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Differences in associations between problematic video-gaming, video-gaming duration, and weapon-related and physically violent behaviors in adolescents.

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Abstract

Seemingly mixed findings have been reported on possible relationships between video-gaming and violent or aggressive behaviors. Given the prevalence of gaming in adolescents and potential harms associated with violent behaviors, relationships between problematic gaming, gaming engagement, and risk behaviors involving weapons and physical violence require further research. This study examined in a large sample of high-school students relationships between problem-gaming severity, gaming duration, and violence-related measures including weapon-carrying, having been threatened by someone with a weapon, perceived insecurity, physical fights and serious fights leading to injuries. Potential moderation by sensation-seeking and impulsivity was also tested. Participants were 3,896 Connecticut high-school adolescents. Chi-square, logistic

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Ethics: All procedures performed in human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

regression, and moderation models were conducted. Adolescents with at-risk/problem gaming, compared to low-risk and non-gaming adolescents, reported more weapon-carrying, having been threatened with weapons, feeling unsafe at school, and serious fighting leading to injury. Among those reporting gaming, weekly time spent gaming was associated with problem-gaming severity. Those with longer (versus shorter) gaming durations were more likely to report weapon-carrying and feeling unsafe at school. Sensation-seeking moderated associations between at-risk/problem gaming and weapon-carrying frequency. Associations between gaming quantity and problem-gaming severity and measures of weapon-carrying and physical violence in adolescents suggest that understanding further their mechanistic relationships may be important in promoting safer developmental trajectories for youth. Future longitudinal studies may provide important insight into the etiologies underlying these relationships and such information may help develop more effective prevention and intervention strategies.

Keywords

weapon carrying; video gaming; injury; violence; adolescent; high school

INTRODUCTION

The rising popularity of playing video, computer, internet, and smart-phone games has raised concerns in prevention research networks regarding maladaptive influences on health and risk behaviors (Fineberg et al., 2018; Kim et al., 2016; Mentzoni et al., 2011). The potential for problematic use of video-games, and associations with mental and physical health problems, has been identified in previous research (Desai et al., 2010; Ferguson et al., 2011; Griffiths, 2008). Indeed, ‘gaming disorder’, characterized by a pattern of persistent or recurrent gaming behavior that may manifest as impaired control, increasing priority given to gaming, and continuation/escalation of gaming despite negative consequences, has recently been included in the International Classification of Diseases 11th revision (ICD-11) within disorders due to substance use and addictive behaviors (Billieux et al., 2017).

An estimated 85% of North American middle- and high-school adolescents reported past-year gaming, and 9.4% reported having at least five concerns related to internet gaming disorder, such as preoccupation, tolerance, loss of control, repetition/relapse, withdrawal, escape, disregard of consequences, and disruption to family/school (Turner et al., 2012). A meta-analysis estimated the overall prevalence of problematic gaming as 3.1–8.9%, and 4.2% in children and adolescents (Ferguson et al., 2011), although lower estimates have been reported for internet gaming disorder in the general population (Przybylski et al., 2017) with possible factors relating to differences across studies involving approaches used, populations studied and other factors (Yao et al., 2017). In a Connecticut (U.S.) high-school sample, 4.9% of adolescent video-gamers endorsed three key gaming-disorder features of unsuccessfully cutting back, experiencing an irresistible urge to play, and experiencing growing tension that was only relieved by gaming (Desai et al., 2010).

Data support relationships between video-gaming and aggression, although findings are seemingly mixed. Longitudinal (Anderson et al., 2008; Coyne et al., 2018; Teng et al., 2019)

and meta-analytic (Anderson et al., 2010; Mathur and VanderWeele, 2019; Prescott et al., 2018) research has found associations between gaming and aggression in multiple countries. In laboratory settings, children exposed to violent video-games have demonstrated more dangerous behaviors around simulated fire-arms (Chang and Bushman, 2019). Other studies have reported primarily weak relationships between gaming (including violent games) and aggression (Ferguson, 2015; Ferguson et al., 2013; Ferguson et al., 2012). However, recent meta-analytic reviews found associations between gaming and overt physical violence in children and adolescents converging across multiple studies (Prescott et al., 2018), and meaningful effect sizes in meta-analytic research (Mathur and VanderWeele, 2019). However, the relationship between adolescent problem-gaming severity, gaming involvement, and different dimensions of violent behavior (i.e., weapon-carrying, being threatened with weapons, physical fighting, serious fighting leading to injury, and perceived insecurity) is not well understood, and further research is needed to inform prevention of violence and injury in youth.

Preliminary evidence supports a relationship between problematic gaming and violent behavior (Mehroof and Griffiths, 2010). Higher problem-gaming severity, regardless of game content, was prospectively associated with greater propensities for physical aggression (Lemmens et al., 2011). In addition to greater risk of weapon-carrying and serious fighting, adolescents with problematic gaming may also have differences in health and functioning including substance use and depression (Desai et al., 2010). Inasmuch as these health and functioning differences may co-occur with violent behaviors (Franco et al., 2019; Najman et al., 2019; Oram et al., 2014), these “third variables” potentially have confounding effects in video-gaming and violence research (Ferguson, 2015; Prescott et al., 2018). Hence, studies should consider health and functioning differences in these domains to more accurately assess relationships between problematic gaming and violence-related measures.

In light of concerns for potentially overpathologizing normal gaming behavior, recent reports suggest that high levels of gaming involvement are not necessarily problematic (Billieux et al., 2019). As such, it is important to understand both quantity/frequency measures and problem-gaming correlates separately. While physical violence has been associated with gaming duration, its relationship with problematic gaming may vary under different conditions (e.g., game content, gender) (Goldstick et al., 2018; Lemmens et al., 2011). As such, it is important to understand how measures of violence and aggression may relate both to quantity/frequency measures and problem-gaming correlates separately.

Models of both problematic gaming and violence have suggested common vulnerabilities of inattention, hyperactivity and poor behavioral regulation (Dong and Potenza, 2014; Rohlf et al., 2018; Wojciechowski, 2017). Cognitive-behavioral models indicate that deficiencies in executive control that regulate motivations for reward-seeking and impulsivity may increase risk of problem-gaming behaviors (Dong and Potenza, 2014). Indeed, differences in brain functional activation of executive control networks and performance on inhibition tasks have been observed between individuals with gaming disorders and healthy control participants (Dong et al., 2017; Dong et al., 2015; Dong and Potenza, 2016). Concurrently, ineffective executive or impulse control is also linked to aggression and violence (McCloskey et al., 2009). Childhood deficiencies in executive functioning and impulse control, including

planning, inhibition, set-shifting and working memory, prospectively associate with physical aggression (McQuade et al., 2017; Rohlf et al., 2018). Moreover, individuals with poor executive control are up to 4 times more likely to inflict physical violence on others (King et al., 2018). However, further research is needed to examine relationships between problem-gaming severity, executive or impulse control, and aggression and violence.

The aim of this study was to investigate relationships between measures of problem-gaming severity and gaming duration, and measures of violence-related experiences, and whether impulsivity-related tendencies moderated these relationships. We examined data collected from a cross-sectional survey of risk behaviors in Connecticut high-school students. These data have previously been used to examine correlates of problematic gaming, as well as problem-gambling severity between adolescents with and without serious physical fighting (Desai et al., 2010; Slavin et al., 2013). However, prior studies did not examine problem-gaming severity and video-gaming duration in relation to different violent behaviors while controlling for potentially confounding variables. Hence, the current study adjusts for health and functioning differences in addition to socioeconomic characteristics. We hypothesized that: 1) adolescents with greater problem-gaming severity would be more likely to endorse violence-related measures; 2) adolescents with longer weekly time spent gaming would be more likely to endorse violence-related measures; 3) problem-gaming severity would be associated with weekly time spent gaming; 4) impulsivity and sensation-seeking would moderate associations between problem-gaming severity and gaming duration and violence-related measures.

METHODS

Participants

Recruitment and survey data, consenting procedures, and sample characteristics have been previously described in detail (Desai et al., 2010; Potenza et al., 2011; Zhai et al., 2017). Briefly, invitations were extended to principals of public 4-year and non-vocational or specialized high schools in Connecticut, USA. Additional targeted recruitment from all geographical quadrants of Connecticut, and schools from the three tiers of the state's family socioeconomic-status-related district reference groups. Additional permission from school boards and superintendents was obtained as necessary. Students were reminded that the survey was voluntary and refusal rate was <1%. Among the 4,028 participants who completed the gaming duration measure, 3,896 adolescents who had sufficient data for problematic video-gaming and all five violence-related items were included in analyses.

Survey Characteristics

Description of the variables, and classification of responses were previously presented (Desai et al., 2010; Potenza et al., 2011; Yau et al., 2013). The survey contained 154 questions measuring demographics, health and functioning, violence (i.e., physical fighting), video-gaming, and items derived from established instruments and national surveys of risk behaviors (DuRant et al., 1999).

Measures

Demographic characteristics: Overall findings for the demographic variables of gender, race/ethnicity, school grade (e.g, 10th-grade), and family-structure (living with one parent, two parents, or other arrangement) have been previously reported (Schepis et al., 2008; Yip et al., 2011) and were consistent with findings reported in the 2000 Census of Connecticut residents aged 14–18 years.

Health and Functioning: To account for possible effects of health and functioning variables on gaming (Desai et al., 2010), participants were classified based on whether they reported having: lifetime smoking history; lifetime marijuana use; lifetime history of alcohol use (at least a sip of alcohol); lifetime use of other drugs; and being sad or hopeless for two or more weeks in the past year. Health and functioning variables were included in multivariate analyses as covariates to adjust for potentially confounding effects.

Violence-related Measures: Participants were assessed on violence-related measures including: how many of the past 30 days did they carry a weapon (e.g., gun, knife, or club), and did not go to school because they felt unsafe at or on the way to school; how many times during the past 12 months had someone threatened or injured them with a weapon, were in a physical fight, and were injured in a physical fight requiring medical treatment. Responses of 0 days/times were encoded as “No”, and responses of 1-day/time were encoded as “Yes”.

Gaming Duration: Participants reported on how much time they spent playing video- or computer-games in a typical week. Responses for playing durations were either: None, less than 7 hours, 7–14 hours, 15–20 hours, and 21 hours per week.

Problem-Gaming: Assessment of video-game playing problems was described in a previous publication (Desai et al., 2010). Participants who reported having played video-games in a typical week were asked: did they ever try to cut back on playing; did a family member express concern about the amount of time they spent playing; did they missed school, work, or an important social activity because they were playing; did they think they had a problem with excessive playing; did they ever experience an irresistible urge or uncontrollable need to play; and did they experience a growing tension or anxiety that could only be relieved by playing video-games. Questions were derived from the Minnesota Impulsive Disorder Interview, a valid and reliable instrument used to screen for impulse-control disorders (Grant, 2008; Grant et al., 2005).

Impulsivity and Sensation-Seeking: Impulsivity and sensation-seeking were assessed with the Impulsive Sensation Seeking scale from the Zuckerman-Kuhlman Personality Questionnaire (Zuckerman et al., 1993). The scale contains true/false questions, of which 8 pertain to impulsivity (Cronbach alpha=.70), and 11 pertain to sensation-seeking (Cronbach alpha=.78). Scores were computed for each construct by summing their respective endorsed items (Leeman et al., 2014). The instrument has good internal and face validity, and concurrent validity with other measures of impulsivity and sensation-seeking (Zuckerman et al., 1993).

Gaming Groups

Problem-Gaming Severity: Participants were classified into one of three problem-gaming severity groups. Adolescents who reported no video-game playing in a typical week were classified as non-video-gaming (NVG). Given that there is no official threshold distinguishing problematic and non-problematic video-gaming groups, and consistent with prior thresholds that demonstrated significant between-group differences in risky gambling behaviors (Slavin et al., 2013; Yau et al., 2014; Yip et al., 2014), participants who reported playing video-games and endorsed one or more problem-gaming questions were classified as having at-risk/problem video-gaming (ARPVG). The remaining participants who did not endorse any of the six questions were classified as having low-risk video-gaming (LRVG).

Gaming Duration: Participants who reported playing video-games were additionally classified into groups based on their responses to the gaming-duration question. Participants who reported playing video-games <21 hours-per-week were classified as having shorter-duration-video-gaming (SD-VG) and participants who played ≥21 hours-per-week were classified as having longer-duration-video-gaming (LD-VG). The criteria for classification into gaming duration groups were previously established in nationwide studies of Youth Risk Behavior Surveillance conducted by the Centers for Disease Control and Prevention (Kann et al., 2018).

Statistical Analysis

As described previously (Slavin et al., 2013; Yip et al., 2011), data were double-entered and randomly spot-checked to ensure accuracy. Statistical analyses were conducted using SPSS 25. Pearson chi-square analyses (two-tailed) compared demographic characteristics and violence by problem-gaming severity. A Bonferroni correction for multiple chi-square comparisons was applied such that results of $p < 0.0025$ were considered significant. Logistic regression models were constructed to calculate odds-ratios (OR) and 95% confidence intervals (CI) for associations between problem-gaming severity and violence-related variables. Pearson chi-squares and logistic regression additionally examined associations between gaming duration and violence-related measures. Follow-up analyses were conducted to examine relationships between problem-gaming severity and video-gaming duration. All regression models were statistically adjusted for gender, grade level, race, family structure. Additional analyses also adjusted for health/functioning differences. Statistical significance was set at $p < 0.05$.

For adjusted models with significant between-group differences for both problem-gaming severity and gaming duration, exploratory analyses tested the moderating role of impulsivity and sensation-seeking in PROCESS (Hayes, 2017). Problem-gaming severity, violence-related measures, and sensation-seeking were included respectively as independent, dependent, and moderator variables. To improve interpretability and satisfy model requirements, scalar violence-related measures (frequencies) were utilized, and problem-gaming severity was entered as multi-categorical (Hayes, 2017). Separate models tested gaming duration as the independent variable, or impulsivity as the moderator. A significant moderating effect was indicated when the independent variable and moderator interaction term reached $p < 0.05$. The statistical procedure also probed the interaction by computing

conditional effects of problem-gaming severity and gaming duration on violence-related measures at 16th, 50th, and 84th percentiles of the moderator. These correspond to the normalized mean and one standard deviation above and below the mean, and ensure estimations do not exceed observed values (Hayes, 2017).

Ethical Considerations

The institutional review board at Yale University and all data collection sites approved the passive parental consent and student assent procedures. Letters were sent to parents to provide information about the study and instructed them to contact the school should they deny permission. Students were given the opportunity to decline participation at any point during the data collection. The study was completed in accordance with the Declaration of Helsinki.

RESULTS

Demographic data are reported in Table 1. Among the 3,896 adolescents studied, 27.4% demonstrated LRVG and 23.4% demonstrated ARPVG. Chi-square analyses showed that problem-gaming severity was associated with gender, grade level, and endorsement of Asian regarding race/ethnicity. Additionally, problem-gaming severity was associated with all five violence-related measures. The proportion of adolescents who endorsed each violence-related item was greater in ARPVG adolescents, relative to LRVG and NVG adolescents.

Problem-Gaming Severity

Table 2 presents logistic regression analyses for differences in violence-related measures between problem-gaming-severity groups after adjustment for demographic and health/functioning measures. Compared to NVG adolescents, LRVG adolescents did not have significantly greater likelihoods of endorsing each violence-related measure ($p > 0.05$). Adolescents with ARPVG compared to those with NVG had significantly greater likelihoods of weapon-carrying ($p = 0.001$), feeling unsafe ($p < 0.001$), being threatened/injured with a weapon ($p = 0.002$). Compared to LRVG adolescents, ARPVG adolescents had significantly greater likelihoods of endorsing weapon-carrying ($p = 0.02$), feeling unsafe ($p = 0.02$), being threatened/injured with a weapon ($p = 0.01$), and engaging in serious fighting leading to injury ($p = 0.02$), but they did not differ on physical fighting ($p = 0.5$). ARPVG adolescents, compared to NVG and LRVG adolescents, had greater likelihoods of endorsing each violence-related measure after adjustment for only demographic characteristics (Supplemental Table 1) and associations were significant at the $p < 0.001$ level, with the exception of physical-fighting between ARPVG adolescents, and LRPV ($p = 0.02$) and NVG ($p = 0.02$) adolescents. When substance-use or depression were separately included as covariates, adolescents with ARPVG, compared to NVG and LRVG, were more likely to report weapon-carrying, feeling unsafe, and being threatened with a weapon (Supplemental Table 2 and 3). ARPVG compared to LRVG adolescents had greater likelihoods of serious fighting leading to injury after adjusting for substance-use or depression (Supplemental Table 2 and 3).

Gaming Duration

Table 3 presents the chi-square results of adolescents who endorsed each violence-related measure between shorter-duration and longer-duration video-gaming. Among those who reported having played video-games, gaming duration was associated with all five violence-related measures (all $p < 0.001$). Greater frequencies of LD-VG adolescents, relative to SD-VG adolescents, endorsed weapon-carrying, feeling unsafe, having been threatened/injured with a weapon, physical-fighting, and engaging in serious fighting leading to injury.

Table 4 shows odds-ratios of endorsing violence-related measures between LD-VG and SD-VG adolescents, adjusted for demographics and health/functioning. LD-VG compared to SD-VG adolescents had significantly greater likelihoods of weapon-carrying ($p < 0.001$) and feeling unsafe ($p = 0.01$), but no differences were observed regarding having been threatened/injured with a weapon, physical fighting, or serious fighting leading to injury (all $p > 0.05$). While adjusting only for demographics (Supplemental Table 4), associations were found between gaming duration and each violence-related measure at $p < 0.001$. Gaming duration was associated with each violence-related measure when depression was controlled, but was only associated with weapon-carrying and feeling unsafe when substance-use was controlled (Supplemental Table 5 and 6).

Among adolescents who played video-games, follow-up chi-square analyses indicated that problem-gaming severity was associated with gaming duration ($\chi^2 = 117.34$, $p < 0.001$). The percentage of ARPVG adolescents with LD-VG ($n = 172$, 18.8%) relative to SD-VG ($n = 741$, 81.2%) was greater than the percentage of LRVG adolescents with LD-VG ($n = 40$, 3.7%) relative to SD-VG ($n = 1,028$, 96.3%). Logistic regressions adjusting for demographics demonstrated that compared to LRVG adolescents, ARPVG adolescents had greater likelihoods of LD-VG relative to SD-VG ($OR = 5.79$, $CI = 3.88-8.64$, $p < 0.001$). After additionally adjusting for health/functioning, significance was retained with numerically greater odds ($OR = 12.1$, $CI = 5.02-29.14$, $p < 0.001$).

Moderation

Moderation results are presented in Table 5 and Supplemental Table 7. As problem-gaming severity and gaming duration retained significant associations with weapon-carrying and feeling unsafe, exploratory analyses tested whether impulsivity or sensation-seeking moderated their associations while controlling for demographics and health/functioning. Problem-gaming severity of ARPVG relative to NVG ($p = 0.01$) and its interaction with sensation-seeking ($p < 0.001$) were associated with greater weapon-carrying frequency (Table 5). Conditional effects showed that ARPVG relative to NVG associated with weapon-carrying frequency when sensation-seeking scores were in the 50th ($b(se) = 0.21(0.07)$, $CI = 0.06, 0.35$ $p = 0.005$) and 84th percentiles ($b(se) = 0.42(0.11)$, $CI = 0.20, 0.64$, $p < 0.001$), but not the 16th percentile ($b(se) = -0.005(0.08)$, $CI = -0.15, 0.14$ $p = 0.95$). LRVG relative to NVG, and its interaction with sensation-seeking were not associated with weapon-carrying. The adjusted model was significant (R^2 : $p < 0.001$) and the interactions accounted for significant additional variance (R^2 : $p = 0.002$).

ARPG relative to LRVG ($p=.01$) and its interaction with sensation-seeking ($p=.03$) were also associated with greater weapon-carrying frequency (Table 5). Conditional effects showed that ARPG relative to LRVG associated with weapon-carrying when sensation-seeking scores were in the 50th ($b(se)=0.22(0.08)$, $CI=0.06,0.38$ $p=0.005$) and 84th percentiles ($b(se)=0.39(0.13)$, $CI=0.24,0.64$ $p<0.003$), but not the 16th percentile ($b(se)=-0.04(0.09)$, $CI=-0.13,0.21$ $p=0.62$). The adjusted model was significant (R^2 : $p<0.001$) and the interaction accounted for significant additional variance (R^2 : $p=0.03$). No significant interactions between gaming duration and sensation-seeking on weapon-carrying were observed. Figure 1 displays the mean weapon-carry frequencies for each problem-gaming-severity group stratified by lower, moderate, and higher (0–16th, 17th–84th, and 85th–100th percentiles) sensation-seeking scores. Together, results indicate that sensation-seeking moderated the association between ARPG, relative to NVG and LRVG, and weapon-carrying frequency.

The interaction terms between impulsivity and problem-gaming severities, and gaming duration in weapon-carrying outcomes were not significant (Table 5). Additionally, no significant interactions were observed for outcomes of feeling unsafe (Supplemental Table 7). Hence, no additional significant moderations were observed.

DISCUSSION

To our knowledge, this is the first study to separately investigate relationships between violence-related measures and both adolescent problem-gaming severity and gaming duration, and moderating effects of sensation-seeking and impulsivity after controlling for potentially confounding health/ and functioning differences. Largely consistent with the first hypothesis, ARPG compared to both NVG and LRVG adolescents had greater likelihoods of weapon-carrying, feeling unsafe, having been threatened/injured with a weapon, and ARPG compared LRVG adolescents had greater likelihoods of serious fighting leading to injury. Partially supporting the second hypothesis, the likelihood of each violence-related measure was different between LD-VG and SD-VG adolescents, but only weapon-carrying and feeling unsafe retained significance after adjusting for health and functioning. Supporting the third hypothesis, problem-gaming severity associated with LD-VG. Regarding the fourth hypothesis, sensation-seeking significantly moderated the problem-gaming-severity/weapon-carrying relationship. Together, the findings highlight areas in video-gaming behavior and youth violence that may need greater attention in developing more effective and targeted preventions.

The results indicate that ARPG adolescents had greater risk for weapon-carrying, feeling unsafe, experiencing weapon-related threats/injuries, and getting into serious physical fights with injuries. A prior analysis of these data showed an association between problematic video-gaming and weapon-carrying, despite using different thresholding (Desai et al., 2010). The results are also consistent with previous findings that greater problem-gaming severity, regardless of violent content in games played, predicted greater propensities for physical aggression (Lemmens et al., 2011). In light of the variability in criteria used in assessing problem-gaming severity across studies, the greater likelihood of weapon-carrying and serious physical fighting in ARPG adolescents further support the link between problem-

gaming behaviors and violence (Ferguson et al., 2011). Participants in the current study include adolescents who may carry weapons for self-defense, to perpetrate violence, or both. As ARPVG adolescents have greater likelihoods of being threatened/injured with a weapon and feeling unsafe, as well as serious physical fighting, self-defense and perpetrating violence may both contribute to weapons-related violence among those with gaming problems. Adolescent perpetrators of violence and bullying are commonly also victims, and may carry a weapon after a violent episode (Erickson et al., 2006; Leary et al., 2003). Importantly, adolescents who have perpetrated and were victims of cyberbullying appear at higher risk of later reporting weapon-carrying (Lu et al., 2019). As digital media and internet gaming become increasing popular, further research should examine motivations underlying weapon-carrying and other violence-related phenomena as they relate to gaming in adolescents.

While video-gaming duration was associated with each violence-related measure when adjusting for demographic characteristics, physically violent experiences (being threatened/injured with weapon, physical fighting, and serious fighting leading to injury) were no longer significant after adjusting for use of tobacco, marijuana, alcohol, and other drugs, and depression. These commonly associated covariates may in part account for associations between gaming duration and arguably more serious forms of violence. Jessor's problem behavior theory proposes that risky behaviors in youth including weapon-carrying, substance use, and gaming may be interrelated and co-vary as part of a multi-problem behaviors syndrome (Donovan and Jessor, 1985; Donovan et al., 1999; Hull et al., 2014). Indeed, amount of gaming is related to alcohol and tobacco use, early initiation of alcohol use, and depression and anxiety severity (Denniston et al., 2011; Maras et al., 2015; Raiff et al., 2012; Wenzel et al., 2009). Additionally, individuals with substance-use disorders and depression are more likely to perpetrate physical violence and partner violence (Franco et al., 2019; Oram et al., 2014). Future studies should test potential mediating effects of substance-use and affective disorders on relationships between gaming behaviors and serious violence.

Violent-game-playing duration has been associated with a four-fold increase in weapon-carrying, and concurrently, the higher prevalence of weapon-carrying among those who experienced victimization (Ybarra et al., 2014). Additionally, duration of playing violent video-games, rather than all games, has been related to physical aggression (Lemmens et al., 2011). Extending these findings, reduced associations between duration of playing any video-games and physical aggression, but not weapon-carrying and feeling unsafe, suggest that adolescents who game extensively may be especially vulnerable to perceived insecurity and weapon-carrying, whereas those exposed to or perpetrating overt physical violence may be attuned to violent game-content beyond co-occurring health and functioning differences. Moreover, highly involved video-gamers may also struggle with substance-use and affective problems that coincide with encountering serious physical violence. The findings suggest that prevention efforts should focus on bolstering health and functioning in video-gaming and physically violent youth.

Consistent with previous evidence (Lemmens et al., 2011), problem-gaming severity was associated with longer gaming duration. While they are related, problematic and extensive gaming are separable constructs, and different mechanisms may underlie person-specific

responses (Billieux et al., 2019; Lemmens et al., 2011). Moderation results indicate that at higher levels of sensation-seeking, but not impulsivity, ARPVG adolescents carried weapons more frequently. Among different personality traits, aggression and sensation-seeking, but not impulsivity had shown associations with online gaming addiction (Mehroof and Griffiths, 2010). Sensation-seeking portends aggressive behaviors, and depends on motivational mechanisms, autonomic responses, and reward sensitivity, which may contribute to reinforcement-seeking in problem-gaming adolescents (Billieux et al., 2015). APRVG adolescents who possess vulnerabilities in sensation-seeking, and potentially other executive control deficiencies, may have greater risk for weapons-carrying. Furthermore, meta-analyses assessing the contributions of playing video-games, particularly with violent content, to aggression produced opposing conclusions (Ferguson, 2015; Mathur and VanderWeele, 2019; Prescott et al., 2018). Inasmuch as sensation-seeking portended greater weapon-carrying in at-risk/problem gamers, problem-gaming and violent individuals have common vulnerabilities in executive control (Dong and Potenza, 2014; Rohlf et al., 2018). Hence, understanding the moderating role of executive control may clarify the debate over the link between video-game playing and aggression. Further confirmatory analyses may focus on the different dimensions of executive control and serious types of physical violence. Together, the findings suggest that it may be important for prevention efforts to focus on potential health behaviors that may distinguish problematic gaming from extensive engagement in relationships with aggressive behaviors in youth with different sensation-seeking tendencies.

Study limitations warrant discussion. We did not assess types of games (e.g., violent, non-violent). Violent and non-violent games have been previously linked to weapon-carrying (Ybarra et al., 2014). While violence-related measures included items for threatening/injuring and feeling unsafe, they did not account for potential motivations underlying each behavior. Self-reported data may be subject to over- or under-reporting. Data from other individuals (including parents and teachers) were not available to verify self-reports. Although the study utilized an epidemiological sample collected from high-schools across Connecticut, generalizability to other jurisdictions may be limited. Furthermore, the cross-sectional data limit interpretations of directional pathways between measures. Longitudinal approaches should examine mechanisms underlying observed relationships.

This is one of the first studies to demonstrate that adolescent with ARPVG, compared to those with LRVG and NVG, were more likely to report weapon-carrying, weapons-related threats, serious fighting with injury, and feeling unsafe. While related to problem-gaming severity, LD-VG in adolescents had stronger associations with weapon-carrying and feeling unsafe beyond potential effects of health/functioning differences. Furthermore, sensation-seeking specifically moderated associations between problem-gaming severity and weapon-carrying. These findings reinforce the need to better understand the differential impact and pathways of problematic involvement and extensive engagement in video-gaming in the etiology of physical violence and weapons-related violence. Prevention efforts in schools and communities that focus on problem-gaming severity in addition to volume of gaming, and underlying sensation-seeking vulnerabilities, may be important for ameliorating risks for violent behaviors and serious injury.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Mean ($\pm$ standard error of the mean - SEM) weapon-carrying frequency in adolescents with non-video-gaming, low-risk video-gaming, and at-risk/problem video-gaming stratified by sensation-seeking levels.

Table 1.

Demographic characteristics between problem-gaming severities

Variable	NVG (N=1915)		LRVG (N=1068)		ARPVG (N=913)		χ^2	p
	N	%	N	%	N	%		
Gender							963.09	<.001
Male	402	21.1	634	60.2	713	79.4		
Female	1500	78.9	420	39.8	185	20.6		
Race/Ethnicity								
Caucasian							10.18	0.01
No	408	21.4	208	19.7	229	25.5		
Yes	1497	78.6	850	80.3	669	74.5		
African-American							3.32	0.19
No	1726	90.6	968	91.5	800	89.1		
Yes	179	9.4	90	8.5	98	10.9		
Asian							19.58	<.001
No	1856	97.4	1011	95.6	845	94.1		
Yes	49	2.6	47	4.4	53	5.9		
Hispanic							1.29	0.52
No	1636	85.9	922	87.1	768	85.5		
Yes	269	14.1	136	12.9	130	14.5		
Other							6.85	0.03
No	1602	87.3	909	88.6	743	84.6		
Yes	233	12.7	117	11.4	135	15.4		
Grade							28	<.001
9th	518	27.1	363	34.1	315	34.5		
10th	530	27.7	296	27.8	244	26.8		
11th	545	28.5	253	23.8	228	25		
12th	318	16.6	151	14.2	125	13.7		
Family Structure							7.5	0.11
One parent	455	24	230	21.9	189	21		
Two parents	1345	71.1	780	74.1	658	73.1		
Other	92	4.9	42	4	53	5.9		
Weapon Carrying							150.21	<.001
No	1666	87	838	78.5	616	67.5		
Yes	249	13	230	21.5	297	32.5		
Felt Unsafe							59.52	<.001
No	1802	94.1	1005	94.1	788	86.3		
Yes	113	5.9	63	5.9	125	13.7		
Threatened/Injured with Weapon							83.56	<.001
No	1679	87.7	903	84.6	677	74.2		
Yes	236	12.3	165	15.4	236	25.8		

Variable	NVG (N=1915)		LRVG (N=1068)		ARPVG (N=913)		χ^2	p
	N	%	N	%	N	%		
Physical Fighting							66.17	<.001
No	1373	71.7	690	64.6	515	56.4		
Yes	542	28.3	378	35.4	398	43.6		
Fighting Injury							67.76	<.001
No	1796	93.8	999	93.5	777	85.1		
Yes	119	6.2	69	6.5	136	14.9		

Note: Non-Video Gaming (NVG), Low-Risk Video Gaming (LRVG), At-Risk/Problem Video Gaming (ARPVG)

Table 2:

Adjusted odds ratios of violence-related measures between problem-gaming severities

Violence Indicators	NVG vs. LRVG		NVG vs. ARPVG		LRVG vs. ARPVG	
	Odds Ratio	95%CI	Odds Ratio	95%CI	Odds Ratio	95%CI
Weapon Carrying	1.26	0.91–1.74	1.78 ^{***}	1.26–2.52	1.48 [*]	1.06–2.07
Felt Unsafe	1.52	0.85–2.73	3.22 ^{***}	1.76–5.87	2.19 [*]	1.15–4.15
Threatened/Injured with Weapon	1.26	0.89–1.78	1.82 ^{**}	1.25–2.63	1.62 ^{**}	1.12–2.35
Physical Fighting	1.04	0.80–1.36	1.13	0.83–1.54	1.12	0.82–1.52
Serious Fighting Leading to Injury	0.65	0.36–1.15	1.38	0.80–2.39	2.45 ^{**}	1.30–4.62

Note:

^{*}
p .05,^{**}
p .01,^{***}
p .001. Non-Video Gaming (NVG), Low-risk Video Gaming (LRVG), At-risk/Problem Video Gaming (ARPG). Odds Ratios adjusted for demographics, substance-use, and depression.

Table 3:

Chi-squares for violence-related measures between gaming durations

Violence Measures	Shorter Duration Video-Gaming		Longer Duration Video-Gaming		χ^2	p
	N	%	N	%		
Weapon Carrying					66.56	<.001
No	1348	76.2	106	50		
Yes	421	23.8	106	50		
Felt Unsafe					83.65	<.001
No	1638	92.6	155	73.1		
Yes	131	7.4	57	26.9		
Threatened/Injured with Weapon					42.61	<.001
No	1447	81.8	133	62.7		
Yes	322	18.2	79	37.3		
Physical Fighting					22.64	<.001
No	1108	62.6	97	45.8		
Yes	661	37.4	115	54.2		
Serious Fighting Leading to Injury					66.06	<.001
No	1620	91.6	156	73.6		
Yes	149	8.4	56	26.4		

Table 4:

Adjusted odds ratios of violence-related measures between gaming durations

Violence Measures	<u>Longer- vs. Shorter-Duration Video-Gaming</u>	
	Odds Ratio	95%CI
Weapon Carrying	2.73 ***	1.51–4.94
Felt Unsafe	3.92 **	1.51–10.17
Threatened/Injured with a Weapon	1.29	0.67–2.45
Physical Fighting	1.5	0.83–2.71
Serious Fighting Leading to Injury	1.72	0.66–4.49

Note:

*
p .05,**
p .01,***
p .001. Odds ratios adjusted for demographics, substance-use, and depression.

Table 5.

Moderating effects of sensation-seeking and impulsivity on problem-gaming-severity and gaming-duration associations with weapon-carrying

Model	Weapon-Carrying	
	b(se)	95%CI
<u>Problem-Gaming Severity</u>		
<i>Moderator: Sensation Seeking</i>		
Model Summary: $R^2=0.19$, $f(18, 2345)=20.81^{***}$; $R^2=.01$, $f(2, 2345)=5.59^{**}$		
LRVG vs. NVG	-.004 (.05)	-.11, .10
ARPPVG vs. NVG	.18 (.07) ^{**}	.04, .31
Sensation-Seeking	.01 (.01)	-.01, .03
Sensation-Seeking and [LRVG vs. NVG] Interaction	.01 (.02)	-.03, .05
Sensation-Seeking and [ARPPVG vs. NVG] Interaction	.07 (.02) ^{***}	.03, .11
Model Summary: $R^2=0.19$, $f(16, 1192)=14.00^{***}$; $R^2=.004$, $f(1, 1192)=4.92^*$		
ARPPVG vs. LRVG	.19 (.07) ^{**}	.05, .33
Sensation-Seeking	.04 (.01) ^{**}	.02, .07
Sensation-Seeking and [ARPPVG vs. LRVG] Interaction	.06 (.03) [*]	.01, .11
<i>Moderator: Impulsivity</i>		
Model Summary: $R^2=.19$, $f(18, 2380)=20.87^{***}$; $R^2=.001$, $f(2, 1380)=.18$		
LRVG vs. NVG	.04 (.05)	-.07, .14
ARPPVG vs. NVG	.17 (.07) [*]	.03, .30
Impulsivity	.03 (.01) [*]	.003, .06
Impulsivity and [LRVG vs. NVG] Interaction	.03 (.02)	-.02, .08
Impulsivity and [ARPPVG vs. NVG] Interaction	.05 (.03)	-.01, .10
Model Summary: $R^2=.18$, $f(16, 1214)=14.12^{***}$; $R^2=.002$, $f(1, 1214)=.21$		
ARPPVG vs. LRVG	.14 (.07)	-.003, .29
Impulsivity	.06 (.02) ^{***}	.03, .09
Impulsivity and [ARPPVG vs. LRVG] Interaction	.01 (.03)	-.05, .09
<u>Gaming Duration</u>		
<i>Moderator: Sensation-Seeking</i>		
Model Summary: $R^2=.20$, $f(16, 1192)=15.04^{***}$; $R^2=.002$, $f(1, 1192)=1.80$		
Gaming Duration	.68 (.17) ^{***}	.35, 1.00
Sensation-Seeking	.04 (.01) ^{**}	.02, .07
Sensation-Seeking and Gaming Duration Interaction	.07 (.05)	-.03, .16
<i>Moderator: Impulsivity</i>		
Model Summary: $R^2=.20$, $f(16, 1214)=14.93$; $R^2=.001$, $f(1, 1214)=.13$		
Gaming Duration	.63 (.17) ^{***}	.30, .96
Impulsivity	.05 (.02) ^{**}	.02, .08
Impulsivity and Gaming Duration Interaction	.02 (.07)	-.11, .15

Note:

*
p .05,

**
p .01,

p .001. Non-Video Gaming (NVG), Low-risk Video Gaming (LRVG), At-risk/Problem Video Gaming (ARPVG)

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