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# Internet addiction and executive functions in university students: a systematic review

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# Abstract

Internet addiction is a growing public health problem and university students have number of characteristics which make them a population at risk. Numerous studies suggest a relation between addiction and the impairment of executive functions. This bibliographical review aims to identify neuropsychological variables which indicate a risk of developing an addiction to different internet applications among university students. A systematic search was made of online databases (Medline, PsycInfo, PubMED, ScienceDirect, Scopus & Web of Science) for empirical studies published between 2000 and 2019 on the relation between internet addiction and executive functions in this population. After eliminating duplicates and applying eligibility criteria, a total of 30 studies were selected. The results of these studies suggest an alteration of executive functions due to addiction (inhibitory control, decision-making and verbal fluency), although the findings do not provide a clear internet addiction risk profile. More study is necessary into the nature of this relation, differentiating the different internet applications and controlling certain variables such as gender, the nature of the task and the type of stimuli, in order to design effective addiction prevention strategies.

**Keywords:** internet addiction, executive functions, verbal fluency, university students

# Resumen

La adicción a internet es un problema de salud pública cada vez mayor, y los estudiantes universitarios reúnen una serie de características que les convierte en población de riesgo. Numerosos estudios sugieren una relación entre adicciones y alteración en las funciones ejecutivas. Se presenta una revisión bibliográfica que tiene por objetivo identificar variables neuropsicológicas de riesgo para el desarrollo de la adicción a las diferentes aplicaciones de la web en la etapa universitaria. Se realizó una búsqueda sistemática de estudios empíricos publicados entre 2000 y 2019 sobre la relación entre adicción a internet y función ejecutiva en esta población a través de bases de datos online (Medline, PsycInfo, PubMED, ScienceDirect, Scopus y Web of Science). Tras eliminar registros duplicados y aplicar criterios de elegibilidad, se seleccionaron 30 artículos. Los resultados sugieren la implicación de las funciones ejecutivas (control inhibitorio, toma de decisiones y fluidez verbal), aunque no permiten establecer un perfil de riesgo claro para el desarrollo de adicciones a internet. Parece necesario profundizar en la naturaleza de esta relación, diferenciando entre las diferentes aplicaciones y controlando variables como el género, la naturaleza de la tarea y el tipo de estímulo, con el fin de elaborar estrategias preventivas eficaces.

**Palabras Clave:** adicción a internet, funciones ejecutivas, toma de decisiones, fluidez verbal, estudiantes universitarios.

## Introduction

Internet addiction or the problematic use of the internet has been defined as a mental, behavioural and social disorder related to the repetitive and excessive use of the internet (Tao et al., 2008), characterised by excessive anxiety, impulsive conduct or a lack of self-control with regard to the internet (Shaw & Black, 2015), impairing the ability to function in daily life (Spada, 2014).

Despite the growing scientific interest in this disorder, the conceptual definition and diagnostic criteria for internet addiction remain the subject of controversy (Kuss, Griffiths, Karila & Billieux, 2014). To date, *Internet Addiction Disorder* has not been included in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013), although incorporation of the section "non-substance related addiction" (DSM-5 *appendix*; section III, *emerging disorders*) constitutes a significant advance towards official recognition of the problem. Recently proposed diagnostic criteria for internet addiction include: anxiety to access the internet, social isolation, craving, loss of self-control over internet access, excessive internet use, loss of general interest and withdrawal from reality in a state of dysphoria (Kuss & Lopez-Fernandez, 2016). Similarly, there is no agreement regarding the terminology used when describing this problem. Although the majority of authors refer to *internet addiction* (Chou et al., 2005; Hansen, 2002; Widyanto & Griffiths, 2006; Young, 1998, 2004; Young, Yue & Ying, 2011), other terms commonly in use are *compulsive internet use* (Meerkerk, Van Den Eijnden, Franken & Garretsen, 2010; Meerkerk, Van Den Eijnden, & Garretsen, 2006; Meerkerk, Van Den Eijnden, Vermulst & Garretsen, 2009), *problematic internet use* (Caplan, 2002), and *pathological internet use* (Davis, 2001). In the present study we will use the term *internet addiction* as this is the most commonly used term in scholarship and due to the evident parallels with substance addiction (Meerkerk, Van Den Eijnden, Vermulst & Garretsen, 2009). There are certain mechanisms and similar alterations shared by this type of dependence and other addictive behaviour related to gambling, sex, shopping, food and internet use (Andreassen, Pallesen, Griffiths, Torsheim & Sinha, 2018; Jorgenson, Hsiao & Yen, 2016; Luengo-López, 2004). Specifically, internet addiction is accompanied by mood alterations, social withdrawal and internal conflict (Griffiths, 2005), stress, depression and the use of negative coping strategies (Hasan & Jaber, 2019; Park, Hong, Park, Ha, & Yoo, 2013), as well as sleep

disorders, poor academic performance, attention deficit problems and the tendency to set short-term goals (Aboujaoude, 2010; Wu, Cheung, Ku, & Hung, 2013).

In relation to cognitive processes, substance addiction has been associated with alterations in executive functions. The term executive functions encompasses a series of high level processes (such as inhibition control, working memory and cognitive flexibility) necessary to carry out actions related to achieving goals and responding to changing or complex situations, and whose neuroanatomic substrate is located in the prefrontal cortex (Bausela, 2014). It also includes decision-making (Tranel & Damasio, 2000), which requires the integration of numerous cognitive and emotional processes (Martínez-Selva,. Sánchez-Navarro, Bechara & Román). Closely related to the executive function is what is referred to as processing speed, which rather than a cognitive process *per se* is a property of the processing system itself, referring to the amount of information that can be processed within a unit of time (Ríos-Lago, Periañez & Muñoz-Céspedes, 2004). Executive dysfunction associated with substance abuse is characterised, specifically, by decision-making oriented to short-term reward as well as impaired inhibitory control (Hekmat, Mehrjerdi, Moradi, Ekhtiari & Bakhshi, 2011). These cognitive difficulties are also present in behavioural addictions: alterations in decision-making and impaired attention control in the case of food addiction (Steward et al., 2018), the lack of cognitive flexibility and impulsive behaviour among compulsive gamblers (Marazziti et al., 2008) and difficulties in inhibitory control in hypersexuality disorder (Seok & Sohn, 2018). Similarly, problems in executive functions have been identified in people with internet addiction (Billieux & Van der Linden, 2012).

Internet addiction encompasses different behaviour, including compulsive online shopping, accessing pornographic content, online gaming, social networks and online gambling (Ioannidis et al., 2016; Király, Griffiths & Demetrovics, 2015). Thus, internet addiction may be understood as a series of addictions to specific content. Thus, Davis (2001) distinguishes between general internet addiction and addiction to the content of specific applications. In the latter case, problematic conduct may also take place off-line, although the easy access offered by the internet may aggravate the problem. Even while assuming that addiction to each application may have its own particularities, in all

cases the same criteria of internet addiction described above are recognised (Kuss & Lopez-Fernandez, 2016).

Internet addiction is becoming an serious public health problem, and is increasingly frequent among young people (Kuss et al., 2014), more highly prevalent among university students among whom there is a greater proportion of people with problematic or compulsive internet use (Hsieh, Hsiao, Yang, Lee & Yen, 2019; Krishnamurthy & Chetlapalli, 2018). University students have a series of characteristics which make them an at-risk population for internet addiction: the internet is one of the principal tools of academic work, requiring and justifying a great deal of time spend online; additionally, the work and study schedules of university students tend to be highly flexible, with limited supervision by adults of their online activities. All of these factors favour compulsive internet use and online gaming, gambling, shopping or viewing pornography (Kuss, Griffiths & Binder, 2013). Studies on the prevalence of this behaviour suggest that a significant number of university students show signs of some form of internet addiction, with percentages ranging from 3.2% (Kuss et al., 2013) to 11% (Shao et al., 2018).

University students are also at a very important stage of neurological development, corresponding to the final maturation of the prefrontal cortex (García-Moreno, Expósito, Sanhueza & Angulo, 2008), taking place between late adolescence and early adulthood (Blakemore & Choudhury, 2006; Casey, Giedd & Thomas, 2000). This stage is characterised by the establishment of increasingly complex neuronal circuits which constitute neuro-physical correlate of executive functions (Gogtay et al., 2004). Engaging in addictive behaviour at this stage of life may interfere and/or alter proper cerebral development. Adolescence and early adulthood is also a time of greatest vulnerability to developing addiction since cognitive control is not yet fully developed and thus less effective (Casey, Tottenham, Liston & Durston, 2005) at establishing limits (Liu & Potenza, 2007).

It is necessary to clarify and explore further the relation between internet addiction and executive dysfunction in university students to respond to the following question: are there executive dysfunctions characteristic of internet addiction among university students? The identification of a cognitive risk profile having greater

potential vulnerability will favour the design and implementation of more effective addiction prevention strategies. With this objective, a systematic bibliographical review was made of empirical studies conducted over the last decade.

## Method

The present bibliographical review was conducted according to the PRISMA statement. A number of online databases were consulted (Medline, PsycInfo, PubMED, ScienceDirect, SCOPUS and Web of Science) in order to conduct a systematic review of empirical publications which examine the relation between internet addiction or specific online applications (videogames, online shopping, gambling and/or online pornography) and executive functions. The search was limited to the period from 2000 to 2019, understanding that internet access was fully extended to the entire population in the last decade, due in part to the widespread use of smartphones. The terms used in these studies were: "internet addiction", "online videogame addiction", "online shopping addiction", "online pornography addiction", "online gambling addiction" and "executive functions", "processing speed", "verbal fluency", "inhibition", "working memory", "cognitive flexibility", "decision-making", both in English and Spanish, combined using the Boolean operators AND / OR. While some authors have argued against the inclusion of verbal fluency among the executive functions, considering this more associated with language processing (Whiteside et al., 2016), for others there is a critically important executive aspect to verbal fluency (Aita et al., 2016; Hirshorn & Thompson-Shill, 2006), and so the term "verbal fluency" was included in this review.

Eligibility criteria: for this review, empirical studies written in both English and Spanish were selected which explore the relation between internet addiction and executive functions among university students from the perspective of neuropsychology, neuroscience or psychology. Exclusion criteria were: review articles, book chapters, articles published in other languages, studies unrelated to the subject of interest, studies whose participants were not university students or had other diagnosed pathologies, those which did not specify an evaluation of internet addiction and/or a neuropsychological test to evaluate executive functions, studies which centred exclusively on neuroimaging techniques, biomarkers and genetic studies. Finally, 11,069 studies were found in research databases and 12 in secondary references, for a

total of 11,081, of which 290 were sourced from Medline, 1,208 from PsycInfo, 415 from PubMED, 7,990 from ScienceDirect, 237 from SCOPUS and 929 from Web of Science (WoS). From this total, some 459 studies were eliminated as duplicates and a further 10,592 were rejected for not meeting the eligibility criteria, as indicated in Figure 1.

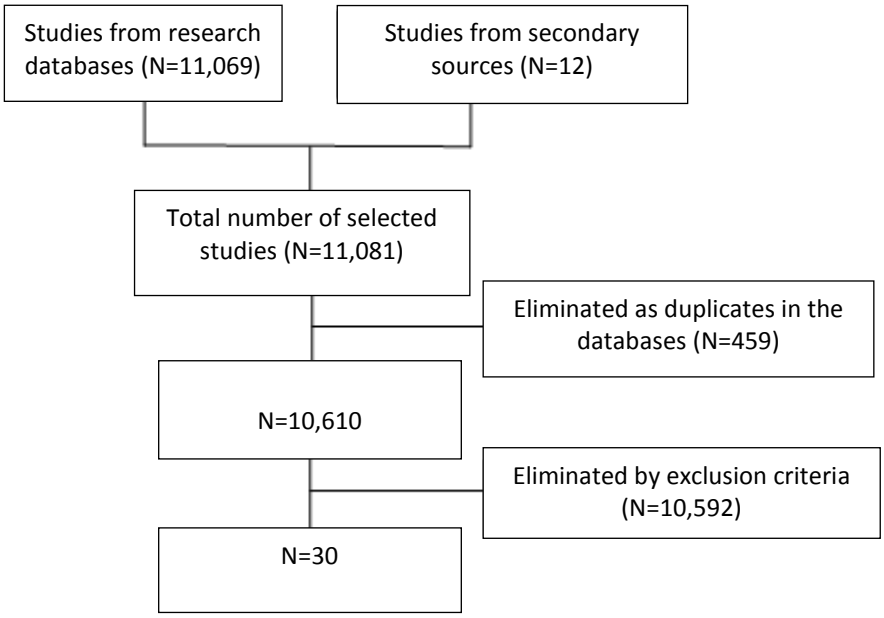


*Figure 1. Flowchart of the review selection process.*

**Results**

The results of the reviewed studies are provided in Table 1 below, including the characteristics of the samples, type of internet addiction (the specific activity or application used compulsively), the instruments used to assess internet addiction and the executive functions, type of analysis and, finally, the principal results and relevant conclusions.

Table 1
***Results of the systematic bibliographical review***

| Study | Sample | Subtype of IA | IA assessment instrument | Assessed EFs | EF assessment instrument | Other tests applied | Type of analysis | Results | Conclusions |
|---|---|---|---|---|---|---|---|---|---|
| Sun et al., (2009) | 113 university students<br>- 52 IA<br>- 61 Control group | General | IAT | Decision-making.<br>Inhibitory control | Modified Gambling Task<br>Go/No-go task | | ANOVA<br>Post-hoc | The IA group scored lower ($p$ =.003) in the Gambling Task, although scored higher in the later blocks ($p$< .001)<br>No differences between groups in Go condition, but greater response precision by addicts in the No-go condition ($p$ =.018). | People with IA:<br>- There is a deficit in decision-making, characterised by delay, caused by an incapacity to learn continencies (slower strategy change).<br>- There is no inhibitory deficit in the Go/No go task, despite lack of control over internet use. |
| Dong, Zhou & Zhao (2010) | 24 male university students<br>- 12 IA<br>- 12 Control group | General | IAT | Inhibitory control | Go/No-go task | | Student's t-test | No differences between groups in response time and precision in either of the two conditions (Go/No-go). | People with IA do not show alterations in inhibitory control. |
| Ko et al., (2010) | 188 university students<br>- 74 IA<br>- 114 Control group | General | DCIA-C | Decision-making | Iowa Gambling Task<br>Balloon Analogue Risk Task (BART) | TPQ | Student's t-test<br>MANOVA | IGT: The IA group choses cards from the "bad deck" during the first 40 turns ($p$=.035) and from the "good deck" in the last 40 (p=.001).<br>There were no differences between groups in the BART test | People with IA:<br>- Better implicit emotional learning among non-addict children (learning in the IGT).<br>- Generally do not make riskier decisions.<br>- They are characterised by the search for novelty. |

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| Saville et al., (2010) | 28 university students<br>- 14 IA<br>- 14 Control group | General | IAT | Decision-making. Inhibitory control | Delay Discounting Task | | Student's t-test | The IA groups seeks immediate reward although to a lesser degree than the control group (*p*=.02). | People with IA show greater impulsivity. |
| Dong et al., (2011) | 34 male university students<br>- 17 IA<br>- 17 Control group | General | IAT | Inhibitory control | Stroop Task | | ANOVA | The IA group is slower in the incongruent condition (*p*<.01) * and commit more errors (p=0.01). | People with IA show less inhibitory control. |
| Pawllikoswki et al., (2011) | 38 university students<br>- 19 IA (gaming)<br>- 19 Control group | Online gaming | IAT SICWoW | Decision-making | Game Dice Task (GDT) | SCL90-R | Student's t-test Correlation ANOVA Repeated measures | Players show poorer performance of the task (p=.002), take more risks (p=.005) and make fewer safe decisions than the control group (p=0.01). The total GDT score is inversely correlated to the IAT score (p=.026). | People with internet gaming addiction show impaired decision-making. There is a direct relation between the severity of addiction and decision-making deficit. |
| Littel et al., (2012) | 52 university students<br>- 25 IA (gaming)<br>- 27 Control group | Online gaming | VAT | Inhibitory control | Go/No-go task | EIS | ANOVA Post-Hoc Correlation | No-go condition (p<.01): more errors by the online gaming addicts group<br>No-go condition: more false alarms (p<.01) and less RT (p<.05).<br>False positives are correlated to weekly hours of play (p<.05)*. | People with online gaming addiction show poorer inhibitory control.<br>The more severe the addiction the worse the inhibitory control. |

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| Bailey et al., (2013) | 149 university students<br>- 70 women<br>- 79 men | Online gaming | MUC PVP | Decision-making | Iowa Gambling Task<br>Temporal Discounting Task | BIS-11 RAS | Canonical correlation | There is an inverse correlation between hours of play and severity of addiction and performance in the IGT ($p$<.05) both in RT ($p$<.05) and in no-risk decisions ($p$<.05)*.<br>Hours of play correlates to impulsivity in FPS games but not in strategy games, where the correlation is inverse. | The greater the severity of addiction and hours of gaming online:<br>- Poorer learning in the decision-making task.<br>- Greater number of high-risk decisions.<br>The relation between gaming addiction, impulsivity and high-risk decision making depends on the type of game (FPS /strategy): strategy game players do not show impulsivity or high risk decision-making. |
| Dong et al., (2014) | 30 male university students<br>- 15 IA<br>- 15 Control group | General | IAT | Inhibitory control | Stroop Task | MINI | ANOVA Repeated measures | The IA group showed worst performance in the task although the differences were not significant. | IA is not related impaired inhibitory control. |
| Xing, et al., (2014) | 34 university students<br>- 17 IA (gaming)<br>- 17 Control group | Online gaming | IAT | Inhibitory control | Stroop Task | | Student's t-test | The group of online gaming addicts commit more errors during the incongruent condition ($p$<.05) and total RT is greater ($p$<.05)*. | Online gaming addicts displayed less cognitive control. |
| Yao et al., (2014) | 52 university students<br>- 26 IA (gaming)<br>- 26 Control group | Online gaming | CIAS | Decision-making | Game of Dice Task original & modified | | Student's t-test ANOVA Correlation | Gaming addicts have lower net and total scores ($p$<.01) and accumulate less money ($p$<.001).<br>The ICAS scores are inversely related to the net ($p$<.001) and total scores of the GDT task ($p$<.001)*. | Online gaming addicts:<br>- Displayed poorer decision-making.<br>- Decision-making oriented towards short term gain.<br>- Performance worsens with the severity of the addiction. |

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| Dong et al. (2015) | 71 university students<br>- 35 IA (gaming)<br>- 36 Control group | Online games | IAT | Inhibitory control | Stroop Task | MINI | Student's t-test | No significant differences were found in the Stroop interference task.. | Despite greater activity during the task in the cingulate cortex, the IA group did not display impaired inhibitory control. |
| Yao et al., (2015) | 102 male university students<br>- 60 IA (gaming)<br>- 42 Control group | Online games | CIAS | Decision-making | Cups Task | | Student's t-test<br>ANOVA<br>Correlation | The gaming addicts group opts for riskier options in disadvantageous conditions ($p$<.001).<br>Direct correlation between CIAS scores and disadvantageous condition ($p$<.05)*. | Online gaming addicts:<br>- Take riskier decisions.<br>- Greater severity of addiction is associated with more disadvantageous decision-making. |
| Balconi et al., (2016) | 28 university students<br>- 12 IA<br>- 16 Control group | General | IAT | Inhibitory control | Modified Go/No-go Task (videogames and gambling) | BIS<br>BAS<br>STIA<br>BDI | ANOVA<br>Repeated measures<br>Post hoc | The IA group displays slower RT in the modified videogame version ($p$=.001) and the modified gambling version ($p$=.001). | People with IA display inhibition deficits when exposed to gratifying stimuli. |
| Dong & Potenza (2016) | 36 male university students<br>- 20 IA (gaming)<br>- 16 Control group | Online games | IAT | Decision-making | Risk Task | MINI | Student's t-test | IA (gaming):<br>During the decision phase, addicts took more risks in a disadvantageous condition ($p$=.039).<br>During the gambling phase, addicts show inferior RT after selecting | People with online gaming addiction take decisions oriented to short term reward and take more risks. |

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| | | | | | | | | a disadvantageous option (*p*=.006). | |
| Jeromin et al., (2016) | 51 university students<br>- 21 IA (gaming)<br>- 30 Control group | Online games | CIUS-WoW | Inhibitory control | Addiction-Stroop Task | Ishihara Test<br>Visual Probe | ANOVA | Addiction Stroop: gamers respond more slowly to words related to computers compared to neutral words (*p*=.001)<br>Visual Probe: no differences between groups were found in RT for images related to computers and neutral images. | Biased attention and difficulties in interference control with verbal stimuli related to computers, but not with visual stimuli. The authors interpret this discrepancy by the facility of gamers to process visual stimuli. |
| Nie et al., (2016) | 316 university students<br>- 53 IA severe<br>- 95 IA moderate<br>- 168 Control group | General | CIAS-R | Verbal fluency | Verbal fluency task | ZSDS<br>RSES | ANOVA<br>Post-hoc | Groups with severe IA have worse semantic verbal fluency than those with moderate IA or non-addicts (*p*=.001). There are no differences between groups in the phonological verbal fluency task. | Impaired semantic verbal fluency may be a reliable marker to identify the transition between moderate and severe addiction. |
| Zhang et al., (2016) | 40 university students<br>- 19 IA (gaming)<br>- 21 Control group | Online games | IAT | Inhibitory control | Addiction-Stroop Task | | ANOVA<br>Repeated measures | There was not interaction between groups (addicts/non-addicts) and type of EE (neutral/related to online gaming). | Addicts showed no attentional bias nor inhibition difficulties when exposed to stimuli related to the addiction. |

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| Balconi et al., (2017a) | 24 university students<br>- 12 IA<br>- 12 Control group | General | IAT | Inhibitory control | Modified Go/No-go Task<br>Videogames<br>Gambling<br>Neutral stimuli | BIS<br>BAS | ANOVA<br>Repeated measures<br>Post hoc | In No/Go, the IA group showed better execution: fewer errors in stimuli related to videogames ($p$=0.001) and gambling ($p$=0.001), as well as slower RT for videogame stimuli ($p$=0.001) and gambling ($p$=0.001). | Existence of attentional bias towards stimuli which may imply reward, characterised by greater cognitive performance when greater control is required. |
| Balconi et al., (2017b) | 25 university students<br>- 12 IA<br>- 13 Control group | General | IAT | Inhibitory control | Modified Go/No-go Task<br>Videogames<br>Gambling<br>Neutral stimuli | STIA<br>BDI | ANOVA<br>Repeated measures<br>Post hoc | Same results as the previous study. | Greater sensitivity to reward may be a crucial variable in the development of addiction. |
| Dong, et al. (2017) | 58 university students (men)<br>- 18 IA (gaming)<br>- 21 Non-IA players<br>- 19 Control group | Online games | IAT | Inhibitory control | Stroop Task<br>Guessing Task | | ANOVA | The group of online gaming addicts showed greater Stroop interference (longer RT) than in non-addict players ($p$=.005) and the control group ($p$=.048).<br>There are no differences between groups in the execution of the Guessing Task. | Addiction to online gaming is related with impaired inhibitory control. |
| He et al., (2017) | 32 male university students<br>- 16 IA<br>- 16 Control group | General | IADC | Decision-making | Force-choice Gambling Task | | Student's t-test | The IA group tends towards riskier decision-making ($p$<.001)*. | Internet addiction is related to impaired decision-making. |

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| Jiang et al., (2017) | 98 university students<br>- 27 (s- OSA)<br>- 43 (m-OSA)<br>- 28 (l- OSA) | Online shopping | OSAS | Inhibitory control<br>Attention control | Modified Stroop Task<br>Dot Probe Task | BIS<br>BAS<br>SCS | ANOVA<br>Correlation | In the Stroop task, the s-OSA group was faster for neutral words than those related to online shopping ($p < .001$). The m-OSA and m-OSA showed no differences by type of word.<br>No differences were found in the Dot Probe Task, nor any relation between the results of the two tasks. | People with online shopping addiction show attentional bias towards EE associated with addiction, characterised by impaired inhibitory control. |
| Wang et al., (2017a) | 39 male university students<br>- 18 IA (games)<br>- 21 Control group | Online games | IAT | Decision-making | Delay Discounting Task | MINI | Student's t-test<br>Correlation | The IA group accesses discounting more rapidly ($p$=.05). There is a positive correlation between RT and the delay is discounting ($p$=.03). | Online gaming addiction is related to higher risk decision-making. |
| Wang et al., (2017b) | 63 male university students<br>- 20 IA (games)<br>- 23 non-IA gamers<br>- 20 Control group | Online games | IAT Criteria DSM-5 | Decision-making | Delay Discounting Task<br>Probability Discounting Task | | ANOVA<br>Correlation | The IA group accesses discounting more rapidly ($p$=.03) and shows greater tendency towards risk ($p$<.05) than the other two groups. Correlation between discounting speed and tendency towards risk ($p$<.001). | Persons with online gaming addiction show:<br>- Deficit in response inhibition.<br>- Riskier decision-making. |

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| Wang et al., (2017c) | 39 university students<br>- 18 IA (games)<br>- 21 Control group | Online games | IAT | Decision-making | Delay Discounting Task | MINI | Student's t-test Correlation | The IA group accessed discounting more rapidly ($p$=.05)<br>There is a direct correlation between the IAT with discounting speed ($p$<.05)*. | Online gaming addicts show impaired inhibitory control than non-addicts. The greater the addiction severity the greater impulsivity in decision-making. |
| Wang et al., (2017d) | 37 university students<br>- 18 IA (games)<br>- 19 Control group | Online games | IAT<br>DMS-5 criteria | Inhibitory control | Addiction Stroop Task | BDI<br>MINI | ANOVA | There was no differences between groups in the execution of the task. | Online gaming addicts show no impairment of the capacity to inhibit responses. |
| Chen et al., (2018) | 76 university students<br>- 36 frequent gamers<br>- 36 occasional gamers | Online games | CIAS<br>IUQ | Cognitive flexibility | Edinburgh Virtual Errands Test (EVET)<br>Dual Task<br>Task-switching paradigm | BDI<br>BIA | Student's t-test | Frequent gamers show better general execution in the EVET test (p<.05), and in various subscales: duration (p=.001), counting (p=.0002), prior planning (p=.001) following plan (p<.05).<br>There were no differences between groups in the Dual Task nor the Task-switching paradigm. | Results indicate that frequent gamers are more efficient in multitasking when performing an ecological task but not in conventional laboratory tests.<br>It is important to consider the effect of the task when evaluating cognitive capacities in online gaming addiction. |
| Su et al., (2018) | 46 male university students<br>- 23 IA (games)<br>- 23 Control group | Online games | IAT<br>IGB | Decision-making | Prisoner's Dilemma Task<br>Chicken Game | TS<br>SVO | ANOVA Repeated measures | There were no differences between groups in the Prisoner's Dilemma.<br>Chicken game: online gaming addicts took fewer cooperative decisions than non-addicts (p<.005.). Addicts showed equal levels of cooperation with friends | More research is needed into the role of cooperative behaviour in relation to the decision-making of online gaming addicts. |

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| | | | | | | | | and other players, while the control group showed greater cooperation towards friends than towards others (p=.005). | |
| Tekin et al., (2018) | 59 university students<br>- 30 IA<br>- 29 Control group | General | IAS | Inhibitory control<br>Cognitive flexibility | Stroop Task<br>Trail Making Test | BDI | U Mann-Whitney | The IA group was slower in the condition of colour and interference (*p*<.01). In the TMT-B, the IA group committed more errors (*p*<.01) and took longer to complete the task (*p*=.005). | People with IA are characterised by attentional cognitive alterations: poor sustained and selective attention and impaired inhibitory control and cognitive flexibility. |

*N*ote IA = Internet addiction; EF= Executive functions; CIA= Internet addiction questionnaire; Test; TPQ=Tridimensional Personality Questionnaire; DCIA-C= Diagnostic Criteria for Internet Addiction for College Students; IGT=Iowa Gambling Task; STIA= State-Trait Anxiety Inventory; BDI= Beck Depression Inventory; IADC= Internet Addiction Disorder Criteria; s-OSA= severe Online Shopping Addiction; l-OSA= low Online Shopping Addiction ; m-OSA= mild Online Shopping Addiction; OSA= Online Shopping Addiction; BIS= Behavioural Inhibitory System; BAS= Behavioural Activation System; SCS= Self-Control Scale; OSAS= Online Shopping Addiction Scale; MINI= Mini International Neuropsychiatric Inventory.

The 30 empirical articles included in this review had a total of 1,830 participants, with a wide variation in sample size, ranging from 216 participants in the study by Ko et al., (2010) to 17 participants in the study by Dong et al., (2011). In terms of gender, the studies included a total of 587 women and 1,243 men, although 15 used a sample consisting entirely of men. The studies which included both genders did not always use homogeneous samples, the proportion of men often exceeding that of women (Sun et al., 2009; Ko et al., 2010), while in other studies the contrary is observed (Nie et al., 2016; Saville et al., 2010).

With regards to the subtype of internet addiction, 12 studies dealt with the disorder in general, without distinguishing a specific form of problematic use. Some 17 studies dealt exclusively with online video game addiction, and 1 focussed on pathological online shopping. No articles were found dealing specifically with addiction to pornography nor online gambling.

Although a significant number of studies use the Internet Addiction Test (IAT; Young, 1998), to assess problematic use or addiction to the internet, a wide number of other instruments were used. The table below (Table 2) provides a brief description of the various assessment tools used in the studies included in this review.

Table 2. *Instruments used to assess internet addiction*

| Instrument | Description | Studies |
|---|---|---|
| *Internet Addiction Test*, IAT (Young, 1998) | Questionnaire adapted to the DSM-IV criteria for pathological gaming. Consisting of 8 dichotomous items evaluating: anxiety, tolerance, abstinence symptoms, loss of control, loss of interest in other activities, concern of others, and use to avoid dysphoria. 5 or more answers in the affirmative ("yes") is considered indicative of internet addiction. No study provided internal consistency data. | Sun et al., (2009); Dong et al., (2010) ; Saville et al., (2010); Dong et al., (2011). |
| *Internet Addiction Scale,* IAS, (Griffith, 1998) | Likert-type scale consisting of 28 items. Scores above 81 are considered indicative of internet addiction. Internal consistency (Cronbach's alpha) is equal to $\alpha$=.94. | Tekin et al., (2018). |
| *Chen Internet Addiction Scale*, CIAS, (Chen et al., 2003) | Questionnaire on a Likert-type scale consisting of 26 items grouped in 5 subscales: compulsive use, abstinence symptoms, tolerance, problems in interpersonal relations and time management. No study provided internal consistency data. | Yao et al., (2014); Yao et al., (2015). |
| *Online Shopping Addiction Scale*, OSAS (Xu, 2007) | Likert-type scale consisting of 22 items evaluating: altered functionality, excessive consumption, abstinence symptoms and pleasure. Internal consistency (Cronbach's alpha) is equal to $\alpha$=.90 | Jiang et al., (2017) |

Table 2 (continued). *Instruments used to assess internet addiction*

| Instrument | Description | Studies |
|---|---|---|
| *Diagnostic Criteria for Internet Addiction for College Students*, DCIA-C, (Ko, Chen, Yang, Lin & Yen, 2009) | Consisting of 3 criteria. Criteria A evaluates characteristic symptoms (anxiety, loss of impulse control, more use than planned, tolerance, abstinence symptoms, loss of control, excessive use and alterations in decision-making). Criteria B evaluates secondary alterations from internet use, while criteria C deals with exclusion criteria. The number of items and internal consistency of the questionnaire was not specified. | Ko et al., (2010). |
| *Internet Addiction Test*, IAT (Young, 2009) | Questionnaire on a Likert-type scale consisting of 20 items evaluating 5 dimensions: psychological dependence, problems at school, work, family life, or sleep alterations and loss of control over time use. Scores above 50 indicate frequent use, scores above 80 are considered indicative of internet addiction. Internal consistency (Cronbach's alpha) varies from $\alpha$=.81 to $\alpha$=.969. | Dong et al., (2014); Xing et al., (2014); Dong et al., (2014); Balconi et al., (2016); Dong et al., (2016); Zhang et al., (2016); Balconi et al., (2017a, b). Dong et al., (2017); Wang et al., (2017a,b,c,d). |
| *Internet Addiction Diagnostic Criteria*, IADC, (Tao et al., 2010) | Consisting of 7 items evaluating: anxiety, abstinence symptoms, loss of control, compulsive use despite negative consequences, loss of interest in other activities and use to avoid dysphoria. No internal consistency data is provided. | He et al., (2017) |
| *Videogame Addiction Test*, VAT, (van Rooij, Schoenmakers, Van den Eijnden, Vermulst & van de Mheen, 2012) | Adapted from the CIUS (Meekerk et al., 2009), A Likert-type scale consisting of 14 items. Internal consistency del test (Cronbach's alpha) is equal to $\alpha$=.93. | Littel et al., (2012). |
| *Compulsive Internet Use Scale World of Worldcraft specific*, CIUS-WoW (Barke, Nyenhuis, Voigots, Gehrke & Kröner-Herwig, 2013) | Likert-type scale. Scores above 25 are considered indicative of internet addiction. Internal consistency (Cronbach's alpha) is equal to $\alpha$=.86. | Jeromin et al., (2016). |
| *Media Usage Questionnaire*, MUQ, (Bailey et al., 2013) | Questionnaire on internet use consisting of 3 items in which the subject reports the number of hours spent playing videogames, the most frequently played games and the time dedicated to the preferred game. | Bailey et al., (2013). |
| *Chen Internet Addiction Scale Revised*, CIAS-R (Mak et al., 2014) | Likert-type scale with 27 items. Scores above 63 are considered indicative of internet addiction. Internal consistency (Cronbach's alpha) varies from $\alpha$=.79 to $\alpha$=.93. | Nie et al., (2016). |

Among the different executive functions, the studies focussed principally on inhibitory control and decision-making. There is a wide disparity among the findings. To assess inhibitory control, studies used the Go/No-go Task, as well as the Stroop task, both original and modified. Several studies were able to associate internet addiction with impaired inhibitory control (Balconi et al., 2016; Dong, et al. 2017; Jeromin et al., 2016; Jiang et al., 2017; Littel et al., 2012; Tekin et al., 2018; Wang et al., 2017b; Xing, et al., 2014; Yao et al., 2014), greater impulsivity (Saville et al., 2010) and reduced cognitive flexibility (Tekin et al., 2018). In contrast, several studies found no such association (Dong et al., 2010; Dong et al., 2014; Dong et al., 2015; Sun et al 2009; Wang et al., 2017d; Zhang et al., 2016), even finding greater inhibitory control in addicts for reward stimuli (Balconi et al., 2017a; Balconi et al., 2017b). One study found that the influence of gaming addiction on inhibitory control depended on the type of game (first person shooter (FPS) vs strategy) (Bailey et al., 2013).

With regards to decision-making, various gambling tests were used (Iowa Gambling Task, Modified Gambling Task; Forced-Choice Gambling Task), discounting tests (Delay Discount Task, Temporal Discount, Probability Discounting), and other tests which involve some form of reward (Game of Dice, Cups Task). Some studies found evidence of impaired decision-making among participants (Dong et al., 2016; He et al., 2017; Pawllikoswki et al., 2011; Sun et al., 2009; Wang et al., 2017b; Yao et al., 2014; Yao et al., 2015). Other studies revealed conflicting results: one found no alterations in decision-making (Ko et al., 2010), another found that alterations either depended on the type of game being played (Bailey et al., 2013) or was associated with cooperative behaviour (Su et al., 2018).

One study evaluated verbal fluency, finding a relation between reduced semantic fluency and internet addiction, but not in the case of phonological fluency (Nie et al., 2016). Impaired cognitive flexibility among addicts was found only in the one study using a specific task (TMT B) (Tekin et al., 2018). Furthermore, a study found better multitasking performance among online gaming addicts, although only in ecological tasks as opposed to artificial laboratory tasks (Chen et al., 2018). Performance within multitasking contexts is thought to be directly related to flexibility and inhibitory control (Rothbart & Posner, 2015). No studies were found that directly address the impact of excessive internet use on working memory.

## Discussion

The aim of the present study was to identify cognitive risk variables for the development of internet addiction among university students. The results suggest, in general terms, the alteration of two very important executive functions, that is, inhibitory control and decision-making. However, the conclusions of the various research studies are not always convergent. Many studies associate impaired inhibitory control with problematic internet use, although a large number of studies refer exclusively to addiction to online gaming. The findings referring to inhibitory control among online gamers should be taken with caution as this type of internet application may have different characteristics (competitiveness, response speed) which are not shared with other applications, such as viewing pornographic content or online gambling. Thus, Bailey et al. (2013) found that impaired inhibitory control is exclusive to FPS game addicts and is not found among players of strategic games, who display levels of cognitive control similar to that of the control group. Another interesting finding is that, in some cases, problems of inhibitory control is not generalised but specific to some type of stimuli. In the case of online shopping addiction, Jiang et al., (2017) found deficient inhibitory control only for stimuli related with the addiction and not in other matters. Jeromin et al., (2016) concluded that impaired inhibitory control among gaming addicts refers only to verbal stimuli, not visual; in contrast, some studies found greater inhibitory control among internet gaming addicts for stimuli which supposed a reward for the subject, which the authors regarded as an indication of greater sensibility to reward and thus a factor in potential vulnerability to addiction (Balconi et al., 2017a; Balconi et al., 2017b). Greater inhibitory control was also deduced from the study by Chen et al., (2018) of online gaming addicts, the results of which indicate better performance in multitasking situations, although only in ecological tasks rather than experimental laboratory tasks. On the whole, these results point to a relation between impaired inhibitory control and internet addiction, although further study is necessary into the nature of this relation with regards to different internet applications or subtypes of internet addiction, analysing variables such as the type of stimuli or task.

The majority of studies into the relation between decision-making and internet addiction also found alterations, generally characterised by the tendency to take greater risks. Here again, the participants in many of these studies are online gaming addicts. As with inhibitory control, this alteration appears to be specific to FPS games compared to strategy games (Bailey et al., 2013). The study indicates this is a consequence of slower changes in

strategy when the conditions of the task are modified (Sun et al., 2009); another indicates alterations in decision-making occur in situations involving cooperative behaviour (Su et al., 2018). The study by Ko et al. (2014) found general performance in decision-making tasks was no worse among addicts, although they displayed a different profile from the control group, tending towards decisions seeking novelty. The disparity of the results may be due to the fact that decision-making tasks may be influenced by ambient variables (Cohen & Aston-Jones, 2005; Ernst & Paulus, 2005) and related with other cognitive variables such as gambler's fallacy (Xue, Lu, Levin & Bechara, 2011). Finally, although the results suggest a tendency towards riskier decision-making among internet addicts, the processes responsible for this tendency (search for novelty, slower learning of new circumstances) should be the subject of extensive research in order to develop and implement effective strategies for the prevention of these types of addictions.

One of the research projects included in this review found alterations in verbal fluency associated with internet addiction, specifically in impaired semantic fluency (not phonological) (Nie et al., 2016). Verbal fluency tasks are often included in neuro-psychological tests, both in research and in clinical contexts, and not only as a measure of language processing (Whiteside et al., 2016), but often as a test of executive control (Aita et al., 2016; Fitzpatrick, Gilbert & Serpell, 2013; Henry & Crawford, 2004). Considering the number of participants in this study, (361), these results would appear to be highly relevant in identifying cognitive profiles associated with internet addiction, and point to the importance of verbal fluency tasks not only as a measure of language processing but also of executive control.

With regard to cognitive flexibility, the results of the two studies which address this process are not convergent. One study (Tekin et al., 2018) found alterations in flexibility tasks in relation to compulsive internet use while another study by Chen et al. (2018) found, in multitasking contexts, differences in execution depending on the nature of the task: poor performance was found in laboratory tests but not in daily contexts. Further study in this aspect is necessary given the importance of flexibility in situations requiring the performance of different tasks simultaneously as is so frequent in normal life. Finally, in this review there is a notable absence of any studies directly addressing the subject of working memory; the inclusion of this function would be highly useful in the study of problematic internet use.

An important limitation in attempting to draw global conclusions from this review refers to the instruments employed to identify internet addiction. In addition to the inherent limitations of self-reporting (such as social desirability), there is also a significant disparity in assessment tests used to identify internet addiction. Some of the instruments, such as the Internet Addiction Test (IAT), or the Internet Addiction Scale (IAS), have demonstrated their consistency and reliability and propose a cutoff score for the diagnosis of internet addiction, permitting a clear grouping of study participants. In contrast, other tools, such as the Diagnostic Criteria for Internet Addiction for College Students (DCIA-C), or the Media Usage Questionnaire (MUQ), developed by the authors of the studies, offer no reliability data or specified cutoff scores, possibly resulting in the case where high scores on questionnaires indicate frequent (or even excessive) internet use but not characteristic of addictive behaviour. This is the case in the study by Bailey et al., (2013), in which 149 participants were assessed using a questionnaire (MUQ) consisting of 3 items evaluating the number of hours of online gaming, the most frequently played games and the time dedicated to the preferred game.

Furthermore, performance in the assessment tests may be influenced by the experience of online gamers in precisely the types of tasks or experimental situations presented in the tests. These two limitations must be taken into consideration when designing future research projects.

Although a study of gender differences was not the subject of this review, the proportion of women in the studies was very low and in half of the studies the participants were exclusively men. Previous studies have shown that young men have greater propensity for problematic internet use, generally online gaming and viewing pornographic content, while young women spend more time on social media (Dufour et al., 2016). Given that previous studies (Adan, 2012; White et al., 2011) have found a greater tendency among men for impulsive behaviour, risky decision-making and substance abuse compared to women, it would be interesting to include gender as a variable in future studies on executive functions and internet addiction.

In conclusion, although empirical studies suggest a relation between executive functions (specifically, inhibitory control, decision-making and verbal fluency) and internet addictions, the findings do not allow the creation of a clear risk profile for internet addiction among university students. Further study is required into the relation between executive

functions and addiction, differentiating the various subtypes of internet addiction. These subtypes present different characteristics which make the comparison of results difficult. It is also important to control certain variables, such as gender, the nature of the assessment tasks and type of stimuli, in order to reach conclusions which will favour the design and implementation of more effective addiction prevention and treatment strategies for the population at risk of developing internet addiction.

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