



Problematic usage of the internet and cognition

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In this current opinions article we synthesize recent evidence exploring neurocognitive deficits in problematic usage of the internet, which support the notion that inhibitory control and decision making deficits occur in problematic usage versus controls, strengthening its theoretical conceptualization. Potential confounders, notably IQ and the presence of comorbidities from the impulsive/compulsive spectrum may account for some of these identified deficits. Most studies focused on gaming, whereas other facets remain relatively understudied. The literature has high levels of methodological issues, such as using non-validated thresholds/instruments, examining only a narrow range of cognitive domains, and overlooking potentially confounding comorbid disorders. Longitudinal studies with rigorous methodologies are needed to address whether cognitive problems associated with problematic internet use play a role in vulnerability, chronicity, or both.

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Current Opinion in Behavioral Sciences 2022, 44:101104

This review comes from a themed issue on **Internet addiction**

Edited by **Naomi Fineberg** and **Marc Potenza**

For complete overview of the section, please refer to the article collection, "**Internet Addiction**"

Available online 12th February 2022

<https://doi.org/10.1016/j.cobeha.2022.101104>

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Introduction

In recent years, there has been significant progress in acknowledging the addictive potential and the harmful effects of human engagement with the online environment [1]. Potential harms exist on many levels of analysis: physical health, mental health, socio-economic parameters [2–5]. Psychiatric classification systems are moving towards incorporating internet gaming disorder as

a separate disorder (International Classification of Diseases 11, ICD-11) or as putative condition in need of further study (Diagnostic and Statistical Manual of Mental Disorders Version 5, DSM-5) [6,7]. The field also steps forward to consider other facets of online engagement [3,8] (e.g. overuse of online pornography, online buying or social media) for inclusion as formal conditions [5–7]. Parallel to that process, the term Problematic usage of the internet (PUI) was coined to describe dysfunctional engagement with multiple facets of internet based activities [3] and PUI is now linked with adverse sequelae in life, including, but not exhaustively poorer health, worse social, vocational or academic outcomes or lower quality of life [2–4]. When PUI is considered categorically, using case-control cross sectional comparisons, it has been associated with structural (reduced gray matter of the supplementary motor area (SMA), left anterior cingulate cortex (ACC), and left dorsolateral prefrontal cortex (DLPFC) [9]), and functional (imbalances involving the fronto-striatal circuits in various facets of PUI [10–12,13**]) neurobiological abnormalities supporting its validity as a construct worth considering in its own right [9,13**,14**]. Most importantly, and for the specific context of this review, it has been suggested that cognitive processes and cognitive responses to specific stimuli form part of the core predisposing parameters influencing the development and establishment of repetitive maladaptive online behaviors [13**]. Executive functions involving the fronto-striatal circuits, including inhibitory control and decision making, have been identified as deficient in group comparisons of PUI versus healthy controls [13**,14**], providing further support for the involvement of fronto-striatal circuits in its pathophysiology. The current review will focus on the newest findings, including trends and developments in PUI and its various facets, and discuss ongoing open debates in the field.

New and interesting findings

A recent meta-analysis capturing all available evidence up to 2017, demonstrated that in case-control comparisons, PUI individuals presented with deficiencies in working memory, motor inhibitory control (Go/NoGo or GNG, and Stop-Signal Task or SST), decision making and Stroop attentional inhibition [14**]. Those results were not moderated by the report of comorbidities, however, the meta-analysis identified a number of weaknesses in how comorbidities were assessed in the included studies. The meta-analysis also identified a large effect for delay discounting deficits in PUI, albeit coupled with critical methodological limitations that disallowed robust

conclusions to be drawn. A more recent meta-analysis up to 2020 focusing on delay discounting only, replicated the large effects in favor of deficits in delay discounting in including internet gaming disorder (IGD) and PUI, versus controls, and also identified challenging methodological issues around the approaches used to capture those differences [15]. An overview of most recent cognitive findings in PUI and IGD are presented in [Table 1](#).

The role of comorbidity in the interpretation of cognitive findings

Considering the highly likely role of comorbidity in influencing observed deficits in cognition in PUI versus HCs, a recent study examined cognitive performance in three separate groups of young adults: HC, PUI without comorbidities and PUI with impulsive/compulsive comorbidities (PUI+). Interestingly, when performance in response inhibition (Stop-Signal Task, SST) and decision making (Cambridge Gambling Task, CGT) was examined, statistically significant differences in performance were identified in PUI+ versus HC but not in PUI versus controls [16]. Those results support the idea that some differences in cognitive performance in PUI versus HC identified in previous studies may be attributed to the underidentification of impulsive/compulsive comorbidities, further highlighting the importance of screening for those disorders in future studies of cognition in PUI. Worryingly, almost none of the literature on PUI in general, or gaming disorder in particular, has appropriately screened for the most common impulsive and compulsive comorbidities (e.g. ADHD, impulse control disorders, gambling disorder, obsessive-compulsive disorder).

Understanding cognitive associations via cross-sectional and longitudinal research

Cross-sectional research provides useful insights on the associations between relevant important parameters of cognition and PUI. For example, considering the decision making domain, a recent investigation using group comparisons between IGD and HCs, the IGD group presented with deficits in quality of decision making (CGT), in line with previous research [17]. Decision making impairments have been a largely replicable result in IGD versus HC comparisons, although results are not always consistent across all paradigms and measures of decision making [18]. A recent study suggesting that IGD participants demonstrate decision deficits with high risky preferences driven by intuition rather than deliberation (based on the inventory for assessing affect-based and cognition-based decision-making), which might be relevant when therapeutic interventions for IGD are considered [19]. However, studies with cross-sectional design disallow a meaningful exploration of the direction of causality or prediction capacity of parameters under study.

Exploring longitudinal associations is crucial in deepening our understanding of mechanisms linking cognitive deficits and PUI presentations. In a recent study with a quasi-longitudinal design, a cohort of young males was followed up for two years (T1 baseline, then annually T2 and T3), for their IGD symptoms and gaming severity. Cognitive performance, including inhibitory control and decision making was assessed at T2 only. Impulsive decision making (inter-temporal choice task at T2) was associated with higher severity of IGD (at T1). On the other hand, lower inhibitory control (Go/NoGo task at T2) was associated with more time spent gaming in the future (at T3) [20]. Taken together, those results highlight the complex and possibly bidirectional nature of causal links between IGD (or PUI) and cognitive deficits and highlight the relevance of timing of testing (i.e. taking into account the natural history and stage of progression of IGD or PUI); however, limitation of the quasi-longitudinal design here is that the lack of baseline scores of cognitive performance disallows the drawing of any causal links. Interestingly, clinical ‘caseness’ of IGD in this cohort dropped from 22% (T1) to 0% (T3), suggesting a natural improvement of IGD over time. The results, however, somewhat align with theoretical conceptualizations of PUI and addictive behaviors in general, in which the earlier versus later stages of the disorders are differentially influenced by various degrees of top-down inhibitory control deficits (predisposing the early stages of behavioral addictions), and altered cue reactivity (perpetuating and enhancing problem behavior). On the other hand, some cognitive domains are likely to be relevant both in terms of vulnerability and chronicity, based on an initial Delphi expert consensus conducted across the wider addiction field [21]. Dysfunction within the inhibitory control network has also been demonstrated in a different study using a slightly different task procedure, that of an emotional GNG task under low and high memory load. That study highlighted the relationship between abnormal emotional influences on response inhibition in patients with IGD, while focusing on the important role of the dorsomedial PFC in that process [22]. Most importantly, what seems to differentiate IGD from recreational gamers, is that the latter group is capable of exerting additional cognitive endeavor to prevent a drop in performance in decision making and impulse control [23].

The role of age, IQ as moderators of cognitive findings

While the preceding studies have examined adult groups, another study examining GNG and decision making in adolescents with clinical diagnosis of IGD versus HCs found that IGD had lower accuracy in NoGo trials (lower motor inhibition) and higher proneness for risky decisions [24]; both results in line with previous research [14], suggesting similarities of cognitive findings across age groups. The accompanying EEG analysis was supporting the theoretical focus on inhibition and reward systems in

Table 1**New selected findings in problematic use of the internet and cognition**

Authors	Journal	Year	Study type	PUI-facet	PUI measure	N	Gender/age	Geographic area	Cognitive domain	Task	Main findings
Problematic usage of the internet (PUI)											
Chamberlain <i>et al.</i>	<i>J Behav Addict</i>	2018	CS-GC	PUI	YDQ	127	Mixed, adults	USA	Inhibitory control Decision making	SST CGT	Statistically significant differences in performance were identified in PUI with comorbidity versus HC but not in PUI without comorbidity versus controls
Vargas <i>et al.</i>	<i>Psych Res</i>	2019	CS-GC	PUI	PIUQ	62	Mixed, adults	USA	Inhibitory control Discounting	GNG Delay discounting	PUI versus non-PUI and HCs found no differences in GNG or delay discounting performance
Ioannidis <i>et al.</i>	<i>CNS Spectr</i>	2020	CS-GC	PUI	YDQ	206	Mixed, adults	USA	Multiple domains	SST, OTS, RVP, CGT, SWM, IED	PUI group was associated with worse performance in RVP, OTS, CGT, SWM
Zhou <i>et al.</i>	<i>Psych Res</i>	2020	L	PUI	CIAS	76	Mixed, adults	China	Executive function Decision making/ discounting	SST, n-back memory, DDT, BART	'Motivational dysfunction' but not 'executive dysfunction' statistically predictive of the later development of PUI among the ADHD cohort
Internet gaming disorder (IGD)											
Ko <i>et al.</i>	<i>Eur Psychiatry</i>	2017	CS-GC	IGD	Semi-structured interview	174	Mixed, adults	Taiwan	Decision making	ADMT	IGD made more frequent risky choices than the controls in the advantage trials but not in the other trial types
Yao <i>et al.</i>	<i>NeuroImage: Clinical</i>	2020	CS-GC	IGD	IAT>50 plus DSM-5	49	Male, adults	China	Decision making/ reward	MIDT	IGD showed comparable behavioral performance on the MID task with healthy controls
Kräplin <i>et al.</i>	<i>J Behav Addict</i>	2020	q-L	IGD	Diagnostic interview	T ₀ = 70 T ₁ = 64 T ₂ = 61	Male, adults	Germany	Inhibitory control Discounting	GNG Delay discounting	Inter-temporal choice task (at T2) was associated with higher severity of IGD (at T1); lower inhibitory control (GNG at T2) was associated with more gaming (at T3)
Shin <i>et al.</i>	<i>Addict Biol</i>	2020	CS-GC	IGD	Clinical interviews	41	Male, adults	Korea	Inhibitory control	Emotional GNG	Abnormal emotional influences on response inhibition in patients with IGD
Li <i>et al.</i>	<i>Psychophysiology</i>	2020	CS-GC	IGD	Diagnostic interview	66	Adolescents	China	Inhibitory control Decision making	GNG Gambling Task	IGD had lower accuracy in NoGo trials (lower motor inhibition) and higher proneness for risky decisions
Park <i>et al.</i>	<i>Cereb Cortex</i>	2020	CS-GC	IGD	Diagnostic interview	68	Mixed, adults	Korea	Inhibitory control Decision making Attentional inhibition	SST CGT Stroop	IGD group presented with deficits in decision making (CGT) but not in pre-potent motor inhibitory control (SST) or (controlled for IQ) attentional inhibition (Stroop Color Word).

Table 1 (Continued)

Authors	Journal	Year	Study type	PUI- facet	PUI- measure	N	Gender/ age	Geographic area	Cognitive domain	Task	Main findings
Raiha et al.	Front Psych	2020	CS- GC	IGD	IAT > 50 plus DSM-5	39	Male, adults	China	Discounting Decision making	Delay discounting SGT	IGD discounted more steeply than the HC group; ↑ proportion of risky choices amongst IGDs Patients with IGD exhibited significantly lower performance in QDM
Kim et al.	Transl Psychiatry	2021	CS- GC	IGD	Clinical interviews	79	Mixed, adults	Korea	Decision making	CGT	

Legend: CS = Cross sectional; CS-GC = Cross sectional with group comparisons; L = Longitudinal; q-L = quasi-longitudinal; PUI = Problematic use of the internet, general internet use (umbrella term); YDQ = Young's Diagnostic Questionnaire; Problematic internet use Questionnaire = PIUQ; AEQ = Addiction-Engagement Questionnaire; CIAS = Chen Internet Addiction Scale; SST = Stop-signal Task; IGT = Iowa Gambling Task; CGT = Cambridge Gambling Task; QDM = Quality of decision making; MIDT = monetary incentive delay task; ADMT = Adaptive decision-making task; SGT = Simple Gambling Task; RVP = Rapid Visual Processing; OTS = One-touch Stocking of Cambridge; SWM = Spatial Working Memory Task; IED = Intra/Extradimensional Task (IED); BART = Balloon Analogue Risk Task; DDT = Delay Discounting Task; TMT-B = Trail Making Test; MCST = Modified Card Sorting Test; HC = Healthy controls.

being involved in IGD pathophysiology [13**]. In adults, a similar study examining event-related potentials (ERPs) showed hypoactivation of the ACC correlating to error commissions on NoGo trials in a group of IGD but not HCs [25], in support of response inhibition deficits involving early unconscious and later conscious error processing. In group comparisons, the IGD group presented with deficits in decision making (CGT) but not in pre-potent motor inhibitory control (SST) or (controlled for IQ) attentional inhibition (Stroop Color Word). Interestingly, the study used IQ as covariate which accounted for group differences in attentional inhibition [25], thus highlighting the relevance of assessing IQ differences in PUI versus HCs and taking those into account in group comparisons of cognition. This has also been one of the recommendations of the recent meta-analysis [14**]. The identification of both inhibitory control and decision making deficits both in adolescents and adults with established IGD supports the idea that commonalities in the neurocognitive associations of IGD and possibly PUI exist across age groups, although future research could focus on supporting this notion further. In another study of adults with IGDs versus HC, delay discounting deficits were identified in the IGD group (IGD discounted more steeply than the HC group) whereas the proportion of risky choices were higher amongst IGDs in a simple gambling task [26]. Those results are again in line with higher impulsivity amongst the IGD group, coupled with less ability to delay gratification and altered reward mechanisms.

Trends and developments

While, as noted above, decision making and inhibitory control have constituted primary areas of focus so far, some research has examined other cognitive domains in IGD and PUI. In one study of young non-treatment seeking adults with heightened impulsivity traits, PUI was associated with worse performance in working memory and decision making, in line with previous research [27]. However, the PUI group was also associated with worse performance in Rapid Visual Processing (RVP), which is a test of continuous and sustained attention. Attention deficit hyperactivity disorder (ADHD) is a comorbidity of PUI which is not typically screened for in cognition studies of PUI. RVP is also commonly impaired in ADHD. In this study, while the PUI/HC groups did not statistically differ for rates of ADHD, the PUI group performed worse in the task, suggesting that ADHD comorbidity would not account for this difference in performance. This opens the question of further exploration of cognitive performance in IGD or PUI using RVP to inform our understanding of the role of sustained visual attention in the relevant cognitive mechanisms [27]. Nevertheless, the epidemiological evidence linking PUI and ADHD is strong, which necessitates a disentanglement of PUI

associations in cognitive domains known to be affected by ADHD.

In a longitudinal study of cognition of PUI, including an assessment of ADHD status, ‘motivational dysfunction’ (classed by combining performance scores in delay discounting and Balloon Analogue test (BART)), but not ‘executive dysfunction’ (classed by combining performance scores of SST and n-back working memory) was statistically predictive of the later development of PUI among the ADHD cohort [28**]. This result supports the importance of decision making and reward processes in the mechanisms leading from ADHD to a PUI comorbidity, something in line with the theoretical model of development of behavioral addictions in the background of existent inhibitory control deficits [13**]. Similarly, another study examining PUI versus non-PUI and HCs found no differences in GNG or delay discounting performance (Problematic Internet Use Questionnaire cut-off ≥ 35 set at the upper quartile of the sample, which falls within the ‘few/average problems with internet use’ range according to the initial scale validation) [29]. Again here, exploratory correlations of PUI–GNG indicated increasing GNG reaction times with higher PUI scores. There is a possibility that GNG deficits apply less when the ‘umbrella construct’ of PUI (and not IGD specifically) is considered, or it might reflect that clinical level impairment of PUI needs to be ascertained in group comparisons. Another important consideration here is that research indicates that PUI may reflect a unidimensional quasi-trait in which most variance in scores is restricted to a subset of people with problems regulating Internet use. As such selecting cut-offs for PUI facets based on conventional analysis may bear questionable validity; instead, cut-offs can be derived from latent class analyses that optimally differentiate subgroups, including those with demonstrable functional impairment [30*].

While the gaming (IGD) facet of PUI has admittedly received most attention in recent research, other areas of PUI, for example, SNS use, online gambling, pornography overuse, online buying-shopping have been examined less individually. An overview of selected recent studies in this area are presented in [Table 2](#).

A few studies have focused on social networking sites (SNS) use; problematic SNS use (or social-network-use disorder) is an entity for which there has been some neurobiological and psychopathological research [31–34]. Experimental research is crucial in providing insights into the psychological mechanisms underpinning problematic internet usage. Using an experimental paradigm of auditory GNG task in adults, attentional impulsivity was associated with higher severity of SNS use symptoms [33]. In a different experimental paradigm, using a modified Iowa Gambling Task (IGT), it was shown that additional confrontation of social-networks-related cues

interferes with decision making [35]. Those results support the idea that attentional impulsivity and impaired decision making identified in other facets of PUI can be observed in problematic SNS use as well. Considering cross-sectional research using group comparisons, using a Dot-Probe task, young individuals from the UK with problematic SNS use were identified to have attentional biases for SNS-related images [36]. Another study identified less accuracy in NoGo trials in university students with problematic SNS use (ad-hoc Problematic Facebook use scale, ‘caseness’ determined by the upper quantile of the sample) during an emotional GNG paradigm using Facebook-related stimuli [37]. In another study group comparisons, identified as problematic SNS users versus HCs (Bergen Facebook addiction scale, cut-off ≥ 19), showed no differences in performance in the Wisconsin Card sorting Test (WCST), while correlations (SNS–WCST), only within the problematic users, were statistically significant [38]. This may suggest that WCST performance might be spared in SNS use disorder, or reflect the need for more rigorous identification of SNS use disorder cases with validated cut-offs for severity and established degree of clinical level impairment [14**]. Another facet of PUI is online gambling. There are many similarities to how gambling disorder presents on a neurocognitive level compared to IGD, particularly in the presence of decision making and response inhibition domain deficits [14**,39]. Problem gambling on smartphones is an increasing concerning issue linked with obsessional traits [40]. A recent study examined gambling disorder, IGD and HCs towards their performance of delay discounting and IGT and confirmed the similarities in steeper discounting and deficient decision making. Interestingly, the IGD group was able to improve in IGT performance towards the end of the task [41]. In another facet of PUI, that of problematic use of pornography (PPU), a recent review considered the impairments identified in PPU (as well as other conditions) in decision making both under risk and ambiguity in PPU as a putative transdiagnostic feature, linking PPU with disorders with addiction-like symptomatology [42]. Other domains, including cue reactivity and delay discounting have been explored, suggesting that PPU can be associated with higher impulsive choice [43]; however, PPU severity was uncorrelated to reaction times to conditioned target stimuli [44]. Considering inhibitory control in adult males with PPU, using a modified SST, high impulsivity was associated with more severe symptoms of PPU during the uncertain go-reaction-time condition [45]. Overall, similarities can be observed in the neurocognitive characteristics of PPU and IGD (or PUI in general), however, more research is required to replicate and expand on those findings and provide a clearer picture of the neurocognitive underpinnings of PPU. Another facet of PUI to consider here is online buying-shopping; using a modified IGT task, online-shopping pictures on disadvantageous decks interfered with

Table 2

New selected findings in PUI facets (SNS, gambling, pornography, buying-shopping) and cognition

Authors	Journal	Year	Study type	PUI-facet	PUI measure	N	Gender/age	Geographic area	Cognitive domain	Task	Main findings
Social Network use disorder (SNS)											
Nikolaïdou <i>et al.</i>	<i>J Behav Add</i>	2019	CS-GC	SNS	AEQ	65	Mixed, adults	UK	Attentional bias	Visual Dot-Probe Pleasantness Rating	Problematic SNS users showed an attentional bias for SNS-related images
Wegmann <i>et al.</i>	<i>Sci Rep</i>	2020	Exper	SNS	sIAT-SNS	112	Mixed, adults	Germany	Inhibitory control Executive function	Auditory GNG, MCST, TMT-B	Interaction effect of attentional impulsivity with performance in the auditory GNG task
Aydin <i>et al.</i>	<i>J Clin Exp Neuropsychol</i>	2020	CS-GC	SNS	BSMAS	284	Mixed, adults	BiH	Executive function	WCST	Group comparisons, problem SNS users showed no differences in performance
Wegmann <i>et al.</i>	<i>J Behav Add</i>	2021	Exper	SNS	s-IAT-SNS	146	Mixed, adults	Germany	Decision making	Modified IGT	Additional confrontation of social-networks-related cues interferes with decision making in the IGT
Moretta <i>et al.</i>	<i>Cogn Affect Behav Neurosci</i>	2021	CS-GC	SNS	PFUS	45	Mixed, adults	Italy	Inhibitory control	Emotional GNG	Problematic SNS users associated with reduced inhibitory control
Online gambling disorder (GD)											
Wöfling <i>et al.</i>	<i>Add Behav</i>	2020	CS-GC	IGD/gambling	Clinical interviews	88/51	Male, adults	Germany	Discounting Decision making	DDT IGT	Similarities between gambling and IGD regarding the DDT point towards a tendency on discounting rewards faster. IGT = gambling < IGD < HC
Problematic online pornography use (PPU)											
Antons and Brand	<i>Behav Add</i>	2018	CS	PPU	s-IATsex	50	Male, adults	Germany	Inhibitory control	Pornographic SST	Higher trait impulsivity and more impulsive action tendencies in uncertain situations (uncertain go-RT) associated with ↑ PPU
Pekal <i>et al.</i>	<i>J Behav Add</i>	2018	CS	PPU	s-IATsex	174	Mixed, adults	Germany	Attentional bias	Visual Probe Task	Attentional bias toward sexual stimuli was associated with ↑ PPU, an association mediated by cue-reactivity and craving

Table 2 (Continued)

Authors	Journal	Year	Study type	PUI-facet	PUI measure	N	Gender/age	Geographic area	Cognitive domain	Task	Main findings
Antons <i>et al.</i>	<i>J Behav Add</i>	2019	CS-GC	PPU	s-IATporn	952	Male, adults	Germany	Discounting	MCQ	Individuals with unregulated use showed significantly higher impulsive choice compared to those with recreational-occasional use.
Market <i>al.</i>	<i>J Behav Add</i>	2021	CS	PPU	s-IATsex	73	Male, adults	Germany	Cue reactivity	Sexual Incentive Delay Task	RT significantly faster to target stimuli in the condition presenting pornographic cues but uncorrelated to PPU severity
Online buying-shopping disorder (Online BSD)											
Trotzke <i>et al.</i>	<i>Add Behav</i>	2019	CS	Online BSD	s-IAT shopping	57	Mixed, adults	Germany	Decision making	Modified IGT	online-shopping pictures on disadvantageous decks interfered with IGT performance only in ↑ online BSD

Legend: CS = Cross sectional; CS-GC = Cross sectional with group comparisons; Exper = Experimental; PUI = Problematic use of the internet, general internet use (umbrella term); PPU = Problematic pornography use; SNS = Social Network Sites use; Online BSD = online Buying-shopping disorder; sIAT-SNS = short Internet Addiction Test modified for social-networking sites; s-IATsex = short Internet Addiction Test modified for internet pornography; s-IATporn = 12-item German short Internet Addiction Test modified for internet pornography; s-IAT shopping = 12-item German short Internet Addiction Test modified for internet shopping; PFUS = Problematic Facebook Use Scale; BSMAS = Bergen Social Media Addiction Scale; AEQ = Addiction-Engagement Questionnaire; IGT = Iowa Gambling Task; WCST = Wisconsin Card Sorting Test; MIDT = monetary incentive delay task; ADMT = Adaptive decision-making task; SGT = Simple Gambling Task; DDT = Delay Discounting Task; TMT-B = Trail Making Test; MCST = Modified Card Sorting Test; MCQ = Monetary Choice Questionnaire; UK = United Kingdom; BiH = Bosnia and Herzegovina; HC = Healthy controls.

IGT performance only in those with high levels of online BSD [46], a result suggesting decision making deficits in online BSD, warranting further investigation as to the putative cognitive associations of online BSD. Finally, in a less explored concept of high media multitasking (engaging with multiple devices/media at the same time), which may be related to higher PUI [47], those with relatively higher media multitasking performed worse in working memory and decision making under ambiguous risk (IGT), but similar in strategic planning decision making (Game of Dice) [47]. Taken together, the above indicate that there is a paucity of data exploring cognition in other specific facets of PUI beyond IGD, with current trends showing similarities across different facets of PUI towards common neurocognitive impairments across all facets. More research, using screening tools with validated cut-offs and clinical level impairment in specific PUI facets is necessary to shed further light into this area.

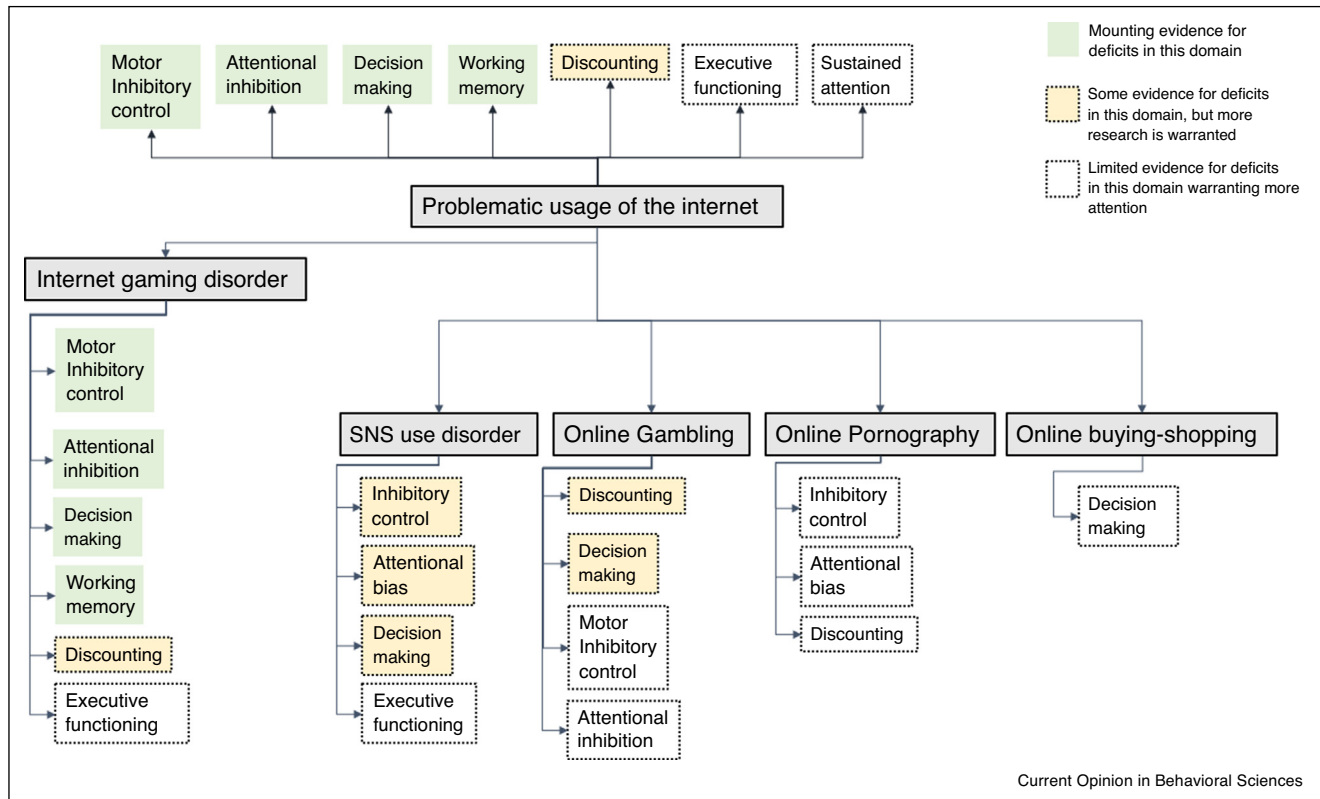
Beyond these domains of cognition, other studies have explored different constructs, for example self-serving biases in real and game-world contexts. In a recent study of Chinese college students, IGD exhibited diminished

self-protection and self-enhancement, potentially reflecting a negative self-concept and diminished ability to self-enhance [48]. An overview of findings by PUI facet and cognitive domain are presented in Figure 1.

Controversy and debate

The concept of PUI and IGD remain under the microscope of scrutiny, and legitimately so. There are many domains that require examination in order to inform debate about whether an entity is to be considered a valid ‘disorder’ such as impairment, co-occurrence of a pattern of symptoms that are coherent over time, showing it is not better accounted for by other already recognized ‘more primary’ conditions (e.g. ADHD, obsessive/compulsive or impulse control disorders, autistic spectrum), showing coherent responses to treatments in clinical trials (for discussion see Ref. [49]). Many of these domains have not been convincingly and extensively examined for PUI and IGD. There is also a lack of clearly reproduced findings as pertains to biological underpinnings, relatively less clinical experience working with these putative disorders, and heated debate around the risk of overpathologizing everyday life, when PUI or IGD are considered and included in modern classification systems of disease in mental health [14^{••},50,51]. As in other areas of

Figure 1



Overview of cognitive findings in problematic usage of the internet. Legend: SNS use = Social network sites use.

science, publication bias is another very important consideration here, which requires robust meta-analytical methodologies to identify and counteract any inappropriate absence of null or inverse effect results. Recent meta-analyses of cognition in PUI and gambling have highlighted this pressing issue in specific cognitive domains [14,39]. While neurobiological evidence for the links of PUI with cognitive deficits and mental ill health is mounting, other areas of

medicine are approaching the same person × online environment interaction from a different perspective. In a longitudinal cohort of 29 576 participants above the age of 50 internet use (not PUI) had a positive statistical association with cognition in a two-year follow up, an effect which was stronger than the reciprocal relationship, which was also positive [52]. This may suggest possible cognitive benefits from interaction with the online milieu, as long as use does not become severe, but could be due to confounding variables. Also, given the pervasive effect that the recent pandemic has had in our lives which are now more digitalized than ever, a recent review paper has taken a different approach considering the complexities of video gaming and cognitive impacts due to their practical, educational, vocational and academic implications conveying putative cognitive benefits [53] (Box 1).

Box 1 The authors' view

We find that cognitive deficits relating to inhibitory control and aspects of decision-making are commonly reported in people with PUI (including the umbrella construct and particular subforms) versus healthy controls. However, there are some aspects that need to be clarified in order to inform theoretical models of PUI and treatment approaches: (a) what is the contribution of commonly overlooked comorbidities? (b) what is the link between deficits and symptoms (in particular, are they vulnerability markers, associated with chronicity of symptoms, both, or just incidental?) (c) if deficits are reproducible, what are their neural underpinnings; and (d) how can these cognitive and biological findings be appropriately leveraged into suitable interventions?

Conclusion

We have synthesized here the most recent evidence on cognition and PUI. Those findings support the notion that inhibitory control and decision making deficits can be identified in group comparisons between problematic users of the Internet and healthy controls. The presence

of comorbidities from the impulsive/compulsive spectrum and IQ, which are often not properly measured or even considered at all, may account for some of these identified deficits. Interesting areas for further cognitive exploration include attentional inhibition and sustained attention, as well as other domains. Some facets of PUI when examined separately require further research to capture cognitive deficits, with future research needing to establish clinical level impairment of PUI in those group comparisons. Overall, those results have strengthened the theoretical conceptualization of problematic usage of the internet as being associated with cognitive deficits in inhibitory control and decision making, though most research thus far has focused on gaming disorder. Rigorous longitudinal research, incorporating an appropriately broad range of validated tools, is needed to more properly characterize PUI and whether cognitive deficits associated with it play a role in vulnerability, chronicity, or both.

Disclosures

Dr Konstantinos Ioannidis is contracted by Cambridge-shire and Peterborough NHS Foundation Trust (via a secondment agreement with Southern Health NHS Foundation Trust) to write service protocols for a regional Gambling Harms Clinic. These funding sources had no role in the design, management, data analysis, presentation, or interpretation and write-up of the manuscript. Dr Chamberlain's involvement in this research was funded by a Wellcome Trust Clinical Fellowship (110049/Z/15/Z). He receives stipends from Elsevier for journal editorial work. Dr Grant reports grants from Otsuka </GS4> and Biohaven Pharmaceuticals and from Oxford Press, Norton, <GS4>McGraw-Hill, and American Psychiatric Publishing outside of the submitted work. Authors received no funding for the preparation of this manuscript. The other authors report no financial relationships with commercial interest relevant to the content of this manuscript.

Human and animal rights and informed consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

Conflict of interest statement

Nothing declared.

Data availability

Data will be made available on request.

Acknowledgements

We are indebted to all the researchers and health workforce who have supported ourselves and our society during these testing times. The authors would like to acknowledge the European Cooperation in Science and Technology COST Action 16207: European Network for Problematic Usage of the internet www.cost.eu. The views presented in this manuscript are not necessarily those of COST.

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