



## Review

# Electrophysiological correlates of problematic Internet use: Critical review and perspectives for future research



Fabien D'Hondt, Joël Billieux, Pierre Maurage\*

Laboratory for Experimental Psychopathology, Psychological Sciences Research Institute, Université catholique de Louvain, Place du Cardinal Mercier 10, B-1348 Louvain-la-Neuve, Belgium

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## ABSTRACT

Problematic behaviors have emerged with the exponential development of the Internet access, with some individuals failing to constrain their Internet use despite its negative impact on their daily lives. Recent neuropsychological and neuroscience studies have suggested that problematic Internet use is notably associated with increased cue-reactivity and reduced inhibitory control. This review of the electroencephalography (EEG) literature shows that most studies have found that impaired self-control abilities (i.e., inhibition and error monitoring) are associated with underactivated frontal regions in problematic Internet users (PIUs). However, some EEG studies in the domain have also demonstrated alterations in the processing of Internet-related cues and emotional stimuli. As a whole, these data therefore suggest that both reflective (top-down) and automatic/affective (bottom-up) systems, postulated by dual-process models as being determinants in decision making, are impaired among PIUs. On this basis, new research avenues are proposed to better understand the development and maintenance of problematic Internet use, according to six main directions respectively related to (1) the identification of vulnerability biomarkers, (2) the investigation of possible lower level cognitive impairments, (3) the exploration of core reflective and automatic/affective symptoms, (4) the evaluation of Internet use heterogeneity and comorbidities, (5) the development of new neuroscience strategies and (6) the elaboration of behavioral and cognitive interventions.

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\* Corresponding author. Tel.: +32 10 479245; fax: +32 10 473774.

E-mail addresses: [fabien.dhondt@gmail.com](mailto:fabien.dhondt@gmail.com) (F. D'Hondt), [joel.billieux@uclouvain.be](mailto:joel.billieux@uclouvain.be) (J. Billieux), [pierre.maurage@uclouvain.be](mailto:pierre.maurage@uclouvain.be) (P. Maurage).

## 1. Introduction

The use of the Internet has grown exponentially during the last two decades, initially in Western countries and more recently worldwide, with nearly three billion people now having constant and cheap Internet access (Internet World Stats, 2014). The Internet has thus become an essential component of everyday life for nearly half of humanity and brings positive outcomes to the large majority of its users, notably by facilitating social communication and access to information and knowledge. However, this expansion of Internet availability has also led to the emergence of problematic conducts. This “problematic Internet use” can be broadly defined as an inability to control Internet use despite its severe negative consequences in the daily life (Spada, 2014; Tam and Walter, 2013).

Internet maladaptive use is generally conceptualized as a behavioral addiction that includes core components of addictive behaviors (Kuss et al., 2014). Heterogeneous terms have been used to describe this condition, from “problematic/dysfunctional Internet use” or “pathological Internet use” to “Internet addiction” or “Internet dependence” (Spada, 2014). Although the public health issues associated to problematic Internet use is no longer debatable, the position that it consists in an addictive behavior is largely controversial (Starcevic, 2013). It has for example also been proposed that problematic Internet use rather consists in a maladaptive coping displayed to face negative life events or comorbid psychopathology (Karddefelt-Winther, 2014; Schimmenti and Caretti, 2010). Moreover, it is worth mentioning that the process by which excessive behaviors (especially Internet-related use) tend to be conceptualized has recently received much criticism (Billieux et al., 2015a,b,d; Karddefelt-Winther, 2014; Mihordin, 2012). This process, described as a *confirmative approach* by Billieux et al. (2015c) generally comprises the three following steps. First, based on initial observations (often clinical), an excessive behavior is a priori considered as an addictive disorder without considering potential alternative conceptualizations. Second, diagnostic criteria and related screening tools are developed, based on the substance abuse framework. Third, the neurobiological and psychological correlates of the newly identified behavioral addiction are explored in light of the established risk factors for substance-related addictions. One important problem of such an approach is that it often over-pathologizes the condition under the scope of investigation, as applying substance use criteria to define a behavior (e.g., gaming) often failed to distinguish high involvement (i.e., a passion) from dysfunctional involvement (Charlton and Danforth, 2007; Griffiths et al., 2015). Recently, notwithstanding inconsistencies in classification and limited evidence regarding both the etiology and the course of the condition, Internet gaming disorder has been included in Section 3 of the *Diagnostic and Statistical Manual of Mental Disorders* [5th ed.; DSM-5]. This specific section of the DSM-5 is devoted to the conditions that deserve further research prior to define them as established mental disorders. The question whether the Internet is the vehicle or the focus of a disorder in problematic Internet users remains also debated (Potenza, 2015). This even led to the proposal that the term “Internet addiction [...] should be replaced by addictions to the Internet-related activities if the pattern of such activities meets the criteria for behavioral addiction” (Starcevic, 2013, page 18). The current “conceptual chaos” that surrounds Internet-related research, which notably complicates the distinction between common behaviors or leisure activities and dysfunctional ones, slows the development of this field, by hampering a reliable comparison across studies, as underlined in recent reviews (Aboujaoude, 2010; Spada, 2014).

In the framework of the current paper, and according to the lack of definitive evidence and consensus regarding the conceptualization, etiology and course of the condition, it has been decided to use the term “problematic Internet users” (PIUs) to describe

individuals displaying Internet-related disorders, despite the majority of previous published papers have used the term “Internet addicts”. In accordance with recent proposals (Van Rooij and Prause, 2014), problematic Internet use will here be considered as a maladaptive pattern of Internet use involving: (1) an apparent loss of control [globally defined as an inability to stop a behavior when initiated or to refrain from this behavior after a period of abstinence (Lyvers, 2000)] over the use of the Internet, as well as irritability, anxiety, and dysphoric mood during attempts to control it; (2) the occurrence of psychological, social, or professional negative consequences; and (3) the presence of obsessive thoughts and worries when it is impossible to use the Internet (Van Rooij and Prause, 2014).

Beyond the debates related to its definition, the exploration of the psychological, cognitive, and social correlates of problematic Internet use now constitutes a growing research field which already led to a better understanding of this maladaptive pattern (Weinstein and Lejoyeux, 2010). However, despite valuable attempts to identify the unique characteristics of PIUs (e.g., Davis, 2001; Karddefelt-Winther, 2014; King and Delfabbro, 2014), most existing studies do not go beyond the mere reproduction of substance-related criteria (Block, 2008; Ko et al., 2009b; Shapira et al., 2003; Tao et al., 2010; Young, 1998), and the specificity of problematic Internet use remains to be clearly established. Moreover, although there are several longitudinal studies (e.g., Gamez-Guadix et al., 2015; Gentile et al., 2011), most studies are cross-sectional, which prevents any interpretation regarding the direction of causation. Furthermore, these studies rarely take into account possible confounding factors, notably personality traits and comorbid psychopathology. This is a central concern as problematic Internet use appears to be often comorbid with other psychiatric states, especially substance use disorders, depression, and social anxiety (Kuss et al., 2014). Another crucial concern is the measure of problematic Internet use (King et al., 2013; Lortie and Guitton, 2013). Several reliable and psychometrically sound tools have been extensively used to screen for problematic Internet use (Chen's Internet Addiction Scale, Chen et al., 2003; Compulsive Internet Use Scale, Meerkerk et al., 2009; Young's Internet Addiction Test, Young, 1998), but although these tests are standardized and adapted to different languages or cultures, they are self-reported measurements and therefore subject to participant bias. Moreover, the cut-offs frequently used with these scales are too sensitive and not internationally recognized, which has among other resulted in an overestimation of the problematic Internet use's prevalence (Kuss et al., 2014). Finally, the social conception of what is an excessive or problematic use probably varies from one culture to another. Consequently, even though the importance and extent of the phenomenon are now widely recognized, wide-ranging prevalence rates are reported: epidemiological studies show prevalence rates ranging from about 1% to more than 25%, depending on the type of sample included (self-selected versus random), the countries in which the studies were done, and the screening questionnaires and diagnostic criteria used (Aboujaoude et al., 2006; Kuss et al., 2014; Villeda et al., 2011).

Despite the above-mentioned debates and the heterogeneity of Internet-related activities [problematic Internet use clearly covering a large range of often unrelated activities (Billieux, 2012; Pawlikowski et al., 2014)], it is now clearly established that problematic Internet use is associated with a wide range of psychological and social negative consequences, namely, increased stress and aggressiveness, interpersonal conflicts, and social isolation, as well as reduced work or academic achievements and reduced well-being (Beard and Wolf, 2001; Kuss, 2013; Kuss and Griffiths, 2011; Kuss et al., 2014). Although several factors have been explored at the cognitive level, such as repetitive thoughts or maladaptive thinking mode (see King and Delfabbro, 2014 for a

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