Computers in Human Behavior 72 (2017) 570–576

Contents lists available at ScienceDirect

Computers in Human Behavior

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

Full length article

Shoot at first sight! First person shooter players display reduced reaction time and compromised inhibitory control in comparison to other video game players

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ARTICLE INFO

Article history:
Received 23 November 2016
Received in revised form
7 February 2017
Accepted 9 February 2017
Available online 20 February 2017

Keywords:
Online video games
MMORPG
MOBA
FPS
Inhibition
Inhibitory control

ABSTRACT

Studies have shown that regular video game use might improve cognitive and social skills. In contrast, other studies have documented the negative outcomes of excessive gaming vis-à-vis health and socio-professional spheres. Both positive and negative outcomes of video game use were linked to their structural characteristics (i.e., features that make the game appealing or are inducements for all gamers to keep playing regularly). The current study tested whether active video gamers from main genres (massively multiplayer online role-playing games, online first person shooter, multiplayer online battle arena) differed in a laboratory task that measured inhibitory control. Eighty-one gamers performed the Hybrid-Stop Task, assessing restraint (go/no-go trials) and cancellation (stop-signal trials) processes of a prepotent response. They completed additional self-reported questionnaires measuring demographics, problematic video game use, impulsivity traits, and depressive symptoms. Results showed that when confounding variables were controlled for, participants who favored online first person shooter were characterized by accelerated motor responses yet reduced abilities to cancel a prepotent response. No differences between groups were identified regarding the restraint process. The findings of this pilot study might have clear implications for video gaming research by supporting the critical importance of distinguishing between video game genres when considering their specific potential benefits and detrimental effects.

1. Introduction

Video games have always benefitted from technological advancements, mostly since the arrival of Internet, which allows gamers to cooperate and to compete against each other all over the world. Online gaming is nowadays a major leisure activity that enrolls millions of players on a regular (most often daily) basis. In the last two decades, a growing number of studies have explored the potential positive outcomes (e.g., improvement of social and interactive skills, promotion of positive affect and well-being, optimization of attentional and executive functions) (Griffiths, Davies, & Chappell, 2004; Zhong, 2011) and negative outcomes (e.g., social conflicts and academic disruption, loss of control, compromised health) (Achab et al., 2011; Longman, O'Connor, & Obst, 2009; Stetina, Kothgassner, Lehenbauer, & Kryspin-Exner, 2011) associated with addictive use of video games in the context of constant development and popularization of these games at a worldwide level. In 2013, Internet gaming disorder was included in Section 3 of the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* as a potential new psychiatric condition (i.e., tentative condition deserving attention for future research) (American Psychiatric Association, 2013). Since then, research on Internet gaming disorder has blossomed (Kuss & Billieux, 2017).

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http://dx.doi.org/10.1016/j.chb.2017.02.027
0747-5632/

A shortcoming about studies conducted on video game outcomes (especially those that considered negative outcomes and excessive usage) is that they largely failed to take into account game genres. Indeed, it is known that each game genre possesses its own structural characteristics (Billieux, Deleuze, Griffiths, & Kuss, 2015; King, Delfabbro, & Griffiths, 2011). Accordingly, game genre can diverge in many aspects, including (but not limited to) addictive potential, underlying motives (e.g., achievement, immersion, socialization), and mobilization of distinct cognitive processes (e.g., sustained attention, inhibitory control).

Several studies conducted on the positive and negative effects of video games were performed with players of massively multiplayer online role-playing games (MMORPG), this game genre long being the most popular. Yet, recent years saw a growing interest in other types of online games, namely, multiplayer online battle arena (MOBA) and, mostly, online first person shooter (FPS). Their growing popularity was especially supported by the development of eSport through the popularization of international events (e.g., international championships or tournaments) simultaneously broadcasted worldwide to millions of viewers (Kollar, 2015).

1.1. Online game genres

The main structural characteristics of MMORPGs, MOBAs, and online FPSs are summarized in Table 1. MMORPGs take place in persistent virtual worlds continuing to exist independently of the player's presence. Gamer's avatar has to constantly progress (e.g., to gain levels and items) through in-game achievements, which are generally favored by successful collaborations and/or competitions with other players. The most famous MMORPG is *World of Warcraft*, reaching peaks of 12 million daily players in 2010 (Statista, 2014). An important aspect of MMORPGs is that they allow different gaming styles, including competition and cooperation with other players, immersion in huge and consistently evolving virtual worlds, and role-playing components (Billieux et al., 2013; Yee, 2006).

In contrast, MOBAs consists of intensive, short gaming sessions (30–45 min), in which teams of players have to destroy the opponent's "headquarters" in battles requiring both strategic abilities (e.g., knowing the strengths and weaknesses of the various game elements) and reactive skills (e.g., to attack or to avoid confrontation). The most famous MOBA is *League of Legends*, a free-to-play game that currently attracts around 100 million active gamers monthly (Statista, 2016).

For their part, online FPSs require motor coordination, rapidity, and reactive skills for ultimately "shooting before being shot." In FPSs, the action is generally centered on a gun (or other similar weapons) and involves confrontations (fights) through a first-person perspective in which the player has to kill enemies (other players or computer generated) while performing different types of missions (e.g., controlling specific areas or territories, capturing a flag).

1.2. Self-control and online gaming

The multidimensional construct of self-control has been extensively investigated in relation to video game involvement, mostly in relation to "dysfunctional", "harmful", or "addictive" video game use (D'Hondt, Billieux, & Maurage, 2015; King, Haagsma, Delfabbro, Gradisar, & Griffiths, 2013). This focus on self-control-related processes is particularly due to the conceptualization of videogame use as "behavioral" addiction (Lopez-Fernandez, 2015) in which impaired self-control (e.g., executive function impairment, poor decision-making and delay discounting, impulsive personality traits) is a central etiological factor (Grant, Potenza, Weinstein, & Gorelick, 2010; Groman, James, & Jentsch, 2009). The available literature indeed suggests relatively similar alterations in cerebral areas underlying self-control in video gaming disorders in comparison to other types of addictive disorders (Fauth-Bühler & Mann, 2017). Case-control studies also showed that problematic online gamers display poor decision-making abilities (Bailey, West, & Kuffel, 2013; Pawlikowski & Brand, 2011) and impaired prepotent response inhibitory control (Littel et al., 2012). An important finding is that impulsivity traits also have a predictive role in the onset and perpetuation of the disorder (Gentile et al., 2011).

Nevertheless, the types of games in which participants were involved were generally not considered in existing studies. Notable exceptions comprised reports that showed impaired decision making under risk in a case-control study involving MMORPG problematic gamers (Pawlikowski & Brand, 2011), impaired inhibitory control (assessed with a go/no-go task) in another case-control study conducted with problematic FPS players (Metcalf & Pammer, 2014), and a tendency toward compromised reward discounting in excessive MOBA gamers (Nuyens et al., 2016). Moreover, violent video games, especially FPSs, have for some time been targeted in studies challenging the idea that these games favor violent and aggressive behaviors, with, to date, mixed and controversial conclusions (Anderson et al., 2010; Ferguson, 2011).

In contrast, a growing body of evidence converged in demonstrating that video game use is susceptible to improve specific cognitive processes (Anguera et al., 2013), which notably opens up promising avenues for developing game-based interventions in various populations, including elderly individuals, conditions marked by impaired self-control (e.g., neuropsychological, impulse control disorders, or addictive disorders) (Thorens et al., 2016), and psychiatric disorders characterized by severe cognitive alterations (e.g., schizophrenia; Amado et al., 2016). To date, among the video game genres described above, demonstrated cognitive benefits were limited to studies conducted on FPSs. More precisely, several reports highlighted that FPS players, in comparison to individuals with little or no gaming experience, display improved top-down guidance of attention (Wu & Spence, 2013), optimized monitoring and updating of working memory (Colzato, van den

Table 1
Comparison of structural characteristics of the three main online video game genres.

Massively multiplayer online role-playing game (MMORPG)	Multiplayer online battle arena (MOBA)	Online first person shooter (online FPS)
Persistent virtual worlds	Achievement (with rankings)	Action, precision, reflexes
Advancement system	Social aspects (cooperation and battles PvP)	Competition and cooperation
Achievement (quests, battles, events)	Short and intense play sessions	Achievement (defeating the enemy, accomplishing missions, reaching objectives)
Exploration and immersion (virtual worlds, lore, stories)	Necessity to play regularly (to maintain level/ranking)	Rewards (better items and weapons)
Social aspects (competition, cooperation, creation of guilds)	eSport (broadcast of international tournament, millions of viewers)	eSport

Note: PvP = player versus player.

Wildenberg, Zmigrod, & Hommel, 2013), improved visuomotor controls (Li, Chen, & Chen, 2016), faster reaction times (Colzato et al., 2013), and better cognitive flexibility (Colzato, van Leeuwen, van den Wildenberg, & Hommel, 2010). It is, however, worth noting that a study focusing on inhibitory control (measured with a stop-signal task) showed identical inhibition capacities between experienced and non-experienced FPS players (Colzato et al., 2013). Nevertheless, to date, no study has compared the effect of regular use of different types of video games on cognitive performances.

1.3. Current study

The current study was designed as a pilot study that aimed at testing whether video gamers favoring different game genres (i.e., MMORPG, MOBA, or online FPS) differed in terms of (1) reaction time and (2) inhibitory control, defined as the capacity to refrain or suppress prepotent motor responses (Friedman & Miyake, 2004). We decided to focus on inhibitory control, as this executive mechanism is a key aspect of self-control involved in the proactive control of goal pursuit (Braver, Gray, & Burgess, 2008; Strack & Deutsch, 2004) and advantageous decision-making (Billieux, Gay, Rochat, & Van der Linden, 2010). Moreover, inhibitory control impairment is a hallmark of addictive and impulsive disorders (Groman et al., 2009; Smith, Mattick, Jamadar, & Iredale, 2014). On the basis of previous studies that showed a potential positive effect of FPS use on a wide range of cognitive processes, we postulated that FPS gamers would present reduced reaction time compared to MOBA and MMORPG gamers. This impact on reactivity could be encouraged by the nature (and structural characteristics) of FPSs, which promotes impulsive choices, i.e., “shooting” more quickly and more accurately than the opponent's players. We also expected reduced inhibitory controls among online FPS gamers because of a compromised trade-off between speed and accuracy (Heitz, 2014). To test these hypotheses, we decided to control for confounding variables (i.e., variables known to influence reaction time and/or inhibitory control), namely, age, gender (only males were included in the study), symptoms of disordered video game use, impulsive personality traits, and depressive symptoms (Billieux et al., 2010; Cross, Copping, & Campbell, 2011; Fales et al., 2008; Littel et al., 2012).

2. Method

2.1. Participants and procedure

Inclusion criteria for this study were being 18 or over, a native or fluent French speaker, and currently and regularly (i.e., almost every day) playing either MMORPGs, MOBAs, or online FPSs. The sample was composed of 86 volunteer gamers recruited on the campus of the Université catholique de Louvain (in the city of Louvain-la-Neuve), through a Facebook announcement, and by word of mouth. They were all males, aged between 18 and 39 years ($M = 21.91$, $SD = 3.84$). Participants were informed about the anonymity of the study and gave their prior consent. They received an incentive of 10 euros at the end of the experiment. The ethical committee of the Psychological Science Research Institute of the Université catholique de Louvain (Belgium) approved the study protocol.

A series of items were used to measure video gaming preferences (listing of video games played, preferred type of video game genre). Participants were also asked to estimate the mean time (in hours) spent playing their preferred genre on a weekly basis. One subject failed to report a preferred type of video game and was thus excluded from the analyses. The proportion of participants playing MOBA was 52% (n = 45), whereas online FPS and MMORPG games were practiced by 41% (n = 35) and 29% (n = 25) of the participants, respectively. Part of the sample (15%, n = 13) also reported playing video games that do not fall under the above-mentioned categories (e.g., online simulation or real-time strategy games).

Group attribution was then determined from self-reported preferred video game genre. The majority of participants (43%, n = 37) indicated MOBA as their preferred genre, whereas 32% (n = 27) indicated that it was FPS, and 25% (n = 21) that it was MMORPG. Part of the sample played more than one genre at the time of the experiment (38% among MOBA players, 11% among FPS players, and 43% among MMORPG players).

After signing the consent form and reading the accompanying information, participants performed a laboratory task that measured different aspects of inhibitory control: The Hybrid-Stop Task (Schachar, Forget-Dubois, Dionne, Boivin, & Robaey, 2011). After completing the task, participants filled self-reported scales in the following fixed order: The Problematic Online Gaming Questionnaire (POGQ; Demetrovics et al., 2012), the UPPS-P Impulsive Behavior Scale (UPPS-P; Billieux, Rochat, et al., 2012), and the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1998). Table 2 defines the various constructs measured by the self-reported scales and reports the internal consistency of self-reported scales their internal consistencies. Participants also completed other measures unrelated to the current study and will be described elsewhere.

2.2. Behavioral task

The Hybrid-Stop Task is a computerized task developed by Schachar et al. (2011) to assess two distinct components of inhibitory control: cancellation (i.e., interrupting an ongoing automatized action) and restraint (i.e., preventing an action when required). The Hybrid-Stop Task comprises three types of trials: (1) go trials (a measure of reaction time), (2) no-go trials (a measure of the restraint process), and (3) stop-signal trials (a measure of the cancellation process). An initial training session composed of 16 trials aims at automatizing the association between target stimuli and response keys. The task then begins, composed of 320 trials divided into five blocks. In go trials (160 trials), the participant has to indicate as quickly as possible the direction in which a black arrow points as it appears in the middle of the screen by pressing specific key buttons. In no-go trials (80 trials), the arrow appears blue, requiring the participant to avoid answering (process of restraint). In stop-signal trials (80 trials), the arrow first appears black before turning blue after a varying quick delay, requiring the participant to interrupt the ongoing action (process of cancellation). The first stop-signal delay of the Hybrid-Stop Task is based on the mean reaction time measured during the training session. A dynamic algorithm continuously modifies the delay on the basis of the participant's performance in each stop-signal trial: 50 ms shorter in the case of failed inhibition (making the next trial easier to inhibit) and 50 ms faster in the case of successful inhibition (making the next trial harder to inhibit).

Participants were instructed to answer as quickly as possible, no matter the type of trial, and to avoid answering when a blue arrow appeared. In the instructions, participants were warned that they must not anticipate the potential appearance of the stop signal, which implies that making errors is inevitable. The efficiency of the restraint process is measured through the percentage of errors at go/no-go trials. The cancellation process is measured through the number of stop-signal errors and the calculation of the stop-signal reaction time (SSRT) (Logan, 1994), which represents the mean time in which the participant is able to perceive a stop signal and to interrupt his/her answer. The integration method was used to determine the SSRT (Logan & Cowan, 1984), this method being

Table 2
Study variables.

Questionnaire	Scale	Scale description	Cronbach's α
Problematic Online Gaming Questionnaire	Total score	Symptoms of problematic online video game use	0.82
Short UPPS-P Impulsive Behavior Scale	Urgency	Tendency to act rashly in intense positive or negative emotional contexts	0.83
	Lack of premeditation	Difficulties taking into account the consequences of an action	0.87
	Lack of perseverance	Difficulties remaining focused on a boring and/or difficult task	0.91
	Sensation seeking	Preference for new experiences and potentially risky activities	0.78
Beck Depression Inventory-II	Total score	Dimensional score of depressive symptoms	0.79
Hours of playtime per week	Mean estimation	Reported estimation of the mean hours devoted to play the preferred genre per week	–
Hybrid-Stop Task	GO RTs	Mean reaction time for go trials	–
	SSRTs	Mean stop-signal reaction times (cancellation process)	–
	SST errors	Percentage of errors for stop-signal trials	–
	GNG errors	Percentage of errors for go/no go trials (restraint process)	–

recognized as the most accurate SSRT estimation (Verbruggen, Chambers, & Logan, 2013). Items in which participants made errors were removed before the calculation of the mean reaction time. To limit the impact of late responses, we suppressed every reaction time to go trials that was longer than the mean for go trials plus 2.5 standard deviations on a subject-by-subject basis.

3. Results

3.1. Data reduction

Four participants were excluded from the analyses: three were considered outliers in terms of time spent playing video games and one had technical problems with the stop-signal task (two FPS gamers, one MOBA gamer, and one MMORPG gamer). The final sample was thus composed of 81 male volunteer gamers aged between 18 and 39 years ($M = 22.07$, $SD = 3.83$).

3.2. Control variables

Before comparing the groups (MOBA, online FPS, MMORPG) on the Hybrid-Stop Task measures, we ran a set of analyses of variance to identify potential group differences within the control variables retained, namely (1) demographics, (2) time spent playing per week, (3) impulsivity traits (UPPS-P), (4) video game excessive use symptoms (POGQ), and (4) depressive symptoms (BDI-II), using Bonferroni-corrected post hoc tests when significant differences were identified. On the basis of recent data questioning the utility of distinguishing between positive and negative urgency (Berg, Latzman, Bliwise, & Lilienfeld, 2015) and the high correlation between these two constructs in the current study ($r = 0.53$, $p < 0.001$), we used a unique score of urgency. Demographics for the final sample are reported in Table 3. A significant difference appeared regarding the mean hours of playtime (online FPS players reported less weekly time spent playing than did MMORPG and MOBA gamers). However, this variable was not significantly correlated with the Hybrid-Stop Task variables and was thus not considered as a covariate.

3.3. Inhibitory control

One-way analyses of variance were computed to compare performances in the Hybrid-Stop Task (reaction time, cancellation process, and restraint process) between groups, while applying Bonferroni-corrected post hoc tests. All results are reported in Table 4 and Fig. 1. Post hoc comparisons revealed that gamers favoring online FPS displayed faster reaction times to go trials and presented a reduced ability to cancel an automatic motor response (higher SSRT) than did gamers favoring MOBA. Although the result is a nonsignificant trend ($p = 0.068$), gamers favoring online FPS also displayed reduced reaction time in comparison to gamers who preferred MMORPG. Gamers favoring online FPS also made more errors in stop-signal trials compared with those who preferred to play MOBA and MMORPG. No difference in reaction time and inhibitory control was demonstrated between gamers whose preferred genre was either MOBA or MMORPG. No group differences were highlighted regarding the restraint process (go/no-go trials).

4. Discussion

This study was designed as a pilot study devoted to the comparison of inhibitory control performances in regular video game players based on their preferred game genre (MMORPG, MOBA, or online FPS) while controlling the influence of potential confounding factors (demographics, weekly hours of playing, symptoms of disordered gaming, impulsivity traits, and depressive symptoms). A Hybrid-Stop Task was used to measure reaction time, along with two components of inhibition: the cancellation and the restraint processes. On the whole, the results showed that individuals favoring online FPS games were characterized by accelerated reaction times and reduced abilities to cancel a prepotent motor response in comparison to individuals favoring MOBA or MMORPG games. Although it clearly appeared that individuals who preferred online FPS made more errors following stop-signals than did gamers who favored MOBA and MMORPG, the picture seems a bit more nuanced when it comes to reaction time, as gamers favoring online FPS are faster than MOBA gamers but not faster than MMORPG gamers. Notably, however, the difference in reaction time between gamers favoring online FPS and MMORPG can be considered a nonsignificant trend ($p = 0.068$). Regarding SSRT (an index of inhibitory restraint depending on both reaction time and errors), it appears that gamers favoring online FPS present lower inhibitory control than do gamers favoring MOBA. An important finding is that 20% of the gamers who indicated that they favor MMORPG also play online FPS, whereas only about 11% of gamers who favor MOBA also play online FPS, which could explain why the differences observed between MMORPG and online FPS are less marked than those observed between MOBA and online FPS. No differences between groups were identified regarding the restraint of a prepotent motor response.

Confirming our hypotheses and the work of Colzato et al. (2013), online FPS gamers displayed decreased mean reaction times. Interestingly, the observation in Table 4 of the standard deviations for reaction times revealed a very small variability within online FPS gamers, giving further support to the view that regular involvement in this particular game genre boosts the reactivity of motor responses. This effect can reasonably be attributed to the

Table 3
Comparison of demographics and questionnaires between genres of favorite online game.

	MMORPG (N = 20, 24.7%)	MOBA (N = 36, 44.4%)	Online FPS (N = 25, 30.9%)	
	M (SD)	*M (SD)*	*M (SD)*	*F*
Demographic measures				
Age	22.90 (3.39)	21.06 (1.79)	22.88 (5.69)	2.366
Hours/week	15.50 (9.22)	16.82 (6.74)	9.98 (5.21)[a]	7.309**
Self-reported questionnaires				
POGQ-Total	42.25 (9.46)	46.36 (8.53)	44.52 (6.82)	1.597
UPPS-Total urgency	18.15 (5.35)	20.75 (4.03)	19.80 (3.85)	2.307
UPPS-Lack of premeditation	6.35 (2.18)	7.78 (2.47)	7.08 (2.23)	2.463
UPPS-Lack of perseverance	7.30 (2.56)	8.25 (3.00)	6.92 (2.29)	1.966
UPPS-Sensation seeking	11.75 (2.65)	11.50 (2.32)	11.76 (2.63)	0.104
BDI-II	7.20 (3.59)	8.56 (5.70)	7.80 (6.08)	0.428

Note. Hours/week = mean hours of online game per week; MMORPG = massively multiplayer online role-playing game; MOBA = multiplayer online battle arena; online FPS = online first person shooter; POGQ = Problematic Online Gaming Questionnaire; UPPS = UPPS-P Impulsive Behavior Scale; BDI-II = Beck Depression Inventory - II.
** $p < 0.005$.
[a] Statistically significant in comparison to MMORPG and MOBA players at $p < .05$ using Bonferroni post hoc tests.

Table 4
ANOVAs on Hybrid-Stop Task scores of online video game genres.

	MMORPG	MOBA	Online FPS	
	M (SD)	*M (SD)*	*M (SD)*	*F*
GO RTs	501.71 (220.88)	525.04 (243.42)	363.85 (43.81)[a]	5.259*
SSRTs	259.54 (51.82)	249.83 (53.28)	291.86 (59.21)[a]	4.477*
SST errors	59.62 (15.23)	59.23 (14.62)	72.95 (16.44)[b]	6.765**
GNG errors	3.06 (3.15)	2.64 (6.78)	3.55 (5.37)	0.192

Note. ANOVAs = one-way analyses of variance; MMORPG = massively multiplayer online role-playing game; MOBA = multiplayer online battle arena; online FPS = online first person shooter; GO RTs = mean reaction time for go trials; SSRTs = mean stop-signal reaction times; SST errors = percentage of errors for stop-signal trials; GNG errors = percentage of errors for go/no go trials. * $p < .05$; ** $p < .005$.
[a] Statistically significant in comparison to MOBA players at $p < .05$ using Bonferroni post hoc tests.
[b] Statistically significant in comparison to MOBA and MMORPG players at $p < .05$ using Bonferroni post hoc tests.

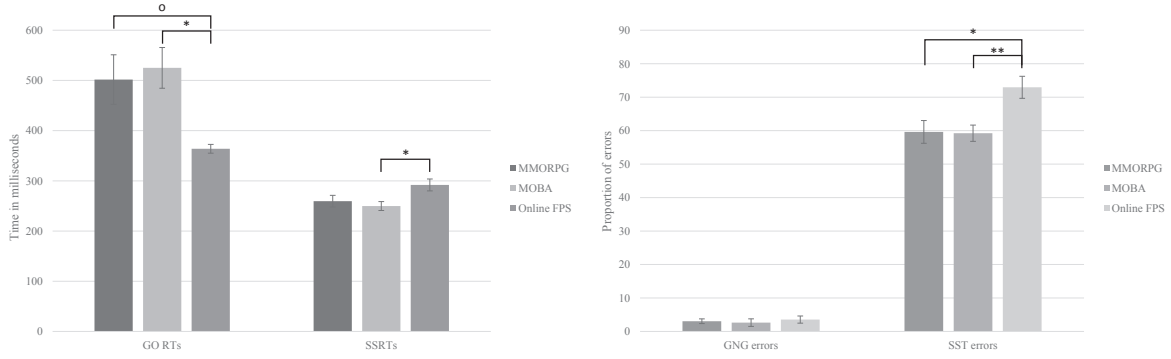

Fig. 1. Mean reaction times, SSRTs, and errors in the Hybrid-Stop Task. * $p < 0.05$; ** $p < 0.005$; $^{o}p = 0.068$. Error bars represent standard errors of the mean. GO RTs = mean reaction times for go trials; SSRTs = mean stop-signal reaction times; GNG errors = go/no-go errors; SST errors = stop-signal task errors; MMORPG = massively multiplayer online role-playing game; MOBA = multiplayer online battle arena; online FPS = online first person shooter.

nature of FPSs (i.e., their structural characteristics reported in Table 1), which puts players into the perspective of fighters who need to react more quickly than their opponents to survive, and eventually win, in the game. In contrast, MMORPGs are more contemplative and less demanding in terms of attention focus and reactivity, alternating between strategic action (combats) and immersive exploration, and MOBAs instead mobilize quick and strategic decision making and collaborative playing.

The analyses also revealed that gamers favoring online FPS make more errors when they need to cancel an automatized prepotent response. It is thus likely that when playing online FPS, an impulsive gamer who is characterized by increased reactivity and diminished inhibition will perform well, with limited direct associated risks (e.g., a failed cancellation process resulting in "friendly fire" will not have consequences in the real life of gamers). Yet, we cannot exclude the possibility that in the real life, this impulsive style is susceptible to engendering negative outcomes. Indeed, reduced efficacy of the cancellation process reflects a poor capacity to inhibit prepotent (or automatic) motor responses (Friedman & Miyake, 2004), which is a core etiological factor of many psychiatric disorders, including addictive disorders (Billieux, Lagrange, et al., 2012; Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009; Smith et al., 2014). Individuals with impaired inhibition of prepotent response have also been shown to be more prone to making detrimental decisions in the long term to obtain immediate gratification (Billieux et al., 2010). Beyond this risk, reduced

inhibitory control has also been linked to other hazardous or problematic behaviors, including aggressive and antisocial behaviors (Plutchik & Van Praag, 1995). Our study findings are also congruent with Dickman's conceptualization of impulsivity (Dickman, 1990), which posits that, depending on the context, an impulsive behavior can be either functional or dysfunctional. Indeed, from the evidence presented above, the impulsive style displayed by online FPS players in our study is probably adaptive in the gaming context, but likely dysfunctional to a certain extent in the context of real-life daily living.

Several limitations have to be acknowledged. First, we did not include a non-gamers group as required in any attempt to document an inhibitory control impairment in certain types of video game players. This choice was, however, deliberate, as our aim was to test the influence of game genre on inhibitory control, not to show impairments in video gamers versus non-gamer participants, as in traditional case-control studies. Second, even though all but one participant successfully identified a preferred type of video game, the study design did not allow us to consider that some participants might be involved in more than one type of video game genre, and we measured only the time spent playing weekly for the preferred gaming genre. Accordingly, subsequent studies either should be conducted with “pure gamers” (i.e., gamers involved in only one type of video game genre), or should control for the involvement in each type of gaming genre by using techniques such as tracking- or diary-based methods. Finally, future studies should also consider individuals who play “casual games” (i.e., simple and short video games playable on smartphones or web browsers, such as *Candy Crush* and *Pokémon GO*), which were not considered here, despite their growing popularity. Nonetheless, we can suppose that these games, because of their simple and repetitive nature, will not engender an effect on attentional and executive processes.

In conclusion, although preliminary, our results revealed neuropsychological differences among gamers that can be understood on the basis of the heterogeneous structural characteristics of online video games. These findings may have clear implications for video gaming research and support the critical importance of distinguishing between video games genres, whether focusing on their benefits (e.g., development of “games for health” or use in neuropsychological rehabilitation) or on their detrimental effects (e.g., development of addictive patterns of use, promotion of maladaptive impulsive behaviors).

Funding

Jory Deleuze is funded by a Special Research Fund (FSR) from the Université catholique de Louvain (Belgium).

Author disclosure statement

No competing financial interests exist.

References

Achab, S., Nicolier, M., Mauny, F., Monnin, J., Trojak, B., Vandel, P., et al. (2011). Massively multiplayer online role-playing games: Comparing characteristics of addict vs non-addict online recruited gamers in a French adult population. *BMC Psychiatry, 11*(1), 144. http://dx.doi.org/10.1186/1471-244X-11-144.

Amado, I., Brénugat-Herné, L., Orriols, E., Desombre, C., Dos Santos, M., Prost, Z., et al. (2016). A serious game to improve cognitive functions in schizophrenia: A pilot study. *Frontiers in Psychiatry, 7*, 64. http://dx.doi.org/10.3389/fpsyt.2016.00064.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: American Psychiatric Publishing.

Anderson, C. A., Shibuya, A., Ihori, N., Swing, E. L., Bushman, B. J., Sakamoto, A., et al. (2010). Violent video game effects on aggression, empathy, and prosocial behavior in eastern and western countries: A meta-analytic review. *Psychological Bulletin, 136*(2), 151–173. http://dx.doi.org/10.1037/a0018251.

Anguera, J. A., Boccanfuso, J., Rintoul, J. L., Al-Hashimi, O., Faraji, F., Janowich, J., et al. (2013). Video game training enhances cognitive control in older adults. *Nature, 501*(7465), 97–101. http://dx.doi.org/10.1038/nature12486.

Bailey, K., West, R., & Kuffel, J. (2013). What would my avatar do? Gaming, pathology, and risky decision making. *Frontiers in Psychology, 4*, 609. http://dx.doi.org/10.3389/fpsyg.2013.00609.

Beck, A. T., Steer, R. A., & Brown, G. K. (1998). *Inventaire de dépression II* (2nd ed.). Paris: Éditions du Centre de Psychologie Appliquée.

Berg, J. M., Latzman, R. D., Bliwise, N. G., & Lilienfeld, S. O. (2015). Parsing the heterogeneity of impulsivity: A meta-analytic review of the behavioral implications of the UPPS for psychopathology. *Psychological Assessment, 27*(4), 1129–1146. http://dx.doi.org/10.1037/pas0000111.

Billieux, J., Deleuze, J., Griffiths, M. D., & Kuss, D. J. (2015). Internet gaming addiction: The case of massively multiplayer online role-playing games. In N. el-Guebaly, G. Carrà, & M. Galanter (Eds.), *Textbook of addiction Treatment: International perspectives* (pp. 1515–1525). New York, NY: Springer Milan.

Billieux, J., Gay, P., Rochat, L., & Van der Linden, M. (2010). The role of urgency and its underlying psychological mechanisms in problematic behaviours. *Behaviour Research and Therapy, 48*(11), 1085–1096. http://dx.doi.org/10.1016/j.brat.2010.07.008.

Billieux, J., Lagrange, G., Van der Linden, M., Lançon, C., Adida, M., & Jeanningros, R. (2012). Investigation of impulsivity in a sample of treatment-seeking pathological gamblers: A multidimensional perspective. *Psychiatry Research, 198*(2), 291–296. http://dx.doi.org/10.1016/j.psychres.2012.01.001.

Billieux, J., Rochat, L., Grazia, C., Carré, A., Offerlin-Meyer, I., Defeldre, A. C., et al. (2012). Validation of a short French version of the UPPS-P impulsive behavior scale. *Comprehensive Psychiatry, 53*(5), 609–615. http://dx.doi.org/10.1016/j.comppsych.2011.09.001.

Billieux, J., Van der Linden, M., Achab, S., Khazaal, Y., Paraskevopoulos, L., Zullino, D., et al. (2013). Why do you play World of Warcraft? An in-depth exploration of self-reported motivations to play online and in-game behaviours in the virtual world of Azeroth. *Computers in Human Behavior, 29*(1), 103–109. http://dx.doi.org/10.1016/j.chb.2012.07.021.

Braver, T. S., Gray, J. R., & Burgess, G. C. (2008). Explaining the many varieties of working memory variation: Dual mechanisms of cognitive control. In A. Conway, C. Jarrold, M. Kane, A. Miyake, & J. Towse (Eds.), *Variation in working memory* (pp. 76–108). Oxford: Oxford University Press.

Colzato, L. S., van Leeuwen, P. J. A., van den Wildenberg, W. P. M., & Hommel, B. (2010). DOOM'd to switch: Superior cognitive flexibility in players of first person shooter games. *Frontiers in Psychology, 1*(8). http://dx.doi.org/10.3389/fpsyg.2010.00008.

Colzato, L. S., van den Wildenberg, W. P. M., Zmigrod, S., & Hommel, B. (2013). Action video gaming and cognitive control: Playing first person shooter games is associated with improvement in working memory but not action inhibition. *Psychological Research, 77*(2), 234–239. http://dx.doi.org/10.1007/s00426-012-0415-2.

Cross, C. P., Copping, L. T., & Campbell, A. (2011). Sex differences in impulsivity: A meta-analysis. *Psychological Bulletin, 137*(1), 97–130. http://dx.doi.org/10.1037/a0021591.

Demetrovics, Z., Urbán, R., Nagygyörgy, K., Farkas, J., Griffiths, M. D., Pápay, O., et al. (2012). The development of the problematic online gaming questionnaire (POGQ). *PLoS One, 7*(5), e36417. http://dx.doi.org/10.1371/journal.pone.0036417.

Dickman, S. J. (1990). Functional and dysfunctional impulsivity: Personality and cognitive correlates. *Journal of Personality and Social Psychology, 58*(1), 95.

D'Hondt, F., Billieux, J., & Maurage, P. (2015). Electrophysiological correlates of problematic Internet use: Critical review and perspectives for future research. *Neuroscience & Biobehavioral Reviews, 59*, 64–82. http://dx.doi.org/10.1016/j.neubiorev.2015.10.005.

Fales, C. L., Barch, D. M., Rundle, M. M., Mintun, M. A., Snyder, A. Z., Cohen, J. D., et al. (2008). Altered emotional interference processing in affective and cognitive-control brain circuitry in major depression. *Biological Psychiatry, 63*(4), 377–384. http://dx.doi.org/10.1016/j.biopsych.2007.06.012.

Fauth-Bühler, M., & Mann, K. (2017). Neurobiological correlates of internet gaming disorder: Similarities to pathological gambling. *Addictive Behaviors, 64*, 349–356. http://dx.doi.org/10.1016/j.addbeh.2015.11.004.

Ferguson, C. J. (2011). Video games and youth violence: A prospective analysis in adolescents. *Journal of Youth and Adolescence, 40*(4), 377–391. http://dx.doi.org/10.1007/s10964-010-9610-x.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General, 133*(1), 101–135. http://dx.doi.org/10.1037/0096-3445.133.1.101.

Gentile, D. A., Choo, H., Liau, A., Sim, T., Li, D., Fung, D., et al. (2011). Pathological video game use among youths: A two-year longitudinal study. *Pediatrics, 127*(2), 319–329. http://dx.doi.org/10.1542/peds.2010-1353.

Grant, J. E., Potenza, M. N., Weinstein, A., & Gorelick, D. A. (2010). Introduction to behavioral addictions. *The American Journal of Drug and Alcohol Abuse, 36*(5), 233–241. http://dx.doi.org/10.3109/00952990.2010.491884.

Griffiths, M. D., Davies, M. N., & Chappell, D. (2004). Demographic factors and playing variables in online computer gaming. *CyberPsychology & Behavior, 7*(4), 479–487. http://dx.doi.org/10.1089/cpb.2004.7.479.

Groman, S. M., James, A. S., & Jentsch, J. D. (2009). Poor response inhibition: At the nexus between substance abuse and attention deficit/hyperactivity disorder. *Neuroscience & Biobehavioral Reviews, 33*(5), 690–698. http://dx.doi.org/10.1016/j.neubiorev.2008.08.008.

Heitz, R. P. (2014). The speed-accuracy tradeoff: History, physiology, methodology, and behavior. *Frontiers in Neuroscience, 8*(150). http://dx.doi.org/10.3389/fnins.2014.00150.

King, D. L., Delfabbro, P. H., & Griffiths, M. D. (2011). The role of structural characteristics in problematic video game Play: An empirical study. *International Journal of Mental Health and Addiction, 9*(3), 320–333. http://dx.doi.org/10.1007/s11469-010-9289-y.

King, D. L., Haagsma, M. C., Delfabbro, P. H., Gradisar, M., & Griffiths, M. D. (2013). Toward a consensus definition of pathological video-gaming: A systematic review of psychometric assessment tools. *Clinical Psychology Review, 33*(3), 331–342. http://dx.doi.org/10.1016/j.cpr.2013.01.002.

Kollar, P. (2015). *League of Legends 2015 world championship broke a bunch of records*. Retrieved August 9, 2016, from: http://www.polygon.com/2015/12/10/9886500/league-of-legends-2015-world-championship-records-viewership-numbers.

Kuss, D. J., & Billieux, J. (2017). Technological addictions: Conceptualisation, measurement, etiology and treatment (editorial). *Addictive Behaviors, 64*, 231–233. http://dx.doi.org/10.1016/j.addbeh.2016.04.005.

Lawrence, A. J., Luty, J., Bogdan, N. A., Sahakian, B. J., & Clark, L. (2009). Impulsivity and response inhibition in alcohol dependence and problem gambling. *Psychopharmacology, 207*(1), 163–172. http://dx.doi.org/10.1007/s00213-009-1645-x.

Li, L., Chen, R., & Chen, J. (2016). Playing action video games improves visuomotor control. *Psychological Science, 27*(8), 1092–1108. http://dx.doi.org/10.1177/0956797616650300.

Littel, M., van den Berg, I., Luijten, M., van Rooij, A. J., Keemink, L., et al. (2012). Error processing and response inhibition in excessive computer game players: An event-related potential study. *Addiction Biology, 17*(5), 934–947. http://dx.doi.org/10.1111/j.1369-1600.2012.00467.x.

Logan, G. D. (1994). On the ability to inhibit thought and action: A users' guide to the stop signal paradigm. In D. Dagenbach, & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189–239). San Diego, CA, US: Academic Press.

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review, 91*(3), 295–327. http://dx.doi.org/10.1037/0033-295X.91.3.295.

Longman, H., O'Connor, E., & Obst, P. (2009). The effect of social support derived from World of Warcraft on negative psychological symptoms. *CyberPsychology & Behavior, 12*(5), 563–566. http://dx.doi.org/10.1089/cpb.2009.0001.

Lopez-Fernandez, O. (2015). How has internet addiction research evolved since the advent of internet gaming Disorder? An overview of cyberaddictions from a psychological perspective. *Current Addiction Reports, 2*(3), 263–271. http://dx.doi.org/10.1007/s40429-015-0067-6.

Metcalf, O., & Pammer, K. (2014). Impulsivity and related neuropsychological features in regular and addictive first person shooter gaming. *Cyberpsychology, Behavior, and Social Networking, 17*(3), 147–152. http://dx.doi.org/10.1089/cyber.2013.0024.

Nuyens, F., Deleuze, J., Maurage, P., Griffiths, M. D., Kuss, D. J., & Billieux, J. (2016). Impulsivity in multiplayer online battle arena Gamers: Preliminary results on experimental and self-report measures. *Journal of Behavioral Addictions, 5*, 351–356. http://dx.doi.org/10.1556/2006.5.2016.028.

Pawlikowski, M., & Brand, M. (2011). Excessive Internet gaming and decision making: Do excessive World of Warcraft players have problems in decision making under risky conditions? *Psychiatry Research, 188*(3), 428–433. http://dx.doi.org/10.1016/j.psychres.2011.05.017.

Plutchik, R., & Van Praag, H. M. (1995). The nature of impulsivity: Definitions, ontology, genetics, and relations to aggression. In E. Hollander, & D. J. Stein (Eds.), *Impulsivity and aggression* (pp. 7–24). New York, NY: John Wiley & Sons.

Schachar, R. J., Forget-Dubois, N., Dionne, G., Boivin, M., & Robaey, P. (2011). Heritability of response inhibition in children. *Journal of the International Neuropsychological Society, 17*(2), 238–247. http://dx.doi.org/10.1017/S1355617710001463.

Smith, J. L., Mattick, R. P., Jamadar, S. D., & Iredale, J. M. (2014). Deficits in behavioural inhibition in substance abuse and addiction: A meta-analysis. *Drug and Alcohol Dependence, 145*, 1–33. http://dx.doi.org/10.1016/j.drugalcdep.2014.08.009.

Statista. (2014). *Number of World of Warcraft subscribers from 1st quarter 2005 to 3rd quarter 2014 (in millions)*. Retrieved December 9, 2014, from: http://www.statista.com/statistics/276601/number-of-world-of-warcraft-subscribers-by-quarter/.

Statista. (2016). *League of Legends MAU 2016 | statistic [statista]*. Retrieved September 21, 2016, from: https://www.statista.com/statistics/317099/number-lol-registered-users-worldwide/.

Stetina, B. U., Kothgassner, O. D., Lehenbauer, M., & Kryspin-Exner, I. (2011). Beyond the fascination of online-games: Probing addictive behavior and depression in the world of online-gaming. *Computers in Human Behavior, 27*(1), 473–479. http://dx.doi.org/10.1016/j.chb.2010.09.015.

Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review, 8*(3), 220–247. http://dx.doi.org/10.1207/s15327957pspr0803_1.

Thorens, G., Billieux, J., Mégevand, P., Zullino, D., Rothen, S., Achab, S., et al. (2016). Capitalizing upon the attractive and addictive properties of massively multiplayer online role playing games to promote wellbeing. *Frontiers in Psychiatry, 7*(167). http://dx.doi.org/10.3389/fpsyt.2016.00167.

Verbruggen, F., Chambers, C. D., & Logan, G. D. (2013). Fictitious inhibitory Differences: How skewness and slowing distort the estimation of stopping latencies. *Psychological Science, 24*(3), 352–362. http://dx.doi.org/10.1177/0956797612457390.

Wu, S., & Spence, I. (2013). Playing shooter and driving videogames improves top-down guidance in visual search. *Attention, Perception, & Psychophysics, 75*(4), 673–686. http://dx.doi.org/10.3758/s13414-013-0440-2.

Yee, N. (2006). Motivations for play in online games. *CyberPsychology & Behavior, 9*(6), 772–775. http://dx.doi.org/10.1089/cpb.2006.9.772.

Zhong, Z.-J. (2011). The effects of collective MMORPG (Massively Multiplayer Online Role-Playing Games) play on gamers' online and offline social capital. *Computers in Human Behavior, 27*(6), 2352–2363. http://dx.doi.org/10.1016/j.chb.2011.07.014.