ORIGINALARTICLE

Little Video-gaming during Adolescence Can Be Protective, But Too Much Is Associated with Increased Substance Use

Short title: Video-gaming and substance use in adolescents

Conflict of Interest: There is no conflict of interest relevant to this article to disclose.

ABSTRACT

Background: Studies have demonstrated inconsistent results regarding the association between video gaming time and substance use in teenagers. Understating intricacies of this association can help with substance use reduction in teenagers.

Objectives: This study aimed to untangle this complex relationship by theorizing and examining a U-shaped association.

Methods: We analyzed two large samples (n_1=7,313 [52.5% female] and n_2=8,079 [51.6% female]) of 8th and 10th graders in the US. Substance use was operationalized as the sum of self-reported number of lifetime use instances of 14 un-prescribed substances. Video game use time (hours/week) was self-reported on a 1 (none) to 9 (40+) scale. Common covariates/ risk factors were included.

Results: Consistently across datasets, partial-correlation between squared video gaming time and substance use ($r = 0.10$, $p<0.001$ in 2014 and $r = 0.08$, $p<0.001$ in 2015) supported the hypothesized u-shaped association. ANCOVA analyses revealed that teenagers playing video games for 1-5 hours a week report on significantly fewer instances of substance use compared to non-gamers ($p<0.001$-0.007) . Post-hoc analyses revealed that those who play at least 30 hours per week report on significantly ($p<0.001$) more instances of substance use (3.92 in 2014 and 3.38 in 2015) compared to teenagers playing video games for 1-5 hours a week (2.17 in 2015 and 1.96 in 2015).

Conclusions: Video gaming time and substance use follow a u-shaped association; light video gaming can be protective in terms of substance use; while too much video gaming is associated with increased substance use.

KEYWORDS: Substance Use, Video Gaming, Teenagers, Adolescents

Introduction

Video gaming is highly popular among teenagers; 72% overall, 84% of teenage boys, and 59% of teenage girls play videogames (Lenhart, Smith, Anderson, Duggan, & Perrin, 2015). It can be associated with several positive aspects of child development (Bavelier et al., 2011). However, it has been also associated with negative phenomena such as school misconduct (Pujol et al., 2016) and reduced school performance (Gentile et al., 2011). Such studies have often relied on the "*displacement hypothesis*" that emphasizes how time spent on videogames detracts from time spent on other important activities (e.g., social, physical, school- or job-related)(Gentile, 2011), which in turn lead to decreased functioning in non-gaming life domains.

One area with major societal implications that may be associated with video gaming is substance use among teenagers. Substance use in this segment is quite common, with 2015 prevalence rates of 5.4 %, 9.8% and 14.3%, in 8th, 10th and 12th grade, correspondingly, in the US (National Institute on Drug Abuse, 2016). This is problematic because substance use and abuse at young age can lead to many persistent conduct, developmental and life functioning problems (Bonomo et al., 2001; Patton et al., 2007). Evidence regarding possible associations between video gaming time and substance use, though, has been mixed. While some studies show that that the time spent on video gaming among adults is associated with alcohol abuse (Wenzel, Bakken, Johansson, Götestam, & Øren, 2009) and among teenagers with nicotine, cannabis and alcohol use (van Rooij et al., 2014), others show that tobacco and alcohol consumption is not associated with video gaming time in the 15-25 age segment (Walther, Morgenstern, & Hanewinkel, 2012) or among grades 9-12 students (McClure & Mears, 1986). This alludes to potential intricacies of this association that should be further theorized and examined, as it prevents child and adolescent clinicians, parents and regulators developing practical guidelines. This study seeks to do address this gap.

To theorize on this association, we note that substance use can relate to video gaming via several mechanisms. First, video gaming may serve as a gateway for substance use by changing reward expectations and reward processing in the brain (Han et al., 2011). As per *reward deficiency theory* (Cloninger, 1987), the modified reward system leads to lower enjoyment from the same level of rewards that excited a person in the past, and hence propels people to seek additional rewards; in the present case, possibly also from substance use. Second, it is possible that there are genetic, psychological predispositions and environmental factors that drive a range of problematic behaviors across life domain (Kreek, Nielsen, Butelman, & LaForge, 2005). For example, genes involved in dopamine receptor deficits increase substance use and excessive video gaming risks (Han et al., 2007), low parental oversight can also be associated with both (Xu, Turel, & Yuan, 2012), and deficit in emotion regulation, impulsivity and coping can be associated with increased substance use and video gaming (Weinstein, 2013; Weinstein, Timor, Ben Abu, & Mama, 2016).

In this study we do not support or refute these explanations. We rather argue that they can all be valid for justifying possible associations between video gaming time and substance use. Nevertheless, we extend the oft-taken simplistic linear association perspective and posit that this association is likely non-linear; a viewpoint that accounts for possible differences between no video gaming, low levels and high levels of video gaming. At low levels of video gaming, it is reasonable to assume no major cognitive and self-control deficits (Pujol et al., 2016). Under these circumstances, relying on the "displacement hypothesis" suggests that video gaming can serve as a positive displacement that reduces the opportunity and motivation to use substances.

That is, light playing of video games may serve the reward needs of adolescents and prevent them from looking for risky yet rewarding activities, such as substance use. Therefore, substance use is likely to be higher among non-gamers than in light gamers.

In contrast, it is reasonable to assume deficient behavioral inhibition (Weinstein, 2013) and disrupted reward processing (Luijten, Schellekens, Kühn, Machielse, & Sescousse, 2017) in people who play video games excessively. Under such circumstances, relying on reward deficiency theory, increased substance use may be enacted in order to compensate for the reduced perceived rewards from video gaming (Cloninger, 1987). It may also stem, as per the abovementioned genetic, psychological predispositions and environmental explanations, from factors that drive both video gaming and substance use (for example, prefrontal cortex deficits that may affect decision making across life domains, see Han, Kim, Lee, Min, & Renshaw, 2010). That is, heavy playing of video games may serve a gateway for substance use, or at least be associated with increased substance use.

The hypothesized reduction in substance use in light gamers compared to non-gamers together with the expected positive association of heavy video gaming with substance use, imply that a U-shaped association can represent this relationship. This bipartite perspective can explain inconsistencies in prior research and pave the way for intervention studies that may use light video gaming as a potential alternative activity to substance use in non-gaming teenagers. We test the hypothesized association with two large cross-sectional datasets of adolescents (n_1=7,333, n_2=8,889). It is supported in both. The replication increases confidence in the findings.

Method

Datasets and Participants

We used the Monitoring the Future dataset collected by the University of Michigan's Institute for Social Research (Bachman, Johnston, O'Malley, & Schulenberg, 2006). We specifically focused on the 8th and 10th grade dataset because it includes self-reported video gaming time together with substance use behaviors. These data were obtained by sampling 150 schools representing 16,000 to 19,000 8th grade students in the US; and 130 schools representing 15,000 to 17,000 10th grade students (Johnston, Bachman, O'Malley, Schulenberg, & Miech, 2015b). Because the survey included over 500 variables, each participant completed a variation of the survey that included a subset of questions (Johnston, Bachman, O'Malley, Schulenberg, & Miech, 2015a). The surveys for fully anonymized, were collected during class time, and parents were given the opportunity to decline participation. These procedures were reviewed and approved by the University of Michigan's Institutional Review Board (IRB) for compliance with federal guidelines for the treatment of human subjects (Johnston, O'Malley, Miech, Bachman, & Schulenberg, 2016).

The 2014 dataset (Johnston et al., 2015a) was used for model testing, and the 2015 dataset (Johnston, Bachman, O'Malley, Schulenberg, & Miech, 2016) for replication/ validation. Response rate for the 2104 data collection was 82% (Johnston et al., 2015a). For the 2015 data collection response rates were 89% and 87% for 8th and 10th grade students, correspondingly (Johnston, Bachman, et al., 2016). Our study focused on the subsets of respondents that provided information on video gaming time; hence, respondents who were not asked this question (n=19,018 in 2014, and n=20,791 in 2014) or did not answer it (n=1,337 in 2014, and n=1,321 in 2015) were removed. Consequently, the 2014 dataset was reduced from 28,536 records to the 8,181 records. Similarly, the 2015 dataset was reduced from 31,162 records to 9,050 records.

Some of these records (868 in the 2014 dataset and 971 in the 2015 dataset) contained missing data regarding our variables. Hence, the analytical samples we used included 7,313 records for 2014 and 8,079 records for 2015. Both of these samples represent 89.3% response rate from those who reported video gaming time.

Measures

Substance use was operationalized as the total score of the lifetime use (number of use instances) of 14 substances: (1) alcoholic beverages (more than a few sips), (2) marijuana (weed, pot) or hashish (hash, hash oil), (3) LSD ("acid"), (4) hallucinogens other than LSD (like PCP, mescaline, peyote, "shrooms" or psilocybin), (5) amphetamines [or other prescription stimulant drugs] without prescription, (6) sedatives without prescription, (7) tranquilizers without prescription, (8) "crack" (cocaine in chunk or rock form), (9) cocaine in any other form (like cocaine powder), (10) MDMA ("Molly", "ecstasy"), (11) heroin using a needle, (12) heroin without using a needle, (13) drugs other than heroin by injection with a needle, and (14) methamphetamine (meth, speed, crank, crystal meth)[1]. Each one of the lifetime substance use items was scored from 1 (0 occasions) to 7 (at least 40 occasions). Hence, the total represents lifetime substance use, ranging from 14 (never used any substance listed here) to 98 (used each of these 14 substances at least 40 times). We had no interest in focusing on the use of specific substances, which may be noised by situational factors such as access and availability and by

[1] Use instance descriptions were sufficiently detailed, defined the substance, and included examples and "street" names. For instance, the question regarding amphetamines was: "Amphetamines [and other stimulant drugs] are sometimes prescribed by doctors for people who have trouble paying attention, are hyperactive, have ADHD, or have trouble staying awake. They are sometimes called uppers, ups, pep pills, and include drugs like Adderall and Ritalin. Drugstores are not supposed to sell them without a prescription from a doctor. Amphetamines do NOT include any nonprescription drugs, such as over-the-counter diet pills or stay-awake pills. On how many occasions (if any) have you taken amphetamines [or other prescription stimulant drugs] on your own -- that is, without a doctor telling you to take them . . . in your lifetime?"

variation in decision making deficits, but rather wanted to capture the overall risk of substance use that is associated with different levels of video gaming.

Video gaming time was assessed with the following question: "About how many hours a week do you spend playing electronic games on a computer, TV, phone, or other device?" Responses ranged from 1= None to 9= 40+ Hours.

Based on prior substance use studies (e.g., Hemovich & Crano, 2009; Roger, 2006; Wagner, Ritt-Olson, Soto, & Unger, 2008), we assumed that males, older adolescents, students of parents with lower education levels, students living in households with one parent and with lower parental education, and those who live in city, are at higher risk for substance use. We hence included these risk factors as covariates: ***Sex*** (What is your sex? 0=Female, 1=Male), ***Grade*** (0=8th or 1=10th), ***Region*** (Northeast, North central, South, West), ***Race*** (How do you describe yourself? Black, White, Hispanic), ***Father Education Level*** (What is the highest level of schooling your father completed? From 1= Completed grade school or less to 6= Graduate or professional school after college), ***Mother Education Level*** (What is the highest level of schooling your mother completed? From 1= Completed grade school or less to 6= Graduate or professional school after college), ***Household Members*** (Which of the following people live in the same household with you? Mother, Father, Siblings), and ***Living Place*** (Where are you living now? Farm, country, city or town). All categorical variables with n categories were dummy-coded with n-1 dummy variables.

Statistical Analysis

Data were analyzed with SPSS 24. Bootstrapping with 1,000 re-samples was employed in all analyses in order to avoid distributional assumptions and for producing 95% confidence intervals

(This approach avoids normality assumptions and issues stemming from outliers. This is important as substance use distributions are likley right-skewed. See Mooney & Duval, 1993); two-tailed tests were performed. As an initial step, sample demographics and descriptive statistics regarding the variables of interest were obtained. Next, the association between video gaming time and substance use was analyzed in three ways. First, 95% confidence intervals for substance use were plotted for each level of video gaming time. Second, partial correlations between substance use and squared video gaming time[2] were estimated. Covariates in this analysis included: sex, grade, region, where a person lives, race, father and mother education, household members, and video gaming time (the first moment of squared video gaming time). This approach is equivalent to multiple regression, but focuses on association and does not assume causality. Significant partial correlation of a squared variable with another variable, after accounting for shared variance with first-order moments and covariates, is indicative of a U-shaped association (Salkind, 2010). Lastly, pair-wise comparisons between substance use at each level of gaming and the substance use of non-gamers (treated as a control group) were performed using Analysis of Covariance (ANCOVA) models that controlled for the possible confounding effects of the covariates used in previous analyses. This allowed for a closer examination of the benefits and harms in terms of substance use that may be associated with different levels of video gaming time, compared to not playing video games. For this analysis, Bonferroni corrections were employed for adjusting significance levels for multiple comparisons: α for rejecting the null hypothesis was set to 0.05/9=0.0056.

Results

[2] Squared video gaming time was operationalized as the video gaming scale raised to the second power. The squared variable is parabolic in nature and its inclusion models the hypothesized U-shaped association (see "the U-Shaped Curve" in Salkind, 2010).

Sample demographics and substance use information for each level of video gaming, as well as for all respondents in the 2014 and 2015 samples are presented in Tables A.1 and A.2, correspondingly, in the Appendix. In both samples the average person reported on more than two instances of substance use during their lifetime (calculated as difference from the base score of 14). Supporting national trends of decline in substance use (National Institute on Drug Abuse, 2016), the lifetime substance use in 2015 [95%CI=16.29-16.48] was significantly lower than this in 2014 [95%CI=16.45-16.68], with $F_{1,15389} = 5.45$, $p<0.020$.

Associations between Video-gaming and Substance Use

Figure 1 visualizes the associations between video gaming time and substance use for 2014 and 2015. Both panels portray a similar picture indicating that there is a decline in substance use from no-gaming to low-levels of gaming of up to about 2 hours a week (indicated by the little overlap of the 95% confidence intervals). After this decline there is some stabilization: a zone in which no further benefits of gaming, in terms of substance use reduction, accrue (indicated by the largely overlapping 95% confidence intervals). However, the association reverses at about 30 hours of video gaming per week (indicated by the higher 95% confidence intervals compared to the 3-29 hours per week zone). This provides initial informal support for the hypotheses.

*** Figure 1***

We next tested the hypotheses directly. In the 2014 dataset, squared video gaming significantly partially-correlated with lifetime substance use (0.10, p<0.000, 95%CI=[0.06;0.13]) after controlling for video gaming (0.08, p<0.000, 95%CI=[0.05;0.11]), sex (0.03, p<0.021, 95%CI=[0.002;0.06]), school grade (0.20, p<0.000, 95%CI=[0.18;0.22]), region (all dummy variables non-significant), race (Dummy for Black: -0.04, p<0.003, 95%CI=[-0.07;-0.02]), father education (-0.10, p<0.000, 95%CI=[-0.13;-0.07]), mother education (-0.04, p<0.003, 95%CI=[-0.07;-0.01]), where the person lives (all dummy variables non-significant), and members of his or her household (Father: -0.09, p<0.000, 95%CI=[-0.07;-0.02]; Mother: -0.06, p<0.000, 95%CI=[-0.10;-0.02]; Siblings: non-significant).

Similar results were obtained with the 2015 data. Squared video gaming significantly partially-correlated with lifetime substance use (0.08, p<0.000, 95%CI=[0.05;0.11]) after controlling for video gaming (0.06, p<0.000, 95%CI=[0.03;0.09]), sex (0.03, p<0.012, 95%CI=[0.01;0.06]), school grade (0.21, p<0.000, 95%CI=[0.19;0.24]), region (Northcentral: -0.05, p<0.000, 95%CI=[-0.1108;-0.02]; South: non-significant; West: 0.03, p<0.037, 95%CI=[-0.11;-0.05]), race (all dummy variables non-significant), father education (-0.10, p<0.000, 95%CI=[-0.002;0.059]), mother education (-0.08, p<0.000, 95%CI=[-0.11;-0.05]), where the person lives (all dummy variables non-significant), and members of his or her household (Father: -0.06, p<0.000, 95%CI=[-0.09;-0.03]; Mother: -0.06, p<0.000, 95%CI=[-0.10;-0.04]; Siblings: 0.06, p<0.000, 95%CI=[0.03;0.09])[3].

Lastly, ANCOVA models were employed for comparing substance use at each level of video gaming hours/week to substance use at the base/control category of non-gamers, after controlling for the abovementioned covariates. Tables 1 and 2 outline the results, which are fairly consistent across the samples. They provide some support for the "displacement hypothesis" by showing that substance use among those who play video games for 1-5 hours per week is substantially

[3] Because alcohol and marijuana use is likely common, we tested its associations with squared-video gaming, using the abovementioned covariates. Results indicated that squared video-gaming was significantly correlated with lifetime alcohol use (2014: r=0.085, p<0.000; 2015: r=0.046, p<0.001) and lifetime marijuana use (2014: r=0.076, p<0.000; 2015: r=0.055, p<0.000). This implies that alcohol and marijuana do not differ from the observed pattern of substance use- video gaming associations, when examined independently.

lower than substance use of non-gamers. Consistent with H2, the results also show that these benefits of video gaming reverse at about 30 hours of video gaming per week. At these levels of gaming teenagers engage in higher levels of substance use compared to non-gamers, but these differences are not significant after correction for multiple comparisons.

*** Tables 1&2***

Post-hoc Analysis

The ANCOVA results of both datasets suggested that substance use is significantly lower in those who play 1-5 hours per week compared to non-users; while not statistically significant after correction, they also suggested that those who play 30+ hours per week present somewhat higher substance use instances compared to non-gamers. We next compare the 1-5 hours/week (presumed healthy use), 6-29 hours hours/ week (moderate use), and 30+ hours/week (presumed unhealthy use) groups. Table 3 provides the rate of endorsement for each substance in these groups, total substance use in these groups, and statistical comparisons between the groups. These results suggest that across key substances (alcoholic beverages, marijuana, amphetamines, sedatives, tranquilizers, and MDMA) and considering the total lifetime use of all substances, the presumed "healthy video game use " group engages in substantially fewer instances of substance use compared to the presumed "unhealthy video game use" group.

*** Table 3***

Discussion

This research sought to untangle the complex association between video gaming and substance use and in part, explain inconsistent results in past research (Coëffec et al., 2015) and address the need to better account for both positive and negative associations with video gaming (Gentile, 2011). While many such associations have been discussed in a relatively balanced way (Bavelier et al., 2011; Bavelier, Green, Pouget, & Schrater, 2012; Gentile, 2011; Gentile et al., 2009; Gentile, Lynch, Linder, & Walsh, 2004; Pujol et al., 2016), the association of video gaming with substance use has been largely portrayed as positive in direction (Coëffec et al., 2015; van Rooij et al., 2014); that is, video gaming has been typically presented as a risk factor for substance use. Many such studies, though, have focused on a limited set of substances (typically marijuana, alcohol and tobacco) and on people who are at-risk for video gaming addiction (Madran & Cakilci, 2014; van Rooij, Schoenmakers, Vermulst, van den Eijnden, & van de Mheen, 2011). What happens on the other (i.e., left) side of the distribution of video gaming time and with regards to a wider set of substances is left largely unexplained.

In this study we analyze two large datasets and consistently show that the association between video gaming time and substance use is parabolic. We specifically demonstrate that the "displacement hypothesis" that has been typically applied for examining negative outcomes of video gaming time (Gentile, 2011) can also point to possible positive effects of light video gaming in terms of substance use. This happens possibly because light video gaming can serve as a healthy reward-generating activity that can replace exploration in terms of substance use, among with no decision-making deficits. We also show that this benefit is reversed at high levels of video gaming. This is consistent with theories on decision making deficits and reward deficiency that often apply to very high levels of video gaming and substance use. The findings across the two datasets were consistent in supporting the hypothesized U-shaped association between video gaming time and substance use. This may explain why prior studies that largely assumed linear associations obtained inconsistent results (McClure et al., 2004; Walther et al.,

2012) and sheds light on a relatively new possible positive outcomes of light video gaming, namely reduced substance use.

Specifically, the results of the bar-charts and partial correlation analyses showed that on the left side of the video gaming time distribution, there is a decline in substance use instances compared to non-gamers. The ANCOVA analysis provided a more nuanced view and revealed that 1-5 hours of video gaming per week can be associated with reduced instances of substance use compared to not playing video games. This benefit does not increase after this range, and disappears approximately when a person plays video games for more than 30 hour a week. The post-hoc analysis suggested that 1-5 hours of video gaming per week is significantly healthier in terms of substance use compared to 30+ hours of video gaming per week. The benefits of light-moderate video gaming were in terms of substance use reduction here; and they supplement similar views regarding other benefits of light-moderate video gaming (e.g., improved hand eye-coordination) that also accrue only at low levels of video gaming (Pujol et al., 2016).

After revealing the advantages of light gaming in terms of reduced substance use, the ANCOVA analyses pointed to positive video gaming time- substance use associations in people with gaming time of 30+ hours per week. Table 3 further showed that many specific substances (e.g., alcohol, marijuana, amphetamines, sedatives, tranquilizers and MDMA) are significantly more heavily used in this video gaming segment; this paves the way for research on associations between the use of specific substances and video gaming. While we did not measure video gaming addiction risk in this study, people who play for that many hours per week can in some cases meet at-risk for addiction criteria (van Rooij et al., 2011). Hence, it was reasonable to see that our findings on the right side of the video gaming time distribution were consistent with prior research focusing on problematic video gaming (van Rooij et al., 2014; Wenzel et al., 2009).

From a practical standpoint, our findings suggest, assuming the invalidated causality from video gaming to substance use, that light video gaming (1-5 hours per week) among teenagers may be encouraged as a means to help them obtain desired rewards and engage in alternative activities to experimenting with substances. The efficacy of this approach, though, should be examined in future research. Similarly, our findings suggest that those who play videogames for 30+ hours per week possess a riskier substance use profile compared to those who play 1-5 hours per week. Hence, they may merit special attention from parents, therapists and teachers. Video gaming companies may also alert gamers and guardians regarding such levels of video gaming, as they can be associated with increased risk for substance use.

Several limitations to the interpretation of these results are noteworthy. First, data were cross-sectional, included a limited set of risk factors, and the survey was non-nuanced in terms of substance access (e.g., improper amphetamine use can be via hoarding or buying). Future research may collect longitudinal and more nuanced data in order to be able to make stronger inferences. Second, data were self-reported. While the successful replication of the results in two datasets alleviates this concern, future research can corroborate our findings with reports on substance use from multiple sources and objective measures of video gaming time (e.g., computer logs). Third, the observed significant associations were rather small. This is expected given that the video gaming and substance use are indirectly associated (e.g., through reward system changes, or common underlying factors, such as low parental supervision). The replication of the results across datasets alleviates concerns regarding the validity of the observed associations. However, from a practical standpoint, small associations mean that interventions in video gaming time are unlikely to produce large effects. We hence see our findings as making first strides toward understating this association. Future research can open the black box between video gaming and substance use, and detect more proximal predictors of substance use, as a means for developing substance use reduction interventions. Lastly, we did not capture possible video-gaming addiction symptoms. Examining associations between video-gaming addiction and substance use is a promising area for future research.

Conclusion

Video gaming and substance use are two activities with which many adolescents experiment. Theory suggests various reasons for why these two can be associated. Our findings indicate that there is likely a U-shaped relationship between them. They specifically demonstrate that (1) video gaming of 1-5 hours per week may serve as a healthy alternative for experimenting with substances in adolescents, and (2) video gaming time of at least 30 hours a week can be a risk factor or a marker for increased substance use in adolescents.

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Table 1: ANCOVA Results - 2014 Dataset[*,**]

	Case Groups								
	All Gamers	**< 1 HR:(2)**	**1-2 HRS:(3)**	**3-5 HRS:(4)**	**6-9 HRS:(5)**	**10-19 HRS:(6)**	**20-29 HRS:(7)**	**30-39 HRS:(8)**	**40+ HRS:(9)**
Marginal (Adjusted) Mean for Control (Non-gamers) Group	17.04 [16.56;17.62]	17.14 [16.69;17.59]	17.08 [16.57;17.59]	17.11 [16.63;17.66]	17.17 [16.68;17.71]	17.12 [16.61;17.63]	17.13 [16.61;17.62]	17.23 [16.72;17.77]	17.18 [16.63;17.77]
Marginal (Adjusted) Mean for Case Group	16.57 [16.43;16.71]	16.32 [15.94;16.70]	16.10 [15.81;16.41]	16.24 [15.95;16.53]	16.49 [16.13;16.90]	16.49 [16.11;16.91]	16.87 [16.29;17.56]	18.59 [17.47;19.86]	17.84 [17.31;18.40]
***p* (Between-Group Difference)**	0.052	0.007	***0.000***	***0.002***	0.042	0.057	0.540	0.018	0.082
p (Covariates)									
Sex	0.090	0.060	***0.000***	***0.003***	0.033	0.033	0.159	0.026	0.344
Grade	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***
Region-Northcentral	0.633	0.713	0.414	0.917	0.238	0.952	0.416	0.874	0.049
Region-South	0.078	0.325	0.194	0.049	0.047	0.499	0.085	0.162	0.076
Region-West	0.270	0.330	0.295	0.333	0.713	0.186	0.265	0.542	0.012
Race-Black	***0.000***	0.006	***0.002***	***0.000***	***0.004***	0.089	0.011	0.017	0.032
Race-Hispanic	0.271	0.060	0.955	0.054	0.347	0.352	0.193	0.509	0.276
Father Education	***0.000***	***0.000***	***0.000***	***0.000***	***0.001***	0.020	0.222	***0.002***	***0.001***
Mother Education	0.286	0.466	0.056	0.051	0.503	0.762	0.663	0.040	0.496
Household- Father	***0.000***	0.013	***0.001***	***0.000***	***0.000***	0.008	0.009	0.120	***0.005***

Household- Mother	***0.000***	0.027	0.356	***0.002***	0.258	0.122	0.149	0.018	0.238
Household- Siblings	0.820	0.159	0.312	0.031	0.114	0.682	0.527	0.605	0.226
Lives in Country	0.303	0.533	0.946	0.366	0.833	0.659	0.777	0.372	0.991
Lives in City/town	0.372	0.638	0.999	0.326	0.642	0.895	0.971	0.604	0.693

* In squared parentheses are the bootstrapping-based 95% confidence intervals for the marginal (adjusted) group means

** Significant values after Bonferroni correction (*p*<0.0056) are bolded and italicized

Table 2: ANCOVA Results - 2015 Dataset[*,**]

	Case Groups								
	All Gamers	**< 1 HR:(2)**	**1-2 HRS:(3)**	**3-5 HRS:(4)**	**6-9 HRS:(5)**	**10-19 HRS:(6)**	**20-29 HRS:(7)**	**30-39 HRS:(8)**	**40+ HRS:(9)**
Marginal (Adjusted) Mean for Control (Non-gamers) Group	16.58 [16.12;17.13]	16.77 [16.28;17.29]	16.82 [16.32;17.41]	16.81 [16.29;17.44]	16.83 [16.29;17.41]	16.89 [16.33;17.51]	16.93 [16.42;17.55]	17.00 [16.48;17.56]	16.89 [16.32;17.51]
Marginal (Adjusted) Mean for Case Group	16.38 [16.25;16.51]	16.40 [16.10;16.76]	15.91 [15.65;16.19]	16.05 [15.80;16.31]	16.31 [16.01;16.64]	16.64 [16.19;17.07]	16.60 [15.99;17.23]	17.30 [16.32;18.46]	17.57 [16.97;18.20]
***p* (Between-Group Difference)**	0.350	0.184	***0.000***	***0.003***	0.069	0.443	0.397	0.581	0.089
p (Covariates)									
Sex	***0.004***	***0.000***	***0.000***	***0.004***	***0.000***	***0.004***	0.140	0.089	0.115
Grade	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	0.012	0.156	***0.000***
Region-Northcentral	0.016	0.940	0.886	0.200	0.450	0.458	0.799	0.666	0.823
Region-South	0.986	0.911	0.294	0.624	0.311	0.842	0.999	0.449	0.743
Region-West	0.690	0.996	0.696	0.424	0.964	0.869	0.433	0.952	0.561
Race-Black	0.012	0.071	0.402	0.234	0.231	0.145	0.301	0.556	0.221
Race-Hispanic	0.220	0.041	0.314	0.037	0.235	0.997	0.231	0.752	0.371
Father Education	***0.000***	***0.000***	***0.002***	***0.005***	***0.001***	0.046	***0.005***	0.097	***0.005***
Mother Education	0.020	0.199	0.867	0.703	0.608	0.328	0.242	0.473	0.620
Household- Father	***0.001***	0.944	0.678	0.393	0.475	0.778	0.300	0.969	0.257

Household- Mother	***0.000***	0.007	0.013	0.011	0.093	0.072	0.217	0.175	0.015
Household- Siblings	***0.000***	0.183	0.102	0.044	0.024	0.524	0.437	0.217	0.273
Lives in Country	0.696	0863	0.778	0.393	0.408	0.664	0.688	0.928	0.705
Lives in City/town	0.609	0.477	0.326	0.934	0.578	0.243	0.442	0.494	0.679

* In squared parentheses are the bootstrapping-based 95% confidence intervals for the marginal (adjusted) group means

** Significant values after Bonferroni correction ($p<0.0056$) are bolded and italicized

Table 3: Substance Use in Video Gaming Groups*,**

	2014 Dataset				2015 Dataset			
	Healthy VG Use	**Medium VG Use**	**Unhealthy VG Use**	**p-value for Difference**	**Healthy VG Use**	**Medium VG Use**	**Unhealthy VG Use**	**p-value for Difference**
Alcoholic beverages	1.91 [1.85;1.97]	2.08 [2.01;2.16]	2.49 [2.37-2.60]	***0.001***	1.89 [1.83;1.95]	2.02 [1.96;2.08]	2.32 [2.19-2.44]	***0.001***
Marijuana	1.64 [1.58;1.70]	1.74 [1.67;1.80]	2.13 [2.01-2.25]	***0.001***	1.59 [1.54;1.65]	1.70 [1.64;1.76]	2.09 [1.96;2.21]	***0.001***
LSD	1.03 [1.02;1.04]	1.03 [1.02;1.05]	1.05 [1.03;1.08]	0.072	1.03 [1.02;1.04]	1.04 [1.03;1.05]	1.06 [1.04;1.09]	0.005
Hallucinogens other than LSD	1.04 [1.03;1.05]	1.04 [1.03;1.05]	1.06 [1.04;1.08]	0.482	1.02 [1.02;1.03]	1.04 [1.03;1.06]	1.06 [1.03;1.08]	***0.002***
Amphetamines	1.16 [1.14;1.19]	1.19 [1.16;1.23]	1.36 [1.29;1.43]	***0.001***	1.16 [1.13;1.18]	1.30 [1.17;1.23]	1.34 [1.28;1.41]	***0.001***
Sedatives	1.11 [1.09;1.13]	1.15 [1.12;1.18]	1.25 [1.19;1.30]	***0.001***	1.10 [1.08;1.11]	1.13 [1.11;1.15]	1.24 [1.19;1.30]	***0.001***
Tranquilizers	1.07 [1.06;1.09]	1.08 [1.06;1.10]	1.19 [1.15;1.25]	***0.001***	1.07 [1.06;1.09]	1.10 [1.07;1.12]	1.18 [1.14;1.23]	***0.001***
Crack	1.01 [1.01;1.02]	1.02 [1.00;1.03]	1.01 [1.01;1.02]	0.655	1.01 [1.00;1.01]	1.01 [1.00;1.02]	1.02 [1.01;1.05]	0.058
Cocaine	1.03 [1.02;1.04]	1.02 [1.01;1.03]	1.03 [1.02;1.05]	0.605	1.02 [1.01;1.02]	1.03 [1.02;1.04]	1.05 [1.02;1.08]	0.005
MDMA	1.05 [1.04;1.07]	1.07 [1.06;1.09]	1.12 [1.09;1.16]	***0.001***	1.04 [1.03;1.05]	1.04 [1.03;1.06]	1.11 [1.08;1.16]	***0.001***
Heroin using a needle	1.00 [1.00;1.01]	1.01 [1.00;1.02]	1.02 [1.00;1.03]	0.184	1.00 [1.00;1.00]	1.00 [1.00;1.01]	1.03 [1.01;1.06]	***0.001***
Heroin without a needle	1.01 [1.00;1.01]	1.01 [1.00;1.02]	1.02 [1.00;1.03]	0.149	1.01 [1.00;1.01]	1.01 [1.00;1.02]	1.03 [1.01;1.06]	0.006
Non heroin injection with a needle	1.02 [1.01;1.03]	1.02 [1.01;1.03]	1.02 [1.01;1.04]	0.568	1.01 [1.01;1.02]	1.02 [1.01;1.03]	1.05 [1.02;1.07]	0.009
Methamphetamine	1.01 [1.01;1.02]	1.02 [1.01;1.03]	1.03 [1.01;1.05]	0.252	1.01 [1.01;1.02]	1.02 [1.01;1.02]	1.05 [1.02;1.07]	***0.001***
All Substances	16.08 [15.93;16.24]	16.48 [16.28;16.68]	17.78 [17.44;18.14]	***0.001***	15.95 [15.82;16.01]	16.35 [16.18;16.54]	17.63 [17.23;18.03]	***0.001***

* In squared parentheses are the bootstrapping-based 95% confidence intervals for the marginal (adjusted) group means

** Significant values, after Bonferroni correction (p<0.0033), are bolded and italicized

Panel A: 2014 Dataset **Panel B: 2015 Dataset**

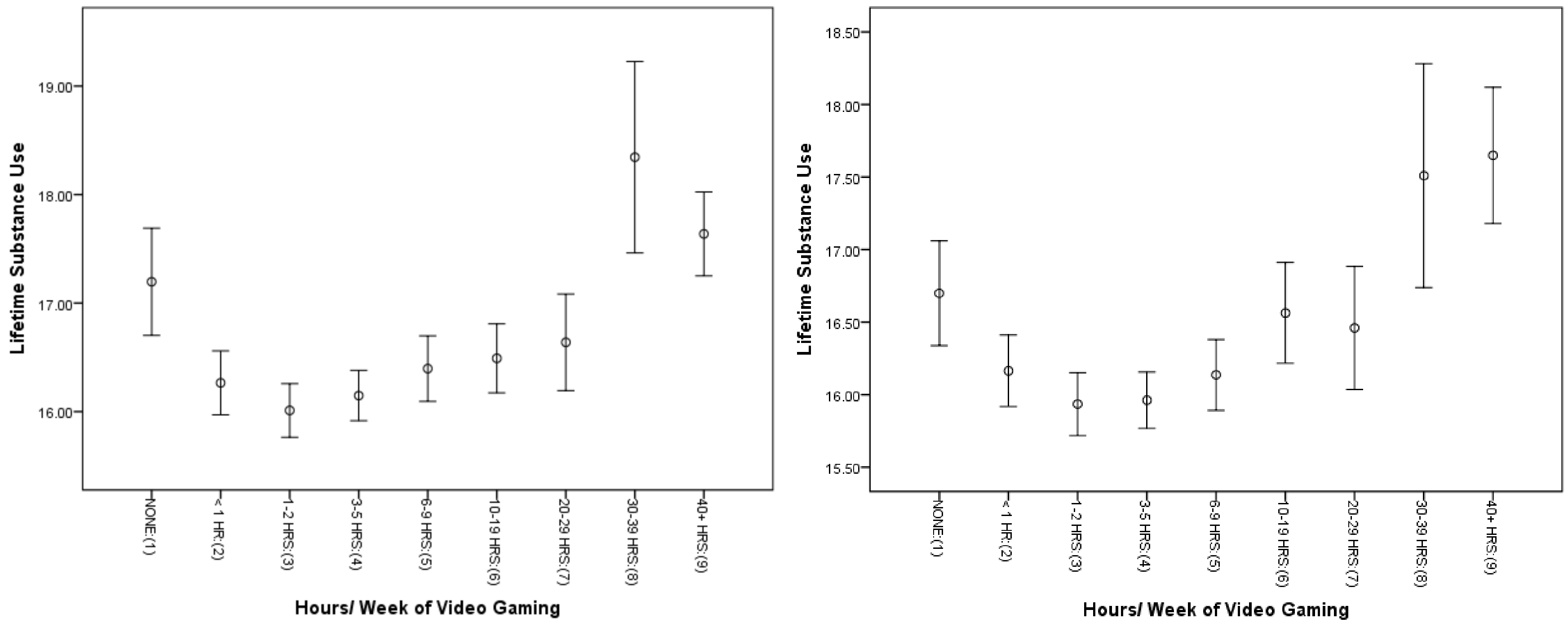

Figure 1: Lifetime Substance Use by Weekly Video-gaming Time: (a) 2014, and (b) 2015*

* Bars represent 95% confidence intervals

Appendix

Table A.1: Demographics and Descriptive Information - 2014 Dataset[*,**]

Video Gaming Hours	None (0) [Non-gamers]	<1 HR / Week	1-2 HRS / Week	3-5 HRS / Week	6-9 HRS / Week	10-19 HRS / Week	20-29 HRS / Week	30-39 HRS / Week	40+ HRS / Week	All
n	625	838	1,180	1,386	999	778	473	206	828	7,313
Sex (% Female)	67.1% 95%CI= [62.5;71.5]	64.6% 95%CI= [60.9;68.2]	51.8% 95%CI= [48.6;55.1]	46.3% 95%CI= [43.3;49.2]	45.1% 95%CI= [41.7;48.5]	47.8% 95%CI= [43.6;51.7]	46.9% 95%CI= [41.7;51.8]	50.6% 95%CI= [43.1;58.7]	52.5% 95%CI= [48.6;56.6]	52.5% 95%CI= [51.3;53.7]
Grade (% of 8th Grade)	36.7% 95%CI= [32.3;40.8]	45.1% 95%CI= [41.5;49.0]	50.1% 95%CI= [46.7;53.5]	51.9% 95%CI= [48.9;54.7]	49.4% 95%CI= [45.6;52.8]	48.6% 95%CI= [44.8;52.7]	47.4% 95%CI= [41.7;52.3]	43.1% 95%CI= [35.0;50.6]	48.6% 95%CI= [44.4;52.7]	48.8% 95%CI= [47.7;50.1]
Race	B:14.5% W:65.7% H:19.8%	B:11.8% W:68.8% H:19.4%	B:13.4% W:63.6% H:23.0%	B:14.5% W:65.9% H:19.6%	B:12.5% W:66.8% H:20.7%	B:12.6% W:70.6% H:16.8%	B:16.0% W:66.5% H:17.6%	B:15.0% W:64.1% H:21.0%	B:22.6% W:59.0% H:18.4%	B:14.5% W:65.7% H:19.8%
Household	Fa: 80.4% Mo: 94.4% Si: 83.1%	Fa: 80.1% Mo: 94.6% Si: 84.4%	Fa: 84.9% Mo: 96.0% Si: 86.8%	Fa: 80.2% Mo: 96.3% Si: 83.9%	Fa: 82.4% Mo: 95.0% Si: 82.7%	Fa: 79.7% Mo: 96.9% Si: 82.8%	Fa: 76.8% Mo: 95.9% Si: 83.4%	Fa: 74.4% Mo: 91.3% Si: 77.5%	Fa: 76.8% Mo: 94.1% Si: 79.3%	Fa: 79.9% Mo: 95.4% Si: 83.1%
Father Education	M= 4.00 SD=1.50	M= 4.15 SD=1.44	M= 4.10 SD=1.44	M= 4.10 SD=1.40	M= 4.06 SD=1.42	M= 4.07 SD=1.39	M= 3.98 SD=1.33	M= 3.72 SD=1.44	M= 3.75 SD=1.38	M= 4.03 SD=1.42
Mother Education	M= 4.29	M= 4.38	M= 4.37	M= 4.27	M= 4.25	M= 4.31	M= 4.18	M= 3.94	M= 4.02	M= 4.26

	SD=1.39	SD=1.33	SD=1.37	SD=1.32	SD=1.38	SD=1.32	SD=1.40	SD=1.36	SD=1.40	SD=1.36
Region	NE:20.4% NC:19.0% SO:39.8% WE:20.8%	NE:18.2% NC:22.6% SO:37.9% WE:21.3%	NE:20.5% NC:22.0% SO:36.1% WE:21.5%	NE:17.6% NC:22.3% SO:39.1% WE:21.0%	NE:19.7% NC:23.6% SO:38.0% WE:18.7%	NE:23.0% NC:27.8% SO:36.6% WE:15.7%	NE:18.6% NC:27.4% SO:34.0% WE:19.9%	NE:14.4% NC:19.8% SO:41.9% WE:24.0%	NE:17.6% NC:20.1% SO:44.5% WE:17.8%	NE:19.2% NC:22.4% SO:38.5% WE:19.9%
Lives in	Fr: 5.9% Co: 17.8% Ci: 76.3%	Fr: 4.7% Co: 15.0% Ci: 80.3%	Fr: 3.0% Co: 15.8% Ci: 81.2%	Fr: 1.6% Co: 15.5% Ci: 82.9%	Fr: 2.9% Co: 14.5% Ci: 82.6%	Fr: 1.8% Co: 14.2% Ci: 84.0%	Fr: 1.3% Co: 17.6% Ci: 81.1%	Fr: 2.4% Co: 15.6% Ci: 82.0%	Fr: 3.1% Co: 14.4% Ci: 82.5%	Fr: 2.9% Co: 15.4% Ci: 81.6%
Lifetime Substance Use	M= 17.20 95%CI= [16.76;17.70] R= 14-78 SD=6.29	M= 16.26 95%CI= [15.98;16.55] R= 14-65 SD=4.34	M= 16.01 95%CI= [15.80;16.27] R= 14-53 SD=4.33	M= 16.15 95%CI= [15.92;16.38] R= 14-53 SD=4.40	M= 16.40 95%CI= [16.11;16.71] R= 14-78 SD=4.87	M= 16.49 95%CI= [16.17;16.82] R= 14-52 SD=4.52	M= 16.64 95%CI= [16.23;17.12] R= 14-65 SD=4.92	M= 18.34 95%CI= [17.51;19.22] R= 14-49 SD=6.42	M= 17.64 95%CI= [17.26;18.07] R= 14-67 SD=5.66	M= 16.58 95%CI= [16.47;16.70] R= 14-78 SD= 4.88

*All variables: M=Mean, SD=Standard deviation, CI=Confidence interval, R=Range

** Race categories: B=Black, W=White, H=Hispanic; Household categories: Fa=Father present, Mo=Mother present, Si=Siblings present; Region categories: NE=Northeast, NC=North-central, SO=South, WE=West; Lives in categories: Fr=Farm, Co=Country, Ci=City/Town

Table A.2: Demographics and Descriptive Information - 2015 Dataset*,**

Video Gaming Hours	None (0) [Non-gamers]	<1 HR / Week	1-2 HRS / Week	3-5 HRS / Week	6-9 HRS / Week	10-19 HRS / Week	20-29 HRS / Week	30-39 HRS / Week	40+ HRS / Week	All
n	718	990	1,292	1,515	1,128	898	521	208	809	8,079
Sex (% Female)	68.9% 95%CI= [65.3;72.1]	67.6% 95%CI= [64.6;70.4]	49.5% 95%CI= [46.8;52.5]	46.8% 95%CI= [44.3;49.4]	46.1% 95%CI= [43.2;49.0]	41.9% 95%CI= [38.5;45.0]	46.6% 95%CI= [42.2;50.9]	46.0% 95%CI= [39.1;53.0]	52.0% 95%CI= [48.5;55.2]	51.6% 95%CI= [50.5;52.7]
Grade (% of 8th Grade)	28.6% 95%CI= [25.1;31.9]	40.6% 95%CI= [37.5;43.7]	49.6% 95%CI= [46.8;52.4]	48.3% 95%CI= [45.8;51.0]	46.1% 95%CI= [43.2;49.2]	44.00% 95%CI= [41.0;47.6]	41.1% 95%CI= [36.5;45.8]	42.6% 95%CI= [35.6;49.5]	49.9% 95%CI= [46.3;53.4]	44.6% 95%CI= [43.5;45.7]
Race	B:13.3% W:66.4% H:20.3%	B:10.4% W:71.9% H:17.7%	B:13.1% W:68.5% H:18.4%	B:11.9% W:67.4% H:20.7%	B:13.9% W:67.8% H:18.4%	B:12.3% W:71.4% H:16.2%	B:11.0% W:73.9% H:15.1%	B:10.0% W:69.4% H:20.6%	B:22.3% W:57.9% H:19.9%	B:13.2% W:68.1% H:18.7%
Household	Fa: 79.4% Mo: 93.7% Si: 81.4%	Fa: 85.0% Mo: 95.8% Si: 84.5%	Fa: 82.8% Mo: 95.0% Si: 84.0%	Fa: 82.8% Mo: 95.5% Si: 82.1%	Fa: 83.6% Mo: 95.8% Si: 81.6%	Fa: 80.5% Mo: 97.1% Si: 81.6%	Fa: 81.8% Mo: 95.7% Si: 83.6%	Fa: 72.9% Mo: 92.5% Si: 79.4%	Fa: 72.8% Mo: 92.4% Si: 79.8%	Fa: 81.3% Mo: 95.1% Si: 82.3%
Father Education	M= 4.04 SD=1.48	M= 4.28 SD=1.41	M= 4.12 SD=1.41	M= 4.17 SD=1.36	M= 4.17 SD=1.38	M= 4.12 SD=1.38	M= 4.16 SD=1.40	M= 3.95 SD=1.38	M= 3.62 SD=1.43	M= 4.10 SD=1.41
Mother Education	M= 4.28 SD=1.45	M= 4.50 SD=1.28	M= 4.35 SD=1.35	M= 4.31 SD=1.34	M= 4.33 SD=1.33	M= 4.39 SD=1.31	M= 4.26 SD=1.31	M= 4.12 SD=1.39	M= 4.03 SD=1.41	M= 4.32 SD=1.35
Region	NE:216%	NE:20.2%	NE:19.2%	NE:20.3%	NE:21.1%	NE:18.6%	NE:20.9%	NE:21.2%	NE:19.8%	NE:20.2%

	NC:17.70% SO:39.8% WE:20.9%	NC:19.5% SO:38.2% WE:22.1%	NC:20.2% SO:40.9% WE:19.7%	NC:20.9% SO:37.9% WE:20.9%	NC:22.1% SO:35.9% WE:20.9%	NC:25.4% SO:35.5% WE:20.5%	NC:23.4% SO:34.7% WE:20.9%	NC:23.1% SO:35.1% WE:20.7%	NC:19.8% SO:45.2% WE:15.2%	NC:21.1% SO:38.5% WE:20.3%
Lives in	Fr: 3.9% Co: 19.1% Ci: 76.9%	Fr: 4.3% Co: 16.2% Ci: 79.5%	Fr: 2.3% Co: 17.3% Ci: 80.3%	Fr: 2.5% Co: 14.0% Ci: 83.5%	Fr: 1.8% Co: 15.0% Ci: 83.2%	Fr: 2.4% Co: 13.5% Ci: 84.1%	Fr: 2.1% Co: 16.0% Ci: 81.9%	Fr: 1.0% Co: 15.1% Ci: 83.9%	Fr: 2.9% Co: 15.5% Ci: 81.6%	Fr: 2.7% Co: 15.6% Ci: 81.7%
Lifetime Substance Use	M= 16.70 95%CI= [16.34;17.07] R= 14-71 SD=4.92	M= 16.16 95%CI= [15.91;16.42] R= 14-42 SD=3.95	M= 15.94 95%CI= [15.72;16.17] R= 14-53 SD=3.97	M= 15.96 95%CI= [15.78;16.15] R= 14-51 SD=3.84	M= 16.14 95%CI= [15.91;16.38] R= 14-57 SD=4.19	M= 16.56 95%CI= [16.23;16.93] R= 14-84 SD=5.29	M= 16.46 95%CI= [16.06;16.91] R= 14-59 SD=4.93	M= 17.51 95%CI= [16.77;18.28] R= 14-51 SD=5.64	M= 17.65 95%CI= [17.17;18.14] R= 14-78 SD=6.79	M= 16.38 95%CI= [16.29;16.49] R= 14-84 SD= 4.71

*All variables: M=Mean, SD=Standard deviation, CI=Confidence interval, R=Range

** Race categories: B=Black, W=White, H=Hispanic; Household categories: Fa=Father present, Mo=Mother present, Si=Siblings present; Region categories: NE=Northeast, NC=North-central, SO=South, WE=West; Lives in categories: Fr=Farm, Co=Country, Ci=City/Town