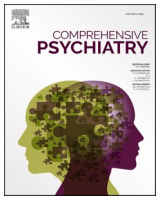
Comprehensive Psychiatry 118 (2022) 152346

Contents lists available at ScienceDirect

Comprehensive Psychiatry

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



Advances in problematic usage of the internet research – A narrative review by experts from the European network for problematic usage of the internet

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https://doi.org/10.1016/j.comppsych.2022.152346
Received 17 December 2021; Received in revised form 29 June 2022; Accepted 9 August 2022
Available online 16 August 2022

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ARTICLE INFO

Keywords:
Problematic usage of the Internet
Behavioral addiction
Gaming disorder
Covid-19 pandemic
Impulsive
Compulsive
Patient and public involvement (PPI)

ABSTRACT

Global concern about problematic usage of the internet (PUI), and its public health and societal costs, continues to grow, sharpened in focus under the privations of the COVID-19 pandemic. This narrative review reports the expert opinions of members of the largest international network of researchers on PUI in the framework of the European Cooperation in Science and Technology (COST) Action (CA 16207), on the scientific progress made and the critical knowledge gaps remaining to be filled as the term of the Action reaches its conclusion.

A key advance has been achieving consensus on the clinical definition of various forms of PUI. Based on the overarching public health principles of protecting individuals and the public from harm and promoting the highest attainable standard of health, the World Health Organisation has introduced several new structured diagnoses into the ICD-11, including gambling disorder, gaming disorder, compulsive sexual behaviour disorder, and other unspecified or specified disorders due to addictive behaviours, alongside naming online activity as a diagnostic specifier. These definitions provide for the first time a sound platform for developing systematic networked research into various forms of PUI at global scale. Progress has also been made in areas such as refining and simplifying some of the available assessment instruments, clarifying the underpinning brain-based and social determinants, and building more empirically based etiological models, as a basis for therapeutic intervention, alongside public engagement initiatives.

However, important gaps in our knowledge remain to be tackled. Principal among these include a better understanding of the course and evolution of the PUI-related problems, across different age groups, genders and other specific vulnerable groups, reliable methods for early identification of individuals at risk (before PUI becomes disordered), efficacious preventative and therapeutic interventions and ethical health and social policy changes that adequately safeguard human digital rights. The paper concludes with recommendations for achievable research goals, based on longitudinal analysis of a large multinational cohort co-designed with public stakeholders.

1. Introduction

In recognition of the global public health and societal costs of problematic usage of the internet (PUI) [1,2] and the need for networked research to address this challenge across different age groups, cultures and jurisdictions [3], the European Network for Problematic Usage of the Internet (EU-PUI) was established in 2018 under the EU COST Action initiative (Cost Action; http://www.cost.eu/COST_Actions/ca/CA16207) funded by the European Commission. The overarching aim of the EU-PUI is to bring together expert scientists and clinicians from a wide variety of disciplines and backgrounds to generate new national and international research initiatives, with an emphasis on public engagement in science, to leverage existing funded research into a more coherent programme with the aim of intervening early and reducing the negative consequences or serious repercussions of PUI in its various forms. "A coordinated multi-national research approach would be invaluable to allow the results to be tested across countries and cultures, to produce richer datasets with a view to ensuring findings can be generalized; and also in order to study local culture-specific issues of relevance to understanding PUI." [1].

Over the past four years, the Network has grown and developed in terms of membership (currently 146 members from 41 different countries) (Fig. 1.) and impact (rapporteurs' report [4]), advancing the field via several landmark research projects e.g. investigating diagnosis [5,6], screening instruments [7–11], underpinning mechanisms [12,13], theoretical models [14], treatments [15,16], including a treatment guideline for managing PUI during the COVID-19 pandemic [17,18], disseminated widely via a large number of publications in open-access peer-reviewed journals, a popular e-book (freely available at http://www.internetandme.eu/resources/) and at a public festival of arts and science (http://www.internetandme.eu/international-festival-of-science-and-arts-problematic-use-of-the-internet-raising-the-public-voice/). Indeed, the effects of the COVID-19 pandemic have brought the problem of PUI into stark relief, as the public has come to rely hugely on the internet for many aspects of everyday life. As general internet usage has increased, vulnerable people have become at risk of losing control over their online behaviours, as evidenced by increasing rates of problematic online gambling and pornography use seen among the young since the onset of the pandemic [19–21].

As one of its first objectives, the Action published its Manifesto [1] which set the groundwork for research in the field. Using the umbrella term PUI to encompass all potentially problematic internet-related behaviours, including those relating to gaming, gambling, buying, pornography viewing, social networking, 'cyber-bullying,'

'cyberchondria', among others, the manifesto described the key research priorities viewed by experts as being a prerequisite for moving the field forward [1]. In sum, these included: 1) development of reliable consensus-driven conceptualisations of PUI, including the main phenotypes and specifiers, related comorbidities and brain-based mechanisms; 2) age- and culture-appropriate assessment instruments to screen, diagnose and measure the severity of different forms of PUI; 3) characterization and quantification of the impacts of different forms of PUI on health and quality of life; 4) definition of the clinical courses of different forms of PUI; and 5) clarification of the possible roles of genetics and personality features as well as 6) social factors in the development of PUI. More distal goals included: 7) generating and validating effective interventions, both to prevent PUI and to treat its various forms once established; 8) identifying biomarkers, including digital markers, to improve early detection and both preventative and therapeutic interventions; and 9) reducing obstacles to timely recognition and interventions.

As the EU-PUI is now entering its final year, it is timely to review the research landscape against those predetermined goals, identifying where important advances have been made, and by the same token, those key goals that remain to be achieved. A review such as this is particularly relevant in the field of PUI, as the digital environment is changing extremely rapidly, not least as a result of the recent pandemic, bringing with it new research challenges needing to be accurately identified and addressed in a timely way.

In this narrative review, we bring together a diverse group of expert researchers working in collaboration with the EU-PUI to review progress in each of the predetermined priority areas [1], by selecting those advances they judge to be of utmost importance, based on their knowledge of the published and emerging literature. By inviting experts from diverse backgrounds to review each topic, we expect this approach will make optimal use of individual expertise, in what remains a relatively narrow field of research, while also correcting for individual biases. We devote an additional section to public engagement and a final section to new and important research challenges that have emerged since the original manifesto was written.

2. Reliable consensus-driven conceptualisation of PUI

From its first definition, as excessive internet use generating psychological, social, educational, and/or work problems in people's lives, the term "Problematic Use of the Internet" (PUI) has gained progressive attention in the scientific literature [22]. Other terms for PUI (e.g., compulsive internet use, problematic internet use, internet addiction, pathological internet use, problematic smartphone use, gaming disorder, problematic social media use) have been used, but PUI has the advantage of not making assumptions about the nosology or underpinning causative mechanisms of the various subcategories. In 2013, in light of increasing incidence, internet gaming disorder (IGD) was listed as candidate mental disorder in need of further study in Section III of the 5th Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). In 2019, based on public health principles of protecting individuals and the public from harm and promoting the highest attainable standard of health, the World Health Organisation defined gaming disorder as a full diagnosis in the 11th Edition of the International Classification of Disease (ICD-11) within disorders due to substance use or addictive behaviours (for the ICD-11 definition, see Table 1), together with gambling disorder [23]. In addition, a diagnostic specifier of 'online' (as opposed to offline) activity was added. However, PUI describes excessive online activities associated with marked functional impairment and/or distress, which may include not only gaming and gambling but also online buying or shopping, cybersex/pornography use [24], social media use [25], cyberchondria, digital hoarding, cyberstalking, and excessive use of online streaming with addictive, impulsive and/or compulsive features [26]. A further new ICD-11 diagnosis for Other Specified or Unspecified Disorders Due to Addictive Behaviours was created to allow for potential diagnosis of some of these problematic behaviours as disorders, should the extent of the problem meet the specified diagnostic criteria. Based on the strength of current scientific evidence, and balancing the need not to over-pathologize everyday-life behaviour, while not trivializing conditions of clinical importance meriting public health consideration, the behaviours judged most likely to qualify for diagnosis within this category include problematic online pornography viewing, shopping/buying and possibly social media use

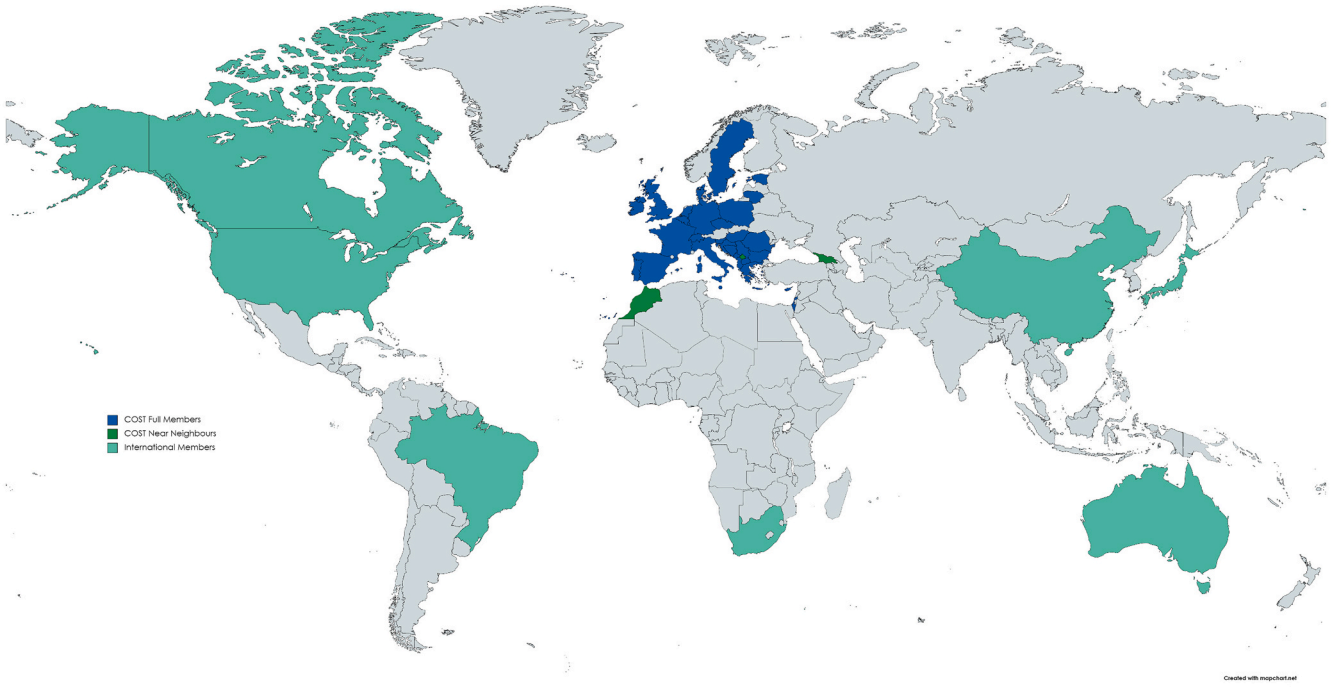

Fig. 1. Map of the 31 COST member countries, 3 near neighbour countries and 7 international observer countries collaborating in CA 16207 – European Network for Problematic Usage of the Internet.

Table 1
Working definitions for various forms of Problematic Usage of the Internet.

Subtypes of PUI	Working definition
Gaming Disorder *ICD-11 Diagnosis* [1]	Persistent pattern of gaming behaviour characterized by all the following: • Impaired control over gaming (e.g., onset, stopping, frequency, duration) • Increased priority given to gaming over other life interests and activities (nutrition, personal hygiene, school or work) • Continuation or escalation of gaming despite negative consequences (family conflict, poor scholastic performance, negative impact on health) • Gaming results in significant distress or impairment in personal, family, social, educational, occupational or other important areas of functioning • Gaming may be continuous or episodic and recurrent but is manifested over an extended period of time (usually $\geq$ 12 months) • Gaming is not better accounted for by another mental disorder and not due to the effects of a substance or medication Includes specifiers for predominantly online or offline behaviour
Gambling Disorder[*] *ICD-11 Diagnosis* [1]	Persistent pattern of gambling characterized by all the following: • Impaired control over the gambling (e.g., timing, frequency, duration, amount bet) • Precedence given to gambling over other life interests and activities • Continued or escalated gambling despite negative consequences (e.g., marital conflict, substantial financial losses or debt, neglected responsibilities) • Long-standing gambling pattern (usually >12 months) (may be continuous or intermittent) • Significant distress or impairment in personal, family, social, educational, occupational or other important areas of functioning • Not better accounted for by another mental disorder or by the effects of a substance or medication Includes specifiers for predominantly online or offline behaviour
Online Buying-Shopping Disorder [1,285,289]	Persistent pattern of buying/shopping characterized by all the following: • Preoccupations with and craving for buying/shopping on the internet • Diminished control over buying/shopping on the internet • Priority given to the use of internet shopping applications and/or excessive purchasing of consumer goods without utilizing them for their intended purposes • Persistent and recurrent dysfunctional buying/shopping results in extreme distress, and/or in significant impairment in personal, family, social, or other important areas of functioning including relationship breakdown, clutter from accumulated goods, indebtedness and deception in order to continue overspending despite financial difficulties • Maintenance or escalation of buying/shopping despite the occurrence of negative consequences • Not better accounted for by another condition (e.g., occurring only during a manic episode), or by the effects of a substance or medication
Cyberchondria [6]	Excessive, repeated online searching for illness-related information that is manifested by: • An urge-driven tendency to excessively seek illness-related information on the Internet • Although intended to provide reassurance, searching increases anxiety, uncertainty and reinforces cyberchondria • Results in significant distress, manifested as increased illness-related anxiety or fear, and/or in impairment in personal, family, social, or other areas of functioning
Compulsive Sexual Behaviour Disorder[#] *(ICD-11 Diagnosis)* [1,55]	Persistent failure to control intense, repetitive sexual urges or impulses resulting in repetitive sexual behaviour manifested by the following - one or more of items 1-3 are required: • Sexual behaviour is the central focus of one's life, with neglect of other important interests, activities or personal responsibilities • Numerous unsuccessful attempts to stop or reduce the sexual behaviour • Continued engagement despite negative consequences (relationship conflict, financial/legal consequences, sexually transmitted infection) or little or no satisfaction from it • Sexual behaviour is manifested over an extended period of time (e.g., 6 months or more). • Not better accounted for by another mental disorder or other medical condition and not due to the effects of a substance or medication • Must result in marked distress for the individual or significant impairment in personal, family, social, educational, occupational, or other important areas of functioning
Cyberbullying [138,286]	Repetitive digital posting of threatening or disparaging messages to another individual, with the following features: • Impaired control over urges to bully using electronic technology as the chosen medium • Continuation or escalation of the behaviour despite the occurrence of negative consequences • The behaviour results in extreme distress to self or others, and/or in significant impairment in personal, family, social, or other important areas of functioning
Problematic Social Media Use [1]	Persistent failure to control social media use, manifest by • Impaired control over the engagement with social media sites (e.g., in terms of timing, frequency, duration) • Precedence given to spending time on social media over other life interests and activities • Continued or escalated social media use despite negative consequences (e.g., poor scholastic performance, negative impact on health, social isolation, interpersonal conflict, neglected responsibilities) • Social media use results in significant distress or impairment in personal, family, social, educational, occupational, or other important areas of functioning • Social media use may be continuous or episodic and recurrent but is manifested over an extended period (at least 12 months)
Digital Hoarding [287]	Excessive accumulation of digital material such as emails, files, media, and software. Accumulation occurs due to either or both: • Repetitive urges or behaviours related to amassing digital items, which may be passive (e.g., accumulation) or active (e.g., excessive acquisition) • Difficulty discarding digital materials due to a perceived need to save digital items and distress associated with discarding them • The symptoms result in significant distress or impairment in functioning e.g., effects on personal organisation or productivity, psychological

(*continued on next page*)

Table 1 (*continued*)

Subtypes of PUI	Working definition
	wellbeing, cybersecurity issues, links with physical hoarding

Problematic use of the smartphone could involve various forms of PUI such as gaming, gambling, social media, etc.

[*] **Excessive stock market trading** may be defined under the ICD-11 Gambling Disorder definition.

[#] **Problematic online pornography use** may be defined under the ICD-11 Compulsive Sexual Behaviour Disorder definition.

[25]. Furthermore, another new ICD-11 diagnosis of Compulsive Sexual Behaviour Disorder, listed in the impulse control disorders, was created which may also be used to diagnose those with serious loss of control over online pornography viewing.

Two main subtypes of PUI have been proposed: one seemingly related to impulsive behaviours (i.e., gaming, gambling, online buying/shopping, cybersex/pornography use, social media use) and another seemingly related more strongly to compulsive behaviours (i.e., cyberchondria, cyberstalking, digital hoarding), although there is substantial overlap regarding the involvement of addictive, impulsive, and compulsive features in all these types of PUI. In terms of specific forms of PUI, most research focus has been on IGD or gaming disorder; however, other types of online activity have been found to exhibit larger magnitude associations with PUI [3]. Further specifiers such as problematic social media use (PSMU) and problematic smartphone use (PSU) have also been proposed [27–30], as have disorders related to these behaviours. Table 1 proposes a working definition for the major forms of PUI and, where available, the ICD-11 diagnostic criteria, to serve as a reference point for future studies of PUI and its sub-categories.

Across almost all measurement tools developed for PUI, including for IGD or gaming disorder, there are pervasive methodological issues including (but not limited to) insufficient use of item-response theory (IRT), lack of validation against appropriate measures of functional impairment, and scant efforts to confirm measurement invariance across different countries and cultures (or to establish lack of invariance and adapt thresholds and scoring appropriately) [33] (for more detail see section 3).

The most widely used questionnaire to assess PUI and Internet Addiction has been the Internet Addiction Test (IAT), originally consisting of 20 questions on a Likert scale from 0 to 5 quantifying preoccupation, compulsive use, behavioral problems, emotional changes and diminished functionality related to internet use as perceived by the respondent. A psychometrically optimized 10-item version of the IAT, the Joint Expert Group-IAT-10 (JEG-IAT-10), has been developed and psychometrically validated (including with IRT) [11]. Various IAT cut-offs to determine presence of PUI (and potentially its severity) have been used throughout the literature [3]. However, psychometric research indicates that IAT scores (and therefore any cut-offs/thresholds) require validation in the specific population being measured and are not universally valid [11].

Cultural and geographical settings can influence the presentation of PUI. In a large meta-analysis of 101 studies with 20,4352 participants from 34 countries, gender plus Asian racial-ethnic grouping was associated with higher levels of PUI [34]. Furthermore, cyberchondria, a behaviour characterized by excessive online searching for medical information associated with health anxiety, has been suggested as having a particularly strong relationship with PUI [6].

Conceptualisation of PUI can be aided by considering the candidate brain-based mechanisms leading to PUI and its persistence, including poor self-regulation, maladaptive emotional coping, and high levels of behavioral impulsivity and compulsivity [14]. (More detailed consideration of biological and cognitive findings in PUI is covered in section 9). These features are also commonly implicated (across geographical regions and cultures) in several psychiatric disorders that frequently accompany PUI (for more detail on comorbidities, see section 2.3), including attention deficit hyperactivity disorder (ADHD), obsessive-compulsive disorder (OCD), and impulse control and substance use disorders, thus suggesting some degree of commonality in underlying biological processes that may ultimately translate into new nosological models. Adolescents are therefore likely to be the most susceptible "at-risk" PUI population worldwide, being vulnerable to the initiation of addictive behaviours due to specific neurodevelopmental brain processes, and their massive exposure to the internet, coupled with lifestyle changes (e.g., attending university) that may offer greater freedom to engage in such activities; as well as such activities being used to cope with difficulties and negative emotions [13]. However, PUI can occur across the whole lifespan, highlighting the need to ensure inclusivity not only of young people but also older samples in PUI research.

Only a few studies have investigated PUI in older individuals (>55 years old): the most frequent psychiatric comorbidities were generalized anxiety disorder, obsessive–compulsive disorder (OCD) and gambling disorder [3]. Indeed, a study found evidence for two putative forms of PUI: one characterized by impulsive problems and occurring in younger people; and the other characterized by compulsive problems and occurring in older people [43]. Longitudinal research at very large scale, using gold-standard measurement tools, is needed to rigorously address subtypes and better understand how PUI may change over time.

Overall, promising steps forward have been made in the development of reliable consensus-driven conceptualizations of PUI, and we now need to move beyond agreeing on diagnostic guidelines (a major step, notwithstanding) to agreeing also on ways to evaluate and assess individuals, both at public health and clinical levels [44]. Thus, although substantial progress has been made along this route, further work is still needed to consolidate what has already been achieved, incorporating high-quality large-scale global research initiatives, with the best tools and statistical methodologies, to ensure findings are reproducible and valid.

3. The epidemiology of PUI in the post-pandemic era

3.1. Prevalence

Numerous studies have investigated the prevalence of problematic online behaviours. The prevalence rates of PUI vary widely and should be approached with caution given the heterogeneity and the relative lack of consistency in terms of the diagnostic criteria for PUI, as well as the diversity of the applied measures and samples. Study design – which includes the geographical regions in which the study is conducted (e.g., Eastern versus Western societies), the assessment tools and clinical cut-offs used (e.g., self-reported scales versus clinical interviews based on diagnostic criteria), and sample representativeness (e.g., nationally representative samples versus convenience samples) – may also potentially influence the prevalence estimates of PUI in general and its subtypes [45–47]. Notably, in the case of disorders that are relatively rare, screening instruments have a low predictive value, meaning that they may overestimate the true prevalence rate of the disorder [48]. Consequently, the prevalence estimates reported in epidemiological studies using self-report screening instruments are typically higher than true prevalence rates. Nevertheless, a recent systematic review and meta-analysis that included 113 epidemiologic studies covering almost 700,000 individuals from 31 nations, and which were published from 1996 to 2018, suggested that there were 53,184 subjects with PUI, with a weighted average prevalence estimated of 7.02% (95% confidence interval, 6.09%–8.08%) [49].

Sampling criteria may also influence prevalence findings; for example, in terms of specific instances of PUI, and using stringent sampling criteria, the worldwide prevalence of gaming disorder was found to be 1.96% [95% CI 0.19–17.12], while it was considerably higher, 3.05% [95% CI 2.38-3.91] when less stringent sampling criteria were applied [50]. Finally, a recent meta-analysis of PUI prevalence

among university students suggested that prevalence rates were increasing year by year [51], suggesting that PUI prevalence rates may also vary over time. This trend, however, may not hold for all forms of PUI [49]. It should be noted that much of the literature inappropriately refers to 'prevalence' when using non-representative samples: but these studies cannot measure prevalence, but rather frequencies of PUI in a specific sample, which is unlikely to generalise.

3.2. Course, age and gender

Younger age and male gender have generally been associated with PUI, but this is not conclusive. It has been argued that there has been a paucity of appropriately designed studies capturing online problematic behaviours across age groups. Particular age groups may be more vulnerable to develop certain types of PUI. For example, whereas youth may be more at-risk of developing PUI with a propensity for viewing online pornography (a vulnerability that may diminish with increasing age), older people might be more prone to develop PUI characterized by problematic use of "time wasters" and streaming media [3]. Moreover, characteristics such as having ADHD or social anxiety symptoms may increase the risk for PUI in youth, whereas presence of generalized anxiety disorder (GAD) symptoms or having gambling disorder or online buying-shopping disorder may predict PUI in older populations, given the natural courses of these conditions that may peak in middle age [3].

PUI has been considered to have a male preponderance in adolescents and adults, although there are seeming discrepancies in the literature. Differences in economic equality, internet availability and sociocultural norms may contribute to variations in global gender-related differences in PUI [52]. Males and females may also differ in terms of the type of online activities chosen, but not all studies agree [27]. Excessive use and greater severity of smartphone use and social media use [53], as well as online buying-shopping disorder [54], have generally been associated with female gender, whereas males appear to be more prone to online gaming [50] and problematic online pornography use [55]. However, the results are far from conclusive [27]. For example, a meta-analysis indicated that patterns of predominantly female problematic social media use and male gaming disorder were not observed uniformly across jurisdictions [31]. Furthermore, patterns of psychological distress associated with gaming and smartphone use may be influenced by other factors, including the COVID-19 pandemic [32]. Some subcategories of PUI, e.g., online gambling, seem to be unrelated to sex/gender [56].

In summary, whereas there may be gender-specific differences in terms of the ways in which PUI manifest, it is plausible that other associated gender-related characteristics account for at least some of the differences in online behaviours, and once clinical and behavioral characteristics are considered, both genders may be similarly affected (e.g., [57–59]).

3.3. Psychiatric comorbidity and PUI

PUI is associated with psychiatric comorbidities, both in younger and older age samples. ADHD, depression, aggressive behaviours, social anxiety, autism spectrum disorder, and suicidal ideation have been implicated both as candidate predictors and as consequences of PUI [35–39].

The association between PUI and internalizing (anxiety and depressive) disorders has been theorized to relate to the mood enhancement hypothesis in that individuals with negative emotions may seek recreational activities to ease stress or escape from distressing emotions (negative-reinforcement motivations). At the same time, social comparisons through social media could generate thoughts of failure resulting, ultimately, in depressive symptoms [40,282]. Moreover, consumption of image-based social media, which is linked to appearance comparisons and fitness content, has been associated with body image disturbances, eating disorders and related psychopathology [41,132], which might have increased during the COVID-19 pandemic [283].

PUI may also co-occur with impulsive problems such as ADHD and conduct disorders. In such cases, impulsivity may represent a particularly relevant factor [35,40,42], although others (e.g., positive-reinforcement motivations) also warrant consideration.

3.4. COVID-19 influences

During the COVID-19 pandemic, internet use in general has increased significantly [18,60]. Increased internet use is not necessarily problematic though [61], with many instances of online activity (online gaming, pornography use, use of Video-on-Demand (VoD) services, for example) considered helpful in managing stress related to the COVID-19 pandemic and subsequent public health measures such as lockdowns, quarantines, and social distancing [62–64]. However, increased online behaviours may become problematic over time, and may vary according to the type of online application; for example, online gaming [64–66], pornography use [67] and smartphone use [68] have seemingly increased, whereas others (e.g., gambling [69]) seem to have declined [70,71]. Longitudinal research will be helpful in determining the impact of COVID-19 on the manifestation and maintenance of these potentially problematic online behaviours [32].

4. Age- and culture-appropriate assessment instruments for different forms of PUI and key comorbidities

Many screening and diagnostic tools have been developed to assess the severity of either PUI in general or specific problematic involvement in online activities on the other hand (e.g., videogames, social network sites, cybersex, TV series streaming, or health-related websites). Given potential influences of factors such as age, cultural and geographical settings on the presentation of PUI (see Section 1), it is important to use validated instruments that have established credentials that could be expected to apply to the population under study.

In the current section, we have selected instruments based on the following criteria: (1) theoretically embedded robust psychometric properties (i.e., theoretically sound factorial structure established through exploratory and confirmatory factor analyses, convincing evidence regarding validity – including links with convergent constructs – and reliability); (2) over-pathologizing considerations (i.e., effort was made to select instruments including no or few items pathologizing typical and/or beneficial outcomes of targeted behaviours); and (3) cross-cultural usage (i.e., multiple validations in different languages, evidence of measurement invariance across languages). The conjoint use of these three criteria implies that some recent and/or potentially relevant instruments not sufficiently validated or adapted in different languages (e.g., the Revised Chen Internet Addiction scale CIAS-R [278], a widely used assessment in Asian countries) were not selected, and the authors concluded that a conservative approach to assessment tool selection was the best option in the current context. Similarly, questionnaires developed to assess specific psychological factors underlying online problematic behaviours (e.g., motives driving the behaviours and dysfunctional cognitions) were not considered. For parsimony reasons, we decided to retain only one or two instruments per condition considered (based on the three selection criteria described above), implying that our selection of assessment instruments may not be exhaustive. We also decided to not consider screening instruments for conditions that are well known and traditionally considered and diagnosed in their offline counterpart (typically gambling and buying/shopping disorders) or screening instruments focusing on specific applications such as "Facebook" or "Tinder". Table 2 indicates for each retained tool in which language the instrument is available. It should be kept in mind that most instruments presented here target so called "emerging" problematic behaviours, which have been developed without reference to standard diagnostic or clinical assessments to provide a gold standard.

Table 2
Description of the selected scales for the assessment of problematic online behaviours.

Problematic online behaviour	Scale	Description of the scale					Dimensionality		Reliability		Validity	
		Conceptualization, development, and diagnostic framework	*N* of items	Response format	Cut-off	Available Languages	Method	Factorial structure	Internal consistency[a]	Test-retest[b]	Convergent /discriminant validity[c]	Criterion validity[d]
Problematic Internet use	Compulsive Internet Use Scale (CIUS) [1]	The CIUS was developed to assess the main symptoms of "Compulsive Internet Use (CIU)" (excessive attachment to the use of the Internet, resulting in psychological, social, and professional impairment"). Items were developed based on Substance Use Disorder criteria (e.g., tolerance, withdrawal, loss of control, etc.), as well as inspired by the criteria for the diagnosis of pathological gambling, OCD, and –at that time– dominant addiction models (e.g., 'component model of addiction'). Items were then refined based on the results from a qualitative study among 17 self-declared excessive Internet users. The original version of the CIUS comprised 14 items (CIUS-14), but subsequent validations have resulted in shortened versions of the scale (CIUS-9, CIUS-7, or CIUS-5). Data presented here refers to the original CIUS-14 (the version with more evidence around its psychometric properties).	14 items	5-point	Yes	English Spanish Italian German French Polish Chinese Finnish Hungarian Dutch Arabic Persian Japanese	EFA & CFA	One factor: Compulsive Internet Use (CIU)	●	○	●	●
Gaming	Internet Gaming Disorder Test [IGDT-10, 2,3]	The IGDT-10 was developed to assess the criteria for the diagnosis of Internet Gaming Disorder as operationalized by the DSM-5. Via experts' discussion, authors proposed one item for each IGD DSM-5 criteria (except for interference criterion, comprised by two items), ensuring that wording was clear and unambiguous.	10 items	3-point	Yes	English Czech French Hungarian Norwegian Persian Spanish Finnish Croatian Chinese	EFA & CFA	One factor: Internet Gaming Disorder (IGD) severity	●	○	●	●
Online Sexual Activities	Problematic Pornography Consumption Scale (PPCS-18) [3]	As explicitly stated by the authors of the scale, "the PPCS was established to assess problematic pornography use, not addiction" [4]. Yet, the scale was based on the 'component model of addiction'. The scale was developed following a theoretically-driven iterative approach in which four psychologists proposed items measuring each of the six components of the model. The original version of the PPCS-18 comprised 18 items, but subsequent validations have resulted in a	18 items	7-point	Yes	English Hungarian Chinese	CFA	Six 1st order factors (salience, mood modification, conflict, tolerance, relapse, and withdrawal) under a 2nd order factor (problematic pornography use')	●	○	●	●

(*continued on next page*)

Table 2 (*continued*)

Problematic online behaviour	Scale	Description of the scale					Dimensionality		Reliability		Validity	
		Conceptualization, development, and diagnostic framework	*N* of items	Response format	Cut-off	Available Languages	Method	Factorial structure	Internal consistency[a]	Test-retest[b]	Convergent /discriminant validity[c]	Criterion validity[d]
		shortened version of the scale (the PPCS-6) [5,6]. Data presented here refers only to the original PPCS-18 (the version with more evidence around its psychometric properties).										
	Short Internet Addiction Test adapted to Online Sexual Activities (S-IAT-Sex) [4]	The S-IAT-Sex is a short scale aimed to measure subjective complaints in everyday life due to the use of the Internet for sexual purposes. Unlike other measures (e.g., the PPCS-18), this scale assesses problematic engagement in Online Sexual Activities (OSAs) in general, rather than in particular OSAs (e.g., pornography, webcams, etc.). As for its development, the S-IAT-Sex was adapted from a short version of the Internet Addiction Test (IAT) by replacing the terms «Internet» or «online» by «Internet sex sites» or «online sexual activities». The original version of the S-IAT-Sex (the 'IAT-Sex') comprised 20 items. However, the shortened version of the scale (S-IAT-Sex) has more evidence around its psychometric properties and removed outdated items.	12 items	5-point	Yes	English German French	CFA	Two correlated 1st order factors: (1) loss of control/ time management and (2) craving/social problems.	●	○	●	●
Social networks	Social Media Disorder Scale (SMD-Scale) [5]	The SMD-Scale conceptualizes problematic social media use as a particular form of Internet Addiction, suggesting that the criteria proposed for other expressions of this overarching condition (e.g., IGD) should be assessed when measuring social media addiction. Accordingly, authors employed the criteria proposed by the DSM-5 for the diagnosis of IGD to develop the SMD-Scale. The original version of the SMD-Scale comprised 27 items. However, the shortened version of the scale (9 items) has more evidence around its psychometric properties.	9 items	Yes/no	Yes	English Dutch Chinese Turkish	EFA & CFA	One factor: Social Media Addiction severity	●	◒	●	●
	Bergen Social Media Addiction Scale (BSMAS) [6]	The BSMAS relies on the "component model of addiction" to operationalize social media addiction according to six addiction criteria: i.e., salience, conflict, mood modification, withdrawal, tolerance, and relapse. The scale was adapted from the previously validated "Bergen	6 items	5-point	Yes	Chinese English Italian Persian Hungarian Turkish	CFA	One factor: Social Media Addiction severity	●	○	●	●

(*continued on next page*)

Table 2 (*continued*)

Problematic online behaviour	Scale	Description of the scale					Dimensionality		Reliability		Validity	
		Conceptualization, development, and diagnostic framework	*N* of items	Response format	Cut-off	Available Languages	Method	Factorial structure	Internal consistency[a]	Test-retest[b]	Convergent /discriminant validity[c]	Criterion validity[d]
		Facebook Addiction Scale" replacing the term "Facebook" by "social media".										
TV series	Binge-Watching Engagement and Symptoms Questionnaire (BWESQ) [7]	The BWESQ aims to assess both problematic and non-problematic binge watching (i.e., watching multiple episodes in a single sitting): The development of the scale is based on the phenomenological study of TV series watching. First, authors conducted a qualitative study of regular TV series users (focus group) to identify common presentations of this behaviour. This information, together with the authors' knowledge about the screening and diagnosis of substance use and addictive disorders, inspired the development of the scale.	40 items	4-point	No	English Spanish French German Italian Chinese Hungarian Arabic Persian	EFA & CFA	Seven correlated 1st order factors: (1) engagement; (2) positive emotions; (3) pleasure preservation; (4) desire/savoring; (5) binge-watching; (6) dependency; and (7) loss of control NB: factors 5, 6, and 7 were the most intimately linked to problematic TV series use.	●	○	●	○
Cyberchondria	Cyberchondria Severity Scale (CSS) [8]	The CSS was developed to assess anxiety resulting from online searches for health information (cyberchondria). The CSS conceptualizes cyberchondria as a multi-dimensional construct, reflecting both anxiety and an element of compulsiveness. Items from the scale were generated based on the review of the literature on cyberchondria and anxiety disorders. The original version of the CSS comprised 33 items (CSS-33), but subsequent validations have resulted in shortened versions of the scale (CSS-30, CSS-15, or CSS-12). Data presented here refers only to the original CSS-33 (the version with more evidence around its psychometric properties).	33 items	5-point	No	English German Polish Turkish Croatian Iranian	EFA, CFA & PCA	Five correlated 1st order factors: (1) compulsion; (2) excessiveness; (3) distress; (4) reassurance; and (5) mistrust of medical professionals. Bifactor model comprising a general cyberchondria domain and the previous 5 specific factors.	●	●	●	○

Note: Criteria for assessing internal consistency, test-retest reliability, and criterion validity was extracted from King et al. [12], whereas criteria for assessing convergent/divergent validity was formulated following the same approach (NB: King et al. did not formulate criteria for assessing this particular aspect). When the same research included multiple samples (e.g., samples from different countries), results from each sample were treated as independent; [a] = Internal consistency, as assessed by Cronbach's alpha or an equivalent index –e.g., McDonalds's omega– (◯ = No available data. ◒ = 1 study reporting internal consistency >0.70. ● = 2 or > 2 studies reporting internal consistency >0.70); [b] = Test-retest reliability (◯ = No available data; ◒ = 1 study with *r* test-retest >0.70; ● = 2 or > 2 studies with *r* test-retest>0.70]); [c] = Convergent and discriminant validity, as assessed by positive (convergent) or negative (discriminant) associations with other scales assessing related constructs (◯ = No available data; ◒ = 1 study reporting association ±0.3 or higher; ● = 2+ studies reporting association ±0.3 or higher); [d] = Criterion validity, as assessed by association with other indicators of problematic engagement in the online behaviour (◯ = No available data; ◒ = 1 study reporting association 0.3 or higher; ● = 2+ studies reporting association 0.3 or higher).

EFA = Exploratory Factor Analysis; CFA = Confirmatory Factor Analysis; PCA = Principal Component Analysis.

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Generalized PUI has for long been assessed through the Internet Addiction Test (IAT) [72]. Yet, this scale, at least in its original version, possesses outdated items and/or items that may pathologize general/normal use of the internet (e.g., "Do you form new relationships with fellow online users?"). A nowadays popular and highly used instrument is the Compulsive Internet Use Scale (CIUS) [73], which possesses well established psychometric properties and does not contain such problematic items. Moreover, the scale (and its short versions) have been validated in many languages [10].

Many screening instruments have been developed in the last two decades to assess IGD [33]. Among them, the IGDT-10 [7] and the IGDS9-SF [74] present multiple advantages, like a reference to an identified nosography (DSM-5 IGD, see [75]), robust psychometric properties, cross-cultural validations, and available cut-off points. Here we decided to retain the IGDT-10 which operationalizes the complex DSM-5 criteria related to "jeopardization of relationships or job" via two items instead of one, to avoid the use of a double-barreled item. It is worth noting that more recent instruments assessing gaming disorder based on the ICD-11 framework are available, but as they have not received extensive psychometric investigation nor cross-cultural validation to date, they were not retained, though it is to be expected that in the future these will turn out to have considerable clinical utility.

Several tools have been developed to assess online sexual activities. Pornography-use disorder has received growing interest [25], and it was decided to select a specific scale measuring it. The Problematic Pornography Consumption Scale (PPCS) [76] was retained, as this scale was anchored in an identified conceptual framework (the "component model" of addiction) and possesses good psychometric properties. We also retained an unspecified online sexual activity scale, as cyber-sexual activities beyond pornography consumption exist (e.g., sex webcam or chat, 3D sexual role-playing games). We retained the short Internet Addiction Test adapted to cybersex (s-IAT-sex) [77], which has well-established psychometric properties and does not include the outdated items present in the original IAT [72].

Social-network-use disorder may constitute an emerging disorder, even if the available clinical evidence remains limited [25]. The most popular existing scale is the Bergen Social Media Addiction Scale (BSMAS) [78,79], which is based on the "component model" of addiction and composed of only six items. Yet, 3 of these items measure criteria (preoccupation, tolerance, mood regulation) that have been criticized in their ability to distinguish high involvement (i.e., intensive but healthy use) from problematic or disordered involvement in online activities [80,81]. For this reason, we also retained another scale which includes fewer items promoting over-pathologisation of social network use, namely the Social Media Disorder Scale (SMDS) [82].

The assessment of binge-watching of TV-series has received growing attention to date [83], as this behaviour has become a "new norm" in terms of TV-series consumption. The only available tool to assess binge-watching that combines robust psychometric investigation and extensive cross-cultural validation is the Binge-Watching Engagement and Symptoms Questionnaire (BWESQ) [84], which has already been validated in nine different languages [85].

Cyberchondria, conceptualized as a trans-diagnostic digital compulsive syndrome [6], has received much interest recently in the COVID-19 context [86,87]. Although several scales have been developed to measure cyberchondria, we retained here the Cyberchondria Severity Scale (CSS-33) [88] which has been suggested as the most established and consensual scale [89].

5. Potential impacts of different forms of PUI on health-related outcomes and quality of life (including cost and burden)

Whereas many studies have shown that various forms of PUI are linked to a multitude of negative health, psychological and social outcomes related to study or work, family, social life and intrapersonal functioning [274], currently no data are available that have assessed the

global burden of PUI in general or for specific internet-use disorders. However, multiple studies have related PUI to detrimental sequelae covering physical and mental health conditions and poor quality of life. In a recent systematic review and meta-analysis on problematic gaming behaviours and health-related outcomes (33 effect sizes in total), robust associations with mental concerns including depression (Pearson's $r = 0.26$), anxiety disorders ($r = 0.28$), obsessive-compulsive disorder ($r = 0.40$), and somatization ($r = 0.40$) were observed [90]. In addition, the systematic review found ADHD, psychoticism, poor life-skills, low school well-being, low self-esteem and higher impulsivity to be related to problematic gaming. Moreover, multiple social health-related factors such as problems in familial relationships and social integration in school or greater levels of loneliness were observed [90]. A separate meta-analysis suggested that PUI also significantly associated with eating disorder general psychopathology ($r = 0.22$) [91], while physical health outcomes included, among others, somatization, decreased levels of physical activity, cardiovascular stress reactions, hand and wrist pain, and sleep problems.

The odds ratio for sleep problems occurring alongside PUI was increased to 2.2 in a systematic review and meta-analysis of 23 studies [92]. In a recent study of undergraduate medical students, PUI was associated specifically with reduced sleep quality and increased resting heart rate [93]. PUI is also associated with a range of mental and physical disorders and increased suicidality [94,95]. In a review on excessive smartphone use in adolescents and young adults, 84 studies supported medical problems including reduced physical fitness, unhealthy eating habits, pain and migraines [96]. Besides mental and physical disorders, general quality of life can also be reduced in association with PUI. In a large Spanish sample of adolescents, health-related quality of life was associated with PUI and was significantly reduced in all dimensions in those with severe PUI [97].

When interpreting the current evidence, it needs to be borne in mind that most findings are based on cross-sectional data. This is of special importance in the case of mental disorders that can be seen as risk factors as well as outcomes of PUI. Therefore, causal relationships cannot be inferred. Moreover, many of the findings are based on samples of adolescents and young adults, and older adults are underrepresented. Interpretation of findings is further restricted due to different definitions of PUI, a wide range of different assessment tools, lack of clinical interview data and other methodological weaknesses such as convenience sampling [47]. A general evaluation of burden related to PUI should additionally cover estimations of loss of productivity due to PUI. Although some data exist [98], this area of research remains in its infancy. Altogether, there is a need for a framework for estimating the burden of PUI that includes more sound assessment and longitudinal approaches to understanding PUI and its correlates dynamically.

6. The role of intrapersonal (genetics, personality), social and environmental factors in the aetiology of PUI

6.1. Gene-environment interactions and personality in PUI

Genetic factors contribute to PUI, with studies investigating heritability, prevalence in first-degree relatives of affected individuals and candidate genes [1,99–101]. At the candidate gene level, several genes were reported to associate with PUI, particularly those related to dopaminergic, serotonergic and nicotinic systems, functioning of neurotrophic factors, and stress responsivity [99].

In two studies, links between PUI and the serotonergic and dopaminergic systems were reported, with some conflicting results [102,103]. Nevertheless, the studies demonstrated the importance of environmental and psychiatric factors (e.g., anxiety, depression) [102,103]. Interestingly, the catechol-*O*-methyltransferase (COMT) gene, coding for a dopamine-metabolising enzyme, was associated with altered cognitive performance in individuals with PUI [12]; however, this finding needs to be replicated. Similarly, the monoamine oxidase A (MAOA) gene, coding for a serotonin-metabolising enzyme, was associated with hostility and depression in individuals with IGD [104]. The neuropeptide oxytocin receptor (OXTR) has been recently suggested to influence Instagram social behaviour, linking genetic and environmental factors (e.g., parental relationships) [105]. This suggests that gene-by-environment interactions are important, as previously found for addictive behaviours [106]. Nevertheless, no genome-wide association study (GWAS) of PUI has been conducted to date, in order to overcome the issues of small studies that need replication.

In order to better understand environmental factors related to PUI, epigenomics and transcriptomics including small RNAs could prove useful. According to our current literature search, only one report on the dopamine transporter gene SLC6A3/DAT1 has tested the interaction between PUI, impulsivity, quality of attachment and DAT1 methylation levels [107]. While some positive findings were reported, this study needs replication given the small sample size. At the transcriptomic level, four publications exist. The oldest study reported that expression of the D5 dopamine receptor in peripheral blood lymphocytes of problematic (offline) videogaming was downregulated compared to control subjects [108]. In another study of IGD, expression of the conserved transcription response to adversity (CTRA) genes was assessed in peripheral blood samples [109]. The CTRA expression profiles were related to the positive and negative gaming experience scale. In a small male IGD case-control study, the N-Methyl-D-aspartate (NMDA) receptor subunit GluN3A was downregulated in peripheral blood lymphocytes [110], which should be replicated in a larger cohort. Lastly, expression of microRNAs (miRNAs) that regulate post-transcriptional processes was studied in a IGD case-control study; three miRNAs (hsa-miR-200c-3p, hsa-miR-26b-5p, hsa-miR-652-3p) were identified as being downregulated in the IGD group [111]. Particularly promising was the finding that individuals with all three miRNA alterations presented a higher risk of IGD with an odds ratio of 22 (95% CI 2.29-211.11). This finding may be further refined (e.g., by combining mRNA, miRNA and epigenomics) to identify those at elevated risk, in order to develop earlier preventative measures.

Since our original manifesto, multiple publications have emerged describing personality features associated with PUI [1]. Here we consider some examples, emphasizing the complexity of this topic. Significant sex/gender effects ($N = 776$), in which males exhibited more online gaming, sexual, and gambling behaviours, have been reported [112]. In this study, narcissism was indirectly correlated with higher social media use, 'Machiavellianism' was related to increased online gaming, sexual, and gambling behaviours and sadism was correlated with online sexual behaviours [112]. In a study of PUI in adolescents ($N = 998$), after controlling for demographic variables, two of the 'Big Five' personality factors [113], agreeableness and conscientiousness, were found to be negatively associated with PUI [114]. In contrast, extraversion, neuroticism, and openness to experience were correlated positively with PUI. A separate study ($N = 265$) related low conscientiousness and depression with PUI [115], suggesting that personality features like conscientiousness may be protective and neuroticism a vulnerability factor. On the other hand, avoidance expectancies have been reported to mediate the relationship between maladaptive personality traits and symptoms of IGD [116]. The results related symptoms of PUI to negative affectivity, detachment, and game-related positive and avoidant expectancies. Therefore, they suggest that maladaptive personality tendencies combined with gaming-related positive expectancies and avoidant expectancies are important factors in the development of PUI. In another study of 1300 students, shyness, self-inconsistency, and PUI were related [117], with shyness being negatively associated with self-regulation and self-inconsistency. In a separate study, an indirect relationship between parental rejection (early emotional deficits) and IGD was reported [118]. These two studies suggest a role for strengthening self-esteem as a potential treatment of PUI.

Impulsivity, which has been linked to PUI, is highly heritable and

genetic factors have been linked to impulsivity and substance use [119,120]. Additionally, polygenic risk scores (PRSs) for neuroticism, generalized anxiety, ADHD, schizophrenia and cognitive ability have been associated with internalizing psychopathology in young children [121], and these may be useful for predicting psychopathology in children. Recently, the heritability of neuroticism was found to increase when socioeconomic status and education were taken into account [122], which may also be relevant for PUI. In 4729 unrelated children [123], the PRSs for agreeableness and neuroticism were related to problem-gambling-severity index scores. The extent to which such findings may relate to PUI warrants additional investigation.

In summary, the data support the involvement of genetic and environmental factors in the aetiology of PUI. However, research is at an early stage. GWASs, PRSs, transcriptomics and epigenomics in deeply phenotyped samples hold potential for better understanding PUI.

6.2. Social factors and PUI

In an increasingly digitalized society, social media applications provide unprecedented opportunities to reach or be reached by anybody, anywhere and at any time. Of the multitude of web-based platforms that may lead to PUI, they most directly involve the interplay of a variety of social factors, including socialization, entertainment, support and other types of human interactions.

The impact of social media in relation to PUI has gained increased attention, especially in the context of developmental trajectories from childhood to adulthood. The association between social media use and psychiatric disorders since the very early stages of life has been explored together with the contribution of environmental factors, such as families and schools. For instance, the parent-child relationship, both in terms of quality and quantity, has been related to childhood internalizing and externalizing problems before the age of five years, and correlated with greater screen time exposure in children [124]. Moreover, sharing the media contents of one's children on social media – known as "*sharenting*" – could influence the achievement of individual developmental stages, such as the construction of a personal identity, possibly leading to later frustration and family conflict [125].

Regarding school context, academic satisfaction has been negatively correlated with problematic social media use, while perceived pressure was positively associated [126]. Thus, the need to involve caregivers in more targeted preventative strategies, that include investigating behaviours linked to social media of the entire family, has been suggested [124,125]. The motives, courses, and outcomes associated with greater disclosure on online social platforms in families, seen as the first impactful social group in a person's life, remain under-investigated. More data are needed to comprehend emerging behaviours linked to technological interference due to internet-based applications and social media, such as *phubbing* (the act of snubbing someone who is talking in favour of using the smartphone), *vaguebooking* (posting on social media contents that are intentionally vague but highly personal and emotional), or *nomophobia* (fear of being cut off from mobile phone connectivity) [124,127,128].

The "culture of belonging" to a certain community, "of being seen and acknowledged" online by others, via for instance the number of likes, followers or views, is another key component in understanding the social factors behind problematic social media use [129,130]. Social media sites involve, on the one hand, shortened distances between people, eroding geographical boundaries; on the other, perceived needs to belong to communities may exacerbate pressures of feeling accepted and fears of inadequacy within certain individuals. A "perfect body" is often considered in society as a synonym of personal success and importance. A virtual environment, in which millions of individuals may serve as potential comparisons, may induce considerable perceived social stress, changing people's appreciation of themselves and others [282].

Vulnerable individuals, such as young people undergoing developmental challenges, may react particularly badly to social comparisons strongly tied to social desirability and physical appearances [131,132]. Moreover, the meaning and values of normal behaviours like physical exercise, eating, or taking selfies have been transformed to serve the role of boosting appearance [133], converging in the construction of a virtual self-presentation, where feedback from peer users further exacerbates psychological mechanisms related to social comparisons and anxiety related to appearance and body image [134], thereby worsening quality of life.

Alarming consequences are not only related to problematic social media use, but also to the behavioral and affective responses deriving from prolonged exposure to content presenting "filtered" or "fake" realities, with the risk of excessively objectifying the human body [130,132,134]. Social media trends related to body size and physical appearance, like "thinspiration", "bonespiration", and "fitspiration", may trigger a set of unwanted psychological and behavioral responses to compensate for feelings of inadequacy, body dissatisfaction, or non-belonging among the most vulnerable.

The increased use of social media by many during the COVID-19 pandemic may further exacerbate associated risks, notwithstanding their potential utility in supporting social connectedness and disseminating information about the outbreak globally [17,129]. Thus, the pandemic has constituted a unique opportunity to analyse social behaviours, including with respect to social media. Perceived reliance on social platforms may unveil or enhance dysfunctional mechanisms, especially ones correlated to body image and social acceptance, like appearance anxiety, excessive exercise, eating habits, and usage of supplements to improve either physical activity or body shape [130,135]. Concurrently, mechanisms related to social comparison may lead to repeated checking on others' contents, especially those recognized as most leading and inspiring, investing longer time on active social media activities, like posting, commenting, and sharing content, and passive ones like scrolling and browsing profiles.

Future investigations may consider investigating trends emerging from social platforms to explain underlying social motivations cross-culturally. In this regard, collaboration with social media "influencers" could help researchers keep pace with internet progress which often represents a struggle, especially for implementation in clinical work. Arguably, an even greater challenge for practitioners in mental health will be – and partially already is – to understand potential consequences of prolonged social isolation and to address, with the support of evidence from scientific research, potentially new dysfunctional social media habits.

7. The importance of PUI in the regulation of privacy and brain-machine interaction

In the so-called data economy [136], the above-described social factors may also affect socio-legal relationships (and data-processing ones in particular) involving relevant privacy issues. Personal data are often treated as commodities [137], although in Europe they represent personhood fundamental rights and, as such, cannot be monetised or downgraded [138]. User profiling is an activity based on revenue models that exploit individuals' personal data and monitored preferences gathered during interactive experiences (e.g., browsing the web, using an app, etc.), allowing service providers to promote personalised products, applications, and services to consumers. A causal link with PUI may reside precisely in transnational technology corporations' economic interests in keeping individuals in online interactive loops: the more individuals stay online, the more data they may generate to refine profiling analyses [139]. In turn, these analyses nourish an economic mechanism based on advertising, which requires a constant update of individuals' preferences and behavioral predictions [140]. This mechanism essentially explains the technology corporations' interest in exploiting the so-called "dark patterns" [141] and neuromarketing techniques [142–145] into the design of their services, applications,

platforms and interfaces [146–148].

Arguably, attention-focused designs intend to generate, or possibly exploit, potentially addictive features (e.g., those connected to scrolling, likes, and content-sharing) [149,150] and conditioned responses (e.g. vibrations or red icons for notifications) [143,151–154] that may induce individuals to continue using services. Recent scandals, such as that involving Cambridge Analytica [155,156], have shown that predictive algorithms may be used beyond marketing for manipulating choices, opinions, and behaviours [157,158]. Despite the coming into force of the European General Data Protection Regulation (GDPR) in 2018 [159],[1] a lack of regulation on PUI matters and gaps and gray areas in current privacy rules may permit transnational technology corporations to use potentially invasive technologies to influence certain behaviours (such as expressing political opinions, yielding data, or purchasing products) in individuals without their awareness [160–163].

Increased usage of digital technologies may render economies, societies and individuals dependent with the risk of 'compelling' them to accept contracts and privacy terms [164,165,139,166–168]. Various mechanisms, including random rewarding [163,169,170], fear of missing out (FOMO) [171], the "privacy paradox" [172,173], or the need to access essential goods provided in a multi-monopolistic market [139], may promote acceptance of "take it or leave" conditions through 'all-in' consent [174–177]. Such phenomena may be particularly important considering that the possibility of current technologies evolving into a whole Internet of Things (IoT) intelligent environment (the so-called Internet of Everything [IoE]) [178]. Such changes may not be a standalone technological development. For example, the combined effects of the robotic revolution, together with Augmented and Virtual Reality,[2] Brain-Machine Interactions[3] and Speech Interfaces[4] that may accompany IoT/IoE changes, warrant consideration.

For example, neuromodulation is a technique that may be used to treat mental and neurological disorders such as depression, Parkinson's disease and PUI (see section 8). Neuromodulation provides electrical or magnetic stimuli to specific brain regions and modifies neuronal excitability and thus potentially feelings and behaviours [182–185]. This technology is moving into the commercial market, with wearable brain-stimulation devices for non-medical purposes, such as relaxation, fitness, mood or physical strength enhancement, meditation, and concentration [186–192]. These devices may be considered as an upcoming part of the IoE in a fully connected environment designed to allow platforms and apps to interact with them, allowing two-way personal (brain)-data gathering and analysis [193,194]. Such devices may not only influence an individual's brain activity, but also trace its dynamic processes and related brain data [195].

Here, an important consideration is the possibility of devices actively influencing emotions, feelings, and physiological activities. From a legal perspective, these features form the basis for decision-making and represent elements for knowing and influencing emotions during random human activities. This potentially gives service providers new powers to modify individuals' behaviours, feelings, and perceptions. This development may impact free will and connected legal principles that govern social relationships (e.g., contracts, privacy, elections). In the wake of Brain-Machine Interaction technologies, brain-computer interfaces represent a form of human enhancement involving direct communication and interaction between the brain and computers [196–200], and may allow remote kinetic commands (e.g., robotic prosthetics, brain games, and mind-controlled drones) [201–207] and even smart drugs supply [208,209].

Due to their direct interaction with the brain/mind, brain-computer interfaces and wearable brain-stimulation devices may have the potential to trigger addictive behaviours by both stimulating the brain and influencing decision-making process directly. Such capabilities suggest the importance of ethical and legal considerations concerning mind/brain integrity as a main principle within the fundamental human rights spectrum.[5]

PUI and Data Protection regulation may be connected by broader socio-legal needs to protect individuals and ensure that autonomy of free will and connected liberties are respected. There is a need for regulations to consider these matters. Thus, there is a need to simulate interdisciplinary discussions among the different (scientific and humanistic) communities regarding PUI and socio-legal considerations relating to Brain-Machine Interactions in order to take action to regulate them appropriately.

Indeed, studies on the mechanisms of PUI development may be seen to promote related business practices with negative consequences. Therefore, an important question that may be raised concerns the way in which future research may or should prevent the findings from being applied to commercial markets that might promote PUI. This kind of question actually implies different levels of potential legal solutions. First of all, research results can and should remain freely available and usable because this is the precise purpose of the scientific research and progress. Research centres and universities may want to define via contract their relationships with private funders concerning the commercial exploitation of their results and their limits according to ethical or scientific criteria. However, this remains a partial solution that, furthermore, is tied to the actual negotiating power that the parties can manage.

More impactful solutions may come from updating the regulation of Internet providers. An example is the EU regulatory proposal currently in discussion to govern the activities of online intermediates (the so-called Digital Service Act [DSA]). The legislative text prohibits interfaces to exploit dark patterns practices aimed at misleading people. Precisely, the DSA aims to ban providers of intermediary online services from adopting, deceiving or nudging techniques toward recipients of their services, and, therefore, from using dark patterns to distort or impair the autonomous decision-making process of individuals. This is only a first step toward regulating these phenomena, but nevertheless, such a solution does not adequately deal with the potential harmful effects concerning addiction and PUI.

8. Effective and emerging interventions for PUI that can be delivered at scale

Research investigating interventions for PUI remains at an early stage, but is steadily developing, particularly in Europe and East Asia. The main treatment modalities comprise various forms of psychological therapy and to a lesser extent pharmacotherapy. There is currently insufficient evidence to determine which of these modalities shows greater efficacy, or whether combined approaches confer any added benefit. Moreover, most interventional research has focused on therapeutic interventions for established disorders, particularly in the fields of internet related gambling and gaming, and there has been very little research into preventative strategies. Thus, while a recent study demonstrated that manualized cognitive behavioral therapy–based interventions may produce a reduction in PUI symptom-severity among 'at risk' children and young people, a reduction in the incidence of new cases has yet to be demonstrated [275].

Recent studies have used network analysis that conceptualizes PUI as a network of interacting symptoms to identify core symptoms (i.e., symptoms that are highly connected to other symptoms, which may

[1] Considered worldwide as the highest standard of protection for data subjects.

[2] I.e. what has been recently called "metaverse" [179].

[3] Meaning the set of BCI, DBS and WBSD technologies.

[4] A.k.a. smart speakers, conversational user interfaces, virtual assistants or agents, and digital butlers or secretaries [180,181].

[5] Article 3 of the Charter of Fundamental Human Rights of the European Union [210].

differ by age or developmental stages, such as secrecy of internet use, empty life, less sleep, failure to stop, feeling depressed), with theoretical implications for preventative interventions. Specifically, it is hypothesized that providing adolescents and their caregivers with psychoeducation on the roles of these symptoms to facilitate nonconflictual conversations, may potentially prevent the development and/or maintenance of PUI in vulnerable adolescents and promote more healthy internet use [279,280].

While there is no fully agreed-upon first-line psychotherapy for all forms of PUI, the evidence base has been growing [211–213]. Examining only therapies based on randomized clinical trials, the literature suggests that some form of cognitive behavioral therapy (CBT) may be the most effective but definitive statements as to its benefits await more testing owing to methodological shortcomings in the design and implementation of the existing studies, including (but not limited to) small study samples, lack of appropriate control conditions, inconsistent diagnostic definitions and symptom severity measurement and limited information on treatment adherence [15,16,214–216].

CBT for PUI, which generally has focused on cognitive restructuring and promotion of alternate healthy behaviours [215], has shown benefit for both adolescents and adults, has been successfully used in either an individual or a group format, and has been delivered either in person or via the internet [15,217,218]. In the case of adolescents with PUI, family therapy and school-based group CBT have also shown benefit [219–221], and some regions are trialling therapies in 'digital detox' nature retreat settings [222]. Methodological innovations may provide more insight in what usage patterns and content use of e-health CBT programs are related to improvement in PUI symptoms [223]. For example, future studies should clarify if effects can only be achieved with abstinence [273]. Emerging research suggests that web-based delivery methods e.g., via mobile applications and virtual reality interventions, if shown to be efficacious in randomized controlled trials, have the potential to offer particular advantages for delivering such interventions at scale, such as improved accessibility, efficiency of time management, equitability of access, anonymity and large participant numbers across geographic boundaries (see section 9). Digital therapies may also represent an attractive and low-threshold option for those with low levels of motivation [274].

In relation to pharmacological treatments, studies have largely examined the treatment of PUI, IGD, and internet-based gambling disorder, using agents such as antidepressants and stimulants. Current research suggests a potential therapeutic effect of escitalopram [224], bupropion [225–229], methylphenidate [230], and atomoxetine [231] for PUI. However, many studies are limited by small sample sizes, rarefied samples (unlikely to reflect a disorder at large), lack of control groups, and inconsistent measurements of and definitions for PUI. Moreover, most pharmacological treatment trials have involved samples with common comorbidities and used current treatments for the relevant comorbid disorders. Therefore, the literature cannot at this stage determine evidence-based pharmacological treatments for PUI per se [277], though it may provide scope for determining potentially efficacious treatments for cases of PUI occurring with different comorbidities.

Another emerging form of potential treatment for PUI involves non-invasive neurostimulation, using techniques such as transcranial magnetic stimulation [276] and transcranial direct current stimulation (tDCS). These techniques are thought to mediate their effect in PUI via stimulation of cortical brain cells and modification of their related functions [232,233], thereby increasing cognitive control and better regulation of craving and emotions [234–238]. Of the available techniques, tDCS is relatively safe, simple, and inexpensive to administer and can be provided remotely; thus, it may be particularly suited for delivery to large populations. However, while preliminary data showed that tDCS improved gaming-disorder symptoms and neuroimaging profiles [234], in general, more clinical trials are needed to investigate the efficacy of different forms of non-invasive neurostimulation in reducing PUI severity.

In summary, although the limited available treatment evidence includes some promising findings, particularly in relation to short-term effects of CBT, there is a need for more higher-quality research, including large, pre-registered, randomized clinical trials, to develop best practice guidelines and determine cost-effective options in PUI treatment.

9. Biomarkers of PUI, including potential digital markers, for early detection and intervention

Biomarkers occupy an intermediate position between underlying aetiology and the ultimate manifestation of a disorder [239] (or set of disorders), and so may be useful to better understand biological and other processes that account for variation in vulnerability or chronicity [240]. In the context of mental disorders, biomarkers can be pragmatically defined as intermediate markers of brain function grounded in the neurosciences. While the natural history of PUI is yet relatively unknown, identifying reliable biomarkers of PUI may be very important, if the disorder is shown to necessitate early clinical intervention with substantial impact on clinical outcomes, while supporting the biological validity of the PUI construct as a whole. This is because it may be possible to screen for and detect these markers and use them in combination with other known risk factors to detect 'at risk' individuals, prior to the onset of overt symptoms.

It should be noted that even for relatively well-studied mental disorders, such as OCD, it has proven difficult to identify valid biomarkers, with most evidence being in support of particular objective neurocognitive tasks [241]. For PUI, which is not well defined or arguably not well differentiated from other mental disorders, even detected candidate biomarkers may not relate to PUI per se, but to other concomitant disorders. However, this is the case for many psychiatric disorders for which comorbidity is frequent.

Putative biomarkers of PUI may reside in the brain on a cognitive level, and/or in brain structure or function. Some studies have hypothesized that a reduction in executive functioning and inhibitory control due to an increased activity of the mesocorticolimbic system may contribute first to engagement in online behaviours and, ultimately, to the persistence of PUI. More specifically, cognitive control failures in IGD have been linked, in a small study, to imbalanced interactions within central executive, salience and default mode networks [35]. A meta-analysis involving 2922 participants across 40 case-controlled studies comparing cognition in people with PUI (broadly defined) with that of healthy controls showed that PUI was associated with significant impairment in inhibitory control (Stroop task Hedge's $g = 0.53$; stop-signal task $g = 0.42$; go/no-go task $g = 0.5$), decision-making ($g = 0.49$) and working memory ($g = 0.40$). Age, gender, geographical area of reporting or the type of predominant online behaviour did not significantly moderate the observed relationships [13]. Those cognitive characteristics align with the Interaction of Person-Affect-Cognition-Execution (I-PACE) model [14] with respect to proposed difficulties in decision-making and inhibitory control. Thus, based on grouped data, poor inhibitory control and executive dysfunction act as a cognitive marker of PUI. However, as the studies were largely cross-sectional in nature, it cannot be determined whether these cognitive features represent a cause or consequence of PUI [288], and longitudinal studies following the progression from vulnerability to full PUI are needed to illuminate this important point. Moreover, as these changes were detected in grouped data, the extent to which they may be used to discriminate an individual at high risk of PUI remains uncertain.

Regarding neuroimaging, an activation likelihood estimation (ALE) meta-analysis focusing on changes in structural brain measures detected in voxel-based morphology (VBM) studies of PUI found that PUI was characterized by significantly reduced gray matter in the anterior cingulate cortex (ACC), dorso-lateral prefrontal cortex (DLPFC) and supplementary motor area (SMA), regions linked to reward processing, habit learning, and top-down inhibitory control [242]. Specifically, the

DLPFC contributes to executive functioning, cognitive control and decision-making under explicit conditions and has previously been hypothesized to be involved in the development and maintenance of internet addiction [243]. Similarly, the ACC receives input from dopaminergic projections and contributes to reward processing, which may relate to craving. The SMA may also be important in action monitoring, important for top-down control. Other meta-analytic data suggest that some forms of PUI (IGD) may be linked to altered functional brain activation in related neural networks as compared to healthy controls [244].Taken together with the neurocognitive results, these imaging findings suggest disruption in brain structure and function related to cortical inhibition of the generation and execution of reward-based responding, both in generic PUI and in specific forms such as IGD [288].

Regarding potential biomarkers discussed above, one critical and common limitation has been the absence of a robust control of confounding variables such as comorbidities (ADHD, OCD, impulse control disorders, gambling disorder, autistic spectrum, and others [13,242,245]), and limited standardization and validation of assessment tools or PUI definitions. Such limitations highlight the strong need for additional rigorous research that carefully disentangles the contribution of comorbidities and other variables that may relate to biological mechanisms of PUI.

Finally, the extensive use of smart technology (smart phones & wearables) and considerable amounts of information they may gather, position remote devices and technologies as candidates for amassing large-scale databases for behavioral, personal and social day–to-day activities. Harnessing smart devices into the clinical field has introduced new, real-time, data sources that hold promise in characterizing clinical functioning, as well as in offering new opportunities for remote interventions on large scales and short timeframes. Employing big data analyses may enable characterization of 'digital phenotypes' underlying one or more disorders and of individuals at elevated risk.

Research into PUI mechanisms is unusual in that the maladaptive behaviour that is directly linked to the disorder mostly occurs within the digital environment and can be captured via digital tools. Thus, digital markers, consisting of digital use patterns or signatures may include maladaptive durations, timings, and types or manners of usage which characterize and differentiate PUI from routine, casual or normative engagement with online environments (e.g., by monitoring online internet usage in comparison with changes in diurnal variation, limited human contact, limited geographical movement, or restricted circles of friends).

Preliminary work using digital technologies is being explored in other areas of psychiatry as well (e.g., in OCD), highlighting the importance of such an approach, which provides scope for the early identification of problematic usage, richness of data to complement the clinical picture and the potential for digital intervention [246]. At the same time, such approaches require cautious ethical and privacy safeguards, including ensuring that informed consent is obtained and that data are collected and used appropriately, both in terms of their original intended use, and their future possible use by organizations or researchers. Like digital markers for PUI, digital markers for treatment success of psychological (online) interventions can be studied using machine learning. Thus, these approaches may identify additional markers, besides biomarkers, that can be related to patterns in development of PUI and its treatment [223,247].

10. Reducing obstacles to timely recognition and interventions

A key obstacle to the timely recognition of PUI is the *ubiquity and general societal endorsement* of internet-related technology and use. The common and widespread use of the internet, its being perceived as a safe tool, the presence of digital natives (i.e., younger people who have been raised in the digital age, in close contact with computers, the internet, gaming consoles, mobile phones, social media, and tablets [251]) who may be unaware of possible risks, and the slow development of possible negative consequences that may hide risky behaviour are all important factors interfering with early detection and intervention.

Difficulties in defining the boundaries of internet behaviours (e.g., distinguishing hazardous use of the internet from PUI) may also hinder early detection. Related obstacles include the lack of reliable thresholds on standardised rating scales, or other biomarkers, that can be readily applied to detect those who are engaging beyond the boundaries of healthy internet use and are thus at increased risk of developing PUI. Another factor may involve the tendency of the individual to *minimize the severity* of the behaviour (e.g., parents of youth with gaming problems often seek treatment for their children). Further, the *presence of comorbidities* of mental disorders, either as a risk factor or as a consequence of PUI, may overshadow PUI, such that by focusing exclusively on the mental disorder, PUI may get overlooked.

Arguably, the widespread use and acceptance of the internet is likely to come at the cost of increased risk of PUI for vulnerable populations. The higher the global prevalence of internet use at work, in social communications and in recreational pursuits, and the more reliant we become on this communication mode, the more important it becomes to ensure the activity can be monitored for adverse consequences. PUI may negatively affect many domains: physical health (e.g., back pain, obesity, eating and sleep disturbances), mental health (e.g., depression, anxiety, substance-use disorders), family interactions and other social relationships and academic performance [248,249]. These health concerns have recently led the European Parliament's Scientific Foresight Unit (STOA) to conduct a study on the harms associated with internet use in the European Union, which has recommended implementation of more active community and clinical interventions to facilitate the early detection of PUI [250]. Improving the early detection of risky online behaviours and of PUI may be important to prevent negative consequences of prolonged PUI behaviours and represents a new policy step.

Early detection may be implemented at three different levels: 1) national, organizational and professional; 2) community; and 3) individual use [248]. Achieving uniformity of screening tools and the independent delivery of these at national levels across the world would be a gold-standard approach as it would ensure the ability to identify geographic areas of significant harm and collaborate on supporting the specific region with public health approaches to reduce prevalence. For example, scientific initiatives could be implemented to disseminate state-of-the-art, relevant research. Webpages could be created, containing high quality scientific resources, contact information for national organizations and experts in the field, and tools for screening (e.g., validated scales to detect PUI), among other approaches. At a more local professional level, promoting knowledge about internet-related problems among health professionals will be an important step to engage people in treatment when concerns are identified [252]. Of note, when screening for PUI, it is important to screen for other psychiatric conditions that may become a focus of intervention (e.g., obsessive-compulsive-spectrum, depressive, anxiety, substance-use and personality disorders) [253].

At a community level, actions to detect and prevent PUI at the earliest possible opportunity should be provided via families, schools, and other communities [254]. PUI should be treated like other well-known concerns, in an evidence-based manner and without geographic or financial barriers to accessing treatment. Those who are close to children and adolescents (e.g., teachers, families, caregivers) should be informed by validated educational programs. For example, some school interventions targeting the identification of risk indicators have been found to be effective [255].

At the individual level, self-screening tools and other test options may be offered using online platforms or apps [1]. Easy-to-understand information about potential risks connected to PUI should also be available for individuals, on trusted web platforms and channels. Information should be provided in different languages. In this regard, social media engagement of public health organizations, or public involvement of social media celebrities (especially popular 'influencers'

and science bloggers) could help in efficient communication of scientific findings and in promotion of the study of PUI [284].

11. Public engagement

The importance of involving members of the public in the design and conduct of health research is internationally established, with evidence that it can improve the quality, relevance and beneficial outcomes of research, while reducing health and social research wastage [256–261]. By 'public' we refer to a wide range of citizens with first-hand experience of the phenomenon under study, including patients, caregivers, service users, (like members of the gaming community or individuals skilled at using social media platforms), and members of organizations that represent service users.

The terms 'patient and public involvement' (PPI) or 'citizen involvement' are commonly used to describe research conducted 'with' or 'by' members of the public, rather than 'to', 'about' or 'for' them [262]. PPI involves citizens in all stages of research, including early during the developmental stages of research, prior to the design stage, and may be especially important for emerging research disciplines (like PUI), when underpinning constructs are not well understood [263]. There are also strong ethical and political arguments supporting PPI in decision-making about research and health care services, as a citizens' right [264,265], to provide a fair opportunity for equal, safe and dignified collaboration, co-production and co-authorship alongside researchers.

Recognizing the potential of PPI for envisioning, identifying, prioritizing and planning future research on PUI, we have engaged with citizens in multiple ways within our EU-PUI COST Action (CA16207). International consultation exercises across six European countries were a starting point, involving diverse groups of citizens, including young people, students, parents, teachers, and health professionals [263]. This consultation aimed at identifying the *present awareness* (knowledge base and knowledge gaps), *ongoing concerns* (attitudes, beliefs, perceived difficulties and specific worries) and *future needs* of citizens regarding PUI. These activities represented a pioneer attempt both in the area of PUI and in the involved countries, witnessing great public interest in PUI but lack of opportunities for participation.

Our next step was to create an opportunity to "raise the public voice" on PUI, in dialogue with health and social care professionals, and other expert scientists. In collaboration with members of the public, including teachers, young people, parents and gamers, and representatives of the Action, we organized the first International Festival of Science and Arts on PUI that was attended by 278 people and involved five round table discussions [266]. This event provided a valuable insight into the experiences, attitudes and concerns of members of the wider public and seldom-heard groups. Discussions revolved around the community aspect of PUI, including the effect of PUI on families and the increasing gap in technical knowledge and understanding among the public, linked to the speed of development of emerging technologies.

As a result of these initiatives, we established and consolidated a collaboration network with citizens and initiated multiple collaborative enterprises. For example, members of the public were involved as co-organizers of the PUI Festival. Additionally, the PUI Companion Book [267] for interest groups and vulnerable populations of citizens was revised by lay members of the public for clarity and content utility. Finally, this paper, which provides an update of our original research manifesto [1], has been revised by two members of the public (T.H. and M.G.), included herewith as co-authors.

Looking ahead, we aim to create an infrastructure for the sustained involvement of citizens in PUI research, and in the development of intervention programs to address PUI. We are creating the first international reference group for PUI including members of the public, prepared and willing to collaborate with research teams. Citizens will be provided with training and support and treated with openness and recognition of the value of their participation and contributions. The training program and the strategy will be co-designed by a team of experts and members of the public. It is anticipated that these groups will serve as advisory bodies on new PUI research studies and initiate user-led research.

As the largest international network of researchers on PUI, we will continue to raise awareness regarding best practices of PPI, including ethical and reporting issues in scientific journals [263]. It is important that health journals provide the opportunity and guidance for PUI researchers to clearly describe how citizens have been involved in the research being reported. There are now some excellent examples of PPI policies and statements in health journals, developed in collaboration with patients and members of the public [268], demonstrating the recognition by journal editors of the value and impact of PPI in research. Some journals (e.g., *Lancet Psychiatry, Comprehensive Psychiatry*) include lay reviewers in the peer-review process. User-friendly PPI reporting checklists, such as the Guidance for Reporting Involvement of Patients and the Public (GRIPP2) [269] are recommended for use by citizen reviewers and researchers alike, to ensure that research publications provide clear and open reporting of PPI, addressing both successes, challenges, and impacts, in order to promote shared learning practices [270].

12. Conclusions

Increased use of digital media, so valuable for communication during times of extreme social distancing, has resulted in increased exposure to risk of PUI among specific vulnerable groups and early evidence that the problem is growing [18]. By the same token, widespread increase in digital competency, necessitated by the COVID-19 pandemic, has meant that accessing digital health resources has become a more familiar activity, offering important new and potentially cost-effective digital opportunities for preventative and therapeutic assessments and interventions delivered at scale.

As with any other serious public health issue, we need first to recognize it. In the first section of this manifesto, we have reviewed the considerable progress made in phenotyping. However, many conceptual gaps still remain, including a full understanding of the impact of factors such as age, gender and co-occurring mental disorders on the expression of PUI, and the related underpinning mechanisms, across the full range of disorders and behaviours.

Once PUI is recognized, a better grasp of the epidemiology, prevalence, spread, risk factors and natural course is important for providing meaningful clinical interventions. In the second section, we draw attention to discrepancies in the existing epidemiological data, much of which was obtained before the pandemic. In particular, there is wide variability in prevalence estimates reported across studies, largely reflecting methodological inconsistencies. Additionally, it remains unclear whether the increased rates of some forms of PUI reported following the onset of the pandemic represent a short lived phenomenon or a sustained problem. This situation suggests the need for largescale multinational longitudinal studies employing reliable measurement instruments in non-convenience samples, to determine the full extent of PUI and the influences of the COVID-19 pandemic. In particular, such work should include putative epidemic-related influencing factors, such as measures of individual COVID-19-related anxiety, vaccine hesitancy and post-pandemic adjustment [281] in longitudinal analyses.

An essential next step therefore is to advance from a descriptive (and somewhat subjective approach) to build quantitative tools which will be able to reliably measure (and report) the severity of the phenomena. In section 3, we review the age- and culture-appropriate assessment instruments that have been developed for screening, diagnosis, and measuring of PUI and its response to treatment. Despite advances, there remains a shortage of consensus-based screening or severity rating scales for many PUI disorders and behaviours. Screening instruments validated against the landmark ICD-11 diagnostic criteria for gaming disorder would represent a major advance. One key knowledge gap, of major

public health relevance in terms of developing early intervention strategies, is to determine reliable thresholds (e.g., standard cut-offs on established rating scales) for determining the boundaries between normal behaviours, 'hazardous' behaviours (i.e., 'at-risk' states), and PUI. Cohort studies that prospectively follow participants over several years to allow for development of disordered behaviours among vulnerable groups would provide a robust method for determining these metrics.

Quite often a disorder impacts not only the patient, but also extended groups including family members and society at large. In section 4, we consider the substantial burden of PUI on the individual, in terms of physical and mental health, the family, and society. Obtaining accurate health economic data on the financial costs of PUI is an important information gap on the road map for treatment development. Difficulties in determining causality are discussed, based on current studies, and highlight the need for future studies to determine the impacts of PUI on children, adolescents and younger and older adults.

The aetiology of PUI is likely to involve complex interactions between genetic and environmental factors. Section 5 describes contemporary knowledge regarding genetic and personality factors in different forms of PUI, while the impact of social factors in the development of PUI is developed in Section 6. PUI is very often linked to social media and interactions between vulnerability and social factors are relevant here. Population-based studies bringing together systematic measurement of genetic, personality and social factors are likely to advance our understanding of how these intrinsic and extrinsic factors interact in disorder development and treatment response.

A major concern related to the digital era involves safeguarding individual privacy and decision-making. The temptation to abuse accumulated data, including preferences, opens the door to potential misuse. This is true for all individuals using the internet, particularly those with PUI. Furthermore, development of brain-machine interactions with the capacity to influence decision-making and thereby individual autonomy and connected liberties raises broad socio-legal safeguarding concerns. The implications for individual human rights are highlighted in section 7, citing the importance of regulation to address these matters. Thus, there is considerable need for interdisciplinary research (scientific and humanistic) to take action to govern developments.

When establishing interventions for PUI, it is important to consider the magnitude of the problem and consequently to harness innovative and ecologically valid strategies. The heart of the problem, the internet, can also be part of the solution, as described in section 8. While CBT focused on cognitive restructuring and promotion of alternate healthy behaviours has shown benefit and may be effectively delivered online, better designed studies to determine effectiveness in the longer-term are needed. In section 9, an update on biomarkers of PUI as a basis for early detection and intervention is provided. A further complementary section (10) considers the new frontiers of passive digital monitoring and "digital fingerprints", providing a road map for future research involving cognitive, behavioral and passive digital assessment to generate a potentially more complete and ecologically valid phenotyping approach.

The 'rule of thumb' that the duration of untreated illness is associated with a less favourable outcome is likely to pertain for a disorder with addiction characteristics like PUI, highlighting the importance of early identification and recognition for paving the way to secondary prevention, as described in section 10. However, to date, preventative strategies remain barely researched or implemented. In this respect, learning lessons from the COVID-19 pandemic, it is important to include the public in efforts; that is, to listen, to educate, to involve, to convince or, in other words, to fully engage them. In section 11, we consider the importance of continuing to involve citizens in PUI research and in the development of intervention programs to address PUI, along with raising awareness regarding best practices of PPI.

The above-mentioned insights and knowledge represent the results of four years of efforts by a network of European and international experts and public stakeholders, working in unison (with the support of EU grant COST initiative entitled: EU-PUI COST Action (CA16207)). The advantage of this effort has been a cross- national coordination that extended beyond the geographical confines of Europe to include global experts from other continents and cultures. Nevertheless, four years represents a relatively short time frame to achieve the ambitious research goals as described in our inaugural Manifesto [1] considering the novelty and underexplored nature of this area of science, and many goals remain only partially accomplished. The authors of this updated manifesto submit, based on their experience, that PUI is growing in proportion, and thus there is a need for early detection and recognition, as a basis for preventative intervention. In this respect, a better understanding of adaptive factors and behaviours that support resilience and healthy internet use are likely to be of particular value. Development of appropriate and innovative treatments (that may include changing lifestyle approaches from maladaptive to adaptive) is warranted as well. Public awareness, targeted identification, secondary prevention, and validated innovative treatments are all needed to combat the under-recognized PUI challenge.

A promising way forward is with a longitudinal study that uncovers the impact of rapidly increasing digitalization on the mental health and wellbeing of vulnerable groups, particularly children and young people. Such studies have been conducted, for example, in South Korea, and these could serve as examples for studies in other jurisdictions [271], albeit with a need to carefully consider use of validated measures. Exploring PUI vulnerability and resilience factors that moderate mental health and wellbeing will be important. The knowledge that is gained from such studies could be applied to devise and test age- and gender-appropriate digital behavioral health interventions, focusing on self-management of ill-health prevention. Such studies may also help build a roadmap for initiating health and social policy and practice change, based on the principles of safeguarding fundamental rights and promoting public health [272]. These efforts will require major investment in high-quality, large-scale global multidisciplinary research, ideally co-designed with public stakeholders, incorporating optimal tools and statistical methodologies.

Declaration of interests and source of funding

This publication 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, http://www.cost.eu).

Natalie Hall, Giovanna Cirnigliaro, Christine Lochner, Joël Billieux, Jesús Castro Calvo, Edna Grünblatt, Susanne Walitza, Ornella Corazza, Lior Carmi, Giovanni Martinotti, Célia M D Sales, Julia Jones, Biljiana Gjoneska, Orsolya Király, Beatrice Benatti, Matteo Vismara, Ilaria Cataldo, Gianluigi M Riva, Maèva Flayelle, Thomas Hall and Morgan Griffiths report no declaration of interests.

Naomi Fineberg reports research grants from UK National Institute for Health Research (NIHR), Orchard OCD, European COST Action, royalties/licenses from Oxford university press, payment or honoraria for lectures/presentations/speakers bureaus/manuscript writing/educational events from Global Mental Health Academy. She also received support for attending meetings and/or travel from British Association for Psychopharmacology, European College for Neuropsychopharmacology (ECNP), Royal College of Psychiatrists, International College for Neuropsychopharmacology, European COST Action, World Psychiatric Association, International Forum for Mood and Anxiety disorders, American College for Neuropsychopharmacology. She is/was also chair in the ECNP Review Board and in the World Psychiatric Association scientific section for OCD and anxiety, she is the secretary of the International College of Obsessive Compulsive Spectrum disorders and board member of the Orchard advancing research in OCD. She leads a national OCD treatment service. She is the editor in chief for Comprehensive Psychiatry journal. She

gives expert advice on psychopharmacology to the UK Medicines and Healthcare products Regulatory Agency (MHRA).

Jose M Menchon has received research or networking funding from the Spanish official research agencies CIBERSAM-ISCIII and AGAUR, has received consultation fees from Janssen, lecture fees from AbBiotics, Exeltis, and research funding from Janssen, AbBiotics, Novartis, and Medtronic in the last 36 months.

Bernardo Dell'Osso has served as consultant/ speaker for Janssen, FB Health, Lundbeck, Angelini, Arcapharma, Livanova, and Neurapharma.

Matthias Brand (to University of Duisburg-Essen), Astrid Müller (to Hannover Medical School) and Hans-Jürgen Rumpf (to University of Lübeck) receive grants from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) in the context of the Research Unit FOR 2974 Affective and cognitive mechanisms of specific Internet-use disorders (project number 411232260).

Marc Potenza has consulted for Opiant Pharmaceuticals, Idorsia Pharmaceuticals, AXA, Game Day Data, and the Addiction Policy Forum; has been involved in a patent application with Yale University and Novartis; has received research support (to Yale) from Mohegan Sun Casino and the National Center for Responsible Gaming; has participated in surveys, mailings or telephone consultations related to drug addiction, impulse-control disorders or other health topics; has consulted for and/or advised gambling and legal entities on issues related to impulse-control/addictive disorders; has provided clinical care in a problem gambling services program; has performed grant reviews for research-funding agencies; has edited journals and journal sections; has given academic lectures in grand rounds, CME events and other clinical or scientific venues; and has generated books or book chapters for publishers of mental health texts.

Sam Chamberlain's research was funded by a Wellcome Trust Clinical Fellowship (110049/Z/15/Z & 110049/Z/15/A). He receives honoraria from Elsevier for editorial work.

Zsolt Demetrovics's contribution was supported by the Hungarian National Research, Development and Innovation Office (KKP126835, K134807). Orsolya Király's contribution 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. ELTE Eötvös Loránd University receives funding from the Szerencsejáték Ltd. to maintain a telephone helpline service for problematic gambling. Zsolt Demetrovics has also been involved in research on responsible gambling funded by Szerencsejáték Ltd. and the Gambling Supervision Board and provided educational materials for the Szerencsejáték Ltd.'s responsible gambling program. The University of Gibraltar receives funding from the Gibraltar Gambling Care Foundation. However, these funding aren't related to this study and the funding institution had no role in the study design or the collection, analysis, and interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Eric Hollander receives Research Grants from Department of Defense, Orphan Products Division of Food and Drug Administration, Roche, GW Pharma. He has consulted from Roche, GW Pharma and he receives editorial fees from Elsevier.

Julius Burkauskas in the past several years has been working as a consultant at Cogstate, Ltd. These did not influence opinion declared in the present study in any way.

Daniel L King has received research funds from the Australian Research Council, Victorian Responsible Gambling Foundation, European Association for the Study of Gambling, National Association for Gambling Studies and the World Health Organisation. He declares no conflicts of interest in relation to this manuscript.

Dan J Stein has received research grants and/or consultancy honoraria from Discovery, Johnson & Johnson, Lundbeck, Sanofi, Servier, Takeda and Vistagen.

Jon E Grant has received research grants from the TLC Foundation for Body-Focused Repetitive Behaviours, and Otsuka, Biohaven, and Avanir Pharmaceuticals. He receives yearly compensation for acting as editor-in-chief of the Journal of Gambling Studies and has received royalties from Oxford University Press, American Psychiatric Publishing, Inc., Norton Press, and McGraw Hill.

Stefano Pallanti has received research grant (GRANT NIH R21 DA042271-01A1 "Modulating Inhibitory Control Networks in Gambling Disorders with Theta-Burst Stimulation").

Henrietta Bowden-Jones is on the WHO advisory expert group on gaming disorders.

Michael Van Ameringen reports being on the Advisory Boards of Allergan, Almatica, Brainsway, Lundbeck, Otsuka, Purdue Pharma (Canada), Tilray and Vistagen; he is on the Speaker's Bureau for Allergan, Lundbeck, Purdue Pharma (Canada), Otsuka, Pfizer and Takeda; he has received research support from Purdue Pharma (Canada), the Canadian Foundation for Innovation and Hamilton Academic Health Sciences Organisation (HAHSO) and honoraria from UpToDate.

Konstantinos Ioannidis is contracted by Cambridgeshire and Peterborough NHS Trust (via a secondment agreement with Southern Health NHS Trust) to write service protocols for a regional Gambling Harms Clinic.

Anna E Goudriaan reports ZonMw grant VIDI scheme #91713354.

Murat Yücel's role on this paper was funded through a National Health and Medical Research Council Fellowship (NHMRC; #APP1117188). Murat Yücel also receives funding from other NHMRC schemes, Monash University, and Australian Government funding bodies such as the Australian Research Council (ARC), Australian Defense Science and Technology (DST), and the Department of Industry, Innovation and Science (DIIS). He has also received philanthropic donations from the David Winston Turner Endowment Fund, Wilson Foundation, as well as payments in relation to court-, expert witness-, and/or expert review-reports. Finally, he has received funding to conduct sponsored Investigator-Initiated trials (including Incannex Healthcare Ltd). These funding sources had no role in the design, management, data analysis, presentation, or interpretation and write-up of the data.

Joseph Zohar has received grants or research supports from Lundbeck, Servier, Brainsway & Pfizer, NIH, DoD. He has received honoraria or consultation fees from Servier, Pfizer, Abbott, Lilly, Actelion, AstraZeneca, SunPharma, Roche and Brainsway. He participates in company sponsored: Lundbeck, Roche, Lilly, Servier, Pfizer. He is in the speaker's bureau for Abbott, SunPharma and Brainsway.

Acknowledgements

The authors wish to acknowledge the members of the International College of Obsessive-Compulsive Disorders (http://www.ICOCS.org) who have contributed to the development of this manuscript. We are grateful to members of the European College of Neuropsychopharmacology (ECNP) Obsessive Compulsive and Related Disorders Research Network (OCRN) whose comments have shaped this manuscript in its development. The ECNP OCRN is component of the ECNP-Network Initiative (ECNP-NI) and receives financial support from the ECNP, to support its academic activities. We thank the members of the public, young people and parents/carers who have collaborated with this COST ACTION, including the PUI Festival and the PUI Companion Book, with particular thanks to Thomas Hall and Morgan Griffiths for their valued support and contribution to our work. We also would like to thank the early career network on PUI which now counts over 60 early career scholars, and it is one of the legacies of our COST ACTION.

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