Research Report

Acute exposure to difficult (but not violent) video games dysregulates cognitive control

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ABSTRACT

Recent research has suggested that acute exposure to violent video games inhibits the capacity for self-control across neurological, cognitive, and behavioral domains. However, the games used in previous research to reach these conclusions often confound violence with other game features, such as game difficulty. Here, participants were randomly assigned to play one of four versions of a video game, wherein content (violent or not) and difficulty (easy or difficult) were orthogonally manipulated, prior to completing a cognitive control task. Results showed that playing a difficult video game produced decrements in cognitive control, but only if the game was perceived to be difficult, and that perceptions of game difficulty may mediate this relationship. Game content, by comparison, had no effect on cognitive control. Findings are discussed in terms of understanding effects of difficult games on cognitive processes that have important implications for social behavior.

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1. Introduction

One of the most fascinating human abilities is self-control, or the ability to effectively override one's automatic and habitual responses in the service of goal-directed or socially appropriate behavior. This unique skill is often vital for intrapersonal salubrity and interpersonal harmony. Indeed, numerous problems and negative social interactions seem to be caused by a relative lack of self-control: impulsivity, addictive behaviors, criminality, aggression toward others, and many more. Thus, understanding factors that affect self-control has far-reaching implications for understanding numerous social and behavioral phenomena.

Some research has suggested that the use of violent video games can cause short-term (Gabbiadini, Riva, Andrighetto, Volpato, & Bushman, 2013) or long-term (Hummer et al., 2010; Wang et al., 2009) impairments in the strength of self-control. However, these studies have often confounded other game features with game violence, leaving it unclear as to what specific game feature is responsible for the observed changes. The present research attempts to identify the game features (if any) that cause short-term changes in attention control.

1.1. Attention control and self-control

The control of attention might be one of the most fundamental forms of self-control (Gailliot & Baumeister, 2007). After all, it is difficult to imagine how someone could respond appropriately to diverse situations without first attending to the contextually relevant stimuli within them. This is perhaps why previous research has suggested that *attention control* can be thought of as the first line of defense against numerous deleterious behaviors, and that a relative lack of this control can lead to self-control failure across many behavioral domains (Baumeister, Heatherton, & Tice, 1994). Because numerous stimuli are often present in our environment at any one point in time, it is the job of attention to determine which ones are important for subsequent information processing and which ones can be safely ignored. In other words, controlling attention requires self-control because attention can automatically orient to extraneous, non-relevant objects in the environment (see Schneider & Shiffrin, 1977).

Much of the research on attention control has involved tasks in which participants are asked to differentiate between concomitant information or ignore conflicting signals (Rueda, Posner, & Rothbart, 2004). A classic example of such a task is the Stroop task (Stroop, 1935). A typical Stroop task requires participants to name the color of ink in which a color word is printed. This rule is simple to follow when the ink color and color word are congruent (e.g., when the word blue is written in blue ink), but is difficult to follow

when these two sources of information are incongruent (e.g., when the word blue is written in red ink). Overriding the prepotent response to read the color word on incongruent trials requires attention control, as attention must be oriented to the color of the ink in which a word is written rather than to the color word itself in order to perform well at the task (for similar findings, see Fairclough & Houston, 2004; Gailliot et al., 2007).

According to the strength model of self-control, volitional acts of self-regulation exhaust a global psychological resource pool, thereby leaving individuals with fewer available resources for subsequent attempts at self-control (i.e., 'depletion effects'; see Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Vohs, & Tice, 2007). In other words, much like an intense physical challenge can diminish the ability to demonstrate prowess in other physical domains, the ability to implement attention control is theorized to be reduced following initial acts of self-control. Demonstrations of this effect date back several decades and are abound in current research. For example, participants who endured unpredictable, rather than predictable, electric shocks performed worse on a subsequent Stroop task, presumably due to the greater strain on mental endurance (Glass & Singer, 1972). Similar effects also have been shown in several recent laboratory experiments (e.g., Baumeister et al., 1998, 2007; Job, Dweck, & Walton, 2010; Vohs & Heatherton, 2000; Vohs et al., 2008). For example, Job et al. (2010) reported that participants who performed a depleting task requiring cognitive control committed more errors on incongruent trials during a subsequent color-word Stroop task (Stroop, 1935). Findings such as these have led some researchers to speculate that attention control and self-control draw from the same limited resource pool (see Gailliot & Baumeister, 2007). In other words, exercising self-control (attention control) on one task should reduce the amount of attention control (self-control) that could be recruited for a subsequent, demanding task, an idea that has received considerable empirical support (e.g., Gailliot, Schmeichel, & Baumeister, 2006; Vohs, Baumeister, & Ciarocco, 2005; Vohs & Faber, 2004).

More recent research on depletion effects suggests considerable inter-individual variability in the experience of self-control depletion manipulations and related outcomes. Indeed, one recent meta-analysis provides evidence of heterogeneity across depletion studies (Hagger, Wood, Stiff, & Chatzisarantis, 2010). Hagger and colleagues reported that this heterogeneity can in part be explained by how difficult the task is perceived to be, which often varies according to levels of previous experience with the task. In other words, degree of impairment in task performance is moderated by perceptions of task difficulty.

However, the estimated population effect size of the depletion effect reported by Hagger et al. (2010), $d = 0.62$ (95% confidence interval [0.57, 0.67]), has been the subject of recent skepticism. Specifically, based on a re-analysis of the data used by Hagger and colleagues, Carter and McCullough (2013, 2014) argued that the effect size reported in the initial meta-analysis is overstated and posit that the extant evidence on depletion effects could largely be an artifact of publication bias. They reported a pattern of excess significance (that is, more significant results in studies than those studies' power would indicate as likely) in studies of cognitive depletion. Most importantly, when attempting to correct for this publication bias, the depletion effect size was estimated to be indistinguishable from zero. Carter and McCullough concluded by suggesting that researchers should re-examine the magnitude of depletion effects in future studies. That is, further research on depletion – whether it exists, how it can be manipulated, and how it influences subsequent outcomes and behavior – is needed. Previous research suggests that exposure to violent video games can cause increases in deleterious behaviors that require self-control. It is this possibility that we explore in more detail in the sections that follow.

1.2. Violent video games and self-control

Whereas decades of research have been conducted on the relationship between exposure to violent video games and aggressive behavior (see Anderson et al., 2010; Ferguson & Kilburn, 2010; Greitemeyer & Mügge, 2014), comparatively few studies have examined the acute effects of violent games on laboratory analogues of self-control. Because increased aggression can, in part, stem from decreased self-control (DeWall, Baumeister, Stillman, & Gailliot, 2007), the extent to which violent games contribute to self-control failures also might have implications for aggression-related outcomes.

Only one study to date has examined the acute effect of violent game exposure on a behavioral measure of self-control (see Gabbiadini et al., 2013). In this study, Gabbiadini and colleagues predicted that, in line with moral disengagement theory, individuals high in moral disengagement should interpret immoral behaviors in a video game as justifiable, thereby increasing the likelihood of self-control failures following game play. To test this idea, participants were assigned to play one of two violent games (*Grand Theft Auto [GTA] III* or *GTA: San Andreas*) or one of two nonviolent games (*Pinball 3D* or *Mini Golf 3D*). During game play, a 100-g bowl of M&M's was positioned next to the participant's computer. The experimenter instructed participants that they could consume the M&M's at their leisure, but that high amounts of candy consumption within brief periods of time is unhealthy. Participants who played a violent game consumed more M&Ms. than did participants who played a nonviolent game, a finding interpreted as evidence that violent games can lead to lapses in self-control. The estimated magnitude of this effect was large, $d = 1.29$, and similar results were found on measures of cheating and aggression. Gabbiadini and colleagues speculated that engaging in unconstrained, morally reprehensible behaviors in a violent video game can undermine subsequent efforts at self-control.

Similar effects of violent games have been observed on attentional cognitive control, rather than general self-control. For example, experimental research has shown that acute exposure to violent games can undermine the neural correlates of cognitive control. Wang et al. (2009) reported that, compared to participants who played a nonviolent game (*Need for Speed*), participants who played a violent game (*Medal of Honor*) for a period of 30 min showed decreased activation in areas of the prefrontal cortex during a subsequent cognitive control task, an effect consistent with reduced implementation of cognitive control (see also Hummer et al., 2010).

1.3. Disentangling violence from other in-game dimensions

A common methodological problem shared by most studies investigating these questions is that game 'violence' is almost always confounded with specific game contexts and contents. For example, *GTA* differs from *Mini Golf 3D* and *Pinball 3D* on a host of dimensions other than violence and criminal behavior. *GTA* requires the player to successfully navigate a dynamic, challenging game environment in which the player must manage *direct* competition and conflict in order to play the game effectively. By comparison, *Mini Golf 3D* and *Pinball* 3D require the player to interact with a confined, simplistic game environment in which the player might experience, at the most, minimal levels of *indirect* conflict. These between-game differences are confounds which may be responsible for the negative effects on self-control.

At least one piece of evidence points to game difficulty as being an important factor to consider in self-control related outcomes. This evidence stems from emerging research suggesting that thwarted in-game competence predicts increased post-game aggressiveness (see Przybylski, Deci, Rigby, & Ryan, 2014; study

6). Specifically, participants in this study were assigned to play one of two versions of the classic game *Tetris*: one version that used the game's standard algorithm (normal game play), or one version that used an adjusted algorithm which deliberately gave players the least useful pieces possible (excessively difficult game play). Following game play, participants decided how long a future participant should hold his or her hand in a bucket of painfully cold water, a measure of aggressive behavior. Participants in the excessively difficult game play condition assigned longer ice-water submersion times. This study suggests that changes in aggressive behavior associated with video game exposure could be due in part to the depletion of self-control resources through challenging game play.

These issues are critical to understanding the effect of violent video games on social behaviors, particularly aggression. A number of models emphasize the role of priming in video game exposure effects on behavior (see Carnagey & Anderson, 2003; Huesmann, 1986), whereas other models (see Denson, DeWall, & Finkel, 2012; Giancola, 2000) underscore a key role for higher-order cognitive processes in mediating aggression. For example, provoked individuals retaliate more severely if their self-regulatory resources have been depleted than if they have not (Denson, von Hippel, Kemp, & Teo, 2010; DeWall et al., 2007; Finkel, DeWall, Slotter, Oaten, & Foshee, 2009). If difficulty of violent games depletes a common psychological resource required to control aggressive impulses, priming of aggressive thoughts might be only one part of a more complicated causal pathway linking violent video game exposure with aggression. Therefore, separating violent game content from factors likely to affect attention or cognitive control, such as overall game difficulty, can better illustrate the precise mechanisms responsible for video game effects on aggression.

1.4. The current experiment

With these issues in mind, models explicating the conditions under which self-control is likely to suffer are especially relevant to considerations of how exposure to certain types of video games may affect attention, cognition, and behavior. Previous research examining the effect of violent game exposure on a measure of self-control has been interpreted through the lens of moral disengagement theory (Gabbiadini et al., 2013); however, it is possible that these effects are more due to cognitive fatigue associated with challenging game play than due to reprehensible or antisocial in-game behavior.

Therefore, the purpose of the current study was to independently examine effects of video game content (violent and nonviolent) and game difficulty (easy and difficult) on a measure of attention control (the spatial Stroop). This was achieved by orthogonally manipulating game content and difficulty in an experimental design. Such efforts are rare but essential to specifying how short-term exposure to violent games influences outcomes related to attention or self-control. In line with previous research on the strength model of self-control, and in contrast to the moral disengagement theory of self-control, we predicted that game difficulty, but not violence, would be associated with impaired cognitive control during the spatial Stroop task. This was the overarching prediction that informed the experimental design of the study. Exploratory analyses investigated theoretically-relevant individual differences, specifically previous game experience, because previous work has shown that less-experienced players often experience the game manipulations differently than more-experienced players (e.g., Bartholow, Sestir, & Davis, 2005; Engelhardt, Bartholow, Kerr, & Bushman, 2011), and because studies have shown that acute exposure to video games does not affect everyone in the same way (e.g., Bartholow & Anderson, 2002; Engelhardt, Bartholow, & Saults, 2011). For example, experienced players might find the difficult game to be less challenging, and thus, less depleting, than might less-experienced players.

2. Method

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study (Simmons, Nelson, & Simonsohn, 2012).

2.1. Participants

Two hundred thirty-eight undergraduates (33% women) ranging in age from 18 to 24 years ($M = 18.6$; $SD = .95$) were recruited through an internet based sign-up system and participated in exchange for course credit. Since there was no *a priori* estimated effect size, sample size was set to collect 60 per cell.

2.2. Video game manipulations

Four versions of the *Doom* video game were created for the current experiment using *Doom* toolkits (id Software, 1994; Judd, 2011; vd Heiden, 2012). *Doom* is a violent first-person shooter game in which players shoot and kill zombies and demons. Across versions, various structural (e.g., locations of doors and walls, positions of monsters) and mechanical game features (e.g., character movement, tool behavior) were held constant. The games differed only with respect to violent content and difficulty. All games were played on a desktop computer.

The violent versions of the game were adapted from the *Doom* modification *Brutal Doom* (Abenante, 2012); the nonviolent versions were adapted from the *Doom* modification *Chex Quest* (Digital Café, 1996), a children's game once included in cereal boxes. Table 1 provides details on how game content and game difficulty were manipulated across conditions. These video game files are hosted publicly at https://osf.io/3cb9m/ (Hilgard, 2013). Cover stories explaining the setting and monster behavior were crafted for each condition to bolster the experimental manipulations.

2.3. Measures

2.3.1. Attention control task

Participants completed a version of a spatial Stroop task similar to that used in previous research (Salthouse, Toth, Hancock, & Woodward, 1997). The task requires participants to indicate (via button press) as quickly and accurately as possible the direction (left or right) an arrow is pointing, ignoring the physical location of the arrow (left or right side of the screen). Performance is generally faster and more accurate on trials in which the direction of the arrow matches the side of the screen on which it appears (*compatible trials*) compared to trials in which arrow direction and screen location oppose one another (*incompatible trials*). To increase the demand for cognitive control on incompatible trials, compatible trials were made twice as frequent as incompatible trials. This proportion was meant to strengthen the prepotent response tendency to favor the screen location as a response cue (see Nieuwenhuis, Yeung, Van Den Wildenberg, & Ridderinkhof, 2003).

Each trial began with a fixation cross presented in the center of the screen for 1 s, followed by a blank screen for 200 ms, after which the stimulus (i.e., arrow) was presented for 150 ms on either the left or right side of the screen. Participants were given 600 ms from stimulus onset to make a response. If a response did not occur within this response window, a "too slow" feedback screen

Table 1
Content and difficulty manipulations.

	Content	
	Nonviolent	Violent
Appearance and behavior of in-game characters	Aliens attempted to hit player with boogers	Monsters tried to shoot, bite, and claw the player
Result of hitting game characters with gunfire	Aliens bloodlessly disappeared with a gentle, twinkling sound	Monsters exploded into intense gore, blood splattered on the floor and walls, teeth and limbs sent bouncing across the floor
Type of gun used	"Zorcher" (similar to a large remote controller)	Massive Gatling gun
Ammo and character health	Zorcher pellets, food, and Chex cereal armor	Boxes of bullets, health packs, and body armor
	Difficulty	
	Easy	Difficult
Behavior of in-game monsters	Monsters moved at one- quarter speed, did not attack the player	Monsters moved at default game speed, used bullets, fireballs or boogers
Player ammunition	Weapon could be fired indefinitely, unlimited ammo	Weapon consumed ammo at a normal rate, required ammo to use

appeared for 200 ms, indicating to the participant that quicker responding was required. Inter-trial intervals varied randomly between 200 and 400 ms. The entire task consisted of 480 trials (5 blocks of 96 experimental trials).[1] The primary purpose of including a large number of trials was to increase the precision with which reaction times on compatible and incompatible (less frequent) trials could be measured.

The dependent variable of interest, indexing the extent to which participants were able to exert control during the task, was the magnitude of the RT compatibility effect (incompatible trial RT minus compatible trial RT). Specifically, because the task goals require quick and accurate responses, slower responses to incompatible (relative to compatible) trials represent poorer implementation of attention control. Similar to previous research, response latencies that fell below or above 2 SDs from a participant's mean latency were replaced with latencies exactly 2 SDs above or below that mean (see Klauer, Rossnagel, & Musch, 1997). Trials on which participants responded incorrectly were excluded from RT analyses.

2.3.2. Post-game questions

Following all other experimental procedures, participants responded to a set of 23 questions using scales ranging from 1 (strongly disagree) to 7 (strongly agree) meant to index their perceptions of the game version they played; relevant items are presented in Table 2.[2]

Similar to previous research (e.g., Anderson & Dill, 2000; Bartholow et al., 2005), participants were asked to list their 3 favorite video games and, for each game, to list how many hours they spent playing it during an average week. Average video game exposure was calculated by summing across the average video game hours per week.

2.4. Procedure

Upon arrival to the lab and after informed consent was obtained, participants were randomly assigned to one of four video

Table 2
Post-game survey items.

I was frustrated by the video game I played
I felt excited while playing the video game
I felt engaged while playing the video game
I found the video game I played to be interesting
I found the video game I played to be arousing (i.e., not sedating)
I found the video game I played to be challenging[a]
I felt my attention was diverted to multiple objects during the video game
I felt the video game required me to track multiple objects at one time
I felt the video game required the use of multiple buttons
I felt the video game featured a great amount of violence
I felt it was difficult to find my way through the video game level[a]
I felt I needed quick reflexes to play the video game effectively[a]
I felt that the gun or zorcher I used was satisfying
I felt the gun or zorcher I used was effective
I felt the characters in the video game moved quickly
I felt the monsters in the video game were difficult to get rid of[a]
I felt the monsters in the video game put up a good fight[a]
I felt the video game controls (e.g., movement, firing gun) were hard to get used to[a]
I felt the video game I played required mental effort (i.e. brain power) to play it well[a]
I felt that I was comfortable with the controls by the end of the video game session[a]
I felt the video game I played was emotionally exhausting
I felt like I behaved aggressively during the video game
I felt like I was helping the characters in the video game

[a] Item on perceived difficulty composite (indicated by exploratory factor analysis).

game conditions: easy nonviolent ($n = 60$), easy violent ($n = 59$), difficult nonviolent ($n = 59$), or difficult violent ($n = 60$). Before participants were exposed to any discussion or stimulus related to their assigned video game, they first practiced the spatial Stroop task, completing 1 block of 32 trials.

Next, participants reviewed a cover story consistent with their assigned game condition. In the nonviolent game versions, participants were asked to play a hero tasked with returning confused and upset aliens to their home planet by using a teleporter. The nonviolent easy cover story informed participants that the aliens will walk toward them and wait to be sent home; the nonviolent difficult cover story informed participants that the aliens will try to hit them with boogers. In the violent game versions, participants were asked to play as a space marine tasked with shooting and killing demons from hell. The violent easy cover story informed participants that the monsters will walk toward them and wait to be killed; the violent difficult cover story informed participants that the demons will try to shoot the player with bullets or fireballs. All cover stories gave examples of in-game characters (aliens in the nonviolent game condition; demons in the violent game condi-

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[1] A portion of the total trials (25%) were 'no-go' trials, but since behavior on these trials was not influenced by the experimental manipulation, they will not be discussed in the current report.

[2] Because it was unclear which items best measured perceived game difficulty, the survey response data matrix was submitted to a parallel analysis (Fabrigar, Wegener, MacCallum, & Strahan, 1999) in order to determine the number of factors to be extracted (4 in the current study) from an exploratory factor analysis (EFA) using Promax rotation. Items with factor loadings greater than .3 in absolute value on one factor only were retained. This analysis yielded a perceived difficulty factor comprised of 8 items, which were then averaged to form a composite ($\alpha = .83$).

tion), power-ups (bowls of fruit in the nonviolent game condition; health packs in the violent game condition), and controls.

Participants played their assigned game unobserved for a period of 15 min. Participants then completed the 5-block spatial Stroop task (5 blocks of 96 trials), followed by the post-game rating questions and debriefing.

3. Results

3.1. Data screening

Data from 33 participants were not included in the analyses: 10 due to extremely poor spatial Stroop task performance, 11 because of computer failures during game sessions, and 12 due to the computer failing to properly record responses during the spatial Stroop task. A Fisher's exact test showed that these participants were not disproportionately represented in certain conditions ($p = .49$). Thus, our final sample consisted of 205 participants (64 women).

3.2. Manipulation checks and preliminary analyses

A general linear model (GLM) predicting perceptions of violent content including Game content (Violent, Nonviolent) and previous game experience as factors showed a main effect of Game content, $F(1,201) = 89.9$, $p < .0001$, indicating that people perceived more violent content in the violent game versions ($M = 5.02$, $SD = 1.14$) than in the nonviolent game versions ($M = 2.74$, $SD = 1.22$), $d_{unbiased} = 1.93$ [1.59, 2.26]. The main effect of previous game experience and the Game content × previous game experience interaction were nonsignificant predictors of this outcome ($Fs < 2.7$, $ps > .10$).

Perceptions of game difficulty were submitted to a similar analysis. Results showed a main effect of Game difficulty, $F(1,201) = 74.3$, $p < .0001$, indicating that people who played the difficult game versions found the game to be more difficult ($M = 2.94$, $SD = 0.97$) than people who played the easy game versions ($M = 1.97$, $SD = 0.74$), $d_{unbiased} = 1.11$ [0.82, 1.41]. The analysis also showed a main effect of previous game experience, $F(1,201) = 19.6$, $p < .001$, $r = -.30$ [−.16, −.41], such that previous game experience was negatively associated with perceived game difficulty. That is, more experienced players perceived all games as less difficult. These effects were qualified by a Game difficulty × previous experience interaction, $F(1,201) = 11.5$, $p < .001$. This interaction was probed by examining the bivariate relationships between previous game experience and perceived difficulty separately for the difficult and easy game conditions. Consistent with our hypotheses, no relationship between previous game experience and perceived game difficulty was observed among people who played the easy game, $r = -.08$ [−.28, .12], $p = .41$, whereas a negative relationship between these two variables was observed among people who played the difficult game, $r = -.44$ [−.27, −.58], $p < .0001$. In other words, inexperienced players found the challenging game to be more difficult than the easy game, while experienced players found both games to be easy.

3.3. Planned experimental design analysis

The Stroop compatibility effect was initially analyzed using a 2 (Game content) × 2 Game difficulty) analysis of variance. Results from this analysis showed that the compatibility effect did not meaningfully differ between participants who played the violent game ($M = 39.72$, $SD = 24.86$) and participants who played the nonviolent game ($M = 41.69$, $SD = 24.56$), $F(1,201) = 0.38$, $p = .54$, $d_{unbiased} = -0.08$ [−0.36, 0.20]. Contrary to our hypotheses, the compatibility effect did not differ between participants who played

Table 3
Correlations between primary study variables.

Variable name	1	2	3	4
1. Content	–			
2. Difficulty	0.02	–		
3. Experience	0.03	−0.02	–	
4. Compatibility effect	−0.04	0.07	−.14[*]	–

Note: Content = manipulated game content (nonviolent or violent); Difficulty = manipulated game difficulty (easy or difficult); Experience = previous video game experience; Compatibility Effect = Incompatible RTs – Compatible RTs.
   [*] $p < .05$.

the difficult game ($M = 42.44$, $SD = 29.95$) and participants who played the easy game ($M = 38.77$, $SD = 23.18$), $F(1,201) = 1.12$, $p = .29$, $d_{unbiased} = 0.15$ [−0.13, 0.43]. The Game content × Game difficulty interaction was also a negligible predictor of this outcome, $F(1,201) = 0.26$, $p = .61$, $r = .04$ [−.10, .17].

3.4. Exploratory analyses

We next tested our exploratory hypothesis, examining the effects of game difficulty on Stroop compatibility effect as moderated by previous experience with video games. A stepwise regression model was constructed to test the main and interactive effects of Game content, Game difficulty, and previous game experience on the compatibility effect; bivariate relationships between variables in the model can be seen in Table 3. Game content, Game difficulty, and previous game experience were entered on the first step, all two-way interactions were entered on the second step, and the 3-way interaction was entered on step three. Game experience was mean centered prior to creating interaction terms. Only the statistically significant results are discussed.

Model results are given in Table 4. The analysis showed a main effect of previous game experience on the first step, indicating that people with more previous game experience showed smaller RT compatibility effects (i.e., better cognitive control) than people with less previous game experience. The Game difficulty × previous game experience interaction emerged as a significant predictor on the second step, $p = .016$, $r = .17$ [.03, .30]. Examination of the bivariate relationship between previous game experience and the magnitude of the compatibility effect showed that these two variables were correlated in the difficult game condition ($r = -.30$ [−.11, −.46], $p = .002$), but not in the easy game condition ($r = .03$ [−.16, .23], $p = .736$) (see Fig. 1 for a graphical depiction of this interaction).[3] Thus, inexperienced, but not experienced, players who played a challenging game experienced the game as difficult and showed subsequent impaired Stroop performance. By comparison, participants who played an easy game, irrespective of their previous experience with video games, did not experience impairments on the Stroop task. No other effects were significant.

Given that the manipulated game difficulty variable affected perceptions of game difficulty for individuals low but not high in previous game experience, we examined our final exploratory hypothesis using a moderated mediation analysis (i.e., conditional indirect effects; see Preacher, Rucker, & Hayes, 2007) in which previous game experience was modeled as a moderator of the relationship between manipulated game difficulty and perceptions of game difficulty on the size of the RT compatibility effect. This analysis suggested a conditional indirect effect (but did not reach statistical significance, $t = -1.97$, $p = .0502$), which was then probed

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[3] Although the distribution of the previous game experience measure was positively skewed, similar patterns of significance were observed when conducting analyses using a nonparametric (i.e., Spearman rank correlation) approach. We therefore present the game experience measure in Fig. 1 in its original scale.

Table 4
Stepwise regression model predicting the magnitude of the compatibility effect.

Predictors	Δ Adj. R^2	β	95% CI for β
Step 1	0.01		
Content		−0.04	[−.18, .10]
Difficulty		0.07	[−.07, .21]
Experience		−0.14[*]	[−.00, −.27]
Step 2	0.02[^]		
Content × difficulty		0.05	[−.09, .19]
Content × experience		0.04	[−.10, .18]
Difficulty × experience		−0.24[*]	[−.11, −.37]
Step 3	0		
C × D × E		0.01	[−.17, .19]

Note: Content = manipulated game content (nonviolent or violent); Difficulty = manipulated game difficulty (easy or difficult); Experience = previous game experience; C × D × E = 3-way interaction involving content, difficulty, and experience. Higher-level steps include all variables from previous steps in the regression model.
[^] $p = .06$.
[*] $p < .05$.

for regions of significance using the Johnson–Neyman technique (Johnson & Neyman, 1936; see Pedhazur, 1997). This technique identifies the range of values on a given variable (here, previous game experience) where the effect of another variable (here, manipulated game difficulty) differs significantly. The point estimate of the magnitude of the indirect effect was 2.89, and the estimated value at which the moderator of the conditional indirect effect (i.e., previous game experience) transitioned from significant to non-significant was 11.3 h of game play per week. The 95% bootstrapped confidence interval (bias corrected and accelerated; $N = 5000$) at 11.3 h of game play per week showed that this effect ranged from .29 to 6.2. In other words, in the difficult game condition only, higher levels of perceived difficulty were associated with larger compatibility effects among individuals who play video games fewer than 11.3 h per week.

4. Discussion

The current experiment is the first to demonstrate that acute exposure to difficult video games can adversely affect attention control, as determined by performance on a common laboratory cognitive control task. Here, this effect was significant for individuals playing up to 11.3 h of video games per week. With even more challenging games, this effect could be applicable to individuals who tend to play more frequently. By comparison, violent game content had comparatively little effect on subsequent cognitive control, in contrast to previous research suggesting that violent in-game behaviors can cause atrophy of self-control (Gabbiadini et al., 2013).

One possible explanation for the current results is that challenging video game play taxes a common mental resource required for adequate performance on a subsequent, challenging task. This line of reasoning is supported by research showing that people who first engage in a challenging task are less able to exert self-regulatory control on subsequent tasks (e.g., Muraven, Tice, & Baumeister, 1998; Richeson & Shelton, 2003). Here, the extent to which mental effort was exerted during the video game, reflected in variability on the perceived game difficulty measure, appeared to predict the availability of self-regulatory resources for engaging in the spatial Stroop attention control task.

In previous studies examining effects of video game exposure on self-regulatory outcomes, game content and game difficulty typically have been confounded. Researchers have attempted to address this issue by asking participants exposed to violent and nonviolent video games to rate how challenging the games were (e.g., Wang et al., 2009). Such an approach is indirect at best, and it does not guarantee that the manipulated game content variable is not confounded by other gaming factors, such as competitiveness (Adachi & Willoughby, 2011) or other unmeasured variables. The best way to ensure that game violence is not confounded with difficulty is to orthogonally manipulate these variables. The current study is among the first to experimentally separate these con-
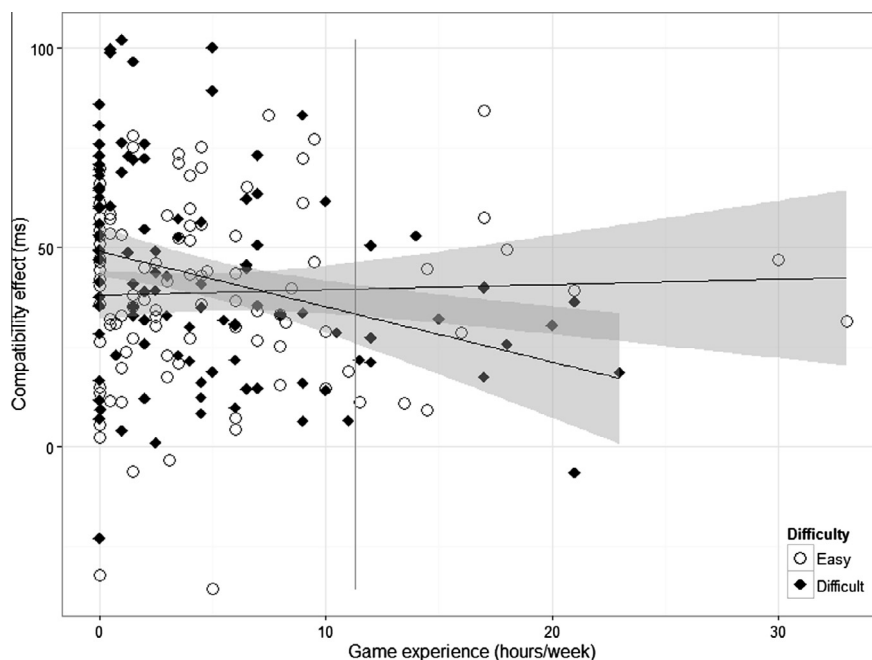

Fig. 1. Compatibility effect as a function of previous game experience and manipulated Game difficulty. More positive compatibility effects reflect poorer cognitive control. The vertical bar denotes the point at which perceived game difficulty no longer mediates the relationship between manipulated Game difficulty and the Stroop compatibility effect.

structs, thereby permitting clearer inferences concerning their effects on higher-order attention and cognitive control outcomes.

The current findings may have implications for understanding video game effects on aggression. Given the causal link between acute exposure to violent games and increases in aggressive behavior (see Anderson et al., 2010), the current data suggest that, in addition to some of the oft-cited mechanisms of this effect, such as the priming of aggressive constructs in memory (see Sestir & Bartholow, 2010; Todorov & Bargh, 2002), desensitization to violence (see Engelhardt, Bartholow, Kerr, et al., 2011), and social/interaction learning processes (see Bandura, 2001; Tedeschi & Felson, 1994), the cognitive demand of game play might deplete cognitive resources typically deployed in the service of inhibiting aggression, irrespective of whether that game play is violent or nonviolent. Several models posit that cognitive control, and inhibitory ability in particular, is important for controlling aggression (e.g., Denson et al., 2012; Giancola, 2000). To the extent that inhibiting aggression relies, at least in part, on the same cognitive control mechanisms responsible for inhibiting prepotent response tendencies in the spatial Stroop task, the current results point to depleted control as a potential (but certainly not only) factor linking acute exposure to violent action games to short-term increases in aggression. However, because the measure of attention control used in the current experiment relied on the control of spatial attention and perception, the extent to which generalizations from these findings to other forms of control (e.g., resisting aggressive impulses or chocolate candies) remains uncertain. In other words, future research is needed to examine the extent to which cognitive depletion influences aggressive responding following exposure to games with violent content, as hypothesized links between these variables are speculative based on the current study. Additionally, the current findings suggest that violent content has little or no effect on cognitive control.

Although the current experiment provides important preliminary evidence on the effects of game difficulty and content on a measure of self-control, there are some limitations. First, the effect of manipulated game difficulty was not uniform across levels of previous game experience, which likely contributed to the lack of a direct effect of this manipulated variable on the compatibility effect. In future studies it might be desirable to recruit samples more homogeneous with respect to previous gaming experience and to tailor game difficulty accordingly. Second, the present study examined only acute effects of game difficulty and game violence. The study therefore cannot speak to the findings of cross-sectional research examining purported consequences of long-term video game use (e.g. Hummer et al., 2010). However, we urge these researchers to consider that violent and nonviolent games are often different in many dimensions other than violent content (Hilgard, Engelhardt, & Bartholow, in preparation). Third, the violent video games used in this study involve a more fantastic, less realistic setting than those used in Gabbiadini et al., 2013. It is possible that there was nothing immoral about the violence perpetrated in the game, leading to an absence of moral-disengagement effects of violent content on self-control. However, apparent depletion of cognitive resources following challenging game play is an interesting phenomenon in its own right, and one that should be considered and controlled for in future research. As discussed previously, self-control is a crucial ability, and decrements in this ability could have negative implications for behaviors other than aggression that also require some degree of behavioral control. For example, the short-term effects of challenging game play might increase the probability of acting impulsively, spending more money than intending to spend, or eating more than intending to eat. Finally, the statistically significant results of this study should be interpreted with caution. While significant, the Game difficulty × previous game experience interaction was discovered

through exploratory, not confirmatory, analysis. This moderated mediational relationship through perceptions of difficulty had a small *p*-value, but nonetheless did not reach statistical significance. Thus, while these findings suggest an "ego depletion" effect of challenging game play, the strength of the evidence is modest, and must be considered in the context of current skepticism surrounding depletion (see Carter & McCullough, 2013, 2014).

In conclusion, the current findings are the first to demonstrate that brief exposure to a challenging video game, irrespective of violent content, can impair processes that rely on the control of attention and the inhibition of prepotent responses. These results further suggest the possibility that, consistent with previous research (Przybylski et al., 2014), the effects of violent games on measures of self-control might not be entirely (or even partly) driven by exposure to violent content specifically. Further research will need to investigate the extent to which cognitive depletion may cause or moderate video game effects on aggressive behavior. To that end, we urge researchers to use 'modded' video games that control for factors other than violence in their experimental research (see Elson, Breuer, Van Looy, Kneer, & Quandt, 2013; Hilgard, Engelhardt, & Bartholow, in preparation). By doing so, scholars of media violence effects can obtain a better estimate of the extent to which game violence affects outcomes that rely on self-control.

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