games on children's reading recognition skill is not statistically significant, but relative to reading time, video game time has a negative effect on this skill. Video games to not appear to affect child short-term memory, at least as far as memory for digits is concerned.

The second key finding of this analysis is that there is no evidence in the data that video game playing contributes to behavior problems in children. The results suggests that the positive correlation between video game playing and aggressive behavior in children, found in the literature, is most likely due to the correlation between video game playing and observed and unobserved characteristics of children. Once these characteristics are held fixed, I find that the effect of video game playing on the incidence of disturbed and antisocial behavior in children is, in fact, negative. There are no statistically significant effects of video game playing on children's emotional problems.

The findings of this analysis provide evidence against the policies that impose restrictions on the sale of video games to children in addition to the current self-regulatory system of video game industry. Such policies may not help to reduce behavior problems in children, but prevent children from improving their cognitive skills by playing video games. On the other hand, this study looked at the effect of video games in general and did not investigate the effects of violent video games. An interesting extension to this study would be to look at the effects of different types of video games on child cognitive and non-cognitive skills, as well as investigate if there is any heterogeneity in the effects of video game playing by child and family characteristics.

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A The measure of family food expenditure

To construct a measure of family's food expenditure per person, I divide a family's expenditure on food by the number of equivalent adults in the family unit. The number of equivalent adults is calculated by weighting the members of a family unit as follows: the first adult in the family is assigned the weight 1, the second adult is assigned the weight 0.5, and the children are assigned the weight 0.3[31]. This weighting scheme assumes that additional food cost for the second adult in a family is equal to 50% of the food cost for the first adult and that additional food cost for each child is 30% of that amount. I use the data from the core PSID surveys for the construction of this variable. A family's expenditures on three types of food - consumed at home, delivered to home, and eaten out - are reported in these surveys. I add expenditures on all types of food to obtain the total family food expenditure. The amount of food stamps is included in a family's expenditure on food consumed at home for those families that receive food stamps. Food expenditure is measured in 1997 dollars per week.

[31] I followed a methodology used to construct equivalized income of a household to calculate the number of equivalent adults and equivalized food expenditure of a family (http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:Equivalised_disposable_income). I deviate from this methodology by assigning the weight 0.3 to all children under 18 years of age, rather than assigning the weight 0.5 for the children 14 years of age or older and the weight 0.3 for the younger children.

B Additional tables

Table 4: Weighted means of other inputs

	Wave I	Wave II	Wave III	All waves
Books == 10 to 19	0.08	0.12	0.17	0.12
Books == 20 or more	0.84	0.76	0.66	0.75
Museum == sometimes	0.40	0.36	0.34	0.37
Museum == frequently	0.28	0.18	0.16	0.20
Breakfast	0.95	0.88	0.85	0.89
Food expend., 1997$ pp/wk	57.26	61.59	64.52	61.15
No of activities w/PCG	0.02	0.04	0.01	0.03
Warmth(love)==Once/wk	0.03	0.06	0.06	0.05
Warmth(love)==A few times/wk	0.12	0.18	0.17	0.16
Warmth(love)==Everyday	0.83	0.71	0.70	0.74
Warmth(appr)==Once/wk	0.08	0.20	0.23	0.17
Warmth(appr)==A few times/wk	0.43	0.47	0.43	0.45
Warmth(appr)==Everyday	0.46	0.26	0.21	0.30
Warmth(part)==Once/wk	0.19	0.27	0.30	0.25
Warmth(part)==A few times/wk	0.40	0.38	0.30	0.37
Warmth(part)==Everyday	0.31	0.13	0.09	0.17
Warmth(talk)==Once/wk	0.09	0.15	0.15	0.13
Warmth(talk)==A few times/wk	0.34	0.44	0.46	0.42
Warmth(talk)==Everyday	0.54	0.33	0.26	0.37
Changed school	0.04	0.05	0.03	0.04
Moved	0.15	0.22	0.27	0.21
Observations	1227	1705	941	3873

Table 5: Means of demographic characteristics

	Unweighted	Weighted
Male	0.498	0.486
Age at child interview	11.329	11.666
Age at PCG interview	11.314	11.649
Black	0.370	0.137
Hispanic	0.072	0.126
Other race	0.034	0.052
Annual family inc, k 1996$ pp	25.777	28.775
Both parents	0.622	0.727
Educ of PCG == college	0.215	0.262
SMSA	0.546	0.507
Observations	3406	3406

Table 6: Baseline results, ceteris paribus effects of other time inputs, child FE estimates

	(1) Reading	(2) Probl solv	(3) ST mem	(4) Ext beh	(5) Int beh	(6) Aggr beh
Video games	0.001	0.004**	−0.002	−0.005**	−0.003	−0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
TV	0.001	0.002*	0.000	−0.001	−0.002	−0.002
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Computer	0.006***	0.006***	0.004*	−0.002	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
School	0.002*	0.004***	0.001	0.002	0.002	0.001
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Reading	0.007**	0.004	0.002	−0.008	−0.004	−0.003
	(0.003)	(0.003)	(0.005)	(0.005)	(0.006)	(0.006)
Events	0.005	0.002	0.000	0.009*	0.003	0.008
	(0.003)	(0.003)	(0.005)	(0.006)	(0.005)	(0.007)
Active leis.	0.000	0.004**	0.001	−0.003	−0.004	−0.002
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Creative act.	0.003	0.001	−0.002	0.003	0.003	0.001
	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.005)
Trad. games	−0.002*	−0.001	−0.001	0.005**	0.005*	0.001
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.003)
Socializing	−0.000	−0.000	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Org. act.	−0.001	0.003	−0.005	−0.001	0.002	−0.008
	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)	(0.005)
Passive act.	−0.001	0.000	0.001	−0.001	−0.002	−0.000
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Duties	0.000	0.001	−0.001	0.001	−0.000	0.000
	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)
Basic needs	−0.000	−0.001	−0.001	0.004**	0.004*	0.002
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Missing	0.005	0.006**	0.007	0.002	0.002	0.002
	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)	(0.006)

Notes: Standard errors (clustered at the family level) in parentheses. 3,873 child-year observations. Regressions control for the other inputs described in Section 5.1, age, and time fixed effects. *denotes statistical significance at the 10% level; **denotes statistical significance at the 5% level; ***denotes statistical significance at the 1% level.

Table 7: Baseline results, other inputs, child FE estimates, cognitive skills

	(1) Reading	(2) Probl solv	(3) ST mem
Books == 10 to 19	0.026	0.039	0.029
	(0.038)	(0.044)	(0.048)
Books == 20 or more	0.031	0.063	0.122***
	(0.037)	(0.040)	(0.044)
Museum == sometimes	−0.007	0.021	−0.010
	(0.027)	(0.024)	(0.031)
Museum == frequently	−0.005	−0.056*	−0.038
	(0.033)	(0.032)	(0.039)
Breakfast	0.006	0.053	0.006
	(0.034)	(0.041)	(0.045)
Food expend., 1997$ pp/wk	0.000	0.000	0.001
	(0.001)	(0.001)	(0.000)
log(age)	3.106***	2.739***	2.563***
	(0.121)	(0.107)	(0.134)
2002	−1.454***	−1.268***	−1.199***
	(0.066)	(0.063)	(0.082)
2007	−2.463***	−2.109***	−2.023***
	(0.122)	(0.115)	(0.146)

Notes: Standard errors (clustered at the family level) in parentheses. 3,873 child-year observations. Regressions control for the time inputs. *denotes statistical significance at the 10% level; **denotes statistical significance at the 5% level; ***denotes statistical significance at the 1% level.

Table 8: Baseline results, other inputs, child FE estimates, non-cognitive skills

	(1) Ext beh	(2) Int beh	(3) Aggr beh
No of activities w/PCG	−0.016	0.008	−0.021
	(0.022)	(0.022)	(0.027)
Warmth(love)==Once/wk	−0.023	0.012	−0.138
	(0.091)	(0.095)	(0.113)
Warmth(love)==A few times/wk	−0.041	0.028	−0.090
	(0.079)	(0.085)	(0.103)
Warmth(love)==Everyday	−0.107	−0.001	−0.148
	(0.083)	(0.088)	(0.105)
Warmth(appr)==Once/wk	0.008	0.056	−0.058
	(0.068)	(0.073)	(0.088)
Warmth(appr)==A few times/wk	0.010	0.025	−0.078
	(0.072)	(0.074)	(0.091)
Warmth(appr)==Everyday	0.018	0.033	−0.049
	(0.081)	(0.083)	(0.101)
Warmth(part)==Once/wk	−0.018	0.011	−0.077
	(0.047)	(0.049)	(0.058)
Warmth(part)==A few times/wk	−0.092*	−0.036	−0.108*
	(0.051)	(0.052)	(0.063)
Warmth(part)==Everyday	−0.142**	−0.131*	−0.133*
	(0.066)	(0.069)	(0.079)
Warmth(talk)==Once/wk	−0.177**	−0.106	−0.117
	(0.072)	(0.070)	(0.098)
Warmth(talk)==A few times/wk	−0.142**	−0.078	−0.198**
	(0.069)	(0.069)	(0.093)
Warmth(talk)==Everyday	−0.202***	−0.146**	−0.222**
	(0.074)	(0.072)	(0.100)
Changed school	0.161**	0.179**	0.077
	(0.082)	(0.079)	(0.097)
Moved	0.031	0.049	−0.012
	(0.039)	(0.044)	(0.050)
Age	−0.210*	−0.004	−0.440***
	(0.125)	(0.118)	(0.143)
Age^2	0.030***	−0.003	0.038***
	(0.007)	(0.007)	(0.009)
Age^3	−0.001***	−0.000	−0.001***
	(0.000)	(0.000)	(0.000)
2002	−0.448	0.492	0.337
	(0.559)	(0.513)	(0.630)
2007	−0.895	0.975	0.562
	(1.053)	(0.963)	(1.187)

Notes: Standard errors (clustered at the family level) in parentheses. 3,873 child-year observations. Regressions control for the other inputs described in Section 5.1, age, and time fixed effects. *denotes statistical significance at the 10% level; **denotes statistical significance at the 5% level; ***denotes statistical significance at the 1% level.