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## Comprehensive Psychiatry

journal homepage: [www.elsevier.com/locate/comppsy](http://www.elsevier.com/locate/comppsy)

## Problematic use of the internet during the COVID-19 pandemic: Good practices and mental health recommendations

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## ARTICLE INFO

## Keywords:

COVID-19 pandemic  
Addictive behaviors  
Problematic internet use  
Online gaming  
Online gambling  
Online pornography

## ABSTRACT

With the onset of the COVID-19 pandemic and the accelerated spread of the SARS-CoV-2 virus came jurisdictional limitations on mobility of citizens and distinct alterations in their daily routines. Confined to their homes, many people increased their overall internet use, with problematic use of the internet (PUI) becoming a potential reason for increased mental health concerns. Our narrative review summarizes information on the extent of PUI during the pandemic, by focusing on three types: online gaming, gambling and pornography viewing. We conclude by providing guidance for mental health professionals and those affected by PUI (with an outline of

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<https://doi.org/10.1016/j.comppsy.2021.152279>

Available online 20 October 2021

0010-440X/© 2021 The Authors.

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immediate research priorities and best therapeutic approaches), as well as for the general public (with an overview of safe and preventative practices).

## 1. Introduction

At the start of 2020, the world experienced the onset of a pandemic. A novel coronavirus (SARS-CoV-2) began spreading globally, leading to a worldwide increase in the cases with coronavirus disease 2019 (COVID-19), and culminating with the official proclamation of a pandemic by the World Health Organization [1]. To mitigate disease spread, jurisdictions often imposed restrictions that led to closing of businesses and limitations on human activities [2]. The movement of citizens became reduced both outwards from their countries of residence (due to closed borders and imposed travel bans) and inwards within the confines of their homes and families (due to imposed lockdowns, curfews or quarantines). Thus, the acceleration of the infection decelerated the daily rhythms of countries and continents, affecting 81% of the global workforce [3].

With the COVID-19 pandemic came a ‘new normality’ [4]. The behavioral norms and standards for spatial distancing were rapidly introduced, and new patterns and practices for socializing were widely adopted [5]. Virtual interactions became increasingly favored over in-person meetings, and private video chat sessions rapidly replaced public gatherings. Working from home and remote schooling were strongly recommended or implemented, professional meetings were frequently conducted online, and classrooms and seminars migrated to online educational courses and webinars. Collective sporting activities and entertainment events were also reduced while indoor activities increased, with digital technologies enabling many processes [6,7]. As a result, people increased their usage of the internet, as reported by major information and communication services in the wake of the pandemic [8–10]. However, the quantity of screen time often does not equate with quality time spent with friends, family, colleagues and associates. On the contrary, sustained feelings of loneliness may accompany diminished physical closeness and intimate belongingness. Research has suggested possible mental health risks [11,12], cautioning that COVID-19 and behavioral addictions (including problematic use of the internet or PUI), might constitute two pandemics that may intersect and represent a significant public health threat [13].

The ensuing mental health problems [14–17], can be associated with conditions or behaviors that involve excessive or problematic use of the internet [18–20], as PUI develops at the expense of the physical, emotional, and (importantly) the mental well-being of the individual [21]. PUI and COVID-19 share certain similarities in that both are distributed across all ages and populations (including young and adult citizens from low-, middle-, and high-income countries across continents), so combined together, both may affect multiple types of healthcare provision and prevention interventions. For example, individuals who had been receiving care for PUI at the onset of the pandemic, may have been faced with decreased availability of healthcare professionals and services as a consequence of increasing pressures on healthcare systems [17], along with reduced socialization due to stay-at-home measures [22]. Some affected individuals have been suffering from social disconnection and a so-called ‘disease of isolation’ accompanied by a perceived lack of social support and feelings of loneliness [23]. Thus, the mental toll of prolonged quarantines [22,24], along with increased exposure to the internet, may further isolate some people and lead to neglect of meaningful relationships, exacerbating PUI behaviors. People with preexisting mental health issues may be at particular risk of experiencing severe difficulties due to COVID-19-related restrictions of movement [25,26]. Uncertainties and fears surrounding the novel situation may accentuate underlying anxieties and attenuate well-being. Generalized feelings of dysphoria and distress, along with strict measures for spatial distancing may strain ties

with family and friends, which in turn may lead to dysfunctional, disrupted or damaged relationships. Taken together, the listed factors, coupled with increased internet exposure, may increase the risk for PUI in susceptible individuals. In addition, people who were largely unaffected prior to the pandemic are not immune to experiencing PUI during the pandemic [2,25]. New cravings for internet use and potentially harming behaviors may arise for multiple reasons including work-from-home practices and workplace absenteeism together with temporal disorientation and disruption of circadian rhythms [27,28]; job insecurities or losses together with motivations to fill new time voids; decreased earnings and financial problems together with motivations to reduce emotional distress and depression [29,30].

In short, many individuals could potentially experience elevated risk for PUI during the pandemic, while their underlying conditions and many potential causes may interrelate and exacerbate one another, to further intensify problems. These exceptional circumstances call for increased attention on the complex nature of PUI.

## 2. PUI in the time of the COVID-19 pandemic

The present narrative review summarizes knowledge on PUI during the COVID-19 pandemic and represents latest scientific consensus by a consortium of experts in the field. It provides a broad overview on studies that are: (a) *relevant* in the field (i.e., published in peer reviewed journals and highly referenced); (b) *related* to topics of interest (i.e., PUI, COVID-19 and mental health); as well as (c) *representative* of the subject (i.e., reviews, commentaries and perspective articles, or large-scale investigations with many participants or countries).

The covered studies refer to prevalent types of PUI and fall within authors’ area of expertise. Specifically, we focus on gaming and gambling, because they are officially recognized as ‘disorders due to addictive behaviors’ in the latest edition of International Classification of Diseases [31], as well as pornography viewing due to its sharp increase at the start of the pandemic [32].

### 2.1. Gaming

In the early days of the pandemic, online gaming was cautiously recommended as a healthy pastime by the World Health Organization [33] and promoted by the gaming industry, sometimes via joint campaigns like the “Play apart together” initiative [34]. Some preliminary findings have also supported the notion that internet gaming represents a relatively safe and economic way to reduce feelings of loneliness and emotional distress while remaining indoors [35,36]. In addition, distant socialization with friends via video entertainment was regarded as a way to avoid other harmful behaviors (e.g., alcohol and other substance use), while gaming was viewed as a potential mechanism to “inform interventions aimed at improving mental health” [15, p. 4]. As a result, gaming companies, live-streaming platforms and internet providers in North America, Europe and Asia (like Fortnite, Youtube Gaming, Twitch and Verizon) registered record increases in internet consumption during the pandemic, for downloading, viewing, playing and streaming of games or e-sports [8,9,36,37]. Furthermore, school closures, event cancellations and stay-at-home measures have also increased the opportunities for prolonged and intensified playing of video games [9], particularly among help-seeking individuals and others with gaming problems [35,38,39].

Gaming disorder is included in the latest revision of the International Classification of Diseases (ICD-11), and both online and offline gaming may have adverse impacts on life functioning of susceptible individuals [31]. Therefore, moderation of gaming should be promoted [37]. Also,

playing online games with loved ones (as opposed to strangers) should be considered [40] alongside alternative ways for indoor socialization like board games [41], because they comprise meaningful social activities with a potential to enrich the social life of isolated individuals. The possibilities for monitoring of gaming behaviors in children should be supported for parents, independent of needs for home-schooling and socialization [37,41,42]. They pertain to the *quantity of screen-time* (e.g., by making sure that the meals are screen-free, or that screens are avoided one hour prior to bedtime), as well as the *screen-time quality* (e.g., by frequent checks and making sure that the gaming content is age-appropriate) [43]. In addition, innovations from the gaming industry should be encouraged with respect to the development of video games and mobile applications that can increase self-monitoring and mood-tracking practices [44] and thus promote psychological and physical health of consumers [8].

## 2.2. Gambling

While land-based gambling has decreased during the lockdown, engagement in online gambling has increased, particularly for individuals with earlier online gambling experiences and preexisting gambling problems, classified as high-risk players as supported by majority of findings [45–49], with some notable exceptions [50]. In the time of the pandemic, people may engage in gambling as a way to relieve underlying anxieties about general welfare and fears about individual health, be entertained during protracted periods of boredom and loneliness, or replace one addictive habit with a more affordable, especially when trying to compensate for the reduced support from the addiction and associated services (even though increases in telehealth utilization may in part offset this last set of factors) [51]. These and other unique factors may contribute to gambling in times of the pandemic, which include but are not limited to: (a) diminished availability of sporting events on which to gamble or land-based gambling venues (e.g., casinos, betting shops, bingos and arcades), together with the persisting availability of the internet; and (b) worsening of economic conditions, together with hopes for fast financial relief. Combined, these factors may promote changes in gambling behaviors at individual and population levels. For example, sport bettors may start reporting a higher degree of gambling problems as they start substituting land-based with online casino gambling, which has been associated with heavy financial losses. In this regard, early studies have suggested shifts from sports to non-sports gambling like online casinos and lotteries during the COVID-19 pandemic [45,52]. However, other studies have failed to demonstrate evidence for such changes [47,50,53,54], so there is a need for more systematic research of this subject. Individuals who are at most risk for increased gambling during the pandemic appear to include people with more pronounced gambling problems, increased alcohol consumption and psychiatric distress, suggesting interventions may be particularly targeted at these individuals [55].

Gambling disorder is included in the ICD-11 [31], so the risks of online gambling should be properly emphasized during the pandemic. In this respect, public health organizations and trusted professionals (as opposed to inaccurate and untrustworthy information sources) should intensify communication with the general public, in order to raise awareness, caution against potential consequences of gambling, and offer timely advice on safe practices. For instance, adequate information regarding high-risk online games (with high-speed of play or unfamiliar conditions), will prevent new or inexperienced players from making uninformed and impulsive financial decisions [56]. Specialized support and digital treatment by professional addiction services should be made available for players who intensified their gambling behavior during the pandemic [54,55].

## 2.3. Pornography viewing

The official proclamation of the pandemic on March 11, 2020 [1]

was associated with a rapid increase in the use of online pornography (by an average of 11.6%) by March 17, 2020, with variations ranging from 4% to 24% across 27 different countries, as reported by Pornhub [32]. Along with changes in the extent of pornography use [57], other related aspects also changed [58]. These include unconventional times of usage (with peak usage increases from 1 am to 3 am, which speculatively may relate to altered sleeping patterns when self-isolated or increased secretive practices when confined with an intimate partner), unusual search keywords (including searching for COVID related pornography), and increased engagement in illegal pornography [59].

An increase in problematic pornography use is likely, especially when it is utilized as a substitute for other addictive substances (e.g., drugs or alcohol) and behaviors (e.g., compulsive sexual activities with partners) that may become less available during the pandemic, due to stay-at-home measures [60]. Pornography viewing falls under a category of impulse control disorders, labeled as compulsive sexual behavior disorders in the latest edition of the ICD-11 [31]. However, to yield deeper insight, it might be researched directly and separately from other diagnoses. Empirical validation of interventions in randomized clinical trials is needed. In the interim, online self-help forums and remote counseling sessions with professionals may help to prevent or alleviate such problems, especially among young adults who may be particularly vulnerable [57–59].

## 3. Mental health guidelines in the time of the COVID-19 pandemic

The subject of PUI is addressed by a biopsychosocial range of disciplines, including biological sciences (genetics and neurophysiology), medical sciences (psychiatry and neurology), and behavioral and social sciences (with emphases on psychology and public health) [21]. PUI in the time of COVID-19 should therefore be regarded from a broad mental health perspective. In the following sections, we provide guidance for mental health professionals and for people affected by PUI (outlining research priorities and best therapeutic approaches), as well as for the general public (suggesting safe and preventive practices).

### 3.1. Research priorities for mental health professionals

Research priorities in the mental health domain have been considered within biopsychosocial frameworks. *Biological and medical research priorities* highlight the need for the immediate development of comprehensive and standardized registries, with representative samples from clinically relevant cases of individuals who have been infected with the SARS-CoV-2 virus [12,15]. Such databases may include genetic, neurophysiological and immunological data, so they could be utilized for investigation of underlying mechanisms in brain pathologies linked to a COVID-19 diagnosis. Over time, the wealth of stored data and the multidisciplinary research could prove to be useful for explorations in PUI and novel related disciplines, helping to make advancements in the early diagnosis, treatment and prognosis of diseases [21]. *Psychological research priorities* include development of measures for rapid monitoring and reporting of epidemiological indices and clinical data related to acute mental health conditions or detrimental behaviors that are emerging during the pandemic (e.g., anxiety, depression, self-harm and suicide). Standardized international instruments for effective screening and assessment of those conditions might prove invaluable in times of the pandemic. When it comes to the specific domain of PUI under COVID-19, differentiating between *high* and *problematic* internet use is the first challenge that needs to be addressed by means of applying adequate instruments and consulting interested groups of citizens [61]. The PUI in general could be quickly assessed with the Problematic Internet Use Questionnaire (PUIQ) existing in longer (18 items) version [62] and shorter (9 or 6 items) variants [63,64], all recommended based on their brevity, ease of use and good psychometric properties [65]. However, it should be highlighted that no single measure is clearly

superior, and detecting specific types of PUI would require use of corresponding instruments. For example, the Ten-Item Internet Gaming Disorder Test (IGDT-10) [66] and Internet Gaming Disorder Scale – Short Form (IGDS9-SF) [67] are brief instruments for rapid assessment of gaming disorder, reported to have good psychometric properties in a recent systematic review of literature [68], and also recommended by a group of experts [43]. According to the same group, a 3-item screening test called the National Opinion Research Centre DSM Screen for Gambling Problems (NODS-CLiP) [69] or a 9-item scale called the Problem Gambling Severity Index (PGSI) [70], are particularly suitable for rapid screening of problematic gambling. As regards the problematic pornography use, one of the longer instruments with wider use among scholars is the Cyber Pornography Use Inventory (CPU) [71], while the Problematic Pornography Consumption Scale (PPCS) [72] and the Problematic Pornography Use Scale (PPUS) [73] are shorter questionnaires that have been recommended in a recent review of literature [74]. In addition, psychological studies should consider multiple time-series analyses, process evaluations, qualitative research and longitudinal surveys [11]. Existing theoretical models, postulating etiological, developmental and therapeutic aspects of PUI, should also be tested in the context of COVID-19 [23,75,76]. These measures cumulatively may offer additional understanding of underlying mechanisms and coping strategies related to mental health concerns, and propose effective strategies for intervention in behavioral addictions and PUI [16]. *Social research priorities*, on the other hand, may help to identify gaps in existing systems for social support, especially in light of protracted lockdowns and quarantines. Equity of access to physical facilities for testing and treatment of underlying conditions, along with systems for online support [17,77], might prove indispensable when aiming to help disadvantaged families and vulnerable individuals, and thus mitigate disparities in healthcare provision [11,78,79]. Indeed, online programs for psychological support and counseling have already proved helpful during the pandemic [80], and this could be very important for those who suffer from different types of problematic internet behaviors. Namely, people with PUI could utilize their internet skills to the best of their abilities, with an aim to improve their health and well-being. The list of advantages includes: easy access and affordability (especially relevant for citizens with high digital literacy); privacy, security and anonymity (especially relevant for mental health patients who fear public scrutiny and stigmatization); as well as flexibility that could be tailored to meet needs of different people (including geographically distanced or isolated, disadvantaged and marginalized individuals).

### 3.2. Therapeutic approaches for vulnerable populations

Regarding the mental health of individuals, particular consideration and support should be given to frontline healthcare professionals [81], because they bear first-hand experience in supporting distressed and unwell individuals during the pandemic. Under such stressful conditions, healthcare workers are often pushed “to make impossible decisions and work under extreme pressures” [82, p. 1], without ‘no harm’ options when choices may involve “whom to harm and how to minimize the harm” [7, p. 6]. The weight of the so-called ‘moral injuries’ falls heavily on medical practitioners, increasing their professional burden, so they are at of becoming vulnerable population themselves, prone to experiencing mental health problems in more severe forms [81,83–87]. Frequently dealing with uncertainty and often “surrounded by death and suffering” [88, p. 3600], health personnel often experience trauma-related symptoms, including depression, anxiety, insomnia, post-traumatic-stress disorder, suicidal ideation [82,89], but also problematic internet behaviors [90]. Increased susceptibility to mental health problems and behavioral addictions among medical staff can occur in parallel with increases in the: (a) physical burden of heavier workloads and frequent rationing, triaging or prioritization of care (often leading to sleep deprivation, burnout and exhaustion); (b) psychological burden of the intensified media coverage, scrutiny and

attention, in addition to the avoidance and stigmatization from close ones (due to heightened exposure to the virus); (c) emotional burden linked to morally conflicting decisions, along with excessive concerns for co-workers and family members; and (d) material burden marked by limited support in logistics (equipment, facilities, machines and medicines), and assistance (leading to limited temporal resources that are further aggravated by unique demands from patients with vulnerabilities and disabilities). COVID-19 related burdens can lead to subsequent increase in problematic internet behaviors among vulnerable healthcare workers [90] because they could use various types of PUI (including gaming, gambling and pornography viewing) as a gateway from stress, anxiety and mental health problems. This can be especially relevant for junior medical staff (who are more accustomed to using the internet), or doctors working in night-shifts (who use the internet to stay awake), or medical workers who are under increased workload (and increasingly use the internet to aid their work). Hence, health professionals should remain mindful of their own health and respectful of their own needs. In addition, telehealth options and counseling sessions, offering mental health assistance, should be made readily available to healthcare professionals [91].

People who were experiencing mental health concerns prior to the pandemic, also deserve attention. During the pandemic, some individuals with obsessive-compulsive disorder (OCD) may experience PUI related to frequent checking of online health information (cyberchondria) [92], compulsive panic buying on the internet [93] or exacerbation of their contamination fears accompanied by excessive washing and cleaning symptoms. Such individuals may benefit from therapeutic approaches tailored toward mitigating effects of the pandemic on their OCD symptoms [94,95]. Timely identification of these patients by careful medical history taking, along with monitoring for signs of suicidal ideation and other risks, represent cornerstones of prevention. Calming, compassionate approaches and psychoeducation based on reliable sources of information, should constitute foundations of counseling sessions that may need to be conducted remotely. In general, maintaining continuity in evidence-based treatment throughout the pandemic should be considered a necessity, even if it requires certain adaptations of healthcare services to the suitable use of digital technology.

Patients who may be particularly vulnerable to PUI in times of COVID-19 are already enduring related co-morbidities like alcohol and other substance use, attention-deficit/hyperactivity, depressive and anxiety disorders [96]. Concerted efforts by mental health specialists and digital services may help to relieve burdens on medical systems and affected lives of individuals during and following the pandemic. These include various telehealth possibilities for scheduling of virtual medical appointments, web-based ‘visits’ of patients, remote monitoring and frequent checkups, as well as digital counseling (via phone, email, web camera or virtual meeting platforms).

At the onset of the pandemic, UNICEF cautioned that children may be especially affected [97], and scientists promptly released guidelines to prevent PUI in adolescents [98]. The protracted lockdowns (with lack of physical recreation), compromises in school structure (due to online education), demands on parents (due to health-related distress, economic factors or other concerns), and the overall discrepancies in lifestyle of parents and children (due to work-from-home practices of parents and home-schooling activities of children), may lead to decreased supervision by parents and possible decrease in self-control or self-discipline of children. These in turn may lead to enhanced use of the internet and increased risk of PUI among school-aged children and adolescents [98–100]. Online support groups and family therapies could provide useful guidance for parents, including advice regarding monitoring of internet behaviors and assistance for children. Additionally, adoption of emotion-regulation and mindfulness strategies may promote adaptive coping. Other affected populations (e.g., older adults) [101] may also benefit from these strategies.

### 3.3. Preventive practices for the general public

In times of enhanced spatial distancing and indoor isolation, the mental health of citizens involves reasonable use of the internet to remain integrated with society and connected with other people. Prevention of PUI is linked to safe and effective internet practices, which should be embedded in daily routines and general lifestyles [89], as well as in specific internet-use-related habits [18,42,43]. General lifestyle considerations may include the following daily routines: physical activities and relaxation practices (aimed to reduce negative feelings and boost positive mood); working and sleeping patterns (which should be conducted in a disciplined manner on a regular basis); family time and alone time, or socialization and self-isolation (which should be well-balanced and well-organized); and educational practices with information updates from reliable sources (which should be constructive and could include updates from reputable news broadcasts, social media accounts of trustworthy medical professionals, or official websites of international health organizations). Specific internet-use-related habits and routines should aim to include: monitoring of one's own behaviors for excessive use of the internet and signs of "impairment in personal, family, social, educational, occupational, or other important areas of functioning" [42, p. 3]; monitoring of others (especially minors or other vulnerable individuals); regulating digital consumption (with the help of analogue tools or interactions with friends); and seeking help for problematic behaviors (as indicated by and with the involvement of medical professionals) [43]. Professional help is recommended when the amount of subjective distress (like fear and anxiety) and objective difficulties (affecting sleep, work and study) are significantly increased. Professional health services should be available via regular protocols, SOS lines and other (country dependent) telehealth options.

### 4. Conclusion

The present narrative review summarizes knowledge on PUI during COVID-19 by focusing on prevalent internet behaviors that: (a) were marked by steep increase at the very start of the pandemic (i.e., online gaming and pornography viewing); and (b) are officially recognized as 'disorders due to addictive behaviors' in the latest edition of the ICD-11 (i.e., gaming and gambling disorder). As addictive behaviors, all instances of PUI represent public health concern, and should be considered from a mental health perspective. This is especially relevant for the present situation, when the COVID-19 disease and the ensuing mental health problems are threatening to become two interrelated pandemics. Thus, we conclude our narrative review by outlining the research priorities, evidence-based therapeutic approaches and preventive practices on PUI in the time of the pandemic, as well as providing guidance and general directions for mental health professionals, patients and the general public. The research priorities pertain to scientists from the biopsychosocial realm of disciplines, and they highlight the need for development of registries for immediate storage of relevant data, tools for rapid assessment of PUI, and online options for treatment of PUI during the pandemic. The therapeutic approaches focus on the needs of populations that are most vulnerable and potentially susceptible to PUI during the pandemic, including healthcare professionals, mental health patients, and children. Preventive practices and general directions consider the needs of the public at large, highlighting the importance of the self-regulated and well-balanced lifestyle, with moderate and reasonable use of the internet during the pandemic.

In essence, the current pandemic has highlighted the importance of mental health and behavioral sciences [102] which complement the medical and pharmaceutical sciences. They compensate for the lack of distribution in "effective prevention (vaccine) or treatment (medicines), by offering safe guidelines for collective behavioral adjustments, and ultimately acting as safeguards of our health" [103]. Under such circumstances, maintaining a balance between safe and problematic use of the internet [42] can promote public health and individual well-being

during and beyond the pandemic.

### Declaration of Competing Interest

**MNP**, **NAF** and **ZD** have been members of a WHO advisory group on the public health consequences of addictive behaviors. **MNP** has: consulted for and advised Game Day Data, the Addiction Policy Forum, AXA, Idorsia, and Opiant Therapeutics; received research support from the Veteran's Administration, Mohegan Sun Casino, and the National Center for Responsible Gaming (no the International Center for Responsible Gambling); participated in surveys, mailings, or telephone consultations related to addictions, impulse-control disorders or other health topics; consulted for law offices and the federal public defender's office in issues related to impulse-control and addictive disorders; provided clinical care in the Connecticut Department of Mental Health and Addiction Services Problem Gambling Services Program; performed grant reviews for the National Institutes of Health and other agencies; edited journals and journal sections; given academic lectures in grand rounds, CME events and other clinical/scientific venues; and has generated books or chapters for publishers of mental health texts. **ZD**: The University of Gibraltar receives funding from the Gibraltar Gambling Care Foundation. ELTE Eötvös Loránd University receives funding from the Szerencsejáték Ltd to maintain a telephone helpline service for problematic gambling. **ZD** has also been involved in research on responsible gambling funded by the Szerencsejáték Ltd's and the Gambling Supervision Board, and has provided educational materials for the Szerencsejáték Ltd's responsible gambling program. **NAF** has been a member of the WHO advisory group on obsessive compulsive disorders. In the past 3 years **NAF** has held research or networking grants from the ECNP, UK NIHR, EU H2020, MRC, University of Hertfordshire; has accepted travel and/or hospitality expenses from the BAP, ECNP, RCPsych, CINP, International Forum of Mood and Anxiety Disorders, World Psychiatric Association, Indian Association for Biological Psychiatry, Sun; has received payment from Taylor and Francis and Elsevier for editorial duties; has accepted a paid speaking engagement in a webinar sponsored by Abbott. Previously, she has accepted paid speaking engagements in various pharmaceutical industry supported symposia and has accepted grants and funding support for various pharmaceutical industry-sponsored studies in the field of OCD treatment. She leads an NHS treatment service for OCD. She holds Board membership for various registered charities linked to OCD. She gives expert advice on psychopharmacology to the UK MHRA and NICE. **SRC** receives an honorarium from Elsevier for editorial work at journals; and previously consulted for Promentis. **SRC**'s research is funded by the Wellcome Trust. Other authors report no disclosures. The above reported institutions had no role in the preparation of the current submission. **JB**: In the past several years **JB** has been working as a consultant at Cogstate, Ltd.

### Acknowledgements

This article is based upon work from COST Action CA16207 "European Network for Problematic Usage of the Internet", supported by COST (European Cooperation in Science and Technology), [www.cost.eu](http://www.cost.eu). **MNP**'s involvement was supported by the Connecticut Council on Problem Gambling. **OK** was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences, and by the ÚNKP-21-5 New National Excellence Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund. **ZD**'s contribution was supported by the Hungarian National Research, Development and Innovation Office (KKP126835). The funding agencies had no role in the decision to publish, or in the content or preparation of the manuscript.

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