Computers in Human Behavior 45 (2015) 228–234

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

The influence of video games on executive functions in college students

Melissa T. Buelow *, Bradley M. Okdie, Ashley B. Cooper

The Ohio State University Newark, USA

ARTICLE INFO

Article history:
Available online 2 January 2015

Keywords:
Video games
Executive functions
Decision making
Problem solving
Cognition

ABSTRACT

Video game play can have a negative effect on affect and behavior, but its relationship with cognition has been mixed. Previous research has shown both positive and negative effects of video game play on attention, memory, and other cognitive abilities; however, little research has investigated its effects on executive functions other than working memory. Additionally, most studies have utilized predominantly male samples. The present study sought to examine the effects of active video game play on decision making, problem solving, and risk-taking. Two hundred twenty-eight undergraduate students (114 female) played one of five different video games (n = 91) or were part of a separate, no-game control condition (n = 137). Scores on the Iowa Gambling Task (IGT), Balloon Analogue Risk Task (BART), and Wisconsin Card Sorting Task (WCST) were then compared. Following active video game play, participants decided more advantageously on the IGT, and made fewer errors and completed more categories on the WCST. No group differences emerged on the BART, and gender did not impact any dependent variables. It appears that active video game play may have positive effects on some executive functions with implications for real-world behavior. Implications for future research are discussed.

1. Introduction

Much research has examined the effects of video game play on cognition and behavior (see Anderson, 2004; Anderson & Bushman, 2001; Barlett, Anderson, & Swing, 2009; for reviews). Most of these studies have focused on the negative consequences of violent video games, such as increased aggressive behaviors, negative affect, and negative cognitions (Anderson, 2004; see Okdie et al., 2014, for discussion). However, other research has highlighted some benefits of video game play such as prosocial behavior (Ewoldsen et al., 2012; Velez, Mahood, Ewoldsen, & Moyer-Guse, 2014). While these studies have added much to our understanding of how violent video games affect cognition, few studies have examined how video game play affects performance on clinical measures of executive functions. The present study sought to examine the effects of video game play on executive functions.

1.1. Executive functions

Executive functions refer to higher-order cognitive abilities tied to the frontal lobes of the brain, and encompass such abilities as planning, organization, set shifting, problem solving, working memory, and decision making (Lezak, Howieson, & Loring, 2004). Multiple theories have been put forth regarding the organization of executive functions. One theory is that executive functions comprise a single construct, the central executive, that helps organize these higher-order cognitive abilities (Della Sala, Gray, Spinnler, & Trivelli, 1998). Others have proposed a multiple-systems approach to understanding executive functions. Anderson (2002) proposed a four-process model that includes: (1) cognitive flexibility (including working memory and divided attention), (2) goal setting (including planning and initiation), (3) information processing (including fluency and speed of processing), and (4) attentional control (including self-regulation and self-monitoring). Anderson indicated that these four subsystems integrate together to form one overall executive control system. Diamond (2013) proposed a three-factor model of executive functions in which inhibition, working memory, and cognitive flexibility worked together to influence higher-order executive functions such as reasoning, planning, and problem solving. The tasks utilized in the present study assess problem solving and decision making, both of which could be considered higher-order executive functions per Diamond's (2013) model.

1.2. Video games and cognition

Despite the vast number of studies examining video games and cognition, no clear pattern has emerged. The data suggest that

* Corresponding author at: Department of Psychology, The Ohio State University Newark, 1179 University Drive, Newark, OH 43055, USA. Tel.: +1 (740) 755 7808; fax: +1 (740) 366 5047.
E-mail address: buelow.11@osu.edu (M.T. Buelow).

http://dx.doi.org/10.1016/j.chb.2014.12.029
0747-5632/

video game play can both benefit and hinder cognition. For example, some studies have shown improvements in visual (Blacker & Curby, 2013; Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003, 2006) and selective attention (Belchior et al., 2013; Donohue, Woldorff, & Mitroff, 2010; Green & Bavelier, 2006; Karle, Watter, & Shedden, 2010; McDermott, Bavelier, & Green, 2014), including decreased change blindness (Vallett, Lamb, & Annetta, 2013). Conversely, others have found diminished attention (Kronenberger et al., 2005) or have failed to find differences in attention from control participants (Bailey, West, & Anderson, 2010; Collins & Freeman, 2014; Irons, Remington, & McLean, 2011; Wilms, Petersen, & Vangkilde, 2013). Additionally, the results of some previous studies indicate that frequent video game play increases attentional problems in children (Acevedo-Polakovich, Lorch, & Milich, 2007; Chan & Rabinowitz, 2006; Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; Swing, Gentile, Anderson, & Walsh, 2010). Thus, it is possible that video game play, especially in adolescents and young adults who are frequent players, decreases attentional resources in turn negatively affecting executive functions. However, a significant number of studies have shown the opposite—improved attention and executive functioning due to video game play. It is unclear what role video game play has in the development (or worsening) of attentional symptoms in young adults and children.

Despite the fragmentation in the literature on video games and cognition, one consistent finding continues to emerge in the visuospatial realm. Across multiple studies, improvements in mental rotations (De Lisi & Wolford, 2002; Greenfield, Brannon, & Lohr, 1994; Okagaki & Frensch, 1994; Passig & Eden, 2001) and visuospatial tasks more generally (Boot et al., 2008; Feng et al., 2007; Ferguson, 2010; Green & Bavelier, 2003) are seen as a function of video game play, regardless of the game type. Reaction times are faster and more accurate as a function of both recent video game play (Fischer, Kubitzki, Guter, & Frey, 2007) and a history of frequent video game play (Colzato, van den Wildenberg, Zmigrod, & Hommel, 2013). Thus, it appears that video game play may affect different cognitive abilities in positive and negative ways.

1.3. Video games and executive functions

Video game play affects performance on measures of executive functions as well. Within the video game literature, most studies show improved performance on executive tasks (see Kirsh, Olczak, & Mounts, 2005, for exception). For example, improvements have been shown on tasks assessing such executive functions as inhibitory control, task/set shifting, working memory, and abstract reasoning as a function of video game play (Basak, Boot, Voss, & Kramer, 2008; Boot et al., 2008; Maillot, Perrot, & Hartley, 2012; Mathews et al., 2005; Stern et al., 2011). Neuroimaging studies conducted before and after two (Kuhn, Gleich, Lorenz, Lindenberger, & Gallinat, 2014) and four (Colom et al., 2012) months of video game play in "non-gamers" showed increases in gray matter in the frontal lobe. These increases are localized to the dorsolateral prefrontal cortex (DLPFC), an area associated with abstract reasoning and problem solving (Lezak et al., 2004) as well as decision making in some studies (Fellows & Farah, 2005; Manes et al., 2002).

Decision making is a specific executive function that has been extensively researched in patient and non-patient populations, but is rarely examined in the context of video game play. At the most basic level, decision making involves a choice between two or more options. Decision making can occur through calculated and deliberative reasoning, or can be based at least in part on "gut feelings" and emotions (Damasio, 1994; Seguin, Arseneault, & Tremblay, 2007). When decision making relies primarily on emotions and leads toward negative outcomes, this has been referred to as risky decision making (i.e., continued risky decisions even after the risks associated with those decisions is known to the individual; Bechara, 2008). Although not directly assessing decision making, Fischer et al. (2007) found increased risk-taking cognitions following 20 min of active video game play. Only one previous study has examined video games and risky decision making (Bailey, West, & Kuffel, 2013). Bailey and colleagues examined self-reported hours of video game play and performance on the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994), the most common behavioral measure of risky decision making, as well as a delay discounting task and a self-report measure of impulsivity. Participants reporting higher levels of video game play were more impulsive, preferred smaller but more immediate rewards to larger but more temporally distant rewards, and failed to learn to choose advantageously on the IGT (i.e., continued to engage in risky decision making).

However, two large issues exist with the current literature on the effects of video games on executive functions and in studies of cognition in general. First, the majority of the published studies utilize samples composed of only or predominantly male participants (Bailey et al., 2010; Blacker & Curby, 2013; Boot et al., 2008; Collins & Freeman, 2014; Colzato et al., 2013; Donohue et al., 2010; Green & Bavelier, 2006; Wilms et al., 2013). Of those studies utilizing predominantly male samples, only one study examined results with and without female participants, finding no differences after the 15 females were removed from the analyses (leaving 106 males; Blacker & Curby, 2013). A second issue with the current literature is that a significant number of previous studies have been correlational in nature, examining how a previous history of video game experience affects cognition, not how active game play affects cognition (Bailey et al., 2010; Blacker & Curby, 2013; Collins & Freeman, 2014; Colzato et al., 2013; Donohue et al., 2010; Feng et al., 2007; Karle et al., 2010; McDermott et al., 2014; Vallett et al., 2013; Wilms et al., 2013). Thus, it is possible that females may respond differently on cognitive tasks following video game play than males, and pairing these cognitive tasks with active game play (rather than self-reported game play) may provide a more fine-grained picture of the effects of video games on executive functions.

1.4. The present study

The present study sought to examine the influence of active video game play on executive functions in both male and female undergraduate students. According to some research, video game play should lead to worse outcomes on clinical measures of cognition and possibly executive functions. In contrast, other research suggests that video game play might instead lead individuals to perform better on formal measures of executive functions. The present study examined these two competing theories by assessing decision making, risk-taking, and problem solving following 30 min of active video game play. As the effects of video game play on cognition in female participants has not been widely examined in the research to date, our analyses regarding gender differences are largely exploratory in nature.

2. Method

2.1. Participants

Participants were 228 undergraduate students (114 females; M_{age} = 19.23, SD_{age} = 2.59) enrolled in psychology courses at a regional campus of a large Midwestern university and for which