The experimental analysis of problematic video gaming and cognitive skills: A systematic review

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Résumé

Contexte et objectifs: Jouer aux jeux vidéo est devenu l'une des activités mondiales majeures avec des millions de personnes y jouant tous les jours. Suivant ce succès, les jeux vidéo ont grandement évolué, multipliant les genres (p.ex., MMORPG, MOBA, FPS) ; certains de ces jeux demandant un grand investissement de la part des joueurs. Cet investissement peut devenir excessif, voire pathologique, et de nombreuses études ont exploré ce risque, menant à l'inclusion de l'« Usage pathologique des jeux sur Internet » dans l'appendice du DSM-5 (American Psychiatric Association, 2013). Cependant, malgré les risques sous-jacents d'une addiction (p.e.x., pertes de relations, difficultés scolaires), il a également été démontré que le jeu vidéo pouvait significativement améliorer les performances des joueurs (p.ex., performances sur un simulateur de chirurgie, Fanning, Fenton, Johnson, Johnson, & Rehman, 2011; ; meilleure recherche visuelle, Sims & Mayer, 2002). De plus, il a été démontré que le fait de jouer à ces jeux pouvait impacter les capacités cognitives des joueurs (p.ex., Durlach, Kring, & Bowens, 2009). Une revue systématique sur l'impact d'une utilisation pathologique/excessive sur ces capacités a donc été menée. *Méthode*: La recherche d'articles a été menée sur quatre bases de données (p.ex., *Google Scholar, PubMed, Science Direct, PsychINFO*). Afin d'être inclus dans cette revue, les articles revus par les pairs devaient: (i) dater d'au moins 2000 (les jeux vidéo ayant grandement évolué depuis), (ii) inclure au moins une étude expérimentale sur les processus cognitifs des joueurs, (iii) inclure des joueurs excessifs/pathologiques, (iv) être publiés en anglais, et (v) Ne pas avoir été utilisés dans une revue de littérature auparavant (p.ex., études en fMRI). Après sélection des articles et tri des doublons, la recherche a mené à 18 résultats dans 3 sections différentes (c.-à-d., Perception du temps supérieur à la seconde, Inhibition, et Prise de décision). *Résultats*: Les expériences sur la perception du temps montrent des résultats hétérogènes, certaines études ne montrant aucun résultat (p.ex.., Rivero, Covre, Reyes, & Bueno, 2012), d'autres des résultats partiels (Rau, Peng, & Yang, 2006), voire des résultats significatifs (Tobin & Grondin, 2009). Cependant, les études démontrant des résultats (potentiellement) significatifs incluaient des utilisateurs pathologiques, contrairement aux études sans résultats significatifs. Cette différence de population pouvant potentiellement expliquer cette différence. Les études sur l'inhibition montrent le même type de résultats hétérogènes, cependant, une fois ces études classées par type d'inhibition, il apparaîtrait que les joueurs montrent une inhibition de la réponse prépotente réduite (p.ex., au travers de tâches Go/Nogo, Littel et al., 2012), celle-ci étant aggravée lorsque des stimuli liés aux jeux étaient inclus dans la tâche (p.ex., Liu et al., 2014). Cependant, la seule étude ayant exploré l'annulation d'une réponse prépotente n'a pas démontré d'inhibition réduite, les joueurs de jeux-vidéos d'action présentant des temps de réactions réduits (Colzato, van den Wildenberg, Zmigrod, & Hommel, 2013). Finalement, Les études sur la prise de décision montrent des résultats similaires au travers des études, c'est-à-dire des lacunes à prendre des décisions dans des contextes de risque (p.ex., Pawlikowski & Brand, 2011), une prise de décision intacte dans les tâches à contextes ambigus (p.ex., Nuyens et al., 2016), et une tendance à préférer une récompense moindre immédiate à une récompense plus importante après un délai variable (Weinstein, Abu, Timor, & Mama, 2016). *Discussion*: Malgré les divers résultats contraires, et le peu d'étude sur certains processus, il est clair qu'une utilisation pathologique des jeux vidéo peut mener à des difficultés cognitives. Cependant, sachant que les études sur les performances susmentionnées ne recrutaient que des participants sains, il est supposable qu'une utilisation normale mènerait à des performances améliorées, sans aucune contrepartie négative. Plus d'études seraient donc nécessaires afin de déterminer l'impact différent des jeux vidéo sur les processus cognitifs en fonction du degré et type d'utilisation de ceux-ci (c.-à-d., utilisation occasionnelle, fréquente, ou pathologique).

Mots clefs: Jeu Problématique, Usage pathologique des jeux sur Internet, Addiction aux jeux vidéo, capacités cognitives, étude expérimentale.

Abstract

There is now a growing literature demonstrating the excessive gaming can have negative detrimental effects on a small minority of gamers. This has led to much debate in the psychological literature on both the positive and negative effects of gaming. One specific area that has been investigated is the effect of gaming on different types of cognitive skills. The present study carried a systematic review examining the studies that have examined the impact of problematic gaming on cognitive skills. Following a number of inclusion and exclusion criteria, a total of 18 studies were identified that had investigated three specific cognitive skills: (i) multi-second time perception (4 studies), inhibition (7 studies), and decision-making (7 studies). Based on the studies reviewed, the findings demonstrate that the pathological and/or excessive use of videogames leads to more negative consequences on cognitive processes.

Keywords: Problematic gaming, Internet Gaming Disorder, Gaming addiction, Cognitive skills, Experimental gaming studies

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Introduction

As a consequence of the many studies demonstrating the potentially negative effects of excessive videogame play (including interpersonal relationships, increased financial difficulties, and academic difficulties [1–5]), the American Psychiatric Association included 'Internet Gaming Disorder' (IGD) in the Appendix of the latest (fifth) edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [6]. In addition to the negative impact of gaming, there is a large literature base on the more positive impacts among non-problematic players (e.g., [7,8]). Research has shown that trained competences in videogames can be extended to other fields, including visual performance (e.g., saccadic eye movement [9,10], visual processing levels [11-13]), and navigation skills. Furthermore, videogames have been used as a tool to improve people's lives educationally [14,15] and therapeutically [16,17], as well as successfully in health prevention programs for drug use and acquired immune deficiency syndrome (AIDS) [18,19].

Studies of surgical abilities have demonstrated that gamers greatly outperform medical students on different surgery simulators, such as laparoscopic surgery [20,21] or arthroscopy procedures [22]. The findings relating to navigation skills among gamers are far from consistent, with one study showing no significant differences between novice and expert gamers. However, this was only a pilot study with twelve participants [23]. Another study found no relationship between gaming experience and real-life navigation, but a significant relationship with virtual navigation [24]. However, due to the different tasks used, no definitive conclusions can be drawn.

Despite the overwhelming experimental evidence that the playing of videogames can have positive effects, the aim of the present review was to explore the impact of excessive and/or problematic gaming on cognitive skills by reviewing the studies that have used experimental designs. Studies have shown that addiction to drugs or behaviours such as gambling can lead to impaired cognitive skills [25–28]. Such findings provide a good rationale for why this might also be the case among those addicted to videogames. To examine this issue, a systematic review examining such studies was carried out as no such review has ever been carried out previously. It is argued that the present study is important in identifying research and topic gaps and is needed in the present literature concerning the impact of IGD on cognitive functioning.

Method

An extensive literature research was conducted using four databases: *Google Scholar, Science Direct, PubMed,* and *PsycINFO*. All searches included a common set of search words defining the field of study (i.e., video game, gaming, videogame addiction, problematic gaming, pathological gaming, internet gaming disorder), and other words specifying the particular cognitive domain studied (i.e., decision-making, time perception, delay discounting, attention, inhibition, and task-switching). For example, one of the search term entries carried out was "[("videogame" or "gaming" or "videogame") and "decision-making"]". Studies were included if they: (i) dated from 2000 (because videogames have greatly evolved since then), (ii) included problematic/excessive gamers in the sample, (iii) utilized an experimental design, (iv) evaluated cognitive processes, (v) were published in English, and (vi) were peer-reviewed.

Experimental studies in very specific areas of gaming were excluded if they had been extensively reviewed before, such as studies using functional magnetic resonance imaging or electroencephalography [29,30] and the use of videogames being beneficial to surgical skills [21,31], unless the study also included a specific examination of cognitive skills using an experimental design. The search led to 18 papers (see Figure 1) being published in three areas examining cognitive skills: (i) multi-second time perception (4 studies), inhibition (7 studies), and decision-making (7 studies). One study investigated two of these skills.

Add Figure 1 about here

Results

Multi-second time perception

Although the time perception literature is wide ranging, authors agree on a separation between two paradigms: prospective and retrospective time perception [32]. The first is conscious (i.e., participants know that they have to evaluate a time duration before the experiment commences); the second one is unconscious (i.e., the participants do not know that they will have to evaluate a duration before the experiment commences).

The first study exploring time perception among gamers used a retrospective paradigm to assess time distortion [33]. The authors recruited 26 expert players and 38 novices who played *Diablo II* for one of three different durations (i.e., 30, 60, and 90 minutes). After the game session, participants were asked to stop playing, and were assessed on how much time the participant needed to actually stop playing (delay time), the acceptance of the break-off, the satisfaction of the session, and a time estimation of the play duration. Although there were no significant differences for the delay time, acceptance, and satisfaction level between the two groups, expert players tended to underestimate the 60-minute-duration, while the novices overestimated it (although this just failed to reach the statistical significance limit [p = .058]). However, there were several limitations because participants were informed that the experiment would last a maximum of 90 minutes. Participants in the 90-minute-duration group reached an almost perfect time estimation. Furthermore, there were 30% of Internet-addicted participants in the expert group compared to 35% in the novice group. It is therefore possible that many novices just played other games, thus greatly biasing the results.

Tobin and Grondin [34] explored the impact of activity type (i.e., reading or playing a videogame) on prospective and retrospective time perception. They recruited 116 adolescents allocated to two groups (i.e., prospective and retrospective) who performed three consecutive activities (i.e., playing a game for 8 and 24 minutes, and reading a text for 8 minutes). Thus, there was no comparison for the 24-minute-gaming session. The results showed that there was an overestimation of the short duration tasks and an underestimation of the longer tasks. However, because the 24-minute-gaming session had no control task, the reason for the underestimation is unknown, as it could either result from the structural characteristics of videogames, or from the longer length of the activity. All participants estimated the 8-minute-gaming session as shorter than the reading session. The study also compared time perception of "addicted" players (n = 14) to non-addicted players (n = 102). Only the 24-minute-session was significant, with addicted gamers underestimating more greatly the duration of the playing session than the non-addicted gamers.

Wood and Griffiths [35] explored time distortion while playing videogames. Here, 40 participants played one of two videogames (i.e., to allow participants to play a game on their favourite platform, computer or console) for 45 minutes and had to fill in several questionnaires before and after the gaming session. While playing, they were interrupted three times (i.e., after 13, 37, and 45 minutes), asking how long they had played. The only result related to time distortion came from the questionnaire. Two-thirds of the participants (67.5%) frequently/always experienced time loss. No association between videogame play and the duration evaluation was found following each interruption. Because the authors did not inform participants before the experiment that time estimation would be evaluated, a methodological issue arose. The first evaluation of time duration fitted the retrospective definition of time perception, while the two subsequent evaluations arguably fitted the prospective definition. This is because as soon as a participant is asked to make an estimation of play duration, the following estimation(s) will systematically become prospective as players will begin to realize what they are being asked to do [36].

Rivero et al. [37] explored both the sub-second perception (i.e., stimuli between 100 and 1000ms) and multi-second perception (i.e. stimuli between 5 and 60 seconds) in a prospective paradigm by comparing nine frequent players (i.e., 30 hours per week during the past month) and nine occasional players (less than 5 hours per week during the past month). While the frequent players clearly outperformed the occasional ones on the sub-second time perception tasks, there was no difference (positive or negative) for multi-second time perception. However, as time loss relates to long duration (i.e., over 30 minutes), it is understandable that no difference was found in those tasks because they used a shorter duration (i.e., maximum 60 seconds).

Inhibition

Because IGD has been argued to be a behavioural addiction [38], some researchers have associated pathological gaming with inhibition impairment, implying that such players will play because they cannot prevent themselves from doing it. Inhibition in these studies can be defined in two different ways, as either the cancellation of a prepotent motor response (i.e., the ability to inhibit an automatic response) or the restraint of a prepotent motor response (i.e., the ability to stop an already engaged response). Inhibition can be assessed using tasks such as the Go/NoGo, the Stroop, and the Stop-Signal.

The Go/NoGo task is usually carried out in two parts; the first where participants are trained to respond to given stimuli (e.g., pressing two keys according to the direction of an arrow); and a second where participants have to do the same thing, except that when stimuli are slightly different, they cannot answer (e.g., not responding if the arrow is red instead of green). Two studies have shown an impaired inhibition level among gamers [39,40]. One study failed to find any result regarding a Go/NoGo task, but only recruited 30 gamers [41], compared to other studies (n = 52 [39] and n = 66 [40]).

In Stroop tasks, participants see written words that can either be congruent (e.g., the word ‘green’ presented in green colour) or incongruent (e.g., the word ‘green’ presented in red colour). Participants have to press a key according to the colouration, while inhibiting the colour-word written. Two studies have used Stroop tasks to assess inhibition among gamers. While one failed to find any significant association between pathological videogame play and inhibition [40], the other found partial support [42].

Colzato et al. [43] explored the other type of inhibition, the restraint of prepotent motor response, among 26 First-Person Shooter (FPS) gamers (playing at least five hours a week for a year) using the Stop-Signal Task (SST). This is similar to the Go/NoGo task except a change in the stimulus where participants must not respond appears after a delay (e.g., the arrow is green, and after 200ms, it turns red). Here, participants have already created their response and must retain it. Compared to non-players, the FPS gamers did not show any sign of impaired inhibition (i.e., diminished accuracy) and were faster than the control participants.

Two studies have included emotional affect through gaming stimuli during the task, with the purpose of impairing the inhibition of the gamers. Liu and colleagues [44] added gaming pictures in half of the blocks of a classic Go/NoGo task, testing 22 participants (11 addicted gamers, according to the Diagnostic Criteria for Internet Addiction for College student [45]). The analysis showed that gamers only exhibited an impaired inhibition under the gaming-pictures condition, with no significant differences found in the control condition. Ko et al. [46] used a Directed Forgetting Task (DFT) including gaming words with 133 participants (with 64 excessive gamers). In the DFT, participants were presented a series of words, some of them followed with an instruction to "not remember" them. The aim of the task was to inhibit the attentional focus on some of the words. The results matched those of Liu and colleagues [44] because the gamers remembered more gaming-related-words than control participants, but remembered fewer neutral words, thus implying worse inhibition in comparison to non-players.

Decision-Making

Another way of investigating the cognitive processes of problematic videogame play is through impaired decision-making. This has been studied using different paradigms. For instance, decision-making can be assessed through tasks measuring the passage between an unknown situation to a risky one. In such tasks, the participant does not know the rules at the beginning of the task, and learns these through the task (e.g., Iowa Gambling Task, IGT, [47]). This type of task is therefore based on a learning process, with participants having worse scores if they fail to understand or learn these rules. Another way to study such processes is risky decision-making, i.e., tasks where the participants clearly know about the rules as they start the task (e.g., Game of Dice Task, GDT, [48]; Balloon Analogue Risk Task, BART, [49]). Finally, decision-making can be assessed through delay-discounting paradigms, an economic perception of decision-making stating that the more a reward is delayed, the less value will be perceived. In such tasks, participants must make a choice between an immediate and small reward (e.g., £10 now) or a delayed but bigger reward (e.g., £100 in a year). While the first two types of tasks lead to differentiating an impaired learning process (i.e., failing to improve in IGT-like tasks), or impaired basic decision-making (i.e., low scores in risky tasks), the delay-discounting paradigm assesses the inability of problematic gamers to postpone a gaming session.

Two studies have explored risky decision-making using the Probability Discounting Task (PDT) performance of IGD participants in group analysis [50,51]. Both studies recruited 40 participants distributed equally in two groups (i.e., IGD players vs. controls) of 20 participants. In the PDT, participants were presented two choices, in the same design as a delay-discounting task except that instead of delay, the two choices varied in the probability of receiving the reward (e.g., 100% chance of receiving £10 against 10% of receiving £100). The two studies found the same results that impaired decision-making with riskier choices was more prevalent among individuals with IGD. Lin and colleagues' [50] results also reached significance when correlating between addiction severity and risk-taking. However, since Lin and colleagues [50] assessed Internet addiction rather than gaming dependence (using the Internet Addiction Test [IAT, 52]) and recruited participants who spent more than half their Internet time on games, no definitive conclusion can be drawn.

The findings on risky decision-making have been replicated using the Cups Task (i.e., another task assessing probability discounting), showing the same findings, i.e., riskier choices for the problematic gamers [40,53]. Furthermore, using the GDT task among 38 participants (including 19 problematic gamers according to a modified version of the IAT for *World of Warcraft*), Pawlikowski and Brand [54] reported the same finding. In this task, the participants were presented with a dice, and several choices on the possible outcome of the dice, varying in risk (e.g., the dice will be a "1" or the dice could be either a 1, 2, 3, or 4). The riskier the choice, the more money was wagered. If the participants predicted the outcome well, they would receive the money; in the other case, they would lose it. The results showed that at the end of the task, the problematic gamers had less money than the control participants; therefore, the problematic players made riskier choices. Furthermore, the researchers found a significant and negative correlation between addiction severity and GDT score. Yao and colleagues [40] also demonstrated that problematic gamers had a lower improvement in the IGT than non-players.

Two studies have explored the delay discounting abilities of problematic gamers. In the first study, Weinstein, Abu, Timor and Mama [55] tested 40 participants (including 20 problematic players with high scores on the Problematic Online Gaming Questionnaire [POGQ, 56]) on both a Balloon Analogue Risk Task (BART [49]) and a Delay Discounting Task (DDT). Problematic gamers showed poorer results than the control participants. For the DDT, the problematic gamers discounted the rewards more steeply than the control participants (i.e., they preferred immediate and smaller rewards opposed to more important delayed ones). Using another task to assess Delay Discounting (i.e., the Single Key Impulsivity Paradigm, SKIP), Nuyens et al. [57] replicated these findings. The SKIP is an implicit measure of delay discounting, participants having to wait as long as they can before clicking on a picture. The more they wait, the more they earn points or money. In this study, participants could click as much as they wanted on a picture and did not know how much time they had before the picture disappeared. Thus, with this lack of information, participants had two choices, either to click faster, but earn less money, or to wait longer, risking that the picture disappeared. In this experiment, the earliest stages from the SKIP were negatively correlated with the score on the POGQ, while the latest stages were not, implying that even though the problematic gamers had a worse delay-discounting level, they have the same level of learning process.

Discussion

The present review evaluated all the experimental studies relating to cognitive skills and problematic gaming. It was expected that problematic gamers would show an impaired multi-second time perception because time loss is a common consequence among those experiencing videogame addiction [35,58]. Although gamers report frequent time loss, studies exploring multi-second perception abilities among those players demonstrated no consistent results. Some studies showed a clear biased time perception (i.e., without clarifying the paradigm concerned, [34]) or a nearly significantly impaired one (i.e., in a retrospective paradigm, [33]), while other studies show no such association (i.e., in a prospective paradigm, [35,37]). This lack of significant results could be due to the short durations used (i.e., 60 seconds, [37]), or the way that time perception was assessed (i.e., not controlling the prospective and retrospective paradigm while measuring time perception, [35]; using a prospective paradigm, while retrospective time perception seems to be more important, [37]). However, the near significant results [33] may be explained by a lack of rigor because expertise in other games was not controlled for among novice gamers. Furthermore, the study almost reaching significant results [37] and the study yielding significant results [34] included pathological gamers, while the two studies without any significant results did not [33, 35]. Thus, those scattered results could be explained by this difference in the population used.

It has also been hypothesized that problematic gamers engage in pathological gaming due to impaired inhibition. The findings are contrasting with some studies demonstrating a clear impairment among problematic gamers [39,46], or partial support [40,42,44], while others show no such association [41,43]. The differing results may partially be explained by the tasks used, and thus, the type of inhibition tested. Bailey and colleagues [42] found that using a Stroop task, gamers showed impaired inhibition only under a long response-to-stimulus interval, while Yao and colleagues [40] only found an impaired inhibition in the Go/NoGo task, and not in the Stroop Task. This could mean that gamers only show impaired automatic response inhibition and not interference inhibition. However, two studies found that when gaming pictures were included, gamers exhibited poorer inhibition despite measuring two types of inhibition [44,46]. These findings adhere to the concept of urgency developed by Whiteside and Lynam [59], where under emotional affect individuals tend to exhibit poorer inhibition. Gaming-related pictures could have elicited emotional affect, and thus may have impaired the gamers' inhibition. A possible explanation for the unexpected result by Colzato et al. [43] (i.e., players giving in when they want to play) may be the emotional affect involved in gaming. Indeed, the Urgency, Premeditation, Perseverance, Sensation Seeking (UPPS) Impulsive Behaviour Scale [59] describes the lack of inhibition (i.e., urgency) as a difficulty to inhibit a reaction to an emotional stimulus (e.g., drinking alcohol after a break-up). However, another explanation could be the sample included in this study, because this was the only study that including non-problematic videogames users rather than pathological ones.

All studies on decision-making among problematic gamers show similar findings that problematic gamers have impaired decision-making [40,50,51,53,54]. Furthermore, it appears that the excessive gamers tend to make riskier choices [50,54], which could explain their tendency to play videogames more than intended (e.g., playing more despite being more tired the next day). However, the results on the learning processes at stake in the decision-making are unclear, firstly due to the lack of studies on this specific process and secondly due to contrasting results with one study finding poorer results among gamers on the IGT [40], and the others not finding any association between the learning process and addiction severity [57]. The two studies using delay-discounting tasks found that problematic gamers had difficulty in delaying rewards [55,57], which might explain their tendency to play immediately instead of waiting. Consequently, further studies on the learning level of problematic gamers in decision-making tasks are needed, although it might be that problematic gamers only have impaired decision-making with specific learning processes (i.e., ability to learn and apply the rules in a decision-making task) according to the other studies' results. Future studies should also investigate the impact of gaming on cognitive processes examining executive functions using validated models of cognitive processes. For example, the Miyake (60) model of executive functions includes three different functions: (i) shifting (or task-switching), (ii) inhibition, and (iii) updating. According to this model, several tasks are needed to fully explore each of these functions. However, given the poor results in the risky decision-making tasks (e.g.,[50,53]), and the associations between impaired decision-making and inhibition [40], it is more likely that the problematic gamers have an impaired risk evaluation than an impaired learning process. Consequently, more studies exploring the learning processes involved in IGT-like tasks are needed to confirm such an explanation. In addition, the knowledge that gaming addicts are more likely to have impaired decision-making skills could be used by practitioners from a cognitive-behavioural therapy perspective in their therapeutic work with problematic gamers. It may appear particularly efficacious to implement awareness raising and individual reflection of the gaming behaviour in the context of psychoeducation, using daily diaries and group therapy whereby experiences can be shared among the therapy group members, allowing vicarious learning. In addition to this, based on the reported results, therapy should make use of the gamers' specific preferences by including gamification approaches into the therapeutic contexts, such as specific rewards for the completion of therapy sessions, homework and periods of abstinence and discontinued use, which may increase therapy satisfaction and success rates.

However, it is worth noting that the gaming studies field still lacks consensus regarding the assessment of videogame addiction. This lack of consensus may have indirectly impacted the findings and therefore the conclusions of the papers included in this review. Given that most of the studies in the present review used different assessment tools to define the pathological use of videogames (e.g., IAT [52], POGQ [56]), this needs to be taken into consideration when interpreting the findings.

Conclusion

Many previous studies have suggested that videogame play can have a positive impact on cognitive processes for players, but all of these studies were carried out with non-problematic gamers. Based on the studies reviewed here, the pathological use of videogames leads to more negative consequences on cognitive processes. However, this field of study needs more rigor because little is known about the (i) different impacts concerning pathological, excessive, or casual use of videogames, and (ii) impact concerning different game genres. It is recommended that those in the gaming studies field should work in co-operation with game developers to prevent players developing addictive gaming behaviours.

Conflict of Interest

None

References

1. Achab S, Nicolier M, Mauny F, Monnin J, Trojak B, Vandel P, et al. Massively multiplayer online role-playing games: comparing characteristics of addict vs non-addict online recruited gamers in a French adult population. BMC Psychiatry 2011; 11:144.

2. Burešová I, Steinhausel A, Havigerová JM. Computer gaming and risk behaviour in adolescence: A Pilot Study. Procedia - Soc Behav Sci 2012; 69:247–55.

3. Chiu SI, Lee JZ, Huang DH. Video game addiction in children and teenagers in Taiwan. Cyberpsychology Behav: Impact Internet Multimed Virtual Real Behav Soc 2004;7(5):571–81.

4. Gentile D. Pathological video-game use among youth ages 8 to 18: A national study. Psychol Sci 2009;20(5):594–602.

5. Hellström C, Nilsson KW, Leppert J, Åslund C. Influences of motives to play and time spent gaming on the negative consequences of adolescent online computer gaming. Comput Hum Behav 2012;28(4):1379–87.

6. American Psychiatric Association. Diagnostic and statistical manual of mental disorders (5th ed.). Arlington, VA: American Psychiatric Publishing; 2013.

7. Appelbaum LG, Cain MS, Darling EF, Mitroff SR. Action video game playing is associated with improved visual sensitivity, but not alterations in visual sensory memory. Atten Percept Psychophys 2013;75(6):1161–7.

8. Sims VK, Mayer RE. Domain specificity of spatial expertise: the case of video game players. Appl Cogn Psychol 2002;16(1):97–115.

9. Mack DJ, Ilg UJ. The effects of video game play on the characteristics of saccadic eye movements. Vision Res 2014; 102:26–32.

10. West GL, Al-Aidroos N, Pratt J. Action video game experience affects oculomotor performance. Acta Psychol 2013;142(1):38–42.

11. Chisholm JD, Kingstone A. Action video game players' visual search advantage extends to biologically relevant stimuli. Acta Psychol 2015; 159:93–9.

12. Durlach PJ, Kring JP, Bowens LD. Effects of action video game experience on change detection. Mil Psychol 2009;21(1):24–39.

13. Green CS, Bavelier D. Action-video-game experience alters the spatial resolution of vision. Psychol Sci 2007;18(1):88–94.

14. Braghirolli LF, Ribeiro JLD, Weise AD, Pizzolato M. Benefits of educational games as an introductory activity in industrial engineering education. Comput Hum Behav 2016;58:315–24.

15. Dobrescu LI, Greiner B, Motta A. Learning economics concepts through game-play: An experiment. Int J Educ Res 2015;69:23–37.

16. Navarro-Newball AA, Loaiza D, Oviedo C, Castillo A, Portilla A, Linares D, et al. Talking to Teo: Video game supported speech therapy. Entertain Comput 2014;5(4):401–12.

17. King SN, Davis L, Lehman JJ, Ruddy BH. A Model for Treating Voice Disorders in School-Age Children within a Video Gaming Environment. J Voice 2012;26(5):656–63.

18. Enah C, Piper K, Moneyham L. Qualitative Evaluation of the Relevance and Acceptability of a Web-Based HIV Prevention Game for Rural Adolescents. J Pediatr Nurs 2015;30(2):321–8.

19. Elias-Lambert N, Boyas JF, Black BM, Schoech RJ. Preventing substance abuse and relationship violence: Proof-of-concept evaluation of a social, multi-user, tablet-based game. Child Youth Serv Rev 2015;53:201–10.

20. Fanning J, Fenton B, Johnson C, Johnson J, Rehman S. Comparison of teenaged video gamers vs PGY-I residents in obstetrics and gynecology on a laparoscopic simulator. J Minim Invasive Gynecol 2011;18(2):169–72.

21. Jalink MB, Goris J, Heineman E, & Pierie JPEN, ten Cate Hoedemaker HO. The effects of video games on laparoscopic simulator skills. Am J Surg 2014;208(1):151–6.

22. Jentzsch T, Rahm S, Seifert B, Farei-Campagna J, Werner CML, Bouaicha S. Correlation between arthroscopy simulator and video game performance: A cross-sectional study of 30

volunteers comparing 2- and 3-dimensional video games. Arthrosc J Arthrosc Relat Surg 2016;32(7):1328–34.

23. Castell S de, Jenson J, Larios H. Gaming experience and spatial learning in a virtual morris water maze. J Virtual Worlds Res [Internet] 2015;8(1).

24. Richardson AE, Powers ME, Bousquet LG. Video game experience predicts virtual, but not real navigation performance. Comput Hum Behav 2011;27(1):552–60.

25. Kanayama G, Kean J, Hudson JI, Pope JHG. Cognitive deficits in long-term anabolic-androgenic steroid users. Drug Alcohol Depend 2013;130(1–3):208–14.

26. Liang HJ, Lau CG, Tang A, Chan F, Ungvari GS, Tang WK. Cognitive impairments in poly-drug ketamine users. Addict Behav 2013;38(11):2661–6.

27. Ciccarelli M, Griffiths MD, Nigro G, Cosenza M. Decision making, cognitive distortions and emotional distress: A comparison between pathological gamblers and healthy controls. J Behav Ther Exp Psychiatry 2017r; 54:204–10.

28. Leppink EW, Redden SA, Chamberlain SR, Grant JE. Cognitive flexibility correlates with gambling severity in young adults. J Psychiatr Res 2016; 81:9–15.

29. Kuss DJ, Griffiths MD. Internet and gaming addiction: A systematic literature review of neuroimaging studies. Brain Sci 2012;2(3):347–74.

30. Pontes HM, Kuss DJ, Griffiths MD. Psychometric assessment of Internet Gaming Disorder in neuroimaging studies: A systematic review. In Montag, C. & Reuter, M. (Eds.) Springer; 2017.

31. Lynch J, Aughwane P, Hammond TM. Video games and surgical ability: A Literature Review. J Surg Educ 2010;67(3):184–9.

32. Levin I, Zakay D. Time and human cognition: A life-span perspective. Elsevier; 1989.

33. Rau PLP, Peng SY, Yang CC. Time distortion for expert and novice online game players. Cyberpsychol Behav 2006;9(4):396–403.

34. Tobin S, Grondin S. Video games and the perception of very long durations by adolescents. Comput Hum Behav 2009;25(2):554–9.

35. Wood RTA, Griffiths MD. Time loss whilst playing video games: Is there a relationship to addictive behaviours? Int J Ment Health Addict 2007;5(2):141–9.

36. Grondin S, Plourde M. Judging multi-minute intervals retrospectively. Q J Exp Psychol 2007;60(9):1303–12.

37. Rivero TS, Covre P, Reyes MB, Bueno OFA. Effects of chronic video game use on time perception: Differences between sub- and multi-second intervals. Cyberpsychology Behav Soc Netw 2012;16(2):140–4.

38. Griffiths MD. A "components" model of addiction within a biopsychosocial framework. J Subst Use 2005;10(4):191–7.

39. Littel M, van den Berg I, Luijten M, van Rooij AJ, Keemink L, Franken IHA. Error processing and response inhibition in excessive computer game players: an event-related potential study: Error processing in gamers. Addict Biol 2012;17(5):934–47.

40. Yao YW, Wang LJ, Yip SW, Chen PR, Li S, Xu J, et al. Impaired decision-making under risk is associated with gaming-specific inhibition deficits among college students with Internet gaming disorder. Psychiatry Res 2015;229(1–2):302–9.

41. Chen CY, Huang MF, Yen JY, Chen CS, Liu GC, Yen CF, et al. Brain correlates of response inhibition in Internet gaming disorder. Psychiatry Clin Neurosci 2015;69(4):201–9.

42. Bailey K, West R, Anderson CA. A negative association between video game experience and proactive cognitive control. Psychophysiology 2010;47(1):34–42.

43. Colzato LS, van den Wildenberg WPM, Zmigrod S, Hommel B. Action video gaming and cognitive control: playing first person shooter games is associated with improvement in working memory but not action inhibition. Psychol Res 2013 ;77(2):234–9.

44. Liu GC, Yen JY, Chen CY, Yen CF, Chen CS, Lin WC, et al. Brain activation for response inhibition under gaming cue distraction in internet gaming disorder. Kaohsiung J Med Sci 2014;30(1):43–51.

45. Ko CH, Yen JY, Chen SH, Yang MJ, Lin HC, Yen CF. Proposed diagnostic criteria and the screening and diagnosing tool of Internet addiction in college students. Compr Psychiatry 2009;50(4):378–84.

46. Ko CH, Wang PW, Liu TL, Yen CF, Chen CS, Yen JY. The inhibition of proactive interference among adults with Internet gaming disorder. Asia-Pac Psychiatry Off J Pac Rim Coll Psychiatr 2015;7(2):143–52.

47. Bechara A, Damasio AR, Damasio H, Anderson SW. Insensitivity to future consequences following damage to human prefrontal cortex. Cognition 1994;50(1–3):7–15.

48. Brand M, Fujiwara E, Borsutzky S, Kalbe E, Kessler J, Markowitsch HJ. Decision-making deficits of korsakoff patients in a new gambling task with explicit rules: associations with executive functions. Neuropsychology 2005;19(3):267–77.

49. Lejuez CW, Read JP, Kahler CW, Richards JB, Ramsey SE, Stuart GL, et al. Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). J Exp Psychol Appl 2002;8(2):75–84.

50. Lin X, Zhou H, Dong G, Du X. Impaired risk evaluation in people with Internet gaming disorder: fMRI evidence from a probability discounting task. Prog Neuropsychopharmacol Biol Psychiatry 2015;56:142–8.

51. Wang L, Wu L, Lin X, Zhang Y, Zhou H, Du X, et al. Dysfunctional default mode network and executive control network in people with Internet gaming disorder: Independent component analysis under a probability discounting task. Eur Psychiatry 2016; 34:36–42.

52. Young KS. Internet addiction: The emergence of a new clinical disorder. Cyberpsychol Behav 1998;1(3):237–44.

53. Yao YW, Chen PR, Li S, Wang LJ, Zhang JT, Yip SW, et al. Decision-making for risky gains and losses among college students with Internet gaming disorder. PloS ONE 2015;10(1):e0116471.

54. Pawlikowski M, Brand M. Excessive Internet gaming and decision making: Do excessive World of Warcraft players have problems in decision making under risky conditions? Psychiatry Res 2011 15;188(3):428–33.

55. Weinstein A, Abu HB, Timor A, Mama Y. Delay discounting, risk-taking, and rejection sensitivity among individuals with internet and video gaming disorders. J Behav Addict 2016 13;1–9.

56. Demetrovics Z, Urbán R, Nagygyörgy K, Farkas J, Griffiths MD, Pápay O, et al. The Development of the Problematic Online Gaming Questionnaire (POGQ). PLoS ONE 2012;7(5):e36417.

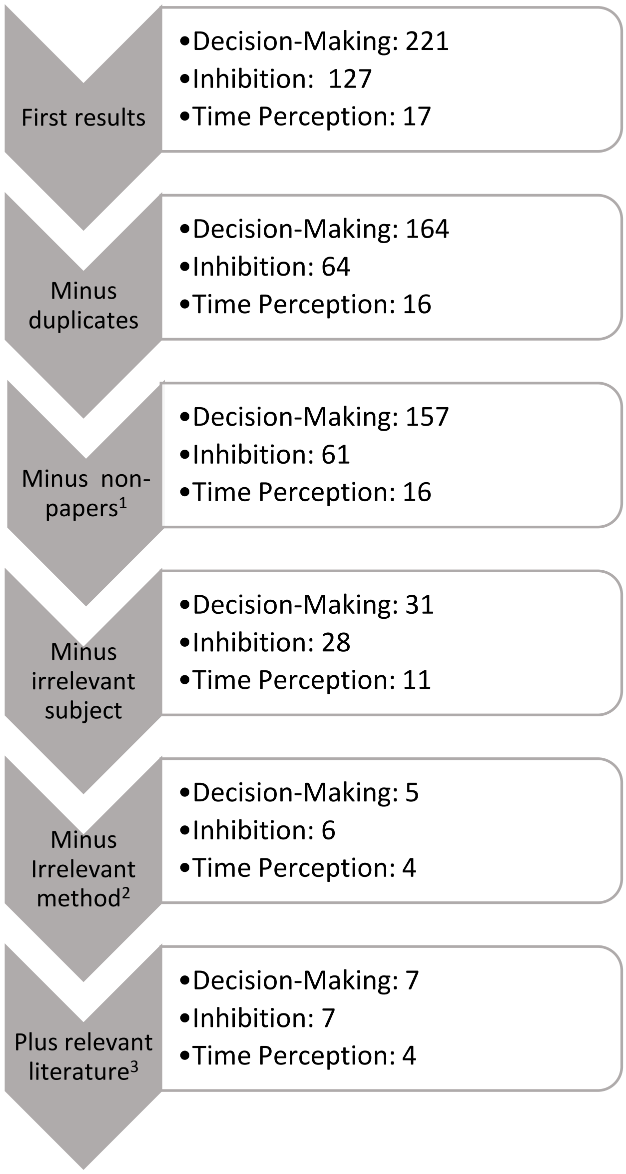
57. Nuyens F, Deleuze J, Maurage P, Griffiths MD, Kuss DJ, Billieux J. Impulsivity in multiplayer online battle arena gamers: Preliminary results on experimental and self-report measures. J Behav Addict 2016;5(2):351–6.

58. Wood RTA, Griffiths MD, Parke A. Experiences of time loss among videogame players: An empirical study. Cyberpsychol Behav 2007;10(1):38–44.

59. Whiteside SP, Lynam DR. The five factor model and impulsivity: Using a structural model of personality to understand impulsivity. Personal Individ Differ 2001;30(4):669–689.

60. Miyake A. The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. Cognit Psychol 2000;41(1):49–100.

Figure 1. Selection procedure in identifying studies evaluated in the present review



Note: [1] e.g., Conference publications, book chapters, errata[2] e.g., EEG studies, fMRI studies, surveys
[3] Papers cited in the present review
Note: [1] p.ex., Publication en Conference, chapitres de Livres, errata ; [2] p.ex., Études EEG, IRM, enquêtes ;
[3] Papiers cités dans les articles présélectionnés