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Does Video Game Use Exacerbate the Relation Between Neurophysiological Deficits and ADHD Symptoms in Children and Adolescents?

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DOES VIDEO GAME USE EXACERBATE THE RELATION BETWEEN NEUROPSYCHOLOGICAL DEFICITS AND ADHD SYMPTOMS IN CHILDREN AND ADOLESCENTS?

by

James Kenneth Goodlad III

Abstract of a Dissertation
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ABSTRACT

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Attention-deficit/hyperactivity disorder (ADHD) is diagnosed based on behavioral symptoms but is thought to have a significant heritable neurological basis, and several brain structures have been implicated. Recent research has focused on the role of environmental factors that may influence the behavioral expression of inattention and hyperactivity-impulsivity in children and teens, particularly when a biological predisposition exists. This study sought to broaden the literature base by examining the extent to which one environmental factor—video game use—moderated the relation between neuropsychological deficits in attention and inhibition and the behavioral symptoms of ADHD. It was hypothesized that gaming frequency and duration as well as deficits in neuropsychological functioning would relate positively to ADHD symptoms. Twenty-five participants (age 10 to 17 years) recruited from the community were administered four neuropsychological tests of attention and behavioral disinhibition and reported on gaming habits while parents completed measures of ADHD symptoms and also reported on the child's video gaming habits. Moderated multiple regression analyses were used to examine the moderating effects of gaming frequency and gaming duration on the association between neuropsychological deficits and ADHD symptom domains beyond control variables (i.e., age, gender, race/ethnicity, family income, IQ). Gaming duration was significantly related to symptoms of inattention. Neuropsychological deficits were not significantly related to symptoms of inattention or hyperactivity-impulsivity. However, the interaction of gaming frequency and sustained attention deficits predicted significant variability in inattention, and the interaction of gaming frequency and set shifting deficits significantly predicted symptoms of hyperactivity-impulsivity. These findings underscore the importance of continued research on environmental factors, such as video game use, that may exacerbate a biological predisposition for ADHD symptoms in children.

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A Dissertation
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CHAPTER I

INTRODUCTION AND REVIEW OF RELATED LITERATURE

Attention-deficit/hyperactivity disorder (ADHD) is a set of developmentally inappropriate behavioral symptoms, including clinically significant problems with inattentiveness, hyperactivity, and impulsivity. ADHD is one of the most commonly diagnosed childhood disorders, with prevalence rates in the United States ranging from 3 to 7%. World prevalence rates are also estimated at around 5.3%, making ADHD among the most prevalent disorders in children worldwide (Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). According to a recent report from the Centers for Disease Control (CDC, 2010), ADHD appears to be on the rise, with prevalence rates based on parent-reported diagnoses increasing approximately 22% during a four-year period, and a cross-sectional study of over 68,000 children between 5 and 17 indicated that approximately 10% of the children were classified as having ADHD (Lingineni et al., 2012).

In addition, ADHD is associated with a number of other negative outcomes in children and adolescents. For example, some studies have demonstrated poorer cognitive performance on standardized tests, finding significant differences between individuals with ADHD and healthy controls (e.g., Weber, Jourdan-Moser, & Halsband, 2007). Children diagnosed with ADHD generally experience more academic problems and academic underachievement compared to their typically-developing peers (e.g., Barry, Lyman, & Klinger, 2002; Frazier, Demaree, & Youngstrom, 2004). ADHD is also often comorbid with other externalizing disorders like oppositional defiant disorder and conduct disorder (e.g., Freitag et al., 2012). A diagnosis of ADHD given during childhood is associated with poorer outcomes in adolescence across multiple domains, including increases in both externalizing and internalizing symptoms, as well as poorer social skills and peer regard (Lee, Lahey, Owens, & Hinshaw, 2008).

Electronic media use like television and movies (i.e., screen media use) is one set of environmental variables that has also been implicated in negative outcomes in children and adolescents (e.g., Coyne, Robinson, & Nelson, 2010; Martins & Wilson, 2012), although some reviews dispute these claims, pointing out methodological flaws (Mitrofan, Paul, & Spencer, 2009). Other research has shown that increased screen media use (e.g., Landhuis, Poulton, Welch, & Hancox, 2007; Zimmerman & Christakis, 2007) is positively associated with ADHD symptomatology. A recent meta-analysis, which included a number of studies discussed here, found a positive association between screen media use and ADHD-related symptoms of inattention in children (Nikkelen, Valkenburg, Huizinga, & Bushman, 2014), though most studies in the meta-analysis dealt primarily with television rather than video games. Video games are another example of electronic media that have recently come under fire by parents, teachers, and psychologists for the negative outcomes associated with their use or overuse (e.g., Sun, 2011). Initially available in the 1970s and created through a merging of newly developed computer technology and video media (Tolchinski & Jefferson, 2011; Williams, 2006), over the last few decades, the soft glow of classic pixelated arcade games has been transformed into cutting-edge and ultra-realistic environments, including sports fields, war zones, outer space, and combat arenas where players are almost constantly bombarded with points, power-ups, unlockable rewards, and increasingly social online content. Video game use has increased significantly since its inception, as approximately

97% of adolescents in the United States have played some type of video games, including console, arcade, portable, computer, or online games (Lenhart et al., 2008).

As video games have increased in popularity over the years, so has the research documenting their associated negative outcomes. Although some studies have demonstrated the positive effects of certain video games, like increased prosocial thoughts and behavior (e.g., Gentile et al., 2009; Greitemeyer & Osswald, 2011) or a reduction in hostility and increase in positive affect (Saleem, Anderson, & Gentile, 2012), most have extrapolated positive associations between violent video games—consistently among the more popular genres of game—and increased aggressive behavior, aggressive thoughts, and increased physiological arousal in children as a result of playing the game (e.g., Anderson & Bushman, 2001; Anderson, Gentile, & Buckley, 2007; Fischer, Aydin, Kastenmüller, Frey, & Fischer, 2012). Some research even indicates that prolonged exposure to video games with violent and aggressive content is associated with increased aggression later in adolescence (e.g., Willoughby, Adachi, & Good, 2012).

Recently, a number of studies have found significant positive associations between frequency and duration of video game use and ADHD symptoms as measured by parent and teacher checklists (e.g., Gentile, Swing, Lim, & Khoo, 2012; Swing, Gentile, Anderson, & Walsh, 2010), and as will be reviewed later, a number of theories exist explaining this consistent positive association. Few studies examining the association between video games and ADHD symptoms consider the interaction of video game use with aspects of executive functioning as measured by neuropsychological tests. Therefore, the overall aim of the current study was to examine how the frequency and duration of video game use as well as the type of games played moderate the relation between neuropsychological deficits in various aspects of executive functioning and the behavioral symptom domains of ADHD. This study investigated whether more frequent and/or longer gaming exacerbates the behavioral manifestation of executive dysfunction. As an exploratory research question, this study also attempted to clarify which games are the most harmful to the behavioral manifestation of executive dysfunction as well as which, if any, types of video games attenuate the relation between executive dysfunction and ADHD symptoms.

Attention-Deficit/Hyperactivity Disorder

Attention-deficit/hyperactivity disorder (ADHD) is considered to be both a behavioral and neurological disorder composed of problems with executive functioning and specific behavioral deficits, including inattentiveness as well as hyperactive and impulsive behaviors (Barkley, 1997b). ADHD was first described by George Still and Alfred Tredgold (Barkley, 1998). Children described by Still demonstrated a variety of problematic behaviors frequently associated with ADHD, including aggression, defiance, excessive emotionality, and problems with sustained attention. According to Still and Tredgold, these children exhibited a “defect in moral control” and appeared to be motivated only by immediate gratification. Initially, hyperactive behaviors were the focus of ADHD (e.g., Chess, 1960), but later problems with attention and impulse control were thought to be of equal or greater importance (e.g., Douglas, 1972).

According to the most recent version of the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5; APA, 2013), to meet criteria for a diagnosis of ADHD, symptoms of inattention or hyperactivity-impulsivity must cause clinically significant impairment across more than one setting (e.g., school, home, workplace) and be inconsistent with developmental level. Symptoms must also have an onset prior to age 12 years. Currently, there are three subtypes of ADHD, including Predominantly Inattentive Presentation (ADHD-PI), Predominantly Hyperactive/Impulsive Presentation (ADHD-PH), and Combined Presentation (ADHD-C). A diagnosis of ADHD-PI requires that an individual meet at least six criteria related to inattentive behavior for a period of at least six months without meeting six hyperactive-impulsive criteria. A diagnosis of ADHD-PH requires that an individual meet at least six criteria related to hyperactive and impulsive behavior over a period of at least six months without exhibiting six inattentive symptoms. A diagnosis of ADHD-C is given if an individual meets criteria for both inattentive and hyperactive-impulsive behavior for at least six months.

Barkley's Model of ADHD

Barkley's (1997a) model of ADHD is among the most well-known and comprehensive. This model of ADHD emphasizes the impairments in an individual's ability to inhibit his or her own behavior as primary. Therefore, ADHD can be conceptualized as a "developmental delay in response inhibition" (Barkley, 1997a, p. 226), wherein the individual's impulsive response to a stimulus is associated with further executive functioning and behavioral problems. Furthermore, this chain of behavioral problems begun by difficulty inhibiting a response may also be responsible for difficulty in activities requiring sustained attention and executive functioning (Barkley, 1997b).

Because behavioral inhibition is central to this particular model of ADHD, it requires further explanation. Behavioral inhibition can be conceived as three separate processes. First, an individual must inhibit a prepotent response (i.e., a behavioral response that has a history of being reinforced almost immediately) to a stimulus or event. Next, the individual must stop ongoing responses to create a period of delay between the original stimulus and response. Finally, the individual must protect this delay from competing responses until self-directed actions allow the individual to perform the most effective goal-directed response (Barkley, 1997b). Individuals with ADHD have difficulty inhibiting prepotent responses and protecting the stimulus-response delay, decreasing the likelihood that self-directed actions or thoughts will allow them to select the most appropriate goal-oriented behavior.

In addition to difficulties in inhibiting prepotent responses, difficulty with response inhibition experienced by individuals with ADHD often leads to impaired executive functioning in areas related to self-regulation (Barkley, 1997b). Self-regulation refers to any behavior or chain of behaviors that affects an individual's response to a stimulus based on future consequences of the event (e.g., Kanfer & Karoly, 1972). These behaviors are not always observable and may be cognitions or thoughts related to behavior, although behavioral impulse control is more predictive of ADHD than is cognitive impulse control. It is important to note that individuals with ADHD often have difficulty weighing the immediate and delayed consequences of a particular behavior (Barkley, 1997b), instead focusing on the immediate reward or punishment associated with the behavior.

According to Barkley's (1997b) model, four executive functions are directly affected by behavioral inhibition and its effects on self-regulatory actions, including self-regulation of affect, motivation, and arousal; the internalization of speech; the process of reconstitution (i.e., breaking down aspects of stimuli and recombining them in novel ways to inform goal-directed behavior); and working memory. The latter, working memory, is perhaps the most pertinent of the four executive functions in Barkley's model to problems with attention. In Barkley's (1997b) model, working memory refers to an individual's ability to hold information, images, or events within the mind, manipulate this data, and then use these manipulated representations for goal-directed behavior. However, for information to be stored for manipulation and use, the individual must first pay attention to it. William James wrote in 1890 that "the essential achievement of the will, in short, when it is most 'voluntary,' is to *attend* to a difficult object and hold it fast before the mind" (James, 1950, p. 815). It is not a coincidence that measures of working memory often correlate highly with measures of attention (e.g., Mariani & Barkley, 1997) and that selective and sustained attention are thought to be significant components of working memory (e.g., Gau & Shang, 2010). In ADHD, however, a lack of response inhibition leads to impulsive behaviors that disrupt sustained attention and make it difficult for an individual to selectively attend to a target stimulus (Barkley, 1997b).

It is important to remember that one of the most significant shortcomings of Barkley's (1997b) model of ADHD is that it does not account for primarily inattentive behaviors without hyperactivity or impulsivity. In that model, Barkley explains that inattention associated with ADHD is more of a secondary symptom than a primary one, and "a consequence of the impairment that poor behavioral inhibition and interference control create in the self-regulation or executive control of behavior" (Barkley, 1997b, p. 84). Early evidence has shown some differences between the Predominantly Inattentive subtype and Combined or Predominantly Hyperactive-Impulsive subtypes in executive functioning deficits. For example, Goodyear and Hynd (1992) found that individuals with an inattentive diagnosis of ADHD showed deficits in selective attention and the speed at which they process information, whereas individuals with a hyperactive-impulsive or combined diagnosis of ADHD were more likely to experience deficits in sustained attention, behavioral inhibition, and affect regulation. This research appears to support Barkley's theory of ADHD as well as the notion that ADHD-PI may, in fact, be a separate disorder (see also: McBurnett, Pfiffner, & Frick, 2001).

Additionally, the question of whether or not ADHD is best conceptualized as a distinct categorical group or as occurring on a spectrum—or dimensionally—has been recently examined. Although ADHD is currently diagnosed and treated categorically, several taxometric analyses have revealed evidence to the contrary. Haslam and colleagues (2006) conducted a taxometric analysis of both children and adolescents and determined that ADHD better fits a dimensional rather than categorical model. Frazier, Youngstrom, and Naugle (2007) also examined the latent structure of ADHD in a clinical sample and found no significant evidence for a taxometric or categorical representation of the disorder, nor evidence for the idea that ADHD subtypes are qualitatively distinct from one another. More recently, Marcus and Barry (2011) conducted a taxometric analysis of ADHD in a general population sample and found support for a dimensional model. Therefore, the current study used a community sample of children and adolescents and treated ADHD symptomatology as a continuous variable, as it appears to naturally occur along a continuum. Furthermore, treating the two symptom domains of ADHD as dimensional is most appropriate for community samples of children. In this case it is likely that many children will experience some problems with inattention or hyperactivity-impulsivity but fewer will meet full diagnostic criteria for the disorder (Baldwin & Dabbs, 2008).

Neuropsychological Deficits and ADHD

Although most diagnoses of ADHD are based upon parent and teacher ratings or direct observation, Goldstein and Naglieri (2008) have pointed out that ADHD is "a problem occurring at the point of performance [that] well defines a disorder of executive functioning" (p. 861). Executive functions, as defined by Biederman and colleagues (2008) are "a group of higher order mental processes that direct an individual's thought, action, and emotion" (p. 45). Thus, consistent with Barkley's (1997b) model, ADHD is a breakdown of executive functions like response inhibition, leading to further disruptions of normal executive functioning, leading to subsequent behavioral symptoms. Therefore, one approach to the study of ADHD is to attempt to examine firsthand the deficits in executive functioning that are thought to be related to behavioral manifestations of the disorder, including an investigation of factors that may increase the likelihood of such manifestations.

Frazier and colleagues (2004) conducted a meta-analysis of studies published up to October 2002 to determine the average effect sizes of laboratory neuropsychological tests and their relation to behaviorally measured ADHD. Unfortunately, due to the limited number of studies using ADHD-PI groups, Frazier and colleagues may have lacked an ADHD-PI subject pool large enough for accurate conclusions about this group. The meta-analysis revealed that, overall, neuropsychological measures tapping into executive functions thought to be associated with ADHD (e.g., selective attention, sustained attention, set shifting, and behavioral inhibition) better discriminated individuals with ADHD from those without a diagnosis. The results also demonstrated that not all neuropsychological measures of executive functions equally discriminate those with

ADHD and typically-developing groups. For example, continuous performance tasks outperformed some aspects of the Wisconsin Card Sort Task and Stop Signal Task (Frazier et al., 2004). However, this meta-analysis was not organized by particular executive dysfunctions and was meant to compare general neuropsychological performance (as a total factor) with other deficits common to ADHD, like cognitive and academic performance. It must be stated that an important gap throughout this literature is that most studies do not separate different groups of children with ADHD, and few studies specifically examine ADHD-PI groups, making it more difficult to determine which neuropsychological tests best differentiate between subtypes of ADHD. Likewise, based on current ADHD diagnostic criteria (APA, 2013), participants with a large number of hyperactive-impulsive symptoms may be included in ADHD-PI groups even when they were excluded from hyperactive-impulsive and combined presentation groups. The current study seeks to examine these associations while allowing ADHD symptoms to vary dimensionally as opposed to treat them categorically.

Although these nuances are not well captured in Frazier et al.'s (2004) meta-analysis of neuropsychological performance as associated with ADHD, it is important to consider that there are several different types of attention, and some fMRI research substantiates the idea of multiple "attention systems" (e.g., Konrad et al., 2006). Although these different systems were initially thought to be associated with certain parts of the brain, more recently, they are believed to be networks within the brain (Reuda, Posner, & Rothbart, 2005). Attention, as a neuropsychological construct, may be voluntary or involuntary, oriented toward thoughts, actions, or perceptions, and spread across a number of tasks or focused on one task (Shallice, Stuss, Alexander, Picton, &

Derkzen, 2008). There are several different components of attention that serve different functions in orienting and focusing one's mental resources on a stimulus or response, including selective attention, sustained attention, and set shifting.

Sustained attention involves an individual's ability to maintain concentration or focus on a single stimulus for an extended period of time. This type of attention is similar to the idea of vigilance, one of Posner and Petersen's (1990) three neural networks of attention. The capacity for selective attention to a stimulus may be a prerequisite to being able to maintain attention on a singular stimulus. Huang-Pollock, Nigg, and Halperin (2006) examined Posner and Petersen's (1990) theory of the vigilance attention system (i.e., sustained attention). The authors sought to differentiate children with ADHD-PI from those with ADHD-C (and from typically-developing children) on the basis of their performance on sustained attention tasks. Using a modified version of the continuous performance task (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), the authors found deficits in attentional vigilance (i.e., sustained attention) in both subtypes of ADHD compared to controls as evidenced by weaknesses in inattentive errors, response variability, and increased errors over time on the CPT. The authors did not report any differences between the subtypes in sustained attention performance, suggesting that their findings support the idea that ADHD-C and ADHD-PI share similar neuropsychological deficits in vigilance and sustained attention (Huang-Pollock et al., 2006).

Kiliç, Sener, Koçkar, and Karakas (2007) examined sustained attention in children diagnosed with ADHD (limited to the ADHD-C subtype only). Using a verbal and non-verbal cancellation task purported to be related to sustained attention, the authors found that children in the ADHD-C group performed significantly worse on the task than controls. These children had slower reaction times and higher rates of omission errors on the three parts of the task that measured sustained attention (a fourth part, based on errors of commission, measured impulsive responses and behavioral disinhibition). This study is particularly interesting, as it included attention tasks based around different sensory modalities (e.g., visual, auditory), which is pertinent to the current study, as video games target both visual and auditory modalities as well. Findings demonstrated that children with ADHD show deficits in both visual and auditory working memory and sustained attention (Kiliç et al., 2007) and that their worse performance on visual attention tasks compared to auditory tasks is evidence for the idea that visual-cognitive tasks require more sustained attention than audio-cognitive tasks, as seen in fMRI studies (Crottaz-Herbette, Anagnoson, & Menon, 2004). Unfortunately, Kiliç et al. (2007) did not include an ADHD-PI comparison group to determine differences between the two ADHD subtypes in sustained attention performance.

Biederman and colleagues (2008) used tests of oral arithmetic and digit span (also referred to as the Freedom from Distractibility Index of the WISC-III) as an estimate of working memory as well as a continuous performance test as a more direct measurement of sustained attention in their longitudinal study of neuropsychological performance in girls with and without ADHD. According to the results, the stability of executive functioning deficits was highest for tests of working memory, which the authors point out is most affected by sustained attention. Additionally, it is important to note that sustained attention (as measured by a continuous performance task) was the only measure of executive function to have a significant interaction with age. Specifically, there were deficits in the 12- to 16-year-old girls but not in older girls. According to the authors, it is possible that the continuous performance task used in the study is only sensitive in distinguishing between girls with ADHD and non-ADHD controls at younger ages. Unfortunately, the authors did not differentiate girls with ADHD by subtype, as girls with ADHD are more likely to be given a diagnosis of ADHD-PI (e.g., Biederman et al., 2002).

Weber et al (2007) found some differences among ADHD-PI, ADHD-C, and healthy control groups on tasks of sustained attention and working memory. The authors compared a group of children diagnosed with ADHD to a separate group of children who showed attention problems in only one setting (e.g., only at school). Weber and colleagues reported group differences in working memory (similar to auditory and visual sustained attention) between those diagnosed with ADHD and those who did not meet full criteria. Among the subtypes, Weber and colleagues found that the ADHD-C group performed within normal limits in attention whereas the ADHD-PI group made more errors on working memory tasks. Unfortunately, Weber et al. (2007) did not report the magnitude of the differences in the study, as the test of neuropsychological difference was not the main focus of their research. Without specific statistical evidence available, the authors' conclusions are not as clear.

Overall, neuropsychological studies of executive functioning have found positive associations between deficits in sustained attention and ADHD symptoms as reported by parents and teachers, although few studies have differentiated between ADHD-PI and ADHD-C—leaving the question of how sustained attention may differentially relate to the ADHD symptom domains unanswered. Furthermore, no studies have examined how this association might be moderated by environmental variables such as video game use. In addition to examining the relation of sustained attention to symptom domains of ADHD, the current study examined how video game use might moderate the relation between poor neuropsychological performance on sustained attention tasks and ADHD symptoms.

Selective attention refers to an individual's ability to focus on a single event or stimulus in the environment while filtering out irrelevant stimuli, thus preventing the individual's response to the target stimulus from being impacted by extraneous information. This type of attention is similar to the concept of an "orienting system," another neural network of attention as proposed by Posner and Petersen (1990). Selective attention is most often conceptualized as a system of visual or auditory attention but can also involve spatial information (e.g., Green & Bavelier, 2006). Many studies have specifically examined selective attention among children with ADHD to determine if deficits in this system of attention are related to the behavioral symptoms of the disorder as well as whether significant and meaningful differences exist between children with ADHD and non-ADHD children in selective attention performance.

Kiliç and colleagues (2007) also measured the differences in selective attention between children with an ADHD-C diagnosis and non-ADHD controls using the Stroop task (Stroop, 1935), a well-known and studied neuropsychological task of selective attention (as well as response inhibition). This research used a modified version of the Stroop task specifically standardized for Turkish children but procedurally very similar to the original task. The authors found that children with ADHD performed significantly worse than controls on several subtests of the Stroop task, including naming the color of colored circles, naming the color of colored neutral words, and naming the color of colored words where color and meaning are incongruent for some of the words (i.e., the interference condition). These three subtests appear to tap into a child's ability to selectively attend to a particular aspect of the stimulus. Although these findings are largely consistent with earlier findings that children with ADHD usually perform worse on the Stroop task than others (e.g., Van Mourik, Oosterlaan, & Sergeant, 2005), these authors did not appear to control for IQ or other variables (e.g., reading ability) that might impact performance on this task.

In another study of ADHD and selective attention that also considered the effects of motivation, reward, and response cost on performance as well as possible differences among subtypes (ADHD-C versus ADHD-PI), Desman, Petermann, and Hampel (2008) examined errors of omission during a Go/No Go task. Although typically considered a task of behavioral inhibition, these authors interpreted errors of omission on the task as deficits in selective attention (as opposed to errors of commission, which usually imply an impulsive or disinhibited response). The authors did not find support for the idea that children with ADHD-PI make more errors of omission, suggesting no significant differences in selective attention from children with ADHD-C. This lack of group difference occurred across all conditions of reward and response cost. However, children with ADHD-PI did show longer reaction times to stimuli than did children with ADHD-C, giving support to the idea that ADHD-PI is more strongly related to deficits in cognitive processing speed and "sluggish cognitive tempo" (SCT; Desman et al., 2008, p. 499) than behavioral disinhibition. However, it must be noted that the small sample size in this study (N = 12) almost certainly restricts its conclusions.

Biederman et al. (2008) conducted a unique longitudinal study of girls with ADHD that further defines the relation between selective attention deficits and symptoms of ADHD. The authors were interested in examining which specific deficits in executive functioning most profoundly affected and were reliably associated with ADHD, as well as the stability of these deficits over time. As a measure of selective attention, Biederman and colleagues also used the Stroop task, measuring color-word reaction times and interference scores as the dependent variables. Globally, the authors found that 79% of girls with ADHD who met the authors' operational definition of executive functioning deficits at baseline continued to do so after the 5-year follow-up. This finding is important because it demonstrates that executive functioning deficits are a stable and reliable predictor of ADHD in girls. It was also concluded that girls who exhibited problems on at least two measures of executive functioning were considered most at-risk for negative academic outcomes, including the need for special education classes or being required to repeat a grade (Biederman et al., 2004). More specific to selective attention deficits, results from the Stroop task indicated that it reliably differentiated between girls with and girls without an ADHD diagnosis at each time point. Biederman and colleagues determined that deficits in selective attention are relevant to an ADHD diagnosis throughout development.

Goth-Owens, Martinez-Torteya, Martel, and Nigg (2010) also used the Stroop task to differentiate children with ADHD and healthy controls on the basis of selective attention skills, as well as differentiate between primarily inattentive children from children with ADHD-C. In this study, the authors created a study-defined primarily inattentive ADHD group of children (referred to as the "ADD" group) who met full criteria for ADHD-PI and exhibited two or less hyperactive-impulsive symptoms. This research group was a more stringent subset (i.e., including only children who would be considered purely inattentive) of the clinical ADHD-PI group, the latter of which includes children exhibiting up to five symptoms of hyperactivity-impulsivity. Goth-Owens and colleagues (2010) found that their “ADD” group performed worse on the Stroop Task than the ADHD-C group, whereas a DSM-defined ADHD-PI group showed no differences in selective attention and interference control compared to the ADHD-C group.

Other studies have attempted to examine the differences in selective attention among different subtypes. Among them, Huang-Pollock, Nigg, and Carr (2005) used a perceptual load paradigm to determine if dysfunction in selective attention is consistently related to different subtypes of ADHD. Perceptual load, a term from cognitive psychology, is measured by “the amount of potentially relevant information within a display, or by the amount of effort required to process that display” (Huang-Pollock et al., 2005, p. 1212). Depending on the amount of stimuli in a display, certain stimuli are processed automatically while other stimuli are ignored, thus making the construct of the perceptual load an excellent paradigm of selective attention. The authors found no evidence for dysfunctional selective attention in either an ADHD-C or an ADHD-PI group. However, longer reaction times in the task were associated with the ADHD-PI group, again (like Desman et al., 2008) suggesting that the two groups are better differentiated by SCT within a selective attention task than by selective attention deficits per se. Thus, although SCT may be a good predictor of a subgroup of individuals with ADHD-PI (McBurnett et al., 2001), it appears that both ADHD-C and ADHD-PI subtypes are generally equivalent in deficits of selective attention relative to a control group.

Overall, a review of the literature indicates that dysfunction in Posner and Petersen's (1990) orienting system (i.e., selective attention) is highly associated with attentional deficits (but not necessarily hyperactive or impulsive behavior) as reported by parents and teachers on behavioral questionnaires. That is, because deficits have been shown in both the ADHD-C and ADHD-PI subtypes (which both share common symptoms of inattention), it is not entirely clear whether such deficits are related to hyperactive and impulsive symptoms. Research that considers the symptom domains separately and dimensionally to determine how they each relate to selective attention deficits would further inform the literature. Unfortunately, there also appears to be a gap in the literature examining variables that moderate the association between selective attention and ADHD symptoms. Therefore, the current study examined the influence of potential environmental moderators—gaming frequency and gaming duration—on this relation as well as determined the association between these deficits and different ADHD symptom domains.

Set shifting refers to the individual's ability to stop directing attention to one stimulus or task in favor of the next stimulus or task. For example, it may refer to a child's ability to appropriately stop playing a video game and start a new task requiring sustained mental effort (e.g., homework, chores). This type of task may be related to Poser and Petersen's (1990) concept of a selection-for-action, or, executive attention, which allows an individual to evaluate responses to a stimulus, as it involves coordination of goal-direction behavior. From the perspective of Barkley's (1997b) model, set shifting may be related to an individual's ability to inhibit an ongoing response, rather than a prepotent response.

A number of studies have examined set shifting in its ability to differentiate children with ADHD from other types of psychopathology. Marzocchi and colleagues (2008) compared groups of children diagnosed with ADHD, a reading disability (RD), and controls on a number of executive functions thought to be associated with ADHD and RD. The authors, conceptualizing set shifting as an "inhibition of an ongoing response" (p. 544) demonstrated that the ADHD group performed significantly worse on the Wisconsin Card Sort Task (WCST; Berg, 1948). Specifically, children with ADHD perseverated longer on incorrect response styles when the demands of the task changed compared to the RD and control group. Interestingly, this study did not include measures of attention (e.g., sustained or selective attention). The authors based this decision on a meta-analysis by Willcutt, Doyle, Nigg, Faraone, and Pennington (2005) that determined that the major domains of executive dysfunction in ADHD were inhibition, planning, and spatial working memory.

In their longitudinal study of the stability of neuropsychological deficits of girls with ADHD, Biederman and colleagues (2008) also used the WCST as a measure of set shifting, with the number of categories completed, perseverative errors, and non-perseverative errors as the dependent variables. The authors reported that at Time 1, executive problems with set shifting (as measured by WCST performance), were the least stable across time (i.e., children were likely to have fewer problems with set shifting at Time 2). The authors suggested that this finding could possibly be due to a learning effect but also noted that the period between testing was approximately five years for each girl in the study (making that possibility less likely). Thus, problems with set shifting may not be an ongoing problem for individuals with ADHD as are some other aspects of executive functioning.

Gau and Shang (2010) examined the differences between an ADHD group, their undiagnosed siblings, and healthy controls on their performance on a set shifting task. The authors used the Intra-dimensional/Extra-dimensional (IED) shifting task which requires both selective attention and set shifting. The intra-dimensional task required participants to selectively attend to stimuli within a relevant dimension, whereas the extra-dimensional task measured the participants' ability to shift their attention to a new set of stimuli. Performance was based on a number of indices, including number of extra-dimensional shift (EDS) errors, errors made prior to the EDS stage, and total errors. The task appears to be similar to the Wisconsin Card Sort Task in that participants are measured on their ability to avoid perseverating.

The authors reported that children with ADHD made more errors on the IED task compared to healthy controls, indicating that these children had more difficulty switching their attention to a new target. Additionally, Gau and Shang (2010) reported that first degree relatives of those with ADHD also experienced significantly more problems in set shifting despite their lack of a clinical level of ADHD symptomatology. This provides interesting evidence in support of the genetic and heritable nature of ADHD. Unfortunately, this study did not provide information regarding specific ADHD subtypes and did not inform the literature as to whether problems with set shifting are more likely to affect those diagnosed with Predominantly Inattentive, Hyperactive-Impulsive, or Combined type ADHD.

Most of the previous research has positively linked problems with Posner and Petersen's (1990) network of selection-for-action attention (i.e., set shifting) and ADHD symptomatology, and some research has even found that set shifting can differentiate children with ADHD from children with other psychopathological or learning problems. However, few studies examine problems with set shifting in conjunction with other risk factors for ADHD. Additionally, most studies do not differentiate between subtypes of ADHD, and the extent to which executive dysfunctions related to set shifting impact both ADHD-PI and ADHD-C are not well understood. The current study attempted to address these gaps in the literature by clarifying how problems with set shifting predict the different symptom domains of ADHD in children and adolescents while also determining if a potential environmental risk factor (gaming frequency and gaming duration) moderates that association.

Behavioral disinhibition refers to the inability of an individual to inhibit a response to a stimulus. As described above in Barkley's (1997b) model of ADHD, most often this response is a prepotent response to a stimulus rather than an ongoing response, as in set shifting. Because behavioral disinhibition is thought to be the core executive dysfunction in ADHD, it has been heavily studied in children and adults (e.g., Desman et al., 2008).

Desman and colleagues (2008), using modified neuropsychological testing, attempted to differentiate deficits in behavioral inhibition from deficits in motivation. As described above in Barkley's (1997b) model, self-regulation of affect, motivation, and goal-directed behavior is a separate executive function often disrupted by problems with disinhibition. In their review of the literature involving reward and response cost components of behavior inhibition studies (e.g., Gomez, 2003), they concluded that ADHD is "both a generalized inhibitory deficit and a response modulation deficit" (p. 484), as children with ADHD showed more difficulty modifying their responses to tasks despite receiving certain rewards or punishments.

These authors conducted two studies of neuropsychological and self-motivational deficits, one comparing the effects of a motivational Go/No Go task on the performance of an ADHD group and a control group of boys and the second comparing performance on this task between children diagnosed with ADHD-C and ADHD-PI. In their first study, Desman et al. (2008) found that children with ADHD-C had worse inhibitory performance than controls despite the presence of rewards or punishments. In their second study, children with ADHD-C made more errors of commission (i.e., disinhibition errors) than did children with ADHD-PI, suggesting that children with ADHD-PI do not experience the same problems with behavioral disinhibition as do children with ADHD-C—consistent with the theory postulated by Barkley (1997b) and others and underscoring the relation between behavioral disinhibition and hyperactivity-impulsivity.

Kiliç and colleagues (2007) also found that an ADHD-C group had faster reaction times on a test of continuous performance as compared to controls. Furthermore, these authors reported higher rates of errors of commission. Combined with evidence for faster reaction time and total completion time, the authors interpret these findings as higher rates of behavioral disinhibition. These results, along with Desman and colleagues' (2008) findings, are consistent with the idea that children diagnosed with ADHD-PI are more likely to experience cognitive sluggishness than the disinhibited and impulsive behavior associated with an ADHD-C or ADHD-PH diagnosis.

Lambek and colleagues (2010) differentiated children with ADHD into a group with executive functioning deficits (+ EF) and a group without deficits (- EF) based on performance on a number of neuropsychological measures. Using a measure of behavioral disinhibition similar to the Go/No Go task as a dependent variable, post hoc analyses revealed that ADHD + EF children had higher variability of performance on this task compared to ADHD - EF children and controls. The authors interpreted this finding as evidence that behavioral inhibition modulates other executive functions and that poor or inconsistent behavioral inhibition (as measured by high Go/No go performance variability) leads to other behavioral impairments, which is consistent with Barkley's (1997b) model of ADHD. Additionally, the authors found support for the idea that ADHD is not always the result of executive functioning deficits and that ADHD + EF "does not simply constitute the more impaired end of the ADHD distribution" (p. 900), findings which underscore the importance of considering possible moderators in the relation between executive function deficits and ADHD symptoms.

In a study considering possible gender differences in behavioral inhibition across ADHD subtypes, Nigg, Blaskey, Huang-Pollock, and Rappley (2002) found behavioral inhibition tasks to differentiate between ADHD-C and ADHD-PI in boys (with the former having more deficits) but found no differences in girls on the same task. Furthermore, Huang-Pollock et al. (2006) found that children with ADHD-C, but not children with ADHD-PI, had lower response thresholds and higher impulsive responding on a test of continuous performance. Citing Sergeant, Oosterlaan, and van der Meere's (1999) cognitive-energetic model of ADHD, these authors explain that children with ADHD-C experience EF problems in both alertness/arousal as well as activation (i.e., these children display more EF deficits in multiple domains), whereas children with ADHD-PI only display EF dysfunction during tests of alertness (e.g., attention).

Contrary to these findings (e.g., Desman et al., 2008; Huang-Pollock et al., 2006; Nigg et al., 2002), however, Huang-Pollack, Mikami, Pfiffner, and McBurnett (2007) found no significant differences between children in an ADHD-C group and children in an ADHD-PI group in their inability to inhibit impulsive responding. Before the neuropsychological assessment, it was demonstrated through parent and teacher reports that the ADHD-PI and ADHD-C groups differed significantly on inattentive and hyperactive-impulsive symptomatology. Using a Go/No Go reaction time test, despite finding deficits among the two ADHD groups compared to healthy controls, children with ADHD-PI and ADHD-C showed equal behavioral disinhibition.

Of note, the results reported by Huang-Pollock and colleagues (2007) demonstrated that the children with ADHD-PI made more improvements in inhibition in the presence of rewards, but only if a lower reward was given before a higher reward. This finding may provide support for a motivational dysfunction pathway to ADHD as proposed in theories of state regulation (e.g., Sergeant, 2005) and delay aversion (e.g., Sonuga-Barke, 2005). Motivation and reward delay aversion may be of particular relevance for children who engage in behaviors, like video games, that feature strong, salient, or constant rates of reward.

Although behavioral disinhibition may be a key factor underlying symptoms of ADHD, it may not be specific to ADHD. For example, Marzocchi and colleagues (2008) examined differences among children diagnosed with ADHD, reading disorders, and controls. Unexpectedly, they did not find any significant differences among these three groups on an inhibition task called Stop Signal Reaction Time (SSRT) in contrast to other differences found among these three groups on neuropsychological measures of set shifting. The authors suggest that generalized inhibitory functioning alone does not differentiate between ADHD, LD, and control groups, which is consistent with Scheres, Oosterlaan, and Sergeant (2001), who also failed to differentiate behavioral disinhibition between an ADHD group and other externalizing groups like individuals with oppositional defiant disorder (ODD) or conduct disorder (CD). Interestingly, both of these studies used the same SSRT task to measure general inhibitory functioning. Such findings highlight the need to consider multiple potential deficits (as was done in the current study) in an attempt to understand a neuropsychological profile of ADHD, particularly to reveal factors contributing to specific symptom domains of the disorder.

Overall, according to the neuropsychological literature, there is a strong link between behavioral disinhibition and ADHD symptomatology. A significant amount of research supports the idea that behavioral disinhibition may be the principle executive functioning deficit behind subsequent neuropsychological deficits like problems with sustained attention, selective attention, and set shifting that have also been linked to ADHD (Barkley, 1997b). Furthermore, when the entirety of the literature is considered, neuropsychological tests of behavioral inhibition seem to differentiate reliably between the subtypes of ADHD, with ADHD-PI groups showing fewer problems with behavioral disinhibition than ADHD-C groups. Although the preponderance of evidence points to a stronger relation between behavioral disinhibition and hyperactivity-impulsivity, more research is needed as some contradictory evidence (e.g., Huang-Pollock et al., 2007) has been found. Furthermore, because behavioral disinhibition may not reliably differentiate between ADHD and other academically or behaviorally impaired diagnostic groups, there is reason to consider its linear relation to the behavioral symptoms of ADHD as measured continuously. Thus, the current study sought to expand on this literature on behavioral disinhibition and ADHD symptoms in children and adolescents by examining the relation between these two constructs as well as how video game use may exacerbate this association.

Although this literature review represents only a select fraction of all literature examining the neuropsychological deficits associated with inattention and hyperactivity-impulsivity, it is demonstrative of the strong association between executive dysfunction and ADHD symptoms in children and adolescents. Albeit other factors are involved in the manifestation of ADHD and impairments in functioning in these areas are not necessarily specific to ADHD, it is clear that deficient selective attention, sustained attention, and set shifting, as well as behavioral disinhibition, are all indicated as playing some role in the behavioral expressions of ADHD. Additionally, given the recent taxometric examinations of ADHD symptoms (e.g., Marcus & Barry, 2011), it is also important to note that inattentive and hyperactive-impulsive symptoms vary dimensionally within the population, and although much of the previous research has examined these symptoms based on categorical groups (i.e., diagnostic groups of ADHD-PI, ADHD-PH, or ADHD-C), the current study seeks to examine the association between neuropsychological deficits and ADHD symptoms when they are examined continuously. Neuropsychological (i.e., laboratory) measures of ADHD are thought to be behaviorally representative of a deeper neurobiological brain dysfunction which, in turn, is partially the result of a genetic predisposition to ADHD, although certainly environmental factors and other individual difference factors can impact such performance as well. More importantly, however, environmental factors may interact with a biologically-based predisposition, and the current study seeks to demonstrate that one such environmental factor (i.e., the frequency and duration of video gaming) may exacerbate the relation between genetically predisposed neuropsychological problems and symptoms of ADHD.

ADHD: A Complicated Etiology

In addition to the immense amount of research conducted in the areas of executive and neuropsychological dysfunction pertaining to ADHD as described above, the etiology literature of ADHD remains quite complex, with significant research connecting inattention and hyperactive-impulsive behaviors to specific neurological damage. Neuroimaging studies have implicated the basal ganglia (Qui et al., 2009) in goal-directed behavior and motor coordination as well as the prefrontal cortex, which is implicated in behavioral inhibition and attention (Arnsten, 2009). Valera, Faraone, Murray, and Seidman (2007) meta-analyzed findings from various fMRI studies and found that the brain areas most often implicated in these studies were in a cerebellar-prefrontal-striatal network. Additionally, some research has demonstrated that certain birth complications are associated with higher instances of ADHD, including low birth weight and premature birth (Halmøy, Klungsøyr, Skjærven, & Haavik, 2012). Family aggregation studies tend to demonstrate strong genetic support for ADHD as having a heritable component (e.g., Steinhausen, Zülli-Weilenmann, Brandeis, Müller, Valko, & Drechsler, 2012). Some research has shown that a parent with ADHD has a 57% chance of giving birth to a child with ADHD (Biederman et al., 1995).

It is important to note that whereas earlier research focused on heritability, brain damage, or developmental difficulties, more recent literature has focused on genetics by environmental interactions, marking a more complex etiology for ADHD symptomatology. For example, recent literature has found a consistent relation between lead burden and ADHD symptoms (e.g., Nicolescu et al., 2010; Nigg et al., 2008), and a recent meta-analysis determined average correlations of r = .16 and .13 between lead burden and inattention and hyperactivity-impulsivity, respectively (Goodlad, Marcus, & Fulton, 2013). Some exclusively psychosocial etiologies of ADHD have been proposed (e.g., Jacobvitz & Sroufe, 1987; Willis & Lovaas, 1977), but most of these theories have not received as much support (Barkley, 2003)

Fairly recently, significant research has been conducted linking exposure to digital media like television to attention problems (e.g., Johnson, Cohen, Kasen, & Brook, 2007; Landhuis et al., 2007; Levine & Waite, 2000; Miller et al., 2007) as one potential environmental etiology of ADHD. Generally, these studies found that hours of television viewed are strongly positively associated with attention problems measured by behavior checklists or observations. For example, as hours of television viewing increases so do ADHD symptoms (although it could certainly be the case that individuals with higher levels of ADHD symptoms seek out more television). Furthermore, some studies controlled for common covariates (e.g., age, gender, socioeconomic status) and found, in a longitudinal design, that childhood television viewing was more strongly associated with adolescent ADHD symptomatology than was adolescent television viewing (Landhuis et al., 2007). Although some research has failed to replicate these findings (e.g., Stephens & Muslow, 2006), most studies demonstrate that television viewing among younger children may be an important risk factor in later attentional problems. With the advent of more media technology and its commonplaceness within young children's lives at home and at school, it is important to consider its impact, whether positive or negative, on behavioral outcomes of children and adolescents.

Video Games and ADHD

In light of the research linking ADHD to television use, more recently researchers have begun to look specifically at the association between video game use and ADHD symptomatology. Ferguson (2010a) pointed out that video games are "one of the newest media forms to be under scrutiny" (p. 66). Gentile and colleagues (2012) identified four hypotheses regarding the relation between video game use and ADHD, including the excitement, displacement, attraction, and third variable hypotheses. According to the excitement hypothesis, screen media like video games may be related to problems with inattention because it seems to make other activities less fun. Christakis, Zimmerman, DiGiuseppe, and MCarty (2004) found that television shows that are "exciting" may hinder a child's ability to sustain attention to less rewarding tasks. Similarly, video games often include vibrant sound effects or music, flashing lights, and lush backgrounds. Games may also include reinforcement (e.g., earning points, unlocking "achievement trophies") at high rates that are not present in the real world at such a high rate or with such a short delay (Bioulac, Arfi, & Bouvar, 2008). It is known that children with ADHD experience more difficulty than typically-developing children in modulating their response to rewards and immediate gratification (Goldstein & Naglieri, 2008). Therefore, activities related to school or work may appear particularly boring due to the lack of immediate reward. Additionally, because video games include almost constant reinforcement of some kind (e.g., sounds, visual messages, or changes in the environment), a child's expectations about natural reward and stimulation (Gentile et al., 2012) may change.

The displacement hypothesis of the ADHD–video games relation suggests that the time a child spends with electronic media (like video games) replaces the time they would spend with other activities that could be used to develop appropriate impulse control or attentional capacity. This hypothesis is, in turn, based on Baumeister, Vohs, and Tice's (2007) strength model of control. Baumeister and colleagues have suggested that all individuals have limited mental resources and energy that can be used for self-control (e.g., Baumeister, Heatherton, & Tice, 1994) and that these resources can be depleted during tasks that require significant focus. Therefore, according to the displacement hypothesis, if a child spends more time playing video games (which requires few self-control resources) than engaging in behaviors like leisure reading (which requires substantially more self-control resources), then time that would be spent developing these resources is spent on other activities, which could cause problems with impulse control and sustained attention.

Based on this perspective, the amount of time a child spends with electronic media (including gaming media) should be predictive of greater problems with sustained attention, with more frequent gaming or longer duration of gaming predicting more attention problems and less impulse control (Gentile et al., 2012). In combination with the excitement hypothesis, video games with the most exciting content should be most predictive of attention problems than other forms of less interactive media, like television or movies. These might be games that offer high levels of immediate reinforcement or have the most interesting content (i.e., fast-paced or aggressive games).

As evidence in support of the displacement hypothesis, Chan and Rabinowitz (2006), using a sample of 72 adolescents (31 males, 41 females) and their parents, surveyed adolescents' video game and Internet use as well as television use and academic performance. When video game use was dichotomized between more and less than one hour, results indicated a significant association between video game use and inattention and total ADHD (but not hyperactivity) symptom scores as measured by the Connors' Parent Rating Scale. However, it is important to keep in mind that this study did not use a dimensional measure of time spent playing video games, thus restricting variance. Additionally, without longitudinal information regarding childhood video game use and attention problems, it is difficult to conclude that one caused the other. Instead, Chan and Rabinowitz's (2006) study may offer support for the attraction hypothesis.

The attraction hypothesis, a third hypothesis for the association between ADHD and video game use, is that electronic media like video games attract children who have problems with attention or impulsivity, and that these children are more likely than those without attention problems or impulsive behavior to engage in gaming. This theory argues that the video games do not necessarily have a causal association with attention problems and impulsive behavior but that the association may be reciprocal (Gentile et al., 2012). Related to the excitement and displacement hypotheses, those with lower self-control (Baumeister et al., 2007) may have a harder time resisting video games because they require such little amounts of self-control compared to other tasks like homework. Therefore, given a choice, children may prefer to play video games than completing schoolwork (or even leisurely reading) because they appear to be less cognitively or physically taxing.

Swing and colleagues (2010) studied two samples of children's video game use and attention problems. The middle childhood sample consisted of 1,323 children (mean age: 9.6 years), whereas the late adolescent sample consisted of 210 young adults (mean age: 19.8 years). In these studies, both child and adolescent screen media use (i.e., video games and television) predicted later attention problems after accounting for earlier attention problems. Swing and colleagues (2010) concluded that this information contradicts the idea of the attraction hypothesis. The authors argued that, because they measured attention problems and screen media use longitudinally, their conclusions regarding the association between screen media use and attention problems were stronger and were less likely due to alternate explanations. For example, they reported that, because earlier attention problems were statistically controlled when predicting later attention problems, it was less likely that the video game–attention problem relation was "merely the result of children with attention problems being especially attracted to screen media" (Swing et al., 2010, p. 219). Instead, this research offered support for the excitement hypothesis. Unfortunately, Swing and colleagues did not test to see if early attention problems predicted a longitudinal increase in video game use, which would also provide support for their claims.

Finally, a fourth hypothesis discussed by Gentile and colleagues (2012), the third variable hypothesis, is that the video games–ADHD association is spurious and that an unknown third variable may account for this association. Several studies have attempted to control for common covariates such as gender and age (e.g., Swing et al., 2010).

However, Gentile and colleagues (2012) revealed that common demographic variables like age, gender, and socioeconomic status did not fully account for the association between attention problems and video game use. It must be noted that it would be unfeasible to enter and control for every conceivable related variable in a regression model, making this hypothesis difficult to test. Additionally, because this hypothesis is based primarily on correlational research, as with any correlational research it is rather difficult to infer causation.

One such study that has shown some support for the third variable hypothesis was conducted by Ferguson (2010b). In this study, several covariates such as negative life events, depression, anxiety, antisocial traits, and family violence, among others, were entered alongside demographic variables and electronic media use (including video game use) in a model predicting attention problems and school performance (i.e., grade point average) in children. The results of this study demonstrated that some of these other variables, such as depression and antisocial traits, were better predictors of poorer school performance than were number of hours spent with electronic media. Ferguson (2010b) “cautiously” concluded that electronic media use may not be a unique predictor of attention problems and academic problems. However, Ferguson’s findings did not preclude the possibility that, even in the absence of a main effect of gaming on ADHD symptoms, it could still have been the case that video game use interacted with some other factor (such as a predisposition to behavioral symptoms of ADHD given a set of neuropsychological deficits) in predicting significant variance in behavioral symptoms of ADHD. Such a possibility was examined in the current study.

Despite the evidence reviewed thus far, not all studies have demonstrated these positive associations between electronic media use (including video games) with symptoms of inattention or impulsive behavior. For example, studies conducted by Obel et al. (2004) and Stevens and Mulsow (2006) both found no association between frequency and duration of television viewing and ADHD symptomatology. Few studies report a non-significant association between video game use and a diagnosis of ADHD. One possible example might be Bioulac and colleagues (2008), who sought to examine the difference between a sample of children with and without ADHD in the frequency and duration of video game playing. Although they reported that children with ADHD might play a little more often than non-ADHD children, no significant differences were found. However, when taking an addictions approach, Bioulac et al. (2008) found that children with ADHD were more likely to experience a more difficult time stopping game play on their own or complying with rules regarding game play.

Irons, Remmington, and MacLean (2011) sought to examine the effects on attentional capacity—if any—that could be attributed to video games. These authors looked specifically at action and first-person shooting (FPS) games under the hypothesis that these games contain a large number of stimuli on the screen at once that must be attended to simultaneously (e.g., enemies, health meter, ammunition supplies). Using a quasi-experimental design, Irons and colleagues sorted undergraduates by the amount of time spent playing FPS games into two groups (i.e., users and nonusers) and used a perceptual load paradigm to study selective attentional capacity. The authors concluded that there were no differences between these two groups and that more frequent video game use did not appear to enhance or hinder selective attention or perceptual load. This research is consistent with other previous findings by Boot, Kramer, Simons, Fabiani, and Gratton (2008), who also failed to find differences in cognitive performance (including attentional skills) of gamers compared to non-gamers.

However, it is important to remember that both of these studies appeared to artificially dichotomize frequency and duration of video game use as opposed to treating these variables as continuous in their final analyses. Placing individuals in dichotomized groups based on an arbitrary cut-point may have contributed to the null findings. The current study addressed this issue by allowing frequency and duration to vary continuously. Furthermore, these studies did not take into account how genetically predisposed neuropsychological deficits may also have contributed to behavioral symptoms of ADHD. The current study argued that video games may act as an environmental risk factor by amplifying the relation between executive dysfunction and the behavioral symptoms of ADHD.

Are All Video Games Bad For Attention Skills?

Ferguson (2007) has written about a possible publication bias in the realm of the video games–aggressive behavior association in favor of publishing studies that show an association between video game use and aggressive behavior. Given that studies with significant findings are more likely to be published in general, such a bias may be present in the video games–ADHD relation as well, with studies demonstrating the positive association between video game use and ADHD symptoms being more likely to be published than studies that show no association. Additionally, although it is true that most studies have focused on the negative effects of video game playing on attention, some research has uncovered potential benefits of particular games. For example, a series of studies demonstrating other benefits to cognitive processes have used a game called Space Fortress (Donchin, Fabiani, & Sanders, 1989). As described by Maclin and colleagues (2011, p. 1173), Space Fortress is a researcher-developed video game that "incorporates difficult motor, memory, dual-task, and visual/attentional" cognitive processes and requires players to selectively attend to certain aspects of the game. The object of the game is for players to control a space ship, attack a space fortress with weapons, and differentially identify "friends" from "foes." The player uses a joystick to navigate the ship and buttons to fire missiles at attackers and dodge enemy fire. Although this game does not appear to have the visual or auditory flair that accompanies most modern video games, it represents an excellent video game paradigm through which researchers can maintain a higher degree of experimental control.

Several studies have used Space Fortress as a measurement of attention, motor control, perception, and other executive functions. For example, Maclin and colleagues (2011) demonstrated that training in the Space Fortress game significantly improved attentional performance on subsequent tasks and that participants who had played the game were more adept in using attentional resources efficiently. Similarly, flight school cadets who were trained with the game showed more proficiency in real flight performance compared to those with no Space Fortress experience, leading the authors to conclude that multitasking and attentional skills learned during the game generalized to a real situation (Gopher, Weil, & Bareket, 1994). However, it is important to remember that in these studies the game was developed by researchers for the specific purpose of understanding cognitive processes. As such, its use was highly controlled by researchers, potentially limiting the external and ecological validity of conclusions.

Other studies have instead focused on improvements in cognitive performance attributed to commercially marketed (i.e., “real”) video games and computer software. Green and Bavelier (2006) defined “action games” as “those that have fast motion, require vigilant monitoring of the visual periphery, and often require the simultaneous tracking of multiple targets” (p. 1466). These types of games often include first-person shooters, combat, fighting, and some racing games. Their research indicated that gamers who more regularly play action video games were more efficient than non-action gamers in their use of visual attention resources. Using a perceptual load paradigm similar to the one described above (i.e., Huang-Pollock et al., 2005) during which task performance is measured during the presence of distracting stimuli, the authors concluded that action video game players had higher perceptual loads than non-action gamers and were, therefore, less visually distracted during the cognitive tasks. Action game players may allocate visual attention more dynamically across the visual field. Additionally, Green and Bavelier (2006) included a training component in order to demonstrate the causal association between action gaming and some attentional abilities. It is important to remember that many studies of gaming’s effects on attention do not include such a training period, making these conclusions more unique and important.

Additionally, as computer technology improves, game developers have begun to creatively adapt video games beyond the screen and controller format. Thus, increasingly, video game systems utilize player-as-the-controller formats to encourage physical activity while gaming. Gaming systems like the Nintendo Wii, Microsoft Xbox Kinect, and Sony PlayStation Move have utilized this technology most extensively, creating games in which the player’s movements are mimicked on the screen to complete game objectives. One researcher found that children playing what they referred to as an "exergame" (i.e., an active video game that requires the player exercise and move around to complete game objectives) exhibited increased executive functions immediately following game play (Best, 2012). Compared to low physical activity games (i.e., games where the child is able to sit down), games with both high physical activity and high cognitive engagement led to higher performance on the ANT-C, a visual discrimination and response inhibition task similar to the flanker task (e.g., Rueda et al., 2004), than games with high cognitive engagement or high physical activity alone. At least some active games may have the potential to allow a child to maintain or even sharpen certain executive functions, although more research is certainly needed in this area.

Thus, it appears that the relation between video game use and attention (and other cognitive skills)—including even the direction of the relation—may depend on the type of video games played. Although the current study's focus was on understanding aspects of gaming that predict increases in the behavioral symptoms of ADHD, a secondary, exploratory goal focused on the types of video games played. Specifically, whether the relation between neuropsychological deficits and the behavioral symptoms of ADHD is strengthened by some types of video games while attenuated by others was explored.

Hypotheses

A current trend in the literature is to examine the association between ADHD and media use. Based on the current literature, electronic media use—and more relevant to the current study, video game use—appears to be related to higher instances of ADHD-related symptoms. Individuals who play video games more often and for longer periods tend to be rated as having more problems with inattention and hyperactive-impulsive behaviors. Therefore, the first hypothesis of the current study was that frequency of video game use (i.e., gaming frequency) and average duration of play (i.e., gaming duration) would be positively related to both symptom domains of ADHD (inattention and hyperactivity-impulsivity; Hypothesis 1).

Additionally, based on the current review of literature, a number of studies have linked neuropsychological deficits and ADHD symptoms. However, few of these studies examine ADHD dimensionally instead of categorically. Because so relatively few of these studies include an ADHD-PI group versus ADHD-C group comparison, and because an ADHD-PI group may still include participants with a large number of hyperactive-impulsive symptoms (consistent with clinical diagnostic criteria; APA, 2013), the differential relation of these neuropsychological deficits to the specific symptom domains of ADHD remains unclear. To fill this gap, the current study examined the relation among neuropsychological measures of selective attention deficits, sustained attention deficits, set shifting deficits, and behavioral disinhibition with ADHD symptom domains (i.e., inattention and hyperactivity-impulsivity) within a community sample. That is, ADHD symptoms were examined as continuous, dimensional constructs rather than examined as diagnostic groups. Generally, it was hypothesized that poorer performance on neuropsychological measures would predict higher levels of ADHD-related behaviors. Specifically, based on the research described above, it was hypothesized that deficits in sustained attention and selective attention would be positively related to behavioral symptoms of both inattention and hyperactivity-impulsivity, whereas set shifting deficits and behavioral disinhibition would be positively related to behavioral symptoms (hyperactivity-impulsivity) only (Hypothesis 2).

Behavioral disinhibition was expected to relate only to hyperactivity-impulsivity, given the preponderance of evidence showing differences between ADHD-C and ADHD-PI groups that suggests that it plays a larger role in hyperactivity-impulsivity. Because deficits in set shifting are conceptualized, theoretically, as disinhibition of an ongoing response (parallel to behavioral disinhibition of a prepotent response), set shifting was also expected to relate only to hyperactivity-impulsivity.

Although a link between video game use and ADHD symptoms has been established, few studies employ the use of neuropsychological measures of inattention, hyperactivity, and impulsivity in the examination of this association. Therefore, the current study sought to incorporate neuropsychological measures along with behavioral questionnaires. It was hypothesized that how often video games are played (i.e., gaming frequency) and average duration of each video game session (i.e., gaming duration) would moderate the association between neuropsychological deficits and behavioral symptoms of ADHD (Hypothesis 3). This is to say that higher gaming frequency and longer gaming duration were predicted to exacerbate the expected associations between selective attention deficits, sustained attention deficits, set shifting deficits, and behavioral disinhibition and the symptom domains of ADHD. Because the idea that video games *cause* behavioral symptoms of ADHD is obviously inconclusive, it was hypothesized that when a child with a predisposition for a lower capacity to manage his or her own behavior (as manifested by neuropsychological deficits) is repeatedly exposed to the artificial environments and schedule of reinforcement of video games, this child would be more likely to display behavioral symptoms of inattention and hyperactivity-impulsivity (i.e., consistent with the excitement hypothesis of the video games–ADHD relation).

Most video game research tends to focus on war, fighting, or first-person shooter video games (e.g., Bijvank, Konijn, & Bushman, 2012; Englehardt, Bartholow, & Saults, 2011; Ferguson & Olson, 2014; Ferguson & Rueda, 2010; Willoughby et al., 2012). These games are popular among children and adolescents for their online and cooperative components, flashy graphics, and high rates or reinforcement for violent or aggressive acts which are often displayed with a high degree of realism (Bijvank et al., 2012). However, they are also the scourge of parents for their realistic violence and reward of aggressive behavior. Unfortunately, few studies have examined the relation of other video game genres, such as real-time strategy (RTS), sports, puzzle, or role-playing games with ADHD symptoms. Further, active motion games, or "exergames" (i.e., games that rely heavily on motion-sensing technology like the Nintendo Wii or Microsoft Kinect), are relatively new in the market and have yet to be studied thoroughly. As an exploratory research question, this study examined if how video games are played (i.e., gaming medium) or the types of video games played (i.e., gaming genre) moderated the association between video game use and ADHD symptoms, but no specific hypotheses were made.

CHAPTER II

METHOD

Participants

Children between the ages of 10 and 17 years were recruited from the community in a medium-sized southern city. Due to difficulties in recruitment and some families' failure to complete all measures, a total of 25 participants were included in the final analyses. However, it is important to note that considerably more children and families scheduled appointments to participate in the study but were unable to do so for various reasons (e.g., transportation issues, time commitment problems). A total of 72% of the children were males (n = 18), and 28% of the children were females (n = 7). A total of 80% of the sample (n = 20) was reported as White/Caucasian, whereas 16% of the sample (n = 4) was reported to be Black/African-American, and 4% of the sample was identified as biracial. Ages ranged from 10 to 17 years with a mean age of 12.84 years (SD = 2.15). The sample's Full Scale IQ ranged from 80 to 130 with a mean of 109.0 (SD = 13.9) as measured by the Kaufman Brief Intelligence Test, Second Edition, with a mean Verbal IQ of 106.6 (SD = 14.6) and a Nonverbal IQ of 108.6 (SD = 12.1).

Children did not need to have a diagnosis of ADHD to qualify, although 32% of children in the study (n = 8) had received such a diagnosis according to parent report. Regarding other psychological diagnoses, 1 child (4%) had an anxiety disorder diagnosis, and 2 children (8%) had a learning disorder diagnosis. None of the children in the study were reported to have received special education services (e.g., Individualized Education Program) in the previous school year, and two children (8%) had received mental health services during the previous year. Regarding extracurricular school activities per caregiver report, 40% of the children in the sample (*n* = 10) played sports at school, 20% (*n* = 5) participated in band or music at school, 12% (*n* = 3) participated in an academic club at school, and 32% (*n* = 8) did not participate in any school-affiliated activities. Regarding activities outside of school, 52% of children (*n* = 13) participated in sports, 8% (*n* = 2) participated in a community service group, 64% (*n* = 16) participated in a religious youth group, 12% (*n* = 3) participated in Boy/Girl Scouts, and 8% (*n* = 2) did not participate in any community activities.

Of the parents and caregivers accompanying children to the study and completing forms on their behalf, 88% (*n* = 22) identified as female. The age of the parents ranged from 29 to 53 years with a mean age of 41.4 years (*SD* = 7.57). A total of 84% of caregivers (*n* = 21) identified themselves as the child's mother, whereas others identified themselves as the child's father (*n* = 2, 8%), step-father (*n* = 2, 4%), and grandmother (*n* = 1, 4%). Regarding race and ethnicity, 80% of respondents (*n* = 20) identified themselves as White/Caucasian, whereas 20% (*n* = 5) identified themselves as Black/African-American. A total of 21 (84%) of caregivers reported that they were married, whereas 3 (12%) reported being divorced and 1 parent (4%) reported being never married and living alone with their child. When asked about their level of education, 40% of respondents noted that they completed some college, 24% of respondents completed a 2-year college program, and 16% held bachelor degrees from a 4-year college or university. When asked about their spouse's level of education, if applicable, 28% had completed some college, 12% had completed a 2-year college program, and 32% had completed a 4-year college or university program. Additional demographic information can be found on Table 1

Table 1

Sample Characteristics: Child and Family Demographics

Child Characteristics		*N* (%)	Mean (*SD*)
Age			12.84 (2.15)
	10	4 (16.0)	
	11	4 (16.0)	
	12	4 (16.0)	
	13	5 (20.0)	
	14	1 (4.0)	
	15	3 (12.0)	
	16	3 (12.0)	
	17	1 (4.0)	
Gender			
	Male	18 (72.0)	
	Female	7 (28.0)	
Race			
	White	20 (80.0)	
	Black	4 (16.0)	
	Other	1 (4.0)	
FSIQ IQ			109.0 (13.9)
Verbal IQ			106.6 (14.6)
Nonverbal IQ			108.6 (12.1)
Psychological Diagnosis			
	ADHD	8 (32.0)	
	Anxiety	1 (4.0)	
	Depression	0 (0.0)	
	Learning	2 (8.0)	
Video Game Use			
	Frequency		5.08 (1.98)
	Duration		2.36 (1.40)
	Enjoyment		8.20 (1.90)

Table 1 (continued).

Rater Characteristics	*N* (%)
Gender	
Male	3 (12.0)
Female	22 (88.0)
Race	
White	20 (80.0)
Non White	5 (20.0)
Marital Status	
Married	21 (84.0)
Separated	0 (0.0)
Divorced	3 (12.0)
Never Married	1 (4.0)
Family Income	
$10,000 - $14,999	3 (12.0)
$15,000 - $24,999	1 (4.0)
$25,000 - $34,999	3 (12.0)
$35,000 - $49,999	3 (12.0)
$50,000 - $74,999	6 (24.0)
$75,000 - $99,999	3 (12.0)
> $100,000	6 (24.0)
Rater Education	
High School Graduate	2 (8.0)
Some College	10 (40.0)
2-year Degree	6 (24.0)
4-year Degree	4 (16.0)
Graduate Degree	3 (12.0)
Spouse/Partner Education	
Less than 12th grade	1 (4.0)
High School Graduate	5 (20.0)
Some College	7 (28.0)
2-year Degree	3 (12.0)
4-Year Degree	8 (32.0)
Graduate Degree	1 (4.0)
	Mean (*SD*)
Age	41.1 (7.5)

Measures

Stroop Task.

The Stroop task (Stroop, 1935) is a well-known neuropsychological task that can be used to assess a number of different cognitive constructs, including selective attention and behavioral inhibition. The task produces a number of different performance scales that require individuals to identify “color words” (e.g., red, green) and color patches. A computerized version of the Stroop was used in the current study. Four computer keys were covered with colored dots, and participants were instructed to press the color key that corresponded with the color of the target word or patch. As the test continued, the participant was asked to press different colored keys for different color targets. All conditions had to be completed as quickly as possible and with as few errors as possible. As reported by Kiliç and colleagues (2007), the object of the Stroop task itself is to “create interference between word reading and color naming” (p. 144). Those performing the task must be able to selectively attend to a certain aspect of the stimulus (i.e., color of the ink) while preventing other aspects of the stimulus from affecting their performance (i.e., semantic content of the word). Performance on the Stroop task was measured through the comparison of reaction times, response latency, and number of errors between task conditions that create interference (i.e., incongruent color-word conditions) and those that do not (i.e., congruent color-word conditions). Several studies have found good construct validity for the Stroop task in that it was able to reliably distinguish between adolescents with attention problems versus other disruptive behavior problems (Homack & Riccio, 2004; Lavoie & Charlebois, 1994) as well as good convergent validity with other neuropsychological measures of attention used to examine ADHD

(Schweiger, Abramovitch, Doniger, & Simon, 2007). The Stroop task contributed only to the selective attention composite as described below.

Continuous Performance Task.

The Continuous Performance Task (CPT; Rosvold et al., 1956) is a well-known computer-based method of assessing several cognitive constructs related to ADHD, including sustained attention and behavioral disinhibition. This paradigm required the child to press the space bar on a computer keyboard following the presentation of the letter X (and to not respond for any other letter). The child was presented with a number of different non-target letters while the letter X appeared more rarely than non-target letters. Furthermore, letters were presented quickly, and the child was encouraged to respond as quickly as possible. The CPT reports different types of data related to the child's performance, including reaction time to the target letter, errors of omission (i.e., the child fails to press the correct button in the presence of the target letter, which is thought to be related to poor sustained attention), and errors of commission (i.e., the child presses the button in the presence of a non-target letter, which is thought to be related to impulsivity and behavioral disinhibition). Epstein and colleagues (2003) found good construct validity for the CPT in that it was strongly related to ADHD symptoms as reported by parent questionnaires and diagnostic interviews. Additionally, the CPT has high convergent validity with other neuropsychological measures of attention as well as discriminate validity with nonverbal memory and other verbal tasks (Schweiger et al., 2007). The CPT contributed to both the sustained attention and behavioral disinhibition composites as described below.

Wisconsin Card Sort Task.

The Wisconsin Card Sort Task (WCST; Berg, 1948) was used as a measure of set shifting. The WCST is a well-known neuropsychological measure that taps into an individual's ability to shift cognitive style "in response to changing environmental contingencies" (Biederman et al., 2008, p. 50). The computerized version of the WCST contained a set of electronic "cards" that featured different geometric shapes presented in different numbers and colors. The object of the task was for the participant to sort each card based on relevant criteria, and depending on the participant's response, he or she immediately was provided brief positive or negative feedback for each response (i.e., "right" or "wrong"). Participants were asked to click on the appropriate target card to match new trials of cards. Additionally, the target sorting criteria changed after a certain number of stimuli, and a participant was considered to have "solved" the criteria after ten consecutive correct responses. Because the participant must adapt to unannounced changes in feedback and reinforcement, this task required the participant to take an active role in shifting his or her attention to target aspects of the stimulus card. The WCST produces several different scores, including total errors and a number of perseverative errors. Langenecker, Zubieta, Young, Akil, and Nelson (2007) reported good convergent validity for the WCST as compared to other common measures of executive functioning, including the Stroop task, Trail-making Test, and a Go/No Go Task. A computer version of this task based on Berg (1948) was used. The WCST contributed to the set shifting composite as described below.

Go/No Go Task.

Several different versions of the Go/No Go task exist as commonly-used measures of behavioral inhibition. The Go/No Go task in the current study followed the task as outlined by Fillmore, Rush, and Hays (2006). The object of the Go/No Go task was for participants to respond by pressing the space bar to a particular stimulus, in this case a green rectangle, as fast as possible. First, a white rectangle appears on the screen, signaling the beginning of the each trial. After a short period of time, the rectangle turns either green or blue. Participants had to inhibit their responses if the rectangle turned blue, but respond as quickly as possible if the rectangle turns green. The time it took for the rectangle to change from white to blue or green varies with each trial. Furthermore, the orientation of the rectangle switched occasionally from horizontal to vertical as an added distraction. Errors of commission (i.e., when a participant presses the space bar in the presence of a non-target stimulus) were interpreted as a measure of behavioral disinhibition, whereas errors of omission (failing to press the space bar in the presence of a target stimulus) were interpreted as deficits in sustained attention, similar to the CPT. Additionally, mean reaction times during go and no-go trials were computed. Although many different versions of the Go/No Go task exist, the psychometric properties of some versions have been demonstrated to have good test-retest reliability (ranging from r=.57 to r=.83) and convergent validity with other measures of executive functioning such as the WCST and Stroop task (Langenecker, Zubieta, Young, Akil, & Nelson, 2007). The Go/No Go task contributed to both the sustained attention and behavioral disinhibition composites as described below.

Vanderbilt ADHD Diagnostic Rating Scale, Parent Version.

Parents completed the Vanderbilt ADHD Diagnostic Parent Rating Scale (VADPRS; Wolraich, Hannah, Baumgaertel, & Feurer, 1998; Wolraich et al., 2004). The Vanderbilt is a highly reliable and well-validated 18-item Likert-type ADHD screening tool. It is a "well-established" screening tool (Pelham, Fabiano, & Massetti, 2005) for inattention, hyperactivity, and impulsivity based directly on DSM-IV-TR (APA, 2000) criteria (which are also consistent with the DSM-5 symptoms; APA, 2013). A rating of 0 indicates that an inattentive or hyperactive-impulsive symptom *never* occurs, 1 indicates *sometimes*, 2 indicates *often*, and 3 indicates *very often*. The parent-rated domains of inattention and hyperactivity-impulsivity were the outcome variables of interest for the current study. Scores for each of these domains were computed by averaging the ratings for the nine items for each domain. The Vanderbilt also includes DSM-IV-based items to screen for oppositional defiant disorder and conduct disorder as well as some internalizing symptoms (again, all also consistent with DSM-5 symptoms for these disorders; APA, 2013). All are also on the same Likert-type scale (Wolraich et al., 1998). Finally, the Vanderbilt includes eight performance items (three academic and five classroom behavior), rated on a Likert-type scale from 1-*Problematic* to 5-*Above Average* (Wolraich et al., 1998; Wolraich et al., 2004).

The authors (Wolraich et al., 1998) reported high Cronbach's alpha (i.e., high internal consistency) for the inattention (.92), hyperactivity-impulsivity (.90), ODD-CD (.91) and Anxiety/Depression (.79) factors of the measure. Additionally, high correlations (r = .79) between the Vanderbilt and the Computerized Diagnostic Interview Schedule for Children (C-DISC; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stonem, 2000) were observed, demonstrating good validity. Low correlations (e.g., Cohen's Kappas = .11–.15; *r* = .24–.34) between parent and teacher versions were observed (Wolraich et al., 2004), but this finding is thought to be related to genuine behavioral differences across settings rather than problems with the measure (e.g., Achenbach, McConaughy, & Howell, 1987).

Internal consistency was calculated for the Vanderbilt ADHD scales of interest (i.e., inattentive symptoms, hyperactive-impulsive symptoms) based on the current sample. For parent report measures, the inattentive scale yielded an alpha coefficient of .90 when examined via symptom severity (i.e., ranging from *never* to *almost always*) and an alpha coefficient of .82 when examined via symptom count based on the diagnostic presence or absence of the symptoms. For parent report measures of hyperactivity-impulsivity, the current sample yielded an alpha coefficient of .84 when examined via symptom severity and .78 when item responses were considered diagnostically. All alpha coefficients were considered appropriate measures and indicative of good internal consistency.

Video Game Questionnaire, Parent- and Self-Report Versions.

Parents were also asked to complete a brief questionnaire regarding their child's video game use. The parent version, developed by Bioulac and colleagues (2008) for use in their study, is a 26-item questionnaire that covers a wide range of both quantitative and qualitative information about their child's video gaming habits, including frequency and duration of gaming sessions (measured dimensionally), qualitative ratings of the child's behaviors (e.g., aggressive, calm) and emotions (e.g., angry, sad) both during gaming and when asked to stop play. The questionnaire also provides information concerning the parents' attitude toward their child's gaming as well as their perception of control over their child's use of video games. Most questions feature dichotomous answers presented in a *yes/no* format, although some items encourage a parent to check all responses that apply (e.g., all emotions or behaviors exhibited by a child during gaming). Although other variables on this measure were of interest for descriptive purposes, the frequency and duration of gaming sessions were the primary variables of interest for the primary study hypotheses, and parent report on these variables were used. Parents were asked on how many days per week (i.e., 0 through 7) their children played video games of any kind (i.e., gaming frequency). They were also asked to estimate the average length of playing time per video game session in hours (i.e., gaming duration). This survey also assessed typical medium (i.e., on what technology do children play games) and genre of video game (e.g., first person shooter, action/adventure, role playing), as well as asked for the three most played video games. For the current study, a self-report version of the Video Game Questionnaire was also administered (to collect children and adolescent self-report data on the same variables) and was created by modifying the parent version appropriately. The child's self-report was used for the exploratory research question about gaming medium and genre.

Kaufman Brief Intelligence Test, Second Edition.

The Kaufman Brief Intelligence Test, Second Edition (K-BIT-2; Kaufman & Kaufman, 2004) is a well-known abbreviated measure of intellectual functioning most often used as a screener for intelligence. The K-BIT-2 has been standardized for children aged 4 years through adulthood, making it an appropriate screener for the current study. It is individually administered and consists of three subtests, including Verbal Knowledge, Riddles, and Matrices. Verbal Knowledge and Riddles measure crystallized intelligence (verbal problem solving and school-related skills through the assessment of word knowledge, general information, and verbal concept formation), whereas Matrices is thought to measure fluid intelligence (nonverbal reasoning based through the perception of relationships and visual analogies). The K-BIT-2 was used to assess IQ of participants both for use as a possible control variable as well as for exclusionary purposes (i.e., for participants with an estimated IQ less than 70).

The K-BIT-2 was standardized using 2,120 examinees ranging from 4 through 90 years of age in a nationally-representative sample. The sample was about equal for each gender. Internal consistency reliability for the three subtests of the K-BIT-2 ranges from .86 to .96. The mean test-retest reliability of the verbal subtests is .91 whereas test-retest reliability for the nonverbal subtest is .88. The mean test-retest reliability for the IQ Composite score is .90. Additionally, the K-BIT-2 has been well-validated through high correlations with other measures of intellectual functioning, including the Kaufman Brief Intelligence Test (K-BIT; $r = .84$), Wechsler Abbreviated Scale of Intelligence (WASI; $r = .90$), Wechsler Intelligence Scale for Children, Third Edition (WISC-III; $r = .76$), and Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; $r = .77$). Descriptive statistics for K-BIT-2 for the current sample are presented in Table 1 and discussed above in the Participants section.

Demographic Information Form.

Each parent completed a demographic information form for their child. Parents reported their child's age, ethnic group/race, and gender. Parents also rated their gross family income based on a series of ranges presented on the form (ranging from 1 – $0-

$4,999 to 9 – $100,000 and above), parental education level, and parental employment. Additionally, parents recorded on the demographic form characteristics of the family, including family structure (e.g., number of parents in the home), number of siblings, and number of hours parents spend time with the child each day. Parents also reported their child's grades, special education enrollment status, and number of school activities as analogues to academic performance. Finally, parents reported which, if any, psychiatric diagnoses the child has from a list of possible diagnoses, as well as psychiatric medications the child regularly takes (if applicable). There were exclusion criteria for children with certain psychiatric diagnoses (e.g., Autism Spectrum Disorder, Intellectual Disability), as well as children with three or more comorbid conditions; however, no children were excluded based on these criteria.

Procedure

Following University IRB approval, children were sampled from the community and local schools in a medium-sized southern university city via email listservs and public fliers around the university campus and local businesses as well as through contact with a representative from local schools. Following written consent from their parents as well as written assent from the children participating, child and adolescent participants were brought into the lab and administered the K-BIT-2 and the computerized versions of the Stroop Task, CPT, WCST, and Go/No Go tasks. Children and adolescents also reported on their own video game use and behaviors using the Self-Report Video Game Questionnaire, which were administered online in the laboratory (via a secure website).

While children were participating in the neuropsychological measures of ADHD, parents and caregivers were administered the demographic information form and two measures of their child's behavior, including the VADPRS and the Parents' Video Game Questionnaire. Parent questionnaires were also administered electronically via a secure online website, and lab assistants provided help with questionnaires as needed. Each child was assigned a random participant number, and only the participant's number was paired with data in the dataset to keep individual responses and performance variables confidential. Children and parents were informed that their participation would allow each of their names to be entered separately into a drawing for a gift card to a large store chain (e.g., Target) as an incentive for their complete participation in the study. After data collection had begun, in an effort to increase enrollment and completion of the study, the incentive procedure was modified (and approved by the IRB) so that children were offered a $10 gift card to a national retailer for their participation in the lab portion of the study. Following distribution of the incentive, families were thanked for their participation and dismissed.

CHAPTER III

RESULTS

Composite Score Creation

For each neuropsychological predictor (i.e., selective attention deficits, sustained attention deficits, set shifting deficits, and behavioral disinhibition), relevant data were imported into SPSS from the Inquisit neuropsychological data collection program and aggregated using SPSS to determine a child's overall performance on the measure (e.g., latency scores, error rates). After data were aggregated for each neuropsychological measure, composite scores of performance in each area were created. To create composite scores, raw scores (e.g., total number of responses, latencies, error rates) were all converted to standardized *z*-scores so that they would be on the same scale. Some *z*-scores were reversed as appropriate; for example, on some measures a faster latency time was indicative of poorer neuropsychological functioning (e.g., greater impulsivity), but on other measures a slower latency time was associated with poorer neuropsychological functioning (e.g., greater inattention). Latency scores from the Stroop task were not standardized as they were all on the same metric (i.e., time). Decisions on which measures were included on which neuropsychological composites were made a priori based on both theory and the empirical literature.

The composite score for sustained attention consisted of scores from three measures from both the CPT and Go/No Go tasks, including mean latency of correct responses and omission error rate on the CPT (i.e., an increase of latency and error rate is indicative of greater inattention) and latency of correct response on the Go/No Go (i.e., an increase in latency is indicative of greater inattention). The associations among these three scores were also examined. Mean latency of correct responses on the CPT was significantly related to both omission error rate on the CPT, $r = .61$, $p = .001$, as well as latency of correct responses on the Go/No Go task, $r = .69$, $p < .001$. Additionally, commission error rate on the CPT was also significantly related to latency of correct responses on the Go/No Go task, $r = .48$, $p = .02$. These three associations are considered appropriate, indicating the composite score for sustained attention was appropriately unitary.

A composite score for selective attention was created by taking the difference between the latency of responses on the color-word congruent and color-word incongruent trials of the measure (i.e., an interference score) while controlling for performance on the color-only control condition of the measure. On this composite scale, an increase in interference latency was thought to indicate a decrease in selective attention. Correlations among scores comprising this ratio were examined, and the association between latency on incongruent and congruent conditions was significant, $r = .86$, $p < .001$, as was the association between incongruent and control condition latencies, $r = .79$, $p < .001$, and the association between congruent and control condition latencies $r = .91$, $p < .001$. These correlations are considered strong, indicating that all scores contributing to the composite score were well interrelated.

The composite score for set shifting consisted of three measures from the WCST, including the total number of trials needed to complete the WCST (i.e., a greater number of trials is indicative of poorer set shifting ability), the sum of perseverative responses calculated by the program (i.e., greater perseverative errors are indicative of poorer set shifting ability), and the total number of completed categories (i.e., fewer total categories completed indicate poorer set shifting). Set shifting variables were correlated, and the association between total trials of the WCST and total perseverative responses was not significantly related, *r* = .004, *p* =.98, whereas the association between total number of WCST trials and the number of categories completed was significantly related, *r* = .70, *p* < .001. The association between total perseverative responses and total completed categories on the WCST was not significantly related, *r* = -.23, *p* =.27. Including perseverative responses into the composite score contributed to poor overall intercorrelations.

A composite score for behavioral disinhibition consisted of three scores from the CPT and Go/No Go tasks, including mean latency of incorrect responses on the Go No/Go task (i.e., faster responses are indicative of poor response inhibition and greater impulsivity) as well as mean latency of commission errors on the CPT (i.e., faster responses are indicative of poor response inhibition and greater impulsivity) and total commission error rate on the CPT (i.e., a greater number of commission errors indicates poor response inhibition and greater impulsivity). The correlation among these variables was also examined. The association between commission error rate on the CPT and the latency on commission errors approached significance, *r* = -.39, *p* =.06, whereas the association between commission error rate on the CPT and latency of incorrect responses on the Go/No Go task was not significant, *r* = -.21, *p* =.32. Further, the association between latency of commission error responses on the CPT and latency of incorrect responses on the Go/No Go task was not significant, *r* = .32, *p* =.12. Latency scores were well-correlated with each other, but the composite score may not have been the best unitary measure of overall behavioral disinhibition.

Descriptive Statistics

Two domain scores for ADHD-related symptoms (i.e., inattention and hyperactivity) were created based on the presence or absence of symptoms according to DSM-5 criteria (i.e., a symptom had to be endorsed as *often* or *very often* by parents to be considered present). Thus, scores could range from 0 to 9 for both inattentive symptoms and hyperactive-impulsive symptoms as behavioral symptoms of ADHD were treated as a continuous variable in each outcome instead of being dichotomized into diagnostic categories (e.g., Marcus & Barry, 2011).

The two video game moderation variables (i.e., gaming frequency and gaming duration) were treated as continuous moderators in subsequent analyses, as they ranged from infrequent and short periods of gaming to frequent and long durations of gaming. Regarding the descriptive nature of moderating variables, gaming frequency (reported as days per week in which video games were played) ranged from 2 to 7 days per week ($M = 5.08$, $SD = 1.97$), whereas gaming duration (reported as time spent gaming per session) ranged from .5 hours to 6 hours ($M = 2.36$, $SD = 1.40$).

All children in the sample were reported to have played video games in the last year. When children and adolescents were asked how much they like video games on a scale from 1 to 10 (1 being *not much at all* and 10 being *very much*), responses ranged from 3 to 10 ($M = 8.08$, $SD = 2.04$). Regarding video game medium, 57.7% of children ($n = 15$) played console (i.e., television-based) video games, 26.9% ($n = 7$) played off-line computer games, 69.2% ($n = 18$) played online computer games, 42.3% ($n = 11$) played portable console games, 73.1% ($n = 19$) played smart phone or tablet-based games, and 3.8% ($n = 1$) played arcade games or pinball, according to parent report. Among the more popular game genres were First-Person Shooting games (n = 19 ranked in the top 3 choices), Action/Adventure games (n = 15 ranked in the top 3 choices), and Sports games (n = 9 ranked in the top 3 choices). No children endorsed the preference of massively multiplayer online role-playing games (i.e., MMORPG), and this category was excluded from further analysis.

Prior to data analysis and hypothesis-testing, all data were examined descriptively (including for skewness and kurtosis). The community sample was not recruited specifically for ADHD symptoms. Therefore, some positive skew was expected on these clinical symptoms. Indeed, hyperactive-impulsive symptoms demonstrated a positive skew (skewness = 1.14); however, inattentive symptoms did not demonstrate any notable skew. Additionally, a positive skew was observed for selective attention deficits (skewness = 1.95), indicating a higher distribution of children without deficits in selective attention in the sample. Additionally, negative kurtosis was observed in measures of sustained attention, set shifting, and gaming frequency, indicating a flatter shape in the distribution. Significant positive kurtosis was observed in the measure of selective attention, indicating a sharper curve of distribution in the sample. No other significant irregularities or outliers were found in the data; therefore, no subjects or variables were removed from the final dataset. Descriptive statistics of variables of interest are reported in Table 2.

Table 2

Descriptive Data for Variables of Interest

			Range			
	M	*SD*	Potential	Actual	Skew	Kurtosis
Inattention Severity	19.20	5.40	9 – 36	11 – 30	.23	-.39
Inattentive Symptoms	2.72	2.59	0 – 9	0 – 8	.74	-.48
Hyp-Imp Severity	17.84	5.04	9 – 36	10 – 30	.97	.64
Hyp-Imp Symptoms	2.28	2.23	0 – 9	0 – 7	1.14	.43
Sustained Att. Deficits Comp.[a]	.00	.85	–	-1.34 – 1.44	.45	-1.26
Selective Att. Deficits Comp.	.25	.24	–	-.05 – .95	1.95	4.22
Set Shifting Deficits Comp. [a]	.00	.66	–	-1.25 – .89	-.27	-1.30
Beh. Disinhibition Comp. [a]	.00	.52	–	-1.20 – .74	-.42	-.36
Gaming Frequency	5.08	1.98	0 – 7	2 – 7	-.47	-1.41
Gaming Duration	2.36	1.40	–	.5 – 6.0	.80	1.78

Note. M = Mean; SD = Standard deviation; Hyp-Imp = Hyperactivity-impulsivity; Att = Attention Comp. = Composite score; Beh. = Behavior; [a] Composites based on a mean (or ratio) of *z*-scores from specific neuropsychological measures.

Preliminary Correlations

A zero-order correlation matrix among all variables of interest was examined to determine how predictor, outcome, and moderating variables were all interrelated (Table 3). Furthermore, zero-order correlations between possible covariates (i.e., age, gender, IQ, race/ethnicity, and socioeconomic status) and the variables included in the tests of hypotheses were also examined (Table 4). Categorical variables like gender and ethnicity (i.e., White/Caucasian and Nonwhite/Not Caucasian) were dichotomized for these analyses. Based on the results of zero-order correlations across variables of interests, child age was significantly correlated with sustained attention deficits, $r = -.83$, $p < .001$. Additionally, parent income was significantly correlated with gaming frequency, $r = .55$, $p = .01$. Full Scale IQ, Verbal IQ, Nonverbal IQ, gender, and ethnicity were not significantly correlated with any of the variables of interest. Although none of the possible control variables related to ADHD symptoms (i.e., the outcome variables), they were still partialled out in subsequent analyses used to test the hypotheses if they significantly related to any variable of interest in the analyses to provide the most conservative test. Specifically, child age was controlled in analyses involving sustained attention deficits, and family income was controlled in analyses involving gaming frequency.

Table 3

Zero-Order Correlations Among Variables of Interest

	2.	3.	4.	5.	6.	7.	8.
1. P (ADHD-I)	.56**	.12	.28	.35	.07	.09	.43*
2. P (ADHD-H)	--	.22	.12	.14	-.02	.12	.36
3. Sustain		--	-.11	.31	.10	-.13	.01
4. Selective			--	-.13	.29	-.01	.34
5. Set Shift				--	.08	-.21	-.08
6. Beh. Dis.					--	-.33	-.06
7. Gaming Freq.						--	.34
8. Gaming Dur.							--

Note. (P) = parent report; ADHD-I = total symptoms of inattention; ADHD-H = total symptoms of hyperactivity-impulsivity; Sustain = sustained attention deficits (based on composite score); Selective = selective attention deficits (based on composite score); Set Shift = set shifting deficits (based on composite score); Beh. Dis. = behavioral disinhibition (based on composite score); Freq. = frequency; Dur. = duration.

** $p < .01$. * $p < .05$.

Hypothesis Testing

The first hypothesis of the current study was that video game use (i.e., gaming frequency and gaming duration) would be positively related to both symptom domains of ADHD (i.e., inattention and hyperactivity-impulsivity). Because there were two video game use predictors and two outcome variables, four correlation analyses were conducted to test Hypothesis 1. These correlations appear in Table 3. As shown, there was not an association between gaming frequency (i.e., days per week) and inattention, r =.09, p =.45, whereas a significant association was observed between gaming duration (i.e., average length of time per gaming session) and inattention, r = .43, p = .02. There was not a significant correlation between gaming frequency and hyperactivity-impulsivity, *r* = .12, *p* = .46, but an association approaching significance was observed between gaming duration and hyperactivity, *r* = .36, *p* = .06. Because family income was significantly related to gaming frequency, additional partial correlations were conducted using family income as a covariate when examining the relation between gaming frequency and ADHD symptoms. The association between gaming frequency and inattention was *pr* =.22, *p* = .31, and the association between gaming frequency and hyperactivity-impulsivity was *pr* =.24, *p* = .55, after accounting for the influence of family income.

To test the second hypothesis (i.e., that the four neuropsychological measures would be related to symptoms of inattention and hyperactivity-impulsivity), correlation analyses were conducted. Again, relations among selective attention deficits and sustained attention deficits with both inattention and hyperactivity-impulsivity were of interest, whereas relations among set shifting deficits and behavioral disinhibition with only hyperactivity-impulsivity were of interest. Therefore, 12 zero-order correlation coefficients were used to test Hypothesis 2. Correlations among neuropsychological variables and ADHD symptoms are reported in Table 3,

No significant associations were found between sustained attention deficits and inattentive symptoms, *r* = .12, *p* = .58, or hyperactivity-impulsivity, *r* = .22, *p* = .30. Similarly, no significant associations were observed between selective attention deficits and inattentive symptoms, *r* = .28, *p* = .18, or hyperactivity-impulsivity, *r* = .12, *p* = .58. Further, no significant correlations were observed between set shifting deficits and hyperactive-impulsive symptoms, *r* = .14, *p* = .51, or between behavioral disinhibition and hyperactive-impulsive symptoms, *r* = -.02, *p* = .92. Additional (exploratory) analyses were conducted and determined that behavioral disinhibition was also unrelated to inattentive symptoms, $r = .07$, $p = .76$, but a trend toward statistical significance was observed between set shifting deficits and inattentive symptoms, $r = .35$, $p = .09$. Controlling for covariates did not change the pattern of findings, as partial correlations between sustained attention deficits and inattentive symptoms, $pr = .23$, $p = .29$, or hyperactive-impulsive symptoms, $pr = .16$, $p = .46$, were both insignificant after controlling for child age.

Table 4

Zero-Order Correlations Between Variables of Interest and Demographic Variables

	FSIQ	VIQ	NVIQ	Gender	Age	Race	Income
P (ADHD-I)	.19	-.06	.28	.07	-.02	-.14	-.17
P (ADHD-H)	.29	.21	.31	.12	-.18	-.29	-.15
Sustain	.16	.03	.30	-.29	-.83**	-.25	-.01
Selective	.11	.15	-.02	.25	-.02	-.17	-.27
Set Shift	-.26	-.31	-.12	-.18	-.22	.32	-.30
Beh. Dis.	-.04	-.05	-.01	.25	.06	.30	-.22
Gaming Freq.	.02	.07	-.06	.20	.11	-.23	.55**
Gaming Dur.	-.08	-.05	-.09	.10	-.08	.16	.14

Note. (P) = parent report; ADHD-I = total symptoms of inattention; ADHD-H = total symptoms of hyperactivity-impulsivity; Sustain = sustained attention deficits (based on composite score); Selective = selective attention deficits (based on composite score); Set Shift = set shifting deficits (based on composite score); Beh. Dis. = behavioral disinhibition (based on composite score); Freq. = frequency; Dur. = duration; FSIQ = Full Scale IQ standard score; VIQ = Verbal IQ standard score; NVIQ = Nonverbal IQ standard score. Gender coded as Male = 1, Female = 2; Race coded dichotomously as White/Caucasian = 0, Nonwhite = 1. ** $p < .01$. * $p < .05$.

Additional (exploratory) analyses were conducted to examine the correlation between total parent-report of ADHD symptoms and all four measures of neuropsychological performance. No statistically significant associations were found between total ADHD symptoms and sustained attention deficits, $r = .18$, $p = .38$, selective attention deficits, $r = .23$, $p = .27$, set shifting deficits, $r = .29$, $p = .17$, or behavioral disinhibition, $r = .03$, $p = .89$. Accounting for child age again revealed an insignificant association between total ADHD symptoms and sustained attention, $r = .17$, $p = .44$.

The third hypothesis (i.e., that video game use would moderate the association between neuropsychological performance and symptoms of ADHD) was tested via 12 moderated multiple regression analyses. Specifically, models examined both sustained attention deficits and selective attention deficits (two predictors) predicting both inattentive and hyperactive-impulsive symptoms (two outcomes) as moderated by both gaming frequency and gaming duration (two moderators), resulting in eight analyses. Additional models examined both set shifting deficits and behavioral disinhibition (two predictors) predicting hyperactive-impulsive symptoms (one outcome) as moderated by both gaming frequency and gaming duration (two moderators), resulting in four more analyses. Moderated multiple regression analyses were conducted using *PROCESS* (Hayes, 2013). For any analyses involving sustained attention, child age was also entered as a control variable on step 1. Likewise, the influence of family income was controlled on step 1 in analyses examining gaming frequency as a moderating variable. The correlation of these covariates with variables of interest is described above and reported in Table 4. In the second step of the model (or the first step if no control variables were needed), each neuropsychological predictor (i.e., selective attention deficits, sustained attention deficits, set shifting deficits, behavioral disinhibition) was entered individually, and one of the two video game use variables (gaming frequency or gaming duration) was entered separately (for a total of two main effects—specific neuropsychological composite score and gaming frequency or gaming duration—tested per model). In step 3 (or the second step if no control variables were needed), one two-way interaction per model (specific neuropsychological composite score X gaming frequency or gaming duration) was entered. The data analytic tool, *PROCESS*, was used to complete the moderated multiple regression analyses (Hayes, 2013). Before creating each interaction term, variables were centered automatically by *PROCESS* (i.e., subtracting the sample mean from each score) to reduce multicolinearity and to aid in the interpretation of any significant interactions. Individual unstandardized coefficients for the interaction terms were examined for significance to determine which gaming variable(s) possibly moderated the relation. Despite only gaming duration relating to inattentive symptoms at the zero-order level, all hypothesized interactions were examined, given that an interaction effect between neuropsychological functioning and gaming frequency or gaming duration in predicting ADHD symptoms could occur in the absence of a main effect for either. Any specific significant interactions were examined individually in a reduced model (entering only the two main effects and the interaction term; Holmbeck, 2002) to determine if the interaction remained statistically significant. If the reduced model held, a post-hoc plot was conducted to determine the nature of the interaction (Frazier, Barron, & Tix, 2004).

Sustained attention deficits.

Due to the covariance between child age and sustained attention deficits, child age was entered as a control variable in the first step of each moderated multiple regression analysis examining sustained attention deficits as a predictor. In addition, when gaming frequency was examined as a moderator, family income was entered as a control variable on the first step (as is also the case for other neuropsychological predictors). With family income and child age entered simultaneously into the first step of the model, the variables did not account for a significant amount of the overall variance in inattentive symptoms. Further, when sustained attention deficits and gaming frequency were entered simultaneously into the second step of the model, the overall model remained an insignificant predictor of inattentive symptoms. However, when the interaction term (sustained attention deficits X gaming frequency) was entered in step 3, the overall model accounted for an amount variance approaching significance, $R^2 = .41$, F (5, 19) = 2.59, $p = .06$. In step 3, gaming frequency trended toward significance, $B = .53$, $SE = .28$, $p = .08$, and the interaction term was significant, $B = -.86$, $SE = .28$, $p < .01$, accounting for a significant increase in variance explained in inattentive symptoms, $R^2\Delta = .28$, $p < .01$ (Table 5). This interaction was examined in a reduced model including only the main effects and interaction and remained significant, $B = -.86$, $SE = .30$, $p < .01$. A plot of this interaction indicated that higher sustained attention deficits were associated with relatively higher inattentive symptoms, irrespective of gaming frequency. However, lower sustained attention deficits were associated with higher inattentive symptoms only under conditions of high gaming frequency (Figure 1).

The influence of child age was partialled out in step 1 of a model examining the moderating effects of gaming duration on the association between sustained attention deficits and inattentive symptoms. Step 1 of this model did not account for a significant proportion of variance in inattentive symptoms. However, when sustained attention deficits and gaming duration were entered simultaneously in step 2, gaming duration emerged as a significant main effect, $B = .83$, $SE = .37$, $p = .03$. In step 3, the interaction term was not significant (Table 6).

The moderated multiple regression model examining gaming frequency as a moderator of the association between sustained attention deficits and hyperactive-impulsive symptoms (accounting for child age and family income) was not significant, with no significant interaction or main effects observed (Table 7). Finally, gaming duration was examined as a moderator in the relation between sustained attention deficits and hyperactive-impulsive symptoms (accounting for child age). Step 1 (with child age as the predictor of inattentive symptoms) was not significant. Step 2 of the model (entering sustained attention deficits and gaming duration simultaneously) also did not significantly predict inattentive symptoms overall; however, the main effect of gaming duration trended toward significance, $B = .58$, $SE = .32$, $p = .08$. The interaction term entered in step 3 was not significant (Table 8).

Table 5

Results of Moderated Multiple Regression Analysis of Sustained Attention Deficits by Gaming Frequency Predicting Inattentive Symptoms

Predictor	Model 1 (Controls)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Income	-.22 (.27)	-.46 (.33)	-.43 (.28)
Child Age	-.01 (.25)	.37 (.45)	.44 (.39)
Sustained Attention Deficits		1.22 (1.15)	1.53 (.98)
Gaming Frequency		.39 (.33)	.53 (.28) †
Sust Att Deficits X Gaming Freq			-.86 (.29) **
R^2	.03	.13	.41 †
$R^2\Delta$		.10	.28 **

Note. Sust Att = Sustained Attention; Freq = Frequency. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses. † trend; $p < .10$. ** p < .01.

Table 6

Results of Moderated Multiple Regression Analysis of Sustained Attention Deficits by Gaming Duration Predicting Inattentive Symptoms

Predictor	Model 1 (Control)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Child Age	-.03 (.25)	.40 (.42)	.33 (.45)
Sustained Attention Deficits		1.17 (1.04)	.96 (1.17)
Gaming Duration		.83 (.37)**	.83 (.36) **
Sust Att Deficits X Gaming Dur			-.26 (.60)
R^2	.001	.23	.24
$R^2\Delta$		.23	.007

Note. Sust Att = Sustained Attention; Dur = Duration. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses. ** p < .01.

Table 7

Results of Moderated Multiple Regression Analysis of Sustained Attention Deficits by Gaming Frequency Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Controls)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Income	-.16 (.23)	-.38 (.28)	-.37 (.28)
Child Age	-.18 (.21)	.06 (.39)	.08 (.39)
Sustained Attention Deficits		.80 (.98)	.88 (.99)
Gaming Frequency		.38 (.28)	.41 (.29)
Sust Att Deficits X Gaming Freq			-.23 (.29)
R^2	.05	.15	.17
$R^2\Delta$		.09	.03

Note. Sust Att = Sustained Attention; Freq = Frequency. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses.

Table 8

Results of Moderated Multiple Regression Analysis of Sustained Attention Deficits by Gaming Duration Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Control)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Child Age	-.19 (.21)	.07 (.37)	.16 (.40)
Sustained Attention Deficits		.71 (.93)	.97 (1.03)
Gaming Duration		.58 (.38) †	.58 (.32) †
Sust Att Deficits X Gaming Dur			.32 (.53)
R^2	.03	.18	.19
$R^2\Delta$		.14	.02

Note. Sust Att = Sustained Attention; Dur = Duration. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses. † trend; $p < .10$.

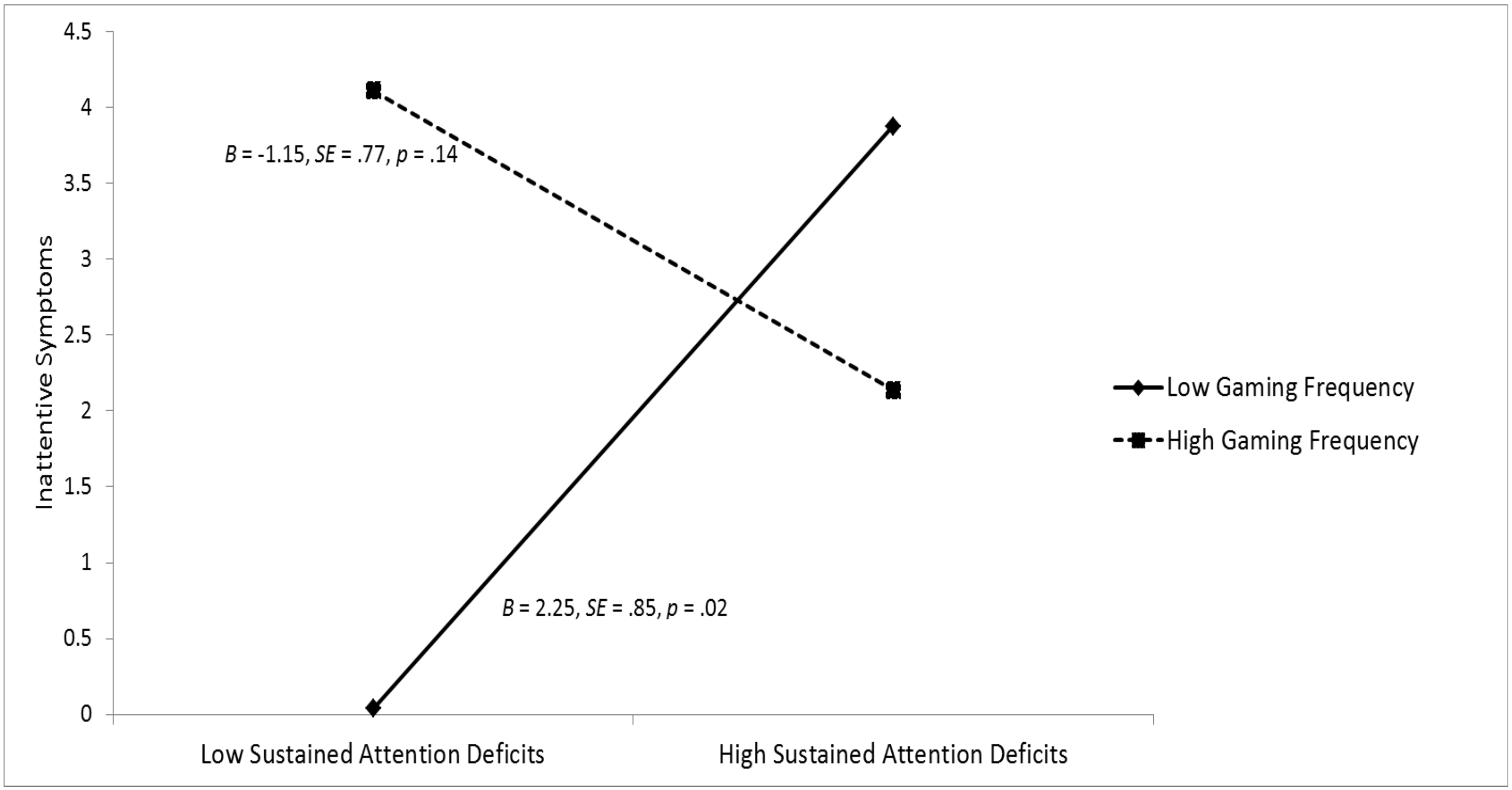

Figure 1. Interaction Between Gaming Frequency and Sustained Attention Deficits Predicting Inattentive Symptoms

*Selective attention deficits***.**

Selective attention deficits did not significantly predict inattentive symptoms when gaming frequency was evaluated as a moderating variable (accounting for the influence of family income; Table 9). However, when selective attention deficits and gaming duration were entered simultaneously to predict inattentive symptoms, the model approached significance, $R^2 = .20$, $F\ (2, 22) = 2.83$, $p = .08$; specifically, the main effect for gaming duration trended toward significance, $B = .70$, $SE = .37$, $p = .07$. In step 2 of the model, the interaction term was not significant (Table 10). Both of the overall models examining selective attention deficits as a predictor of hyperactive-impulsive symptoms, with either gaming frequency (accounting for the variance in family income) or gaming duration as moderators, were not significant; no significant main effects or interactions were observed (Tables 11 and 12).

Table 9

Results of Moderated Multiple Regression Analysis of Selective Attention Deficits by Gaming Frequency Predicting Inattentive Symptoms

Predictor	Model 1 (Control)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Income	-.23 (.27)	-.30 (.33)	-.36 (.35)
Selective Attention Deficits		2.37 (2.35)	2.93 (2.59)
Gaming Frequency		.28 (.33)	.28 (.33)
Sel Att Deficits X Gaming Freq			-.93 (1.74)
R^2	.03	.12	.13
$R^2\Delta$		.10	.01

Note. Sel Att = Selective Attention; Freq = Frequency. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses.

Table 10

Results of Moderated Multiple Regression Analysis of Selective Attention Deficits by Duration of Video Game Play Predicting Inattentive Symptoms

Predictor	Model 1 (Main Effects)	Model 2 (2-way Interaction)
Selective Attention Deficits	1.62 (2.20)	.77 (.40)
Gaming Duration	.70 (.37) †	-.88 (1.58) †
Sel Att Deficits X Gaming Dur		3.13 (3.50)
R^2	.21 †	.22
$R^2\Delta$		.01

Note. Sel Att = Selective Attention; Dur = Duration. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses. † trend; $p < .10$.

Table 11

Results of Moderated Multiple Regression Analysis of Selective Attention Deficits by Gaming Frequency Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Control)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Income	-.17 (.23)	-.33 (.29)	-.31 (.31)
Selective Attention Deficits		.39 (2.06)	.25 (2.29)
Gaming Frequency		.32 (.29)	.53 (.28)
Sel Att Deficits X Gaming Freq			.23 (1.51)
R^2	.02	.08	.08
$R^2\Delta$		.06	.001

Note. Sel Att = Selective Attention; Freq = Frequency. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses.

Table 12

Results of Moderated Multiple Regression Analysis of Selective Attention Deficits by Gaming Duration Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Main Effects)	Model 2 (2-way Interaction)
Selective Attention Deficits	-.05 (1.98)	-2.05 (3.12)
Gaming Duration	.57 (.34)	.47 (.35)
Sel Att Deficits X Gaming Dur		1.17 (1.14)
R^2	.13	.16
$R^2\Delta$		.03

Note. Sel Att = Selective Attention; Dur = Duration. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses.

Set shifting deficits.

Based on the hypotheses, the moderating effects of gaming frequency and duration were examined only for models predicting hyperactive-impulsive symptoms. After controlling for family income in step 1 of the model and entering relevant main effects simultaneously in step 2 (neither of which were significant predictors of hyperactivity-impulsivity), the interaction between set shifting deficits and gaming frequency emerged as statistically significant, B = -1.12, SE =.37, p < .01. The interaction model accounted for a significant amount of variance in hyperactive-impulsive symptoms, R^2 = .20, F (4, 20) = 2.96, p = .05 as well as a significant change in R^2 after accounting for family income and the two main effects, $R^2\Delta$ = .28, F (1, 20) = 8.90, p < .01 (Table 13). This interaction was also examined in a reduced model including only the main effects and interaction and remained significant, B = -1.00, SE = .39, p = .02. A plot of this interaction indicated that higher set shifting deficits were associated with relatively higher hyperactive-impulsive symptoms, irrespective of gaming frequency. However, lower set shifting deficits were associated with higher inattentive symptoms only under conditions of high gaming frequency (Figure 2).

Table 13

Results of Moderated Multiple Regression Analysis of Set Shifting Deficits by Gaming Frequency Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Control)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Income	-.17 (.23)	-.31 (.28)	-.44 (.24) †
Set Shifting Attention Deficits		.39 (.73)	.81 (.64)
Gaming Frequency		.33 (.28)	.56 (.25)
Shift Deficits X Gaming Freq			-1.12 (.37) **
R^2	.02	.09	.37 **
$R^2\Delta$		.07	.27 **

Note. Shift = Set Shifting; Freq = Frequency. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses. † trend; *p* < .10. ** p < .01.

Table 14

Results of Moderated Multiple Regression Analysis of Set Shifting Deficits by Gaming Duration Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Main Effects)	Model 2 (2-way Interaction)
Set Shifting Attention Deficits	.56 (.85)	.65 (.70)
Gaming Duration	.59 (.31) †	.57 (.32) †
Shift Deficits X Gaming Dur		-.22 (.54)
R^2	.16	.16
$R^2\Delta$		.01

Note. Shift = Set Shifting; Dur = Duration. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses. † trend; *p* < .10.

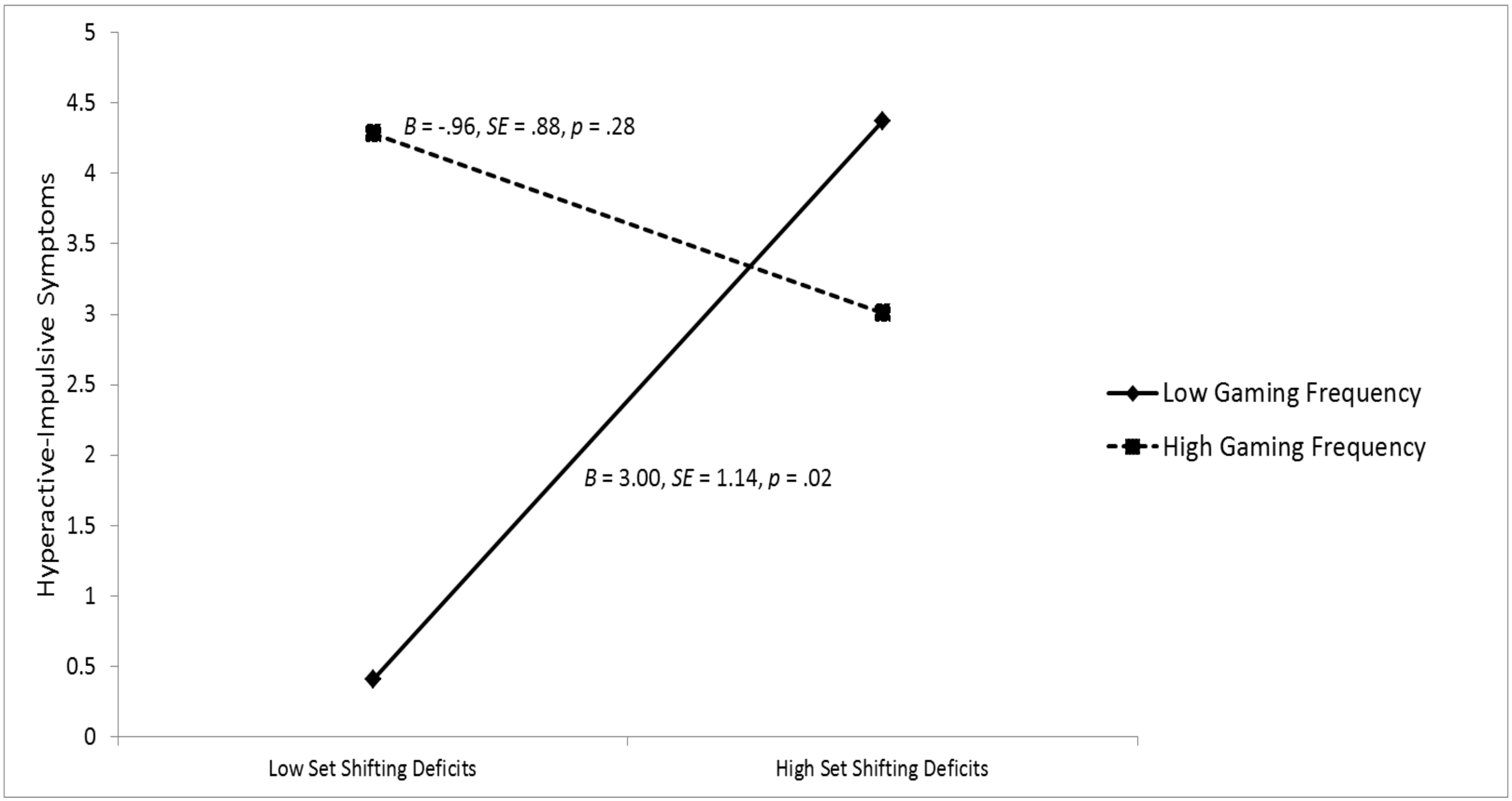

Figure 2. Interaction Between Gaming Frequency and Set Shifting Deficits Predicting Hyperactive-Impulsive Symptoms

Set shifting deficits did not significantly predict hyperactive-impulsive symptoms when entered simultaneously with gaming duration; however, the main effect for gaming duration trended toward significance, $B = .59$, $SE = .31$, $p = .06$. The interaction between set shifting deficits and gaming duration was not significant (Table 14).

Behavioral disinhibition.

Again, based on the hypotheses, behavioral disinhibition was only examined as a predictor of hyperactive-impulsive symptoms. Both of the overall models examining behavioral disinhibition as a predictor of hyperactive-impulsive symptoms, with either gaming frequency (accounting for the variance in family income) or gaming duration as moderators, were not significant; no significant main effects or interactions were observed (Tables 15 and 16).

Table 15

Results of Moderated Multiple Regression Analysis of Behavioral Disinhibition by Gaming Frequency Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Control)	Model 2 (Main Effects)	Model 3 (2-way Interaction)
Income	-.17 (.23)	-.38 (.28)	-.36 (.28)
Behavioral Disinhibition		.03 (.95)	.41 (1.09)
Gaming Frequency		.33 (.29)	.35 (.30)
Beh Dis X Gaming Freq			.42 (.57)
R^2	.02	.08	.11
$R^2\Delta$		.05	.02

Note. Beh Dis = Behavioral Disinhibition; Freq = Frequency. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses.

Table 16

Results of Moderated Multiple Regression Analysis of Behavioral Disinhibition by Gaming Duration Predicting Hyperactive-Impulsive Symptoms

Predictor	Model 1 (Main Effects)	Model 2 (2-way Interaction)
Behavioral Disinhibition	.002 (.52)	.13 (.83)
Gaming Duration	.57 (.32)	.67 (.31)
Beh Dis X Gaming Dur		-1.06 (.68)
R^2	.13	.22
$R^2\Delta$		.09

Note. Beh Dis = Behavioral Disinhibition; Dur = Duration. Unstandardized regression coefficients reported for each predictor. Standard errors are shown in parentheses.

Exploratory Research Questions.

Moderated multiple regression analyses were conducted to examine the possible influence of other gaming variables (i.e., gaming medium and gaming genre) on the association between neuropsychological deficits and symptoms of inattention and hyperactivity-impulsivity. These models were similar to models described for prior analyses, although they did not include earlier steps to account for variance explained by possible covariates given that they were just exploratory in nature. Additionally, these moderated multiple regression analyses examined the interaction between a continuous neuropsychological predictor (i.e., neuropsychological deficits) and a dichotomized moderating variable (i.e., category of gaming medium or genre). Gaming genre and medium were dichotomized as “yes” or “no” for each medium and genre prior to the exploratory analysis. The number of analyses were large, and the risk for Type I error was high.; however, these analyses were considered to take a preliminary look at the nature of the relation among variables. These results should be interpreted with much caution.

Medium of gaming (i.e., on what system games are played) was examined first. Correlations between medium of gaming and demographic variables (as described above) were examined, and no significant associations between these variables were observed (Table 17). Additionally, no significant associations were observed between medium of gaming and ADHD symptoms or neuropsychological deficits (Table 18). Considering all combinations of predictors, moderators, and outcome variables, the exploratory research question about whether video game medium (i.e., home console, online computer games, offline computer games, portable gaming console, tablet/smart phone, arcade games and pinball) would moderate the association between neuropsychological performance and symptoms of ADHD was tested via 36 moderated multiple regression analyses. None of the main effects models or interactions were significant. A number of interactions between neuropsychological deficits and gaming mediums trended toward statistical significance and are noted given that the analyses were exploratory. Marginally significant interactions included: the interaction between selective attention deficits and the use of tablets and smart phones to play games, $B = 12.49$, $SE = 6.03$, $p = .05$; the interaction between selective attention deficits and playing games on a home console, $B = -8.22$, $SE = 4.19$, $p = .06$; the interaction between selective attention and playing offline computer games, $B = 8.63$, $SE = 4.25$, $p = .06$; and the interaction between behavioral disinhibition and the use of tablets or smartphones for gaming, $B = 3.42$, $SE = 1.80$, $p = .07$.

Table 17

Zero-Order Correlations Among Medium of Gaming and Demographic Variables

	FSIQ	VIQ	NVIQ	Age	Gender	Race	Income
Home Console	-.02	.12	-.15	.09	.01	.04	.21
CPU Offline	.28	.34 †	.13	-.04	.01	-.09	-.20
CPU Online	-.25	-.26	-.17	-.09	.24	-.09	.05
Portable	-.13	.04	-.18	-.05	-.37 †	.16	-.25
Tab. or Phone	-.22	-.26	-.15	-.09	-.01	-.13	-.30
Arcade	-.32	.25	.33	.02	-.13	.10	-.17

Note. CPU = Computer; Tab. = Tablet; Arcade = Freestanding arcade games or pinball; FSIQ = Full Scale IQ standard score; VIQ = Verbal IQ standard score; NVIQ = Nonverbal IQ standard score. Gender coded as Male = 1, Female = 2; Race coded dichotomously as White/Caucasian = 0, Nonwhite = 1. Medium of gaming coded dichotomously as 0 = not used, 1 = used. † trend; $p < .10$.

Table 18

Zero-Order Correlations Among Medium of Gaming and Variables of Interest

	Attn.	Hyp	ADHD	Sustain	Select	Shift	Beh. Dis
Home Console	.09	.08	.10	-.03	-.04	.30	-.01
CPU Offline	.03	.08	.06	.07	.17	-.22	.00
CPU Online	.13	.13	.14	.02	.12	-.14	-.08
Portable	-.09	-.15	-.14	.27	.08	.23	.18
Tab. or Phone	-.07	-.17	-.13	-.04	.18	-.04	-.28
Arcade	.34 †	-.03	.20	.22	.15	.14	.15

Note. Att = total inattentive symptoms; Hyp = total hyperactive-impulsive symptoms; ADHD = total ADHD symptoms; Sustain = sustained attention deficits; Select = selective attention deficits; Shift = set shifting deficits; = Beh. Dis. = behavioral disinhibition; CPU = Computer; Tab. = Tablet; Arcade = Freestanding arcade games or pinball; FSIQ = Full Scale IQ standard score; VIQ = Verbal IQ standard score; NVIQ = Nonverbal IQ standard score. Medium of gaming coded dichotomously as 0 = not used, 1 = used.
† trend; $p < .10$.

Video game genre was examined next. Correlations among the 11 genres of video games coded in the current study (i.e., first-person shooter, role-playing, action-adventure, fighting, sports, real-time strategy, motion-based and active, party or board, puzzle or simulation, educational, and music games) were dichotomized based on whether or not children reported that one of the genres was a preferred type of game. Correlation analyses among video game genres and possible covariates (Table 19) and other variables of interest (Table 20) were conducted. Many significant associations among gaming genre and demographic variables were observed. For instance, preference of first person shooting games was strongly correlated with gender, $r = -.80$, $p < .01$ (indicating a preference by boys); preference of sports games was strongly correlated with ethnicity, $r = .73$, $p < .01$ (indicating a preference by nonwhite children); preference of puzzle and simulation games was correlated with gender, $r = .41$, $p < .05$ (indicating a preference by girls); and sports games were negatively correlated with Full Scale IQ, $r = -.54$, $p < .01$. Regarding variables of interest, preference of role playing games were associated with inattention, $r = .48$, $p < .05$, and real time strategy games was negative associated with set shifting deficits, $r = -.43$, $p < .05$.

Considering all combinations of predictors, moderators, and outcome variables, the exploratory research question about whether gaming genre would moderate the association between neuropsychological performance and symptoms of ADHD was tested via 66 moderated multiple regression analyses. Out of these models, two models accounted for significant variance in outcome variables. An overall model in which selective attention deficits predicted inattentive symptoms with role-playing game preference as a moderator accounted for a significant amount of variance in inattentive symptoms, R^2 = .39, F (3, 21) = 4.44, p = .01. Specifically, role-playing game preference was a significant main effect, B = 2.06, SE =.94, p < .05, and the interaction between selective attention deficits and role-playing game preference accounted for a significant change in the variance of inattentive symptoms, $R^2\Delta$ = .14, p < .05. A post-hoc examination of this interaction indicated that lower selective attention deficits were associated with relatively lower inattentive symptoms, regardless of preference for role-playing games. When there was no preference for role-playing games, even higher selective attention deficits were associated with relatively low inattentive symptoms. However, the combination of a preference for role-playing games and relatively higher selective attention deficits was associated with the highest levels of inattentive symptoms. That is, a preference for role playing games exacerbated the association between selective attention deficits and inattentive symptoms. Additionally, an overall model in which selective attention deficits predicted inattentive symptoms with preference of real-time strategy games entered as a moderator accounted for a significant amount of the variance in inattentive symptoms, R^2 = .33, F (3, 21) = 3.47, p < .05, and the interaction between selective attention deficits and preference of real-time strategy games accounted for a significant change in variance accounted for in inattentive symptoms, $R^2\Delta$ = .18, p < .05. A post-hoc examination of this interaction indicated that lower selective attention deficits were associated with relatively lower inattentive symptoms regardless of preference for real time strategy games. When there was a preference for real time strategy games, even higher selective attention deficits were associated with relatively low inattentive symptoms. In contrast, the combination of no preference for real time strategy games and relatively higher selective attention deficits was associated with the highest levels of inattentive symptoms. That is, a preference for real time strategy games attenuated the association between selective attention deficits and inattentive symptoms. Finally of note, preference of sports games emerged as a main effect (accounting for significant unique variance in hyperactive-impulsive symptoms), including when entered simultaneously with: selective attention deficits, $B = -2.62$, $SE = 1.10$, $p < .05$; set shifting deficits, $B = -2.07$, $SE = .90$, $p < .05$; behavioral disinhibition, $B = -2.11$, $SE = .97$, $p < .05$; and (marginally) sustained attention deficits, $B = -1.96$, $SE = .98$, $p = .06$.

Table 19

Zero-Order Correlations Among Gaming Genre and Demographic Variables

	FSIQ	VIQ	NVIQ	Age	Gender	Race	Income
Shooting	.04	.15	-.14	.08	-.80 **	.31	-.25
Role-Playing	.35	.29	.36 †	.10	.09	-.17	-.16
Action-Adv.	.12	.01	.23	.02	-.04	-.41 *	-.03
Fighting	-.10	-.06	.08	-.10	.13	.000	.245
Sports	-.54 **	-.51 **	-.45 *	.13	-.24	.73 **	-.31
Real-Time	.39 †	.35 †	.34 †	.03	-.03	-.22	.19
Motion	.001	-.01	.02	-.05	.14	-.15	.21
Party/Board	-.24	-.24	-.21	-.32	.32	-.19	.01
Puzzle/Sim	-.20	-.13	-.24	.13	.41 *	-.09	.25
Educational	.30	.33	.20	.31	.33	-.10	.14
Music	.05	.001	.08	-.38 †	.04	.12	-.06

Note. Shooting = first-person shooter; Action-Adv. = action-adventure; Puzzle/Sim = puzzle/simulation game; FSIQ = Full Scale IQ standard score; VIQ = Verbal IQ standard score; NVIQ = Nonverbal IQ standard score. Gender coded as Male = 1, Female = 2; Race coded dichotomously as White/Caucasian = 0, Nonwhite = 1.† trend; $p < .10$. * $p < .05$. ** $p < .01$.

Table 20

Zero-Order Correlations Among Gaming Genre and Variables of Interest

	Attn.	Hyp	ADHD	Sustain	Select	Shift	Beh. Dis
Shooting	-.07	-.12	-.11	.16	-.09	.20	-.05
Role-Playing	.48 *	.25	.419 *	.17	.24	.24	.21
Action-Adv.	.10	-.01	.06	-.07	-.05	-.41	-.34 †
Fighting	-.02	-.02	-.02	.27	-.07	.37	.10
Sports	-.33	-.44 *	-.43 *	-.23	-.22	.02	.22
Real-Time	-.21	.04	-.11	.04	.19	-.43 *	.03
Motion	.03	-.17	-.07	-.06	-.18	-.17	-.31
Party/Board	.09	.18	-.15	.12	.29	.03	.12
Puzzle/Sim	-.21	.17	-.04	-.32	-.27	-.24	-.11
Educational	-.06	.25	.10	.33	-.01	-.04	.03
Music	.17	.01	.12	.16	.28	.20	.09

Note. Shooting = first-person shooter; Action-Adv. = action-adventure; Puzzle/Sim = puzzle/simulation game; Att = total inattentive symptoms; Hyp = total hyperactive-impulsive symptoms; ADHD = total ADHD symptoms; Sustain = sustained attention deficits; Select = selective attention deficits; Shift = set shifting deficits; = Beh. Dis. = behavioral disinhibition. Gaming genre coded dichotomously as 0 = not used, 1 = used. † trend; $p < .10$. * $p < .05$. ** $p < .01$.

CHAPTER IV

DISCUSSION

Goal of Current Study

The current study examined the association between neuropsychological deficits in children and adolescents and behavioral symptoms of ADHD. Further, the current study examined a possible moderator of this relation, video game use, defined both by frequency of game play and average duration of video gaming session, as reported by parents. Hypothesis 1 was that the frequency of video game use (i.e., gaming frequency) and average duration of play (i.e., gaming duration) would be positively related to both symptom domains of ADHD (inattention and hyperactivity-impulsivity). This hypothesis was partially supported. A significant association between gaming duration symptoms of inattention was found, such that children with greater symptoms of inattention appear to play video games for longer periods than do children with fewer problems with inattention. Similarly, an association approaching statistical significance was observed between gaming duration and hyperactive-impulsive symptoms. Although not statistically significant, this trend suggested that children who played games for longer periods of time may also have more difficulty controlling impulses or hyperactive behaviors. Interestingly, contrary to prediction, gaming frequency did not relate to either symptom domain of ADHD. This suggests that perhaps how long a child plays video games is more indicative of problems associated with ADHD than is the number of times he or she sits down to play. This information may help inform parents that while daily gaming (i.e., after school, after homework assignments have been completed) is not harmful to a child's behavior, they should take care to monitor how long children are able to play each day. However, although frequency of gaming did not significantly relate to symptoms of inattention and hyperactivity-impulsivity, it is important to note that this association is in the correct direction, and the correlation may become significant with a larger sample size and subsequently increased power.

Hypothesis 2 (i.e., that sustained attention deficits and selective attention deficits would be positively related to inattentive and hyperactive-impulsive symptoms and that set shifting deficits and behavioral inhibition would be positively related to symptoms of hyperactivity-impulsivity) was largely unsupported. No statistically significant associations were observed between any executive functioning deficits and symptoms of inattention or hyperactivity.

This is particularly perplexing given the preponderance of literature that consistently demonstrates correlations between performance on neuropsychological measures of executive functioning, specific executive deficits (i.e., in sustained attention, selective attention, set shifting, and behavioral inhibition), and symptoms of ADHD (i.e., inattention and hyperactivity-impulsivity). For example, a recent study conducted by Lopez-Vicente, Sunyer, Forns, and Torrent (2014) examined a large sample (n = 393) of 11-year-old children and indicated that omission errors and reaction time on the CPT-II were significantly correlated with symptoms of inattention and that inconsistent latency (as measured by standard error of reaction time on the CPT-II) successfully predicted symptoms of hyperactivity-impulsivity. Polner, Aichert, Macare, Costa, and Ettinger (2014) indicated that in a community sample of children with “ADHD-like” traits (i.e., subclinical), poor performance on the Stroop task trended towards an association with inattentive symptoms, and a higher rate of commission errors on the Go/No Go task were related to symptoms of hyperactivity-impulsivity. They also reported that their sample adequately supported the dimensional nature of ADHD.

Further, a number of the studies discussed previously found strong links between ADHD symptomatology and sustained attention deficits (e.g., Huang-Pollock et al., 2006; Weber et al., 2007) and selective attention deficits (e.g., Gau & Shang, 2010; Kiliç et al., 2007) using similar tasks of neuropsychological evaluation. Still, other studies found positive associations between hyperactivity-impulsivity set shifting deficits and increased perseveration (e.g., Marzocchi et al., 2008) and behavioral inhibition (e.g., Huang-Pollock et al., 2006; Huang-Pollock et al., 2007). It is noteworthy that many of these studies used designs in which groups of children diagnosed with ADHD were compared to healthy controls or other groups without significant inattentive or hyperactive-impulsive symptomatology (e.g., learning disorder groups), rather than examining ADHD symptoms as a continuous variable. To that end, they might have selected participants from a clinical population with greater symptoms of inattention or hyperactivity-impulsivity, thus making associations between neuropsychological dysfunction and ADHD symptoms more readily observable (i.e., higher effect sizes for the relations of variables than may exist in the general population). Furthermore, these studies included large subject pools of children both with and without ADHD, making it easier for authors to detect the smaller effect sizes.

It is likely that given the particularly small sample size in the current study that not enough power was available to detect small effect sizes, resulting in a lack of significant associations. Additionally, given that the current study recruited from a community sample of children rather than a clinical sample of individuals with known attention and hyperactive-impulsive symptoms, it is possible that there was not significant variability in executive deficits or ADHD symptomatology for such associations to be detected. Another important factor to consider is that out of the eight children reportedly diagnosed with ADHD, five of them were currently prescribed medication for their symptoms (including both stimulant and non-stimulant medication). Although parents did not report whether children had taken their medication on the day of their participation, the influence of stimulant and non-stimulant medication on executive functioning deficits may have led to improved performance on neuropsychological measures, thus restricting the variability in performance across these measures among a group of children who may have been the most impaired. Further, if children had been taking medication for some time, depending on the efficacy of the medication it might have altered parental perception of inattentive and hyperactive-impulsive symptoms. These are important factors to consider in the interpretation of the current results.

However, it is quite promising to see that within three out of the four composites of executive deficits, individual contributors to the overall composite tended to be correlated in the correct direction with other contributors to the same composite. In some case, like the sustained attention and selective attention composites, the intercorrelation of these contributors were all very strong, indicating that these composites were an appropriate unitary measure of their respective constructs. In the case of weaker intercorrelations, it is hoped that an increase in sample size would result in enough power to detect smaller associations as significant.

Additionally, although not statistically significant due to a lack of power in the study, the magnitude of difference in correlations between gaming duration and sustained attention (*r* = .01) and selective attention (*r* = .34) was noted. This pattern of results suggests that children with sustained attention deficits do not play video games for long periods of time, whereas children with selective attention deficits do, possibly due to the fact that they have more difficulty ignoring the reinforcement provided by video games, or are more distractible by games than are children and adolescents without these deficits.

Finally, it is worth noting that neuropsychological composite scores with weak intercorrelations (i.e., set shifting, behavioral disinhibition) were recreated for subsequent exploratory analyses. Specifically, the composite score for set shifting deficits was split into two separate scores (i.e., a score comprised solely of total perseveration and a score based on total categories completed and total trials completed). Splitting this composite score did not significantly impact the association between set shifting and ADHD symptoms. Likewise, the latency scores contributing to the behavioral disinhibition composite score were deleted, leaving only commission error rate on the CPT as the sole contributor to the composite; this change also did not significantly impact the outcome of the neuropsychological deficits-ADHD symptoms analyses or any subsequent analyses. One possible explanation for the poor intercorellation between the latency scores and commission error rate is that the attention of participants was so impaired that the latency required for processing stimuli in the Go/No Go and CPT tasks prohibited fast, impulsive incorrect responding.

Hypothesis 3 was also partially supported. Although most moderated multiple regression models did not account for statistically significant variance in outcome variables (i.e., symptoms of inattention or hyperactivity-impulsivity), two out of 12 tested interactions were significant. For example, a significant interaction between sustained attention deficits and the frequency of video game use was observed to account for unique variance in symptoms of inattention as well as a significant change in the overall variance accounted for by the model, after accounting for potentially confounding variables (i.e., child age, family income) in earlier steps of the model. This finding indicates that when the children in this sample played video games frequently, the number of inattentive symptoms reported by their parents was also high, regardless of the child's ability to sustain his or her attention during various neuropsychological tasks. However, when video games were played infrequently by children and adolescents, parents reported fewer inattentive symptoms when children had fewer deficits in sustained attention and more inattentive symptoms when children had higher deficits in sustained attention. Therefore, frequent video game use appeared to be related to higher inattentive symptoms in children both with and without neuropsychological deficits in sustained attention. In other words, children who played video games more frequently were also rated as more inattentive regardless of whether they had low or high executive deficits in sustained attention.

Similarly, a significant interaction was observed between executive deficits in set shifting and the frequency of video game use, and this interaction accounted for a significant amount of the variance in symptoms of hyperactivity-impulsivity, as well as a unique change in the variance accounted for compared to any predictors alone. This finding indicates that when children used video games more frequently, parents tended to report higher levels of hyperactivity-impulsivity. However, when video games were used infrequently, low set shifting deficits were associated with low symptoms of hyperactivity-impulsivity, and deficits in set shifting were associated with symptoms of hyperactivity-impulsivity. Therefore, in this sample of children, frequent video game use was associated with greater hyperactive-impulsive symptoms regardless of whether set shifting deficits were low or high.

Notably, in the models examining the interactions between neuropsychological functioning and video game use in predicting ADHD symptoms, gaming duration remained a robust unique predictor across many of the analyses, even when accounting for the variance attributable to neuropsychological functioning. This finding provides additional support for the idea that allowing children to play video games for increased periods of time may be associated with poorer attention and more symptoms of hyperactivity-impulsivity. It should be noted that many of the models explored and described above featured appropriately meaningful effect sizes in the correct direction of influence, and it is hoped that if additional data are collected and continue to show results in the same pattern that more of the relations (main effects and interactions) will reach statistical significance. Particularly, the zero-order correlations for sustained attention deficits, selective attention deficits, and set shifting related to ADHD symptoms with *r*s ranging from .12 to .35. A post hoc power analysis indicated that the current sample size ($N = 25$) only provided power of .12 to .57 to detect true relations between these variables, given those effect sizes. However, a larger sample size may have yielded at least some of these correlations significant. For example, a sample size of $N = 46$ would have appropriately powered the analyses to detect a significant relation between set shifting and inattentive symptoms, given the measured effect size in the current sample.

A number of additional exploratory analyses were conducted to determine the relation, if any, between gaming medium and genre and symptoms of inattention and hyperactivity-impulsivity, as well as the potential moderating effects of medium and genre on the association between neuropsychological deficits and ADHD-related symptoms. Analyses examining gaming medium were largely unsupportive of such an association, and no significant zero-order correlations between gaming medium and neuropsychological deficits or symptoms of ADHD were observed. Likewise, regression analyses indicated no significant interactions. Regarding the types of games played, gaming genre was significantly correlated with a number of demographic variables (e.g., gender, age, ethnicity, IQ). A few interactions between certain dichotomized genres of games, and various neuropsychological deficits explained a significant amount of variance in ADHD-related symptoms. One model demonstrated that playing real time strategy games may attenuate the association between selective attention deficits and symptoms of inattention, whereas use of role-playing games may exacerbate the association. Additionally, preference of sports games appeared to be a consistent significant main effect in a number of different models. However, these findings should be interpreted with caution given the large number of analyses conducted and the relatively few number of significant findings, which may have been due to Type I error. Nevertheless, given the small sample size of the current study, these preliminary results provide some direction for future research in determining which types of video games, if any, are helpful or detrimental to the development of ADHD symptoms, particularly given certain neuropsychological deficits. This type of information will certainly be of use to parents and children in determining what types of games should be played and which ones may be avoided.

Overall, the results of the current study only partially supported the hypotheses and in some cases did not support hypotheses at all (e.g., Hypothesis 2). A great deal of research, as discussed above, has sought to examine the link between executive and neuropsychological deficits and behavioral symptoms of inattention and hyperactivity. Many studies have supported such a link, but it is important to remember that not all have found such an association. For example, one study that employed the CPT and a task similar to the Go/No Go found that executive deficits in behavioral inhibition failed to mediate ADHD-related impulsivity and that behavioral disinhibition may not account for all impulsive responding in children (Raiker, Rapport, Kofler, & Sarver, 2012). Further, some studies as discussed above did not find associations between neuropsychological deficits and ADHD symptomatology (e.g., Biederman et al., 2008; Desman et al., 2008; Scheres et al., 2001). The current results may be considered consistent with this research; however, it cannot be ruled out that a larger sample may have provided more power to detect smaller effect sizes that are meaningful.

It is important to note that although many studies have linked symptoms of ADHD with video game use (e.g., Bioulac et al., 2008; Gentile et al., 2012; Swing et al., 2010), the current study was among the first of its kind to specifically examine video game use in relation to neuropsychological deficits associated with ADHD, as well as to examine video game as one possible environmental moderator exacerbating the association between neuropsychological deficits and symptoms of ADHD. Current results indicated that gaming frequency interacted with sustained attention deficits to predict inattentive symptoms and with set shifting deficits to predict hyperactive-impulsive symptoms after accounting for covariates. The pattern of these interactions may show some support for the attraction hypothesis (Gentile et al., 2012) in that children who are already experiencing deficits at a neuropsychological level may be more interested in video games than those without such deficits and, therefore, may be interested in playing more often. It is also important to note that these interactions may be the result of parents rating children who tend to play video games more frequently as having more symptoms of ADHD regardless of neuropsychological deficits. This may partially explain why gaming frequency did not emerge as a significant main effect in any of the regression models.

Additionally, gaming duration was also related to inattentive symptoms directly and often demonstrated a trend toward significance in predicting hyperactive-impulsive symptoms when accounting for neuropsychological deficits, which was somewhat similar to the findings of Chan and Rabinowitz (2006). The fact that gaming duration emerged as a significant or trending main effect in several models may show some support for Gentile et al.'s (2012) displacement hypothesis. If children are spending increased time on video games (particularly unregulated or unstructured time), this may come at the expense of time spent learning self-control attentional or inhibitory. However, an increase in sample size may lead to more statistical power to detect smaller effect sizes, and stronger conclusions could be drawn from these findings.

Finally, although some research (e.g., Best, 2012) has indicated that certain types of video games (e.g., motion or "exergames") can help to improve neuropsychological performance, current exploratory findings did not support this conclusion. However, real time strategy games significantly moderated the association between selective attention deficits and inattentive symptoms by attenuating the association, and sports video games consistently emerged as a main effect in several moderation models examining the association between neuropsychological deficits and ADHD symptoms. Specifically, these genres of games appeared to have a negative association with symptoms indicating that it may attenuate the relation. Unfortunately, most studies discussed previously have not specifically examined the gaming genres most commonly used by their subject pools, unless they were specifically looking at the association between aggressive behaviors and violent video games. Therefore, making comparisons to previous literature is difficult in this case. Similarly, although current exploratory findings regarding gaming medium were largely inconclusive, there are currently very few studies in which children or their parents are specifically asked about their preferred gaming medium with which to compare the current results. Further research is certainly needed in this area, particularly given the increasing number of platforms on which games may be played (e.g., tablets, smart phones), and the decline of previous gaming mediums (e.g., only one participant endorsed playing video games in an arcade).

Limitations of the Current Study

As with all studies, the current study is not without some limitations. Many studies conducted within a lab in which families must commit a significant amount of their time to attend and complete measures have more difficulty in the recruitment of subjects compared to other forms of research (e.g., online survey data). Therefore, the sample size of the current study is far reduced from the proposed sample size yielded by a power analysis prior to the start of data collection, thereby limiting the conclusions that can be drawn from the data. There are several possible strategies to amend this difficulty in recruitment. One such strategy might be to shift the entirety of data collection online;

however, this method would not have been advisable. Although all neuropsychological measures could have been performed online from the participants' home with minimal modification, this would have certainly been at the expense of standardization as well as the sacrifice of other important data, namely cognitive assessment.

In future research, additional recruitment strategies should be considered to help increase the sample size and dataset. Retooling the study as a school-based evaluation rather than clinic-based evaluation may have allowed for a larger subject pool and allowed recruitment of teachers to contribute to the project, but it was not possible at the time of the current study due to the immobility of the data collection (i.e., cognitive assessment kit, neuropsychology computer). Further, completion of the study through clinics that specialize in assessing disruptive behavior disorders (including ADHD) may also be helpful in the recruitment of children who exhibit clinical symptoms of inattention and hyperactivity-impulsivity, as the current study tended to have fewer children who met diagnostic criteria based upon symptom counts alone. This would help address skewness in some measures of ADHD-related symptoms and executive deficits.

Another possible limitation of the study was the way in which gaming frequency and duration were evaluated. Parents were asked to report the number of days per week children play video games, thus restricting the variance of their report from 0 to 7 days. Future research should consider encouraging parent report as days per month or even hours per month for increased variability. Nevertheless, there did not seem to be a ceiling or floor effect with these measures, and skewness was within acceptable limits. Likewise, it may have been helpful for parents to estimate how long children and adolescents spend on different gaming mediums (e.g., portable device or home console) to see if there were meaningful differences between their use of these devices. For example, in one instance, app-based games may be shorter and easier to start and stop, whereas many console- or computer-based games require a larger time commitment to complete goals or earn levels. Parents could also report on their child's consumption of other screen media use to account for variance explained by frequent or extended television or Internet use, among others.

Finally, a child and adolescent report of how often they play video games might be helpful for future video game studies. Their perception of playing time is likely to differ from caregivers, particularly given the knowledge that children with ADHD often have difficulties with time-management and distortions in time-perception (e.g., Meaux & Chelonis, 2003), but may still prove useful as many children play video games without the knowledge or consent of caregivers. In other words, a child may play video games two days per week for three hours at a time at home, but his or her parent would be unable to account for time spent playing video games at a friend's house or the use of portable gaming devices at school during recess. However, these analyses were beyond the scope of the current study.

Future Directions of Study

Given that many children in the sample reported the frequent use of games as well as a strong overall interest in video games, future research may examine the function of video gaming for children and adolescents and to determine if the function of playing games is different for children with high and low symptoms of ADHD. In a study recently completed by Ferguson and Olson (2013), child-report of motivation toward playing games was studied in 7th and 8th grade students, and four different factors (i.e., fun/challenge, catharsis/autonomy, social relatedness, and boredom) were created based on their report. In this study, children who screened positively on ADHD did not differ from those without ADHD on any of the four factors except for catharsis, which was comprised of items related to "releasing anger or frustration, or escaping the problems of the 'real world,'" (Ferguson & Olson, 2013, p. 159). Knowing children's motivation for gaming may be useful for parents in helping to select the types of games they play, establishing rules for gaming (e.g., rules for how often or how long they play), and for helping determine alternative activities if necessary.

Finally, the current study used a parent- and child-report questionnaire that inquired about typical child reactions to winning, losing, and playing video games, including both emotional (e.g., frustration, sadness, anger, relief) and behavioral reactions (e.g., aggression, destructive behaviors, self-injurious behaviors). Future exploratory analyses could be conducted to determine if children with greater ADHD symptoms experience more frequent or extreme emotions and behaviors while playing video games, due in part to difficulty regulating emotions (e.g., Barkley, 1997b), as well as which types of video games tend to provoke the most adverse reactions. Ferguson and Olson (2014) have already taken steps to examine if children with ADHD are more "vulnerable" to aggression or violence in video games, for instance, but determined that they may not be at higher risk than those without ADHD or other mental health issues. Further, these emotional and behavioral reactions may be tied to child motivations for gaming, as described above. For example, if children with higher ADHD symptomatology report that they play video games more for catharsis or relief, do they also report more feelings of relief or calm behaviors during gaming than their peers? This information would be helpful for parents who are interested in making more informed choices about the games their children and adolescents are allowed to play. Although the current study collected some information regarding emotional and behavioral reactions to gaming, an analysis of these data and how it may be related to child motivations for gaming was beyond the scope of the current project.

Another area that needs continued research, particularly with respect to children and adolescents, is the idea that video games can be used to "teach" or improve executive skills. More specifically, research should focus on what ways, if any, video games may be used therapeutically by providers to help improve executive functioning in children and adolescents with ADHD. Many companies, the most well-known of which may be Lumosity, have made claims that playing game-based applications on mobile devices has been shown to increase memory, attention, and problem-solving skills, whereas other independent teams have not fully supported those findings as generalizing outside of performance of the game itself (e.g., Shute, Ventura, & Ke, 2015; Zickefoose, Hux, Brown, & Wulf, 2013). Finally, as noted in the review of literature, additional games and programs have been created for the sole purpose of improving very specific executive skills. However, only a few studies (e.g., Best, 2012; Shute et al., 2015) have looked at the impact on executive functioning by games that are designed purely for fun and entertainment. The current study did not have a large enough sample to support claims that other types of games (i.e., those with objectives that are not directly educational or neuropsychological) have a significant impact on executive functioning, but preliminary results of this exploratory question suggest that certain genres of games (e.g., real time strategy, sports) may attenuate the association of executive deficits and ADHD-related symptoms. Therefore, continued research in this area will be valuable to parents, educators, and gaming companies alike. Parents will be better informed that the games they select for their children are not harming their attention span or behavioral inhibition skills. Educators may consider the use of certain games or applications in the school curriculum as teaching tools or as rewards for behavior or performance that are not only reinforcing but also beneficial. Finally, gaming companies may use these types of findings to better market their games based on potential neuropsychological effects.

Conclusions

The role of video game use as an external variable related to child and adolescent behavior continues to be of great clinical importance to parents, teachers, and researchers alike. Many concerns about child behavior have been linked to a proliferation in video games and popularity of gaming, both in popular media and empirical research. Similarly, some research has shown that video games and similar computer-based programs can be used to teach or refine executive functioning in children, adolescents, and adults. Although the current study did not fully support all hypotheses, video game use (e.g., gaming frequency and gaming duration) both appear to be important in the prediction of ADHD symptoms. Gaming duration appears more directly related to parent-reported ADHD symptomatology, whereas gaming frequency appears to interact with some executive deficits to exacerbate the association between neuropsychological dysfunction and behavioral symptoms of ADHD. Exploratory analyses also provided information on the moderating (and possibly attenuating) impact of certain types of games or gaming genre. Although the current study contributes to the literature, it is a preliminary investigation with a small sample size, and continued research is needed to better understand the impact video games have on the development of executive functions and ADHD symptoms in children and adolescents.

APPENDIX A

IRB APPROVAL LETTER

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.6820 | Fax: 601.266.4377 | www.usm.edu/irb

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months. Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: **13051501**
PROJECT TITLE: **Does Video Game Use Exacerbate the Relation Between Neuropsychological Deficits and ADHD Symptoms in Children and Adolescents?**
PROJECT TYPE: **Dissertation**
RESEARCHER(S): **James Goodlad, Ph.D.**
COLLEGE/DIVISION: **College of Education and Psychology**
DEPARTMENT: **Psychology**
FUNDING AGENCY/SPONSOR: **N/A**
IRB COMMITTEE ACTION: **Expedited Review Approval**
PERIOD OF APPROVAL: **05/17/2013 to 05/16/2014**

Lawrence A. Hosman, Ph.D. Institutional Review Board

APPENDIX B

MEASURES USED IN THE CURRENT STUDY

Demographic and Diagnostic Form

The following questions refer to you and your family:
Your Gender: Female ___ Male ___ **Your Age:** _____ years
Relation to child: ____________

Location: (City, State) _____________________, _________________

Your Race: White____ Black ____ Hispanic ____ Asian ____ Other _____

Marital Status:
Married ___ Separated ___ Divorced ___ Widowed ___
Never Married/Living Alone ___ Never Married/Living with Someone ___

Education: What is the highest level of education completed by:

Yourself:
_____ 6th grade or less
_____ Junior high school (7th, 8th, 9th grade)
_____ Some high school (10th, 11th grade)
_____ High school graduate
_____ Some college (at least 1 year) or specialized training
_____ College/university graduate (4-year degree)
_____ Graduate professional degree (Master's, Doctorate)

Your Spouse/Significant Other
_____ 6th grade or less
_____ Junior high school (7th, 8th, 9th grade)
_____ Some high school (10th, 11th grade)
_____ High school graduate
_____ Some college (at least 1 year) or specialized training
_____ College/university graduate (4-year degree)
_____ Graduate professional degree (Master's, Doctorate)

Occupation:
Please provide your job title or position, NOT just the name of your employer. If you are retired, please state your prior occupation. If you do not work outside the home, state "unemployed."

What is your occupation? ____
(Please be specific)

What is your spouse's occupation? ____
(Please be specific)

Income: What is the total annual income of your household? (Combine the income of all people living in your house.)
_____ $ 0 -- $ 4,999
_____ $ 5,000 -- $ 9,999
_____ $10,000 – $14,999
_____ $15,000 -- $24,999
_____ $25,000 -- $34,999
_____ $35,000 -- $49,999
_____ $50,000 -- $74,999
_____ $75,000 -- $99,999
_____ $100,000 and above

Please list who lives in your household:

Name	Age	Gender	Relation to Child in study

The following questions refer to the child participating in the study:

Child's first and last name: _________________________

Child's gender: Male____ Female_____

Child's date of birth (MM/DD/YYYY): ____________

How old is the child?: _____

Child's race: White____ Black____ Hispanic____ Asian____ Other______________

What type of school does this child attend?:

Traditional (Public____ Private____ Other____) Home-School_____ Boarding_____

Military ____ College/University ____

Other (Please Specify) __________________

What grade is this child in?: _____

Child's overall performance in school: A-B_____ B-C _____

C-D _____ D-F _____

What extracurricular activities does your child participate in at school (check all that apply):

Sports ____ Band ____ Academic Club ____ Non-academic club ____

Other: ____ None ____

What extracurricular activities does your child participate in outside of school (check all that apply):

Sports ____ Community Service Group ____ Religious/Youth Group ____

Clubs ____ (e.g., boy/girl scouts) Other ____ None ____

Please indicate if this child has ever received any of the following psychological diagnoses:

ADHD: _____ Anxiety disorder: _____ Depression: _____

Bipolar Disorder: _____ Oppositional Defiant Disorder: _____

Conduct Disorder: _____ Mental Retardation: _____

Learning Disorder: _____ (Please specify subtype:______________)

Tic Disorder/Tourette's: _____ Autism Spectrum Disorder: _____

Does your child take any medications for the above disorder(s)? Yes___ No___ If yes, please specify:____

Does your child receive special education services? Yes___ No____ If yes, please specify:____

Does your child receive any mental health services? Yes___ No____ If yes, please specify:____

How well do you get along with your child?:

1 2 3 4 5

Not well At all Well Very Well

On average, how many hours per day do you spend with your child during the week (e.g., doing homework, playing games, reading stories, going on trips, etc)?: ______

On average, how many hours per day do you spend with your child during weekends (e.g., doing homework, playing games, reading stories, going on trips, etc)?: ______

Vanderbilt ADHD Diagnostic Parent Rating Scale (VADPRS)

Please rate your child on the following behaviors. Each rating should be considered in the context of what is appropriate for the age of your child.

Frequency Code: 0 = Never; 1 = Occasionally; 2 = Often; 3 = Very Often

1. Does not pay attention to details or makes careless mistakes, such as in homework	0	1	2	3
2. Has difficulty sustaining attention to tasks or activities	0	1	2	3
3. Does not seem to listen when spoken to directly	0	1	2	3
4. Does not follow through on instruction and fails to finish schoolwork (not due to oppositional behavior or failure to understand)	0	1	2	3
5. Has difficulty organizing tasks and activities	0	1	2	3
6. Avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort	0	1	2	3
7. Loses things necessary for tasks or activities (school assignments, pencils, or books)	0	1	2	3
8. Is easily distracted by extraneous stimuli	0	1	2	3
9. Is forgetful in daily activities	0	1	2	3
10. Fidgets with hands or feet or squirms in seat	0	1	2	3
11. Leaves seat when remaining seated is expected	0	1	2	3
12. Runs about or climbs excessively in situations when remaining seated is expected	0	1	2	3
13. Has difficulty playing or engaging in leisure activities quietly	0	1	2	3
14. Is “on the go” or often acts as if “driven by a motor”	0	1	2	3
15. Talks too much	0	1	2	3
16. Blurts out answers before questions have been completed	0	1	2	3
17. Has difficulty waiting his or her turn	0	1	2	3
18. Interrupts or intrudes on others (butts into conversations or games)	0	1	2	3
19. Argues with adults	0	1	2	3
20. Loses temper	0	1	2	3
21. Actively defies or refuses to comply with adults’ requests or rules	0	1	2	3
22. Deliberately annoys people	0	1	2	3
23. Blames others for his or her mistakes or misbehaviors	0	1	2	3
24. Is touchy or easily annoyed by others	0	1	2	3
25. Is angry or resentful	0	1	2	3
26. Is spiteful and vindictive	0	1	2	3
27. Bullies, threatens, or intimidates others	0	1	2	3
28. Initiates physical fights	0	1	2	3
29. Lies to obtain goods for favors or to avoid obligations (“cons” others)	0	1	2	3
30. Is truant from school (skips school) without permission	0	1	2	3
31. Is physically cruel to people	0	1	2	3
32. Has stolen items of nontrivial value	0	1	2	3
33. Deliberately destroys others’ property	0	1	2	3

34. Has used a weapon that can cause serious harm (bat, knife, brick, gun)	0	1	2	3
35. Is physically cruel to animals	0	1	2	3
36. Has deliberately set fires to cause damage	0	1	2	3
37. Has broken into someone else's home, business, or car	0	1	2	3
38. Has stayed out at night without permission	0	1	2	3
39. Has run away from home overnight	0	1	2	3
40. Has forced someone into sexual activity	0	1	2	3
41. Is fearful, anxious, or worried	0	1	2	3
42. Is afraid to try new things for fear of making mistakes	0	1	2	3
43. Feels worthless or inferior	0	1	2	3
44. Blames self for problems, feels guilty	0	1	2	3
45. Feels lonely, unwanted, or unloved; complains that "no one loves" him or her	0	1	2	3
46. Is sad, unhappy, or depressed	0	1	2	3
47. Is self-conscious or easily embarrassed	0	1	2	3

Please rate your child's academic performance in the following areas:

1. Reading

1-----------------2-----------------3-------------------4-------------------5
Problematic Average Above Average

2. Mathematics

1-----------------2-----------------3-------------------4-------------------5
Problematic Average Above Average

3. Written expression

1-----------------2-----------------3-------------------4-------------------5
Problematic Average Above Average

Please rate your child's classroom behavior in the following areas:

1. Relationships with peers

1-----------------2-----------------3-------------------4-------------------5
Problematic Average Above Average

2. Following directions/rules

1-----------------2-----------------3-------------------4-------------------5
Problematic Average Above Average

3. Disrupting Class

1------------------2------------------3--------------------4--------------------5
Problematic Average Above Average

4. Assignment completion

1------------------2------------------3--------------------4--------------------5
Problematic Average Above Average

5. Organizational skills

1------------------2------------------3--------------------4--------------------5
Problematic Average Above Average

Parents' Video Game Questionnaire – Adapted

Name: __________________ Child's Name: __________________ Relation:

Mother Father

1. Has your child played video games in the last 12 months? Yes No

2. How often does your child play video games? (Number of days per week) ________

3. What are the names (and video game systems) of your child's three most used video games

   a. __________________________ on __________________________ .
   b. __________________________ on __________________________ .
   c. __________________________ on __________________________ .

4. What does your child play video games on? (Several answers are possible, circle all that apply)

   a. Video games on the TV
   b. Portable gaming system (Nintendo DS, PSP)
   c. Video games on computer
   d. Online video games on computer (e.g., Warcraft)
   e. Arcade video games & pinball
   f. Cell phone/smart phone games (e.g., Angry Birds)
   g. My child does not play video games.

5. How long does your child usually play video games (number of hours per session)? __________

6. At home does your child have free access to video games (circle one)? Yes No

7. Have you decided on the conditions of use of the video games? If yes, please list which conditions. (Several answers are possible).

Time in the week:	Yes	No	Conditions: ____________________
Time in the day:	Yes	No	Conditions: ____________________
Maximal playing time:	Yes	No	Conditions: ____________________
Type of game:	Yes	No	Conditions: ____________________

8. Does your child respect the conditions of playing video games (circle one)?

Never Rarely Often Always

9. Does your child stop playing video games on his/her own accord (circle one)?

Never Rarely Often Always

10. Does your child stop playing video games when you ask him/her (circle one)?

Never Rarely Often Always

11. Do you need to get angry to make him/her stop playing video games (circle one)?

Never Rarely Often Always

12. How does he/she react when you make him/her stop playing video games (circle all that apply)?

a. Indifference
b. Agreement
c. Refusal
d. Anger
e. Tears
f. Violence/Aggression
g. Other ____________________

13. What is your child's behavior during video game playing (circle all that apply)?

a. Stays calm   b. Restless   c. Quiet
d. Comments/screams   e. Happy   f. Worried/Sad
g. Frustrated   h. Other ______________

14. How does he/she react when losing on video games (circle all that apply)?

a. Calm   b. Restless   c. Angry
d. Sad/Cries   e. Breaks video game equipment
f. Hurts himself/others   g. Other ______________

15. Has your child missed meals because of playing video games?

Never   Rarely   Often   Always

16. Has your child already lied in order to play video games?

Never   Rarely   Often   Always

Comments: ____

17. When not playing video games does you child read/talk about video games?

Never   Rarely   Often   Always

Comments: ____

18. Is your child's behavior different when he/she does not play video games for several days?

Yes   No

If yes, please specify how:

a. Calm   b. Restless   c. Angry
d. Sad   e. Others ______________

19. Do you think your child's behavior significantly disturbs family relationships because of playing video games (e.g., conflict with parents, conflicts with siblings, withdrawal...)?

Yes   No

If yes, please specify ____

20. Do you think your child's behavior significant disturbs his/her schooling because of playing video games? Yes No

If yes, please specify ____

21. After playing video games, has your child complained about somatic problems (e.g., headache, eye strain, abdominal pain/stomach ache, back pain)? Yes No

If yes, please specify ____

22. Do you think your child has a problem with video game playing? Yes No

23. Do you think your child plays video games too much? Yes No

24. If you think your child plays video games too much, are you worried about it?

Yes No

25. Do other members of the family play video games? Yes No

If yes, please specify:

a. brother(s)/sister(s) b. mother c. father

Comments: ____

26. If your child is taking medication for ADHD, do you think his/her behavior regarding video games has been modified by the treatment? Yes No

If yes, please specify medication and changes noted ________________________

____

Child's Video Game Questionnaire

Name: ___________________ Age: _____________________

Grade: ___________________

1. Have you played video games in the last year? Yes No

2. On a scale from 1 to 10, with 1 being not much at all and 10 being very much, how much do you like to play video games? _____________

3. What video game systems do you have at home (circle each one that you have)?

PlayStation 3 Xbox 360 Nintendo Wii Nintendo 64

PlayStation 2 Xbox Nintendo DS/3DS PlayStation

Portable (PSP) Gameboy Advance iPod/iPhone with games PlayStation

Pinball Machine or Arcade Computer games Online computer games

Sega Dreamcast Other: _____________

4. Which kinds of games are your favorite? Please pick your top 3 by writing a 1, 2, or 3 next to your first, second, and third favorite kind.

War/Shooting Games (e.g., Call of Duty, Battlefield)

Role-Playing Games (e.g., Fallout 3, Skyrim, Mass Effect)

Sports games (e.g., Madden 2012, FIFA, NBA Live)

Fighting games (e.g., Marvel vs. Capcom, Street Fighter IV)

Action/Adventure games (e.g., New Super Mario Brothers, God of War)

Movement Games (e.g., Just Dance, PlayStation Move, Microsoft Kinect)

Racing Games

Puzzle Games

Space Shooter/Flight Simulator games

5. Please tell me what your top 3 favorite games are and what system you play it on

1. _______________ on _______________
2. _______________ on _______________
3. _______________ on _______________

6. How many days a week do you usually play video games? _____

7. How many hours per day do you usually play video games? _____

8. How do you usually **feel** when you play video games (circle any that describe you)?

Calm	Angry	Happy	Sad	Violent
Relaxed	Tense	Energetic	Tired	Worried

9. How do you usually **feel** when your mom or dad tells you to stop playing video games (circle any that describe you)?

Calm	Angry	Happy	Sad	Violent
Relaxed	Tense	Energetic	Tired	Worried

10. How do you usually **act** when you lose in video games (circle any that describe you)?

Calm	Sad/Cry	Scream	Yell/Curse at the game
Throw controller	Punch the ground	Hurt yourself	Hurt someone else

APPENDIX C

CONSENT AND ASSENT FORMS

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

AUTHORIZATION TO PARTICIPATE IN RESEARCH PROJECT

Consent is hereby given to participate in the study titled: Video Game Use and Attention in Children and Adolescents

Purpose: The main goal of this study is to look at the association between neuropsychological functioning, ADHD-related behaviors, and video game use in children and adolescents. A secondary goal of the project is to examine which types of video games may exacerbate or attenuate this association. A third goal of this study is to examine the relation between certain types of video games and behaviors in children and adolescents (e.g., aggression, internalization).

Description of Study: Children will be asked to complete four brief neuropsychological tests administered via computer program. Children will also be administered a brief test of intelligence and three questionnaires to clarify their gaming use, behaviors, and preferences. Testing with each child should take approximately 75to 90 minutes. During this time, a parent or guardian will be asked to complete several questionnaires via secure online survey, including a demographic and diagnostic form, behavioral checklists, and questionnaires clarifying each child's video game use. These questionnaires should take approximately 30 minutes to complete. Additionally, the researcher will provide the parent with a video game log to record video game use for one week. This log may be completed online or on paper based on parent preference. Finally, with parental permission indicated by consenting to this study, the researcher will contact the child's teacher who will be asked to complete some brief demographics and one behavioral questionnaire for the child via secure online website.

Benefits: There are no direct benefits to you or your child for participating in this study. There is no direct compensation for participation; however, each child who participates will receive a $10 gift card to Wal-Mart, Target, or Amazon.com! Further, each family who completes all sections of the study will be entered to win one of three $25 gift cards from a national retailer.

Risks: There is little risk for participants completing the study, although some parents may find it mildly distressing to report some behavior problems of their children or may become aware of problems that had not previously been of concern. Furthermore, children may also find it mildly distressing to report any behavioral concerns related to their video game use. If you have concerns about your child's mood or behavior and would like to seek mental health services, please contact a local mental healthcare provider in your area. A list of local healthcare providers in your area can be obtained through the Mental Health Association, Department of Education for Licensing of Mental Health Professional, or your Primary Care Physician.

Confidentiality: All efforts will be made to protect participants' privacy and to maintain the confidentiality of the information acquired through this project. All paper protocols will be coded with a random number. Once the participants have completed the measures, consent forms will be separated from the responses, and questionnaire responses will be stored in a locked filing cabinet in our research lab separate from identifying information. Responses collected electronically will be stored with identifying information in a separate database from the responses collected.

Subject's Assurance: Whereas no assurance can be made concerning results that may be obtained (since results from investigational studies cannot be predicted) the researcher will take every precaution consistent with the best scientific practice. Participation in this project is completely voluntary, and subjects may withdraw from this study at any time without penalty, prejudice, or loss of benefits. Questions concerning the research should be directed to James Goodlad (270-725-7361) working under the supervision of Dr. Tammy Barry (601-266-5514). This project and consent form have been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research subject should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-6820. A hard copy of this form will be given to the participant in the lab setting.

The lab would like to keep a record of contact information to inquire about participation in future studies. If you would like to be included in the database of research participants and to be contacted to receive information about future studies, please provide your contact information below. This information will NOT be stored with your responses to the questions for the current study.

I would like to be contacted about future studies in the lab for which I or my child may qualify.

Yes _______ No ________

If yes:

E-mail Address: ____

Telephone Number: ____________________________________

Mailing address: _______________________________________

Street address: ___________________________________

City, State, Zip code: ______________________________

By clicking Next, I consent to participate in this study.

(NEXT BUTTON)

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

AGREEMENT TO PARTICIPATE IN RESEARCH PROJECT

We are doing a study to learn about children and adolescent video game use and certain types of behaviors. We are asking for your help because we want to learn about the types of games you play and the behaviors that you do. We also want to learn about the ways in which you think about, pay attention to, and solve certain problems on four different computer games.

If you agree to be in our study, you will be asked to take some short computer tests about the ways you think about and pay attention to problems. You will also be asked to answer some questions about words and pictures and solve certain problems. Finally, you will be asked to answer some questions about video games you play. It should take no longer than an hour and a half to finish everything. When we are done you can ask your parents to contact us at any time if you have questions about this study.

There are two important things to remember. First, you are a **volunteer**, which means you are helping us, but you do not have to unless you want to help. If you decide at any time not to finish, you can tell your parents and stop completing the problems, questions, or computer games. Second, the information that you give will be **private**. All of the information that we get will be used in research, but your name and other information that would let people know it is about you will not be used. Being in the study is up to you, and no one will be upset if you don't start the study or if you change your mind later.

By clicking Next, I consent to participate in this study.
(NEXT BUTTON)

REFERENCES

Achenbach, T. M., McConaughy, S. H., & Howell, C. T. (1987). Child/adolescent behavioral and emotional problems: Implications of cross-informant correlations for situational specificity. *Psychological Bulletin, 101*, 213-232.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders.* (Revised 4th edition). Washington, DC: Author.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th edition). Arlington, Virginia: American Psychiatric Publishing.

Anderson, C. A., & Bushman, B. J. (2001). Effects of violent video games on aggressive behavior, aggressive cognition, aggressive affect, physiological arousal, and prosocial behavior: A meta-analytic review of the scientific literature. *Psychological Science, 12*, 353-359.

Anderson, C. A., Gentile, D. A., & Buckley, K. E. (2007). *Violent video game effects on children and adolescents: Theory, research, and public policy.* Oxford: Oxford University Press.

Arnsten, A. F. T. (2009). Toward a new understanding of attention-deficit hyperactivity disorder pathophysiology: An important role for prefrontal cortex dysfunction. *CNS Drugs*, *23*, 33-41.

Baldwin, J. S., & Dabbs, M. R. (2008). Examining alternative explanations of the covariation of ADHD and anxiety symptoms in children: A community study. *Journal of Abnormal Child Psychology, 36*, 67-79.

Barkley, R. A (1997a). *ADHD and the nature of self-control*. New York: Guilford Press.

Barkley, R. A. (1997b). Behavioral inhibition, sustained attention, and executive functioning: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121,* 65-94.

Barkley, R. A. (1998). *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment.* New York: Guilford Press.

Barkley, R. A. (2003). Attention-deficit/hyperactivity disorder. In E. J. Mash & R. A. Barkley (Eds.), *Child Psychopathology* (Second Edition) (pp. 75-143). New York, : Guilford Press.

Barry, T. D., Lyman, R. D., & Klinger, L.G. (2002). Academic underachievement and attention-deficit/hyperactivity disorder: The negative impact of symptom severity on school performance. *Journal of School Psychology, 40*, 259-23.

Baumeister, R. F., Heatherton, T. F., & Tice, D. M. (1994). *Losing control: How and why people fail at self-regulation*. San Diego, CA: Academic Press.

Baumeister, R. F., Vohs, K.D., & Tice, D. M. (2007). The strength model of self-control. *Current Directions in Psychological Science, 16,* 351-355.

Berg, E. A. (1948). A simple objective technique for measuring flexibility in thinking. *Journal of General Psychology, 39,* 15-22.

Best, J. R. (2012). Exergaming immediately enhances children's executive functioning. *Developmental Psychology, 48,* 1501-1510.

Biederman, J., Faraone, S. V., Mick, E., Spencer, T., Wilens, T., Kiely, K., Guite, J., Ablon, J. S., Reed, E., & Warburton, R. (1995). High risk for attention deficit hyperactivity disorder among children of parents with childhood onset of the disorder: A pilot study. *American Journal of Psychiatry, 152,* 431-435.

Biederman, J., Mick, E., Faraone, S. V., Braaten, E., Doyle, A., Spencer, T.,. & Johnson, M. A. (2002). Influence of gender on attention deficit hyperactivity disorder in children referred to a psychiatric clinic. *American Journal of Psychiatry, 159,* 36-42.

Biederman, J., Monuteaux, M. C., Doyle, A. E., Seidman, L. J., Wilens, T. E., Ferrero, F., & ... Faraone, S. V. (2004). Impact of executive function deficits and attention-deficit/hyperactivity disorder (ADHD) on academic outcomes in children. *Journal of Consulting and Clinical Psychology, 72*, 757-766.

Biederman, J., Petty, C. R., Doyle, A. E., Spencer, T., Henderson, C. S., Marion, B., Fried, R., & Faraone, S. V. (2008). Stability of executive functioning deficits in girls with ADHD: A prospective longitudinal followup study into adolescence. *Developmental Neuropsychology, 33,* 44-61.

Bijvank, M. N., Konijn, E. A., & Bushman, B. J. (2012). “We don’t need no education”: Video game preferences, video game motivations, and aggressiveness among adolescent boys of different educational ability levels. *Journal of Adolescence, 35*, 153-162.

Bioulac, S., Arfi, L., & Bouvard, M. P. (2008). Attention deficit/hyperactivity disorder and video games: A study of hyperactive and control children. *European Psychiatry, 23*, 134-141.

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video-game playing on attention, memory, and executive control. *Acta Psychologica, 129*, 387-398.

Centers for Disease Control and Prevention. (2010). Increasing prevalence of parent-reported attention-deficit/hyperactivity disorder among children: United States, 2003-2007. *Morbidity and Mortality Weekly Report, 59,* 1439-1443.

Chan, P. A., & Rabinowitz, T. (2006). A cross-sectional analysis of video games and attention deficit hyperactivity disorder symptoms in adolescents. *Annals of General Psychiatry, 5,* 5-16.

Chess, S. (1960). Diagnosis and treatment of the hyperactive child. *New York State Journal of Medicine, 60,* 2379-2385.

Christakis, D. A., Zimmerman, F. J., DiGuiseppe, D. L., & McCarty, C. A. (2004). Early television exposure and subsequent attentional problems in children. *Pediatrics, 113*, 708-713.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155-159.

Coyne, S. M., Robinson, S. L., & Nelson, D. A. (2010). Does reality backbite? Physical, verbal, and relational aggression in reality television programs. *Journal of Broadcasting & Electronic Media, 54*, 282-298.

Crottaz-Herbette, S., Anagnoson, R. T., & Menon, V. (2004). Modality effects in verbal working memory: Differential prefrontal and parietal responses to auditory and visual stimuli. *NeuroImage, 21,* 340-351.

Desman, C., Petermann, F., & Hampel, P. (2008). Deficit in response inhibition in children with attention deficit/hyperactivity disorder (ADHD): Impact of motivation? *Child Neuropsychology, 14,* 483-503.

Donchin, E., Fabiani, M., & Sanders, A. (1989). The learning strategies project: An examination of the strategies in skill acquisition. *Acta Psychologica, 71*, 1-311.

Douglas, V. I. (1972). Stop, look, and listen: The problem of sustained attention and impulse control in hyperactive and normal children. *Canadian Journal of Behavioural Science, 4,* 259-282.

Epstein, J. N., Erkanli, A., Conners, C. K., Klaric, J., Costello, J. E., & Angold, A. (2003). Relations between continuous performance test performance measures and ADHD behaviors. *Journal of Abnormal Child Psychology, 31,* 543-554.

Englehardt, C. R., Bartholow, B. D., & Saults, J. S. (2011). Violent and nonviolent video games differentially affect physical aggression for individuals high vs. low in dispositional anger. *Aggressive Behavior, 37,* 539-546.

Ferguson, C. J. (2007). Evidence for publication bias in video game violence effects literature: A meta-analytic review. *Aggression and Violent Behavior, 12,* 470-482.

Ferguson, C. J. (2010a). Introduction to the special issue on video games. *Review of General Psychology, 14,* 66-67.

Ferguson, C. J. (2010b). The influence of television and video game use on attention and school problems: A multivariate analysis with other risk factors controlled. *Journal of Psychiatric Research, 45,* 808-813.

Ferguson, C. J., & Olson, C. K. (2013). Friends, fun, frustration, and fantasy: Child motivations for video game play. *Motivation and Emotion, 37,* 154-164.

Ferguson, C. J., & Olson, C. K. (2014). Video game violence use among “vulnerable” populations: The impact of violent games on delinquency and bullying among children with clinically elevated depression or attention deficit symptoms. *Journal of Youth and Adolescence, 43,* 127-136.

Ferguson, C. J., & Rueda, S. M. (2010). The Hitman study: Violent video game exposure effects on aggressive behavior, hostile feelings, and depression. *European Psychologist, 15,* 99-108.

Fillmore, M. T., Rush, C. R., & Hays, L. (2006). Acute effects of cocaine in two models of inhibitory control: implications of non-linear dose effects. *Addiction, 101,* 1323-1332.

Fischer, J., Aydin, N., Kastenmüller, A., Frey, D., & Fischer, P. (2012). The delinquent media effect: Delinquency-reinforcing video games increase players attitudinal and behavioral inclination toward delinquent behavior. *Psychology of Popular Media Culture, 1,* 201-205.

Frazier, P., Barron, K., & Tix, A. (2004). Testing moderator and mediator effects in counseling psychology research. *Journal of Counseling Psychology, 51*, 115-134.

Frazier, T. W., Demaree, H. A., & Youngstrom, E. A. (2004). Meta-analysis of intellectual and neuropsychological test performance in attention-deficit/hyperactivity disorder. *Neuropsychology, 18,* 543-555.

Frazier, T. W., Youngstrom, E. A., & Naugle, R. I. (2007). The latent structure of attention-deficit/hyperactivity disorder in a clinic-referred sample. *Neuropsychology, 21*, 45-64.

Freitag, C. M., Hänig, S., Schneider, A., Seitz, C., Palmason, H., Retz, W., & Meyer, J. (2012). Biological and psychosocial environmental risk factors influence symptom severity and psychiatric comorbidity in children with ADHD. *Journal of Neural Transmission, 119*, 81-94.

Gau, S. S., & Shang, C. (2010). Executive functions as endophenotypes in ADHD: Evidence from the Cambridge Neuropsychological Test Battery (CANTAB). *Journal of Child Psychology and Psychiatry, 51*, 838-849.

Gentile, D. A., Anderson, C. A., Yukawa, S., Ihori, N., Saleem, M., Ming, L., & ... Sakamoto, A. (2009). The effects of prosocial video games on prosocial behaviors: International evidence from correlational, longitudinal, and experimental studies. *Personality and Social Psychology Bulletin, 35*, 752-763.

Gentile, D. A., Swing, E. L., Lim, C. G., & Khoo, A. (2012). Video game playing, attention problems, and impulsiveness: Evidence of bidirectional causality. *Psychology of Popular Media Culture, 1*, 62-70.

Goldstein, S., & Naglieri, J. A. (2008). The school neuropsychology of ADHD: Theory, assessment, and intervention. *Psychology in the Schools, 45,* 859-874.

Gomez, R. (2003). Underlying processes in the poor response inhibition of children with attention-deficit/hyperactivity disorder. *Journal of Attention Disorders, 6*, 111-122.

Goodlad, J. K., Marcus, D. K., & Fulton, J. J. (2013). Lead and attention-deficit/hyperactivity disorder (ADHD) symptoms: A meta-analysis. *Clinical Psychology Review, 33,* 417-425.

Goodyear, P., & Hynd, G. (1992). Attention deficit disorder with (ADD–H) and without (ADD–WO) hyperactivity: Behavioral and neuropsychological differentiation. *Journal of Child Clinical Psychology, 21,* 273-305.

Gopher, D., Weil, M., & Bareket, T. (1994). Transfer of skill from a computer game trainer to flight. *Human Factors, 36,* 387-405.

Goth-Owens, T. L., Martinez-Torteya, C., Martel, M. M., & Nigg, J. T. (2010). Processing speed weaknesses in children and adolescents with non-hyperactive but inattentive ADHD (ADD). *Child Neuropsychology, 16*, 577-591.

Green, C. S., & Bavelier, D. (2006). Effect of action video games on the spatial distribution of visuospatial attention. *Journal of Experimental Psychology: Human Perception and Performance, 32,* 1465-1468.

Greitemeyer, T., & Osswald, S. (2011). Playing prosocial video games increases the accessibility of prosocial thoughts. *Journal of Social Psychology, 151,* 121-128.

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York: Guilford.

Halmøy, A., Klungsøyr, K., Skjærven, R., & Haavik, J. (2012). Pre- and perinatal risk factors in adults with attention-deficit/hyperactivity disorder. *Biological Psychiatry, 71*, 474-481.

Haslam, N., Williams, B., Prior, M., Haslam, R., Graetz, B., & Sawyer, M. (2006). The latent structure of attention-deficit/hyperactivity disorder: A taxometric analysis. *Australian and New Zealand Journal of Psychiatry, 40*, 639–647.

Holmbeck, G. N. (2002). Post-hoc probing of significant moderational and mediational effects in studies of pediatric populations. *Journal of Pediatric Psychology, 27,* 87-96.

Homack, S., & Riccio, C.A. (2004). A meta-analysis of the sensitivity and specificity of the Stroop color and word test with children. *Archives of Clinical Neuropsychology, 19*, 725-743.

Howell, D. C. (2007). *Statistical methods for psychology* (6th ed.). Belmont, CA: Thomson Wadsworth.

Huang-Pollock, C. L., Mikami, A. Y., Pfiffner, L., & McBurnett, K. (2007). ADHD subtype differences in motivational responsivity but not inhibitory control: Evidence from a reward-based variation of the stop signal paradigm. *Journal of Clinical Child and Adolescent Psychology, 2,* 127-136.

Huang-Pollock, C. L., Nigg, J. T., & Carr, T. H. (2005). Deficient attention is hard to find: Applying the perceptual load model of selective attention to attention deficit hyperactivity disorder subtypes. *Journal of Child Psychology and Psychiatry, 46,* 1211-1218.

Huang-Pollock, C. L., Nigg, J. T., & Halperin, J. M. (2006). Single dissociation findings of ADHD deficits in vigilance but not anterior or posterior attention systems. *Neuropsychology, 20,* 420-429.

Irons, J. L., Remington, R. W., & Maclean, J. P. (2011). Not so fast: Rethinking the effects of action video games on attentional capacity. *Australian Journal of Psychology, 63*, 224-231.

James, W. (1950). *The principles of psychology.* New York: Dover. (Original work published 1890).

Jacobvitz, D., & Sroufe, L. A. (1987). The early caregiver–child relationship and attention deficit disorder with hyperactivity in kindergarten: A prospective study. *Child Development, 58,* 1488-1495.

Johnson, J. G., Cohen, P., Kasen, S., & Brook, J. S. (2007). Extensive television viewing and the development of attention and learning difficulties during adolescence. *Archives of Pediatric and Adolescent Medicine, 161*, 480-486.

Kanfer, F. H., & Karoly, P. (1972). Self-control: A behavioristic excursion into the lion's den. *Behavior Therapy, 3,* 398-416.

Kaufman, A. S., & Kaufman, N. L. (1990). *Kaufman Brief Intelligence Test–Manual*. Circle Pines, MN: American Guidance Service.

Kiliç, B. G, Sener, S., Koçkar, A. I., & Karakas, S. (2007). Multicomponent attention deficits in attention deficit hyperactivity disorder. *Psychiatry and Clinical Neurosciences, 61*, 142-148.

Konrad, K., Neufang, S., Hanisch, C., Fink, G. R., & Herpertz-Dahlmann, B. (2006). Dysfunctional attentional networks in children with attention deficit/hyperactivity disorder: Evidence from an event-related functional magnetic resonance imaging study. *Biological Psychiatry, 59*, 643-651.

Lambek, R., Tannock, R., Dalsgaard, S., Trillingsgaard, A., Damm, D., & Thomsen, P. H. (2010). Validating neuropsychological subtypes of ADHD: How do children *with* and *without* an executive function deficit differ? *Journal of Child Psychology and Psychiatry, 51,* 895-904.

Landhuis, C. E., Poulton, R., Welch, D., & Hancox, R. J. (2007). Does childhood television viewing lead to attention problems in adolescence? Results from a prospective longitudinal study. *Pediatrics, 120*, 532-537.

Langenecker, S. A., Zubieta, J., Young, E. A., Akil, H., & Nielson, K. A. (2007). A task to manipulate attentional load, set-shifting, and inhibitory control: Convergent validity and test-retest reliability of the Parametric Go/No-Go Test. *Journal of Clinical and Experimental Neuropsychology, 29*, 842-853.

Lavoie, M. E., & Charlebois, P. (1994). The discriminant validity of the Stroop color and word test: Toward a cost-effective strategy to distinguish subgroups of disruptive preadolescents. *Psychology in the Schools, 31*, 98-107.

Lee, S. S., Lahey, B. B., Owens, E. B., & Hinshaw, S. P. (2008). Few preschool boys and girls with ADHD are well-adjusted during adolescence. *Journal of Abnormal Child Psychology, 36,* 373-383.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A. R., Evans, C., & Vitak, J. (2008). *Teens, video games, and civics.* (Report No. 202-415-4500). Washington, DC: Pew Internet and American Life Project.

Levine, L. E., & Waite, B. M. (2000). Television viewing and attentional abilities in fourth and fifth grade children. *Journal of Applied Developmental Psychology, 21*, 667-679.

Lingineni, R. K., Biswas, S., Ahmad, N., Jackson, B. E., Bae, S., & Singh, K. (2012). Factors associated with attention deficit/hyperactivity disorder among US children: Results from a national survey. *BMC Pediatrics, 12*. Retrieved from http://www.biomedcentral.com/1471-2431/12/50.

López-Vicente, M., Sunyer, J., Forns, J., & Torrent, M. (2014). Continuous performance test- II outcomes in 11-year-old children with early ADHD symptoms: A longitudinal study. *Neuropsychology, 28*, 202-211.

Maclin, E. L., Mathewson, K. E., Low, K. A., Boot, W. R., Kramer, A., F., Fabiani, M., & Gratton, G. (2011). Learning to multitask: Effects of video game practice on electrophysiological indices of attention and resource allocation. *Psychophysiology, 48*, 1173-1183.

Marcus, D. K., & Barry, T. D. (2011). Does attention-deficit/hyperactivity disorder have a dimensional latent structure? A taxometric analysis. *Journal of Abnormal Psychology, 120,* 427-442.

Mariani, M., & Barkley, R. A. (1997). Neuropsychological and academic functioning in preschool boys with attention deficit hyperactivity disorder. *Developmental Neuropsychology, 13*, 111-129.

Martins, N., & Wilson, B. J. (2012). Social aggression on television and its relationship to children's aggression in the classroom. *Human Communication Research, 38,* 48-71.

Marzocchi, G. M., Oosterlaan, J., Zuddas, A., Cavolina, P., Geurts, H., Redigolo, D., Vio, C., & Sergeant, J. A. (2008). Contrasting deficits on executive functions between ADHD and reading disabled children. *Journal of Child Psychology and Psychiatry, 49*, 543-552.

McBurnett, K., Pfiffner, L., & Frick, P. (2001). Symptom properties as a function of ADHD type: An argument for continued study of sluggish cognitive tempo. *Journal of Abnormal Child Psychology, 29*, 207-213.

Meaux, J. B., & Chelonis, J. J. (2003). Time perception differences in children with and without ADHD. *Journal of Pediatric Health Care, 17,* 64-71.

Miller, C. J., Marks, D. J., Miller, S. R., Berwid, O. G., Kera, E. C., Santra, A., & Halperin, J. M. (2007). Brief report: Television viewing and risk for attention problems in preschool children. *Journal of Pediatric Psychology, 32*, 448-452.

Mitrofan, O. O., Paul, M. M., & Spencer, N. N. (2009). Is aggression in children with behavioural and emotional difficulties associated with television viewing and video game playing? A systematic review. *Child: Care, Health, and Development*, *35*, 5-15.

Nicolescu, R., Petcu, C., Cordeanu, A., Fabritius, K., Schlumpf, M., Krebs, R., Kramer, U., & Winneke, G. (2010). Environmental exposure to lead, but not other neurotoxic metals, relates to core elements of ADHD in Romanian children: Performance and questionnaire data. *Environmental Research*, *110,* 476-483.

Nigg, J., Blaskey, L., Huang-Pollock, C., & Rappley, M. (2002). Neuropsychological executive functions and DSM–IV ADHD subtypes. *Journal of the American Academy of Child & Adolescent Psychiatry, 41*, 59-66.

Nigg, J. T., Knottnerus, G. M, Martel, M. M., Nikolas, M., Cavanagh, K., Karmaus, W., & Rappley, M. D. (2008). Low blood lead levels associated with clinically diagnosed attention-deficit/hyperactivity disorder and mediated by weak cognitive control. *Biological Psychiatry*, *63,* 325-331.

Nikkelen, S. W., Valkenburg, P. M., Huizinga, M., & Bushman, B. J. (2014). Media use and ADHD-related behaviors in children and adolescents: A meta-analysis. *Developmental Psychology, 50,* 2228-2241.

Obel, C., Henriksen, T. B., Dalsgaard, S. Linnet, K. M., Skajaa, E., Thomsen, P. H., & Olsen, J. (2004). Does children's watching of television cause attention problems? Retesting the hypothesis in a Danish cohort. *Pediatrics, 114,* 1373-1374.

Pelham, W. E., Fabiano, G. A., & Massetti, G. M. (2005). Evidenced-based assessment of attention deficit hyperactivity disorder in children and adolescents. *Journal of Clinical Child and Adolescent Psychology, 34,* 449-476.

Polanczyk, G., de Lima, M., Horta, B., Biederman, J., & Rohde, L. (2007). The worldwide prevalence of ADHD: A systematic review and metaregression analysis. *The American Journal of Psychiatry, 164*, 942-948.

Polner, B., Aichert, D., Macare, C., Costa, A., & Ettinger, U. (2014). Gently restless: association of ADHD-like traits with response inhibition and interference control. *European Archives of Psychiatry and Clinical Neuroscience.* Advance Online Publication. doi: 10.1007/s00406-014-0531-7

Posner, M. I. & Petersen, S.E. (1990) The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25-42.

Qiu, A., Crocetti, D., Adler, M., Mahone, E. M., Denckla, M. B., Miller, M. I., & Mostofsky, S. H. (2009). Basal ganglia volume and shape in children with attention deficit hyperactivity disorder. *The American Journal of Psychiatry, 166*, 74-82.

Raiker, J. S. Rapport, M. D., Kofler, M. J., & Sarver, D. E. (2012). Objectively-measured impulsivity and attention-deficit/hyperactivity disorder (ADHD): Testing competing predictions from the working memory and behavioral inhibition models of ADHD. *Journal of Abnormal Child Psychology, 40,* 699-713.

Rosvold, H. E., Mirsky, A. F., Sarason, I., Bransome, E. D., & Beck, L. H. (1956). A continuous performance test of brain damage. *Journal of Consulting Psychology, 20,* 343-350.

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. G., Lercari, L., P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia, 42*, 1029-1040.

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology, 28*, 573-594.

Saleem, M., Anderson, C. A., & Gentile, D. A. (2012). Effects of prosocial, neutral, and violent video games on college students' affect. *Aggressive Behavior, 38*, 263-271.

Scheres, A., Oosterlaan, J., & Sergeant, J. A. (2001). Response execution and inhibition in children with AD/HD and other disruptive disorders: The role of behavioural activation. *Journal of Child Psychology and Psychiatry, 42,* 347-357.

Schweiger, A., Abramovitch, A., Doniger, G. M., & Simon, E. S. (2007). A clinical construct validity study of a novel computerized battery for the diagnosis of ADHD in young adults. *Journal of Clinical and Experimental Neuropsychology, 29*, 100-111.

Sergeant, J. A. (2005). Modeling attention-deficit/hyperactivity disorder: A critical appraisal of the cognitive-energetic model. *Biological Psychiatry, 57*, 1248-1255.

Sergeant, J., Oosterlaan, J., & van der Meere, J. (1999). Information processing and energetic factors in attention deficit/hyperactivity disorder. In H. Quay & A. Hogan (Eds.), *Handbook of disruptive* behavior disorders (pp. 75-104). New York: Kluwer Academic.

Shaffer, D., Fisher, P., Lucas, C. P., Dulcan, M. K., & Schwab-Stonem M. E. (2000). NIMH Diagnostic Interview Schedule for Children, Version IV (NIMH DISC-IV): Description, differences from previous versions, and reliability of some common diagnoses. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*, 28-38.

Shallice, T., Stuss, D. T., Alexander, M. P., Picton, T. W., & Derkzen, D. (2008). The multiple dimensions of sustained attention. *Cortex, 44*, 794-805.

Shute, V. J., Ventura, M., & Ke, F. (2015). The power of play: The effects of Portal 2 and Lumosity on cognitive and noncognitive skills. *Computers and Education, 80*, 58-67.

Sonuga-Barke, E. J. S. (2005). Causal models of attention-deficit/hyperactivity disorder: From common simple deficits to multiple developmental pathways. *Biological Psychiatry, 57*, 1231-1238.

Steinhausen, H., Zülli-Weilenmann, N., Brandeis, D., Müller, U. C., Valko, L., & Drechsler, R. (2012). The behavioural profile of children with attention-deficit/hyperactivity disorder and of their siblings. *European Child & Adolescent Psychiatry, 21*, 157-164.

Stephens, T., & Mulsow, M. (2006). There is no meaningful relationship between television exposure and symptoms of attention deficit/hyperactivity disorder. *Pediatrics, 117*, 665-672.

Stevens, T., & Mulsow, M. (2006). There is no meaningful relationship between television exposure and symptoms of attention deficit/hyperactivity disorder. *Pediatrics, 117*, 665-672.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643-662.

Swing, E. L., Gentile, D. A., Anderson, C. A., & Walsh, D. A. (2010). Television and video game exposure and the development of attention problems. *Pediatrics, 126,* 214-221.

Sun, C. (2011, October). Online cravings. *Newsweek Magazine*. Retrieved from http://www.thedailybeast.com/newsweek/2011/10/16/south-korea-s-video-game-addiction.html

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston: Allyn and Bacon.

Tolchinski, A., & Jefferson, S. D. (2011). Problematic video game play in a college sample and its relationship to time-management skills and attention-deficit/hyperactivity disorder symptomology. *Cyberpsychology, Behavior, and Social Networking, 14,* 489-496.

Valera, E. M., Faraone, S. V., Murray, K. E., & Seidman, L. J. (2007). Meta-analysis of structural imaging findings in attention-deficit/hyperactivity disorder. *Biological Psychiatry, 61,* 1361-1369.

Van Mourik, R., Oosterlaan, J., & Sergeant, J. A. (2005). The Stroop revisited: A meta-analysis of interference control in AD/HD. *Journal of Child Psychology and Psychiatry, 46,* 150-165.

Weber, P., Jourdan-Moser, S., & Halsband, U. (2007). Differences between subtypes of children with ADHD and simple attentional difficulties during an initial assessment. *Acta Paediatrica, 96,* 1511-1517.

Williams, D. (2006). A brief social history of game play. In P. Vorderer & J. Bryant (Eds.), *Playing video games: Motives, response, and consequences*. (pp. 197-212) Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry, 57,* 1336-1346.

Willis, T. J., & Lovaas, I. (1977). A behavioral approach to treating hyperactive children: The parent's role. In J. B. Millichap (Ed.), *Learning disabilities and related disorders* (pp. 109-140). Chicago: Year Book Medical.

Willoughby, T., Adachi, P. J. C., & Good, M. (2012). A longitudinal study of the association between violent video game play and aggression among adolescents. *Developmental Psychology, 48,* 1044-1057.

Wolraich, M. L., Hannah, J. N., Baumgaertel, A., & Feurer, I. D. (1998). Examination of DSM-IV criteria for attention deficit/hyperactivity disorder in a county-wide sample. *Journal of Developmental and Behavioral Pediatrics, 19,* 162--168.

Wolraich, M. L., Lambert, E. W., Bickman, L., Simmons, T., Doffing, M. A., & Worley, K. A. (2004). Assessing the impact of parent and teacher agreement on diagnosing ADHD. *Journal of Developmental and Behavioral Pediatrics, 25*, 41-47.

Zickefoose, S., Hux, K., Brown, J., & Wulf, K. (2013). Let the games begin: a preliminary study using Attention Process Training-3 and Lumosity brain games to remediate attention deficits following a traumatic brain injury. *Brain Injury, 27,* 707-716.

Zimmerman, F. J., & Christakis, D. A. (2007). Associations between content types of early media exposure and subsequent attentional problems. *Pediatrics, 120,* 986-992.