



Testing the spectrum hypothesis of problematic online behaviors: A network analysis approach

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ABSTRACT

The validity of the constructs of problematic Internet or smartphone use and Internet or smartphone addiction has been extensively debated. The spectrum hypothesis posits that problematic online behaviors (POBs) may be conceptualized within a spectrum of related yet distinct entities. To date, the hypothesis has received preliminary support, and further robust empirical studies are still needed. The present study tested the spectrum hypothesis of POBs in an Australian community sample ($n = 1,617$) using a network analysis approach. Psychometrically validated self-report instruments were used to assess six types of POBs: problematic online gaming, cyberchondria, problematic cybersex, problematic online shopping, problematic use of social networking sites, and problematic online gambling. A tetrachoric correlation matrix was computed to explore relationships between online activities and a network analysis was used to analyze relationships between POBs. Correlations between online activities were positive and significant, but of small magnitude ($0.051 \leq r \leq 0.236$). The community detection analysis identified six distinct communities, corresponding to each POB, with strong relationships between items within each POB and weaker relationships between POBs. These findings provide further empirical support for the spectrum hypothesis, suggesting that POBs occur as distinct entities and with little overlap.

1. Introduction

The number of people using the Internet increased from 413 million in 2000 to over 4.95 billion in January 2022 (DataReportal, 2022). Among those, 92.1% accessed the Internet via mobile devices (DataReportal, 2022). Although the Internet has brought unprecedented benefits, problematic use of the Internet and mobile devices has become a major public health issue (WHO, 2015). Such use is manifested through various problematic online behaviors (POBs), including

problematic online gambling, gaming, shopping, sexual activities (cybersex), and social networking (use of social networking sites) (Billieux et al., 2015; Hussain & Starcevic, 2020; Mora-Salgueiro et al., 2021; Müller, Laskowski, Wegmann, Steins-Loeber, & Brand, 2021; Wéry & Billieux, 2017).

Except for problematic online gambling and gaming, POBs are not considered diagnosable mental disorders in the two key classification systems, the Fifth Edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) and

Abbreviations: POB, Problematic online behavior.

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the Eleventh Revision of the International Classification of Diseases (ICD-11; World Health Organization, 2019). Problematic online gambling corresponds to the diagnosis of gambling disorder in DSM-5 and ICD-11, with ICD-11 also recognizing a “predominantly online” subtype of gambling disorder. In DSM-5, problematic online gaming was named Internet gaming disorder and introduced as a provisional diagnostic category that requires further study, whereas in ICD-11, gaming disorder became a fully recognized disorder. Although there is no official diagnostic recognition for problematic cybersex, problematic online shopping and problematic use of social networking sites, these POBs have negative consequences and/or lead to significant functional impairment (De Alarcón, de la Iglesia, Casado, & Montejo, 2019; Müller, Laskowski, Wegmann, Steins-Loeber, & Brand, 2020; Boer et al., 2020). Recent research has sought to improve understanding of the nature and boundaries of POBs and ascertain whether they constitute distinct psychopathological entities worthy of further research and greater attention in clinical practice.

POBs have often been considered manifestations of “problematic Internet use” or “Internet addiction” (Fineberg et al., 2018), “problematic smartphone use” or “smartphone addiction” (Elhai, Dvorak, Levine, & Hall, 2017) and “Internet use disorders” (Montag, Wegmann, Sarisky, Demetrovics, & Brand, 2021). However, there are important limitations to an Internet- or smartphone-centered construct of problematic online activities. The constructs have been criticized on the grounds that the Internet and smartphones are only the means for accessing specific online activities such as online gaming and gambling (Griffiths, 2000; Griffiths & Szabo, 2014; Starcevic & Aboujaoude, 2017). In addition, people may have a tendency not to switch from their preferred online activity to another online activity when they are unable to access it (Griffiths & Szabo, 2014; Lowe-Calverley & Pontes, 2020; Pontes, Szabo, & Griffiths, 2015). This suggests that rather than engaging with the Internet or smartphones per se, people instead tend to go online to engage in their favorite activity.

An alternative to the construct of problematic Internet or smartphone use was formulated through the “spectrum hypothesis” of POBs. This hypothesis posits that POBs may be conceptualized within a spectrum of related, i.e., Internet-mediated entities, which are nevertheless distinct (Billieux, 2012; Starcevic & Billieux, 2017). The differences between POBs pertain to various socio-demographic and psychological variables (e.g., motivations and psychopathological symptoms) with which they have been associated (Starcevic & Billieux, 2017). For example, problematic online gaming was related to shyness and low life satisfaction, while “problematic online pornography use” (a variant of problematic cybersex) was related to a need for sexual gratification (Pawlikowski, Nader, Burger, Stieger, & Brand, 2014). Likewise, problematic use of social networking sites was found to be more common in females and more likely to be associated with anxiety, whereas problematic online gaming was more frequent in males and more likely to be associated with depression (Andreassen et al., 2016). If people with various POBs were characterized as only exhibiting problematic Internet use, these differences would be overlooked. It should be noted, though, that systematic comparisons of the similarities and differences between various POBs are lacking.

The present study used a network approach to investigate associations between constructs. This analysis is a data-driven approach designed to investigate relationships (“edges”) between variables (“nodes”) (Cramer, Waldorp, van der Maas, & Borsboom, 2010). The network constitutes the construct, which is a major conceptual difference from the classic latent variable approach in which variables reflect latent constructs (Guyon, Falissard, & Kop, 2017). Another major difference is that the latent variable approach postulates that items reflect a latent factor, whereas the network analysis assumes the existence of a reciprocal causation between items, which dynamically interact. Therefore, the network analysis allows investigations of the relationships between variables and their strength and clustering, without assuming common causes of latent variables. From a statistical point of

view, the assumption of local independence between items (i.e., covariance between items fully explained by the latent factor) is not required (Guyon et al., 2017).

Previous research using network analysis has demonstrated that POBs are organized as distinct and separate constructs (Baggio et al., 2018; Rozgonjuk, Schivinski, Pontes, & Montag, 2021), providing initial empirical support for the spectrum hypothesis. However, the studies by Baggio et al. (2018) and Rozgonjuk et al. (2021) have some important shortcomings. Baggio et al. (2018) only considered two specific POBs (online gaming and online gambling) and the study sample consisted of young Swiss men, thus limiting generalizability of the findings. Rozgonjuk et al. (2021) included a greater range of POBs (gambling, gaming, watching pornography [as a form of cybersex], shopping, and social networking), but the study only recruited gamers who were mainly young males. In addition, this study did not employ validated scales to assess POBs. Another limitation of these two studies has been the omission of cyberchondria, which denotes excessive or repeated searches for health-related information on the Internet, leading to a heightened anxiety or distress (Starcevic & Berle, 2013). This is likely due to the fact that POBs are often conceptualized as addictive behaviors (Brand, Young, Laier, Wöfling, & Potenza, 2016), while cyberchondria is rather viewed as a repetitive behavior in response to uncertainty (Starcevic & Berle, 2013). Yet, cyberchondria was reported to have a close relationship with problematic Internet use (Fergus & Dolan, 2014; Fergus & Spada, 2017; Starcevic, Baggio, Berle, Khazaal, & Viswasam, 2019), whereby online health searches continue despite the distress caused by this activity (Khazaal et al., 2021) and result in detrimental effects on functioning (Vismara et al., 2020). Therefore, cyberchondria should be investigated alongside other POBs.

The aim of the present study was to employ a network analysis approach to further test the spectrum hypothesis in a population that is more age- and gender-balanced, using validated instruments for assessment of POBs and considering a greater variety of POBs. This approach would constitute a more definitive test of the spectrum hypothesis, with theoretical and practical implications. We investigated the relationships between six types of POBs: problematic online gaming, cyberchondria, problematic cybersex, problematic online shopping, problematic use of social networking sites and problematic online gambling. These POBs were chosen because of their well-documented negative consequences and associated functional impairment (Billieux et al., 2015; Hussain & Starcevic, 2020; Mora-Salgueiro et al., 2021; Müller et al., 2021; Starcevic, 2017; Wéry & Billieux, 2017). In agreement with the results of the aforementioned studies, we expected that POBs were configured as relatively distinct entities, which would support the spectrum hypothesis.

2. Methods

2.1. Design and participants

A cross-sectional study was conducted in an Australian community sample between November 2020 and December 2020. Participants were recruited online using the Qualtrics platform with a quota sampling method based on gender and age groups. The recruitment strategy ensured that participants’ demographic characteristics were similar to those of the general Australian population. There were two inclusion criteria: age between 16 and 60 years and English fluency. Eligible participants were sent a survey link with self-report questionnaires. Incomplete questionnaires and grossly anomalous response sets were excluded by Qualtrics and participants who did not engage in any of the investigated online activities ($n = 9$) were excluded by investigators. The final sample size was 1,617. The Nepean Blue Mountains Local Health District Human Research Ethics Committee approved the study protocol (reference number 2020/ETH00601), with an informed consent implied by survey completion. Participants under the age of 18 received parental permission to complete the survey and used their

parents' Qualtrics account to do so.

2.2. Measures

Demographics. Demographic information included age, gender, country of birth (Australia or outside Australia), education level, employment status, and relationship status.

Participation in online activities and assessment of problematic online behaviors. Participants were asked whether they engaged in each online activity except for online searches for health information. Individual items for each scale are reported in the Supplementary material. If they answered "yes", they were invited to complete the corresponding questionnaires assessing specific POBs. All participants completed the cyberchondria questionnaire.

Problematic online gaming. The Ten-Item Internet Gaming Disorder Test (IGDT-10, Király et al., 2017) assessed Internet gaming disorder according to DSM-5 criteria. Responses were scored on a modified, two-point scale, with total scores ranging from 0 to 10. Internal consistency in the study sample was excellent (Cronbach's alpha = 0.91).

Cyberchondria. The 12-item Cyberchondria Severity Scale (CSS-12, McElroy et al., 2019) was used to measure cyberchondria. Responses were obtained on a five-point scale (1–5), with total scores ranging between 12 and 60. Internal consistency in the present sample was excellent (Cronbach's alpha = 0.95).

Problematic cybersex. The 12-item Short Internet Addiction Test – Sex (SIAT-SE, Laier, Pawlikowski, Pekal, Schulte, & Brand, 2013) assessed problematic cybersex. This scale is derived from the Short Internet Addiction Test (SIAT, Pawlikowski, Altstötter-Gleich, & Brand, 2013) and was demonstrated to have solid psychometric properties (Laier et al., 2013; Wéry, Burnay, Karila, & Billieux, 2016). Responses were collected on a five-point scale (1 to 5), with total scores ranging between 12 and 60. Internal consistency in the study sample was excellent (Cronbach's alpha = 0.96).

Problematic online shopping. The 12-item Short Internet Addiction Test – Shopping (SIAT-SH, Trotzke, Starcke, Müller, & Brand, 2015) was used to assess problematic online shopping. This scale is also derived from the Short Internet Addiction Test (SIAT, Pawlikowski et al., 2013) and was validated by Trotzke et al. (2015). Responses were collected on a five-point scale (1 to 5), with total scores ranging from 12 to 60. Internal consistency in the present sample was excellent (Cronbach's alpha = 0.96).

Problematic use of social networking sites. The 18-item Internet Addiction Test modified for use of social networking sites (IAT-SNS, Rothen et al., 2018) served as a measure of problematic use of social networking sites. The scale is derived from the Internet Addiction Test (IAT, Young, 1998). Responses were obtained on a five-point scale (1 to 5), with total scores ranging from 18 to 90. Internal consistency in the study sample was excellent (Cronbach's alpha = 0.96).

Problematic online gambling. The nine-item Problem Gambling Severity Index (PGSI, Currie, Hodgins, & Casey, 2013; Ferris & Wynne, 2001) was used to screen for problem gambling. Participants were asked about their predominant pattern of gambling: mainly offline, mainly online or both offline and online. Participants who responded "mainly online" and "both offline and online" were considered to be engaged in online gambling. Responses were collected on a four-point scale (0 to 3), with total scores ranging from 0 to 27. Internal consistency in the present sample was excellent (Cronbach's alpha = 0.96).

2.3. Statistical analyses

We first computed descriptive statistics for demographics and participation in online activities. We then computed the tetrachoric correlation matrix of the participation in online activities (presence versus absence) to determine the overlap between them. A Bonferroni correction was used to keep a 5 % error rate. Third, we used network analysis to analyze relationships between POBs, using items of the

questionnaires assessing POB (Golino & Epskamp, 2017). We computed a network analysis including all items of the questionnaires assessing POBs to investigate to what extent POBs were distinct constructs. When POBs were absent, corresponding questionnaire items were coded zero. The network was computed using a Gaussian graphical model (i.e., a pairwise Markov Random Field model) with Spearman correlations (Epskamp, Borsboom, & Fried, 2018). The model used a penalty parameter (gLASSO, based on the extended Bayesian Information Criterion) to set small coefficients to zero. We tested whether items constituted distinct communities using the Spinglass algorithm, a modularity-community detection algorithm which handles negative edges' weights (Traag & Bruggeman, 2009). We computed bootstrapped confidence intervals of estimated edge-weights to identify differences in strengths in within- and between-community edges (Epskamp et al., 2018). We also computed the proportions of within- and between-community positive edges (descriptive statistics). Usual accuracy checks were performed, using the correlation stability coefficient (CS-coefficient) for the nodes' strength and edges' strength (Epskamp et al., 2018). The CS-coefficient should preferably be above 0.5. We also checked the edge-weight accuracy using bootstrapped confidence intervals of estimated edge-weights. As sensitivity analyses, we first computed the network using a mixed graphical model, which considered items as measured on ordinal scales. Second, as we estimate a large number of parameters, we dropped the number of nodes, as recommended by (Epskamp et al., 2018). We randomly kept six nodes for each POB. The results were similar to those reported in the Results section.

We used R 4.1.2 for all analyses, including the package bootnet 1.5 to estimate and visualize the network and for bootstrap estimations (default = "EBICglasso" with corMethods = "spearman") and the algorithm "spinglass.community" from the igraph 1.2.11 package to detect community.

3. Results

Table 1 shows demographic data and numbers and proportions of participants who engaged in various online activities. The most common online activities were online shopping (92.3 %) and use of social networking sites (88.0 %). More than one half of the participants played video games (58.0 %), whereas online gambling and cybersex were less frequent (19.5 % and 39.6 %, respectively).

Table 2 presents tetrachoric correlations between various online activities at the level of their presence versus absence. Such correlations

Table 1
Demographic data and numbers and proportions of participants who engaged in online activities (n = 1617).

Variables	% (n)
Demographics	
Age ¹	37.2 (12.3)
Gender	
Female	51.6 (834)
Male	48.4 (783)
Level of education	
Primary/secondary/trade	53.8 (870)
Tertiary	46.2 (747)
Relationship status	
Single	42.4 (685)
Married/de facto relationship	57.6 (932)
Employment status	
Not in paid employment	32.2 (520)
Paid employment	67.8 (1097)
Participation in online activities	
Cybersex	39.6 (640)
Online gambling	19.5 (316)
Online gaming	58.0 (937)
Online shopping	92.3 (1493)
Use of social networking sites	88.0 (1423)

¹ Mean and standard deviation are reported.

Table 2

Tetrachoric correlations between online activities at the level of their presence versus absence.

	1	2	3	4	5
1. Cybersex	1	–	–	–	–
2. Gambling	0.169***	1	–	–	–
3. Gaming	0.236***	0.183***	1	–	–
4. Shopping	0.057*	0.089***	0.051*	1	–
5. Social networking	0.073**	0.182***	0.187***	0.123***	1

* p <.05.

** p <.01.

*** p <.001, with Bonferroni correction.

are not reported for online health searches because participants were not asked whether they engaged in this activity. Pairwise correlations between online activities were all positive and statistically significant at the 0.05 level, but of small magnitude ($0.051 \leq r \leq 0.236$).

The main network is depicted in Fig. 1. The community detection analysis identified six different communities of items, corresponding to each POB. Overall, within-community edges were stronger than between-community edges (Fig. 2), suggesting strong relationships between items within each POB and weaker relationships between POBs. Table 3 shows the percentage of positive edges (number of positive edges divided by the number of possible edges). Each POB had a large proportion of within-community edges (ranging between 71.2 % and 100 %), meaning that items were well connected within each POB. On the contrary, the proportions of between-community edges were smaller (ranging from 0.9 % to 21.8 % between pairs of POBs).

We tested the pattern of results for distinct subgroups based on their sociodemographic characteristics. In all subgroups (age below mean/above mean, females/males, tertiary/non-tertiary education, single/married or in a de facto relationship, and paid employment/not in paid employment), we found that POBs constituted separate communities.

The CS-coefficients were acceptable (0.75 for both nodes' strength

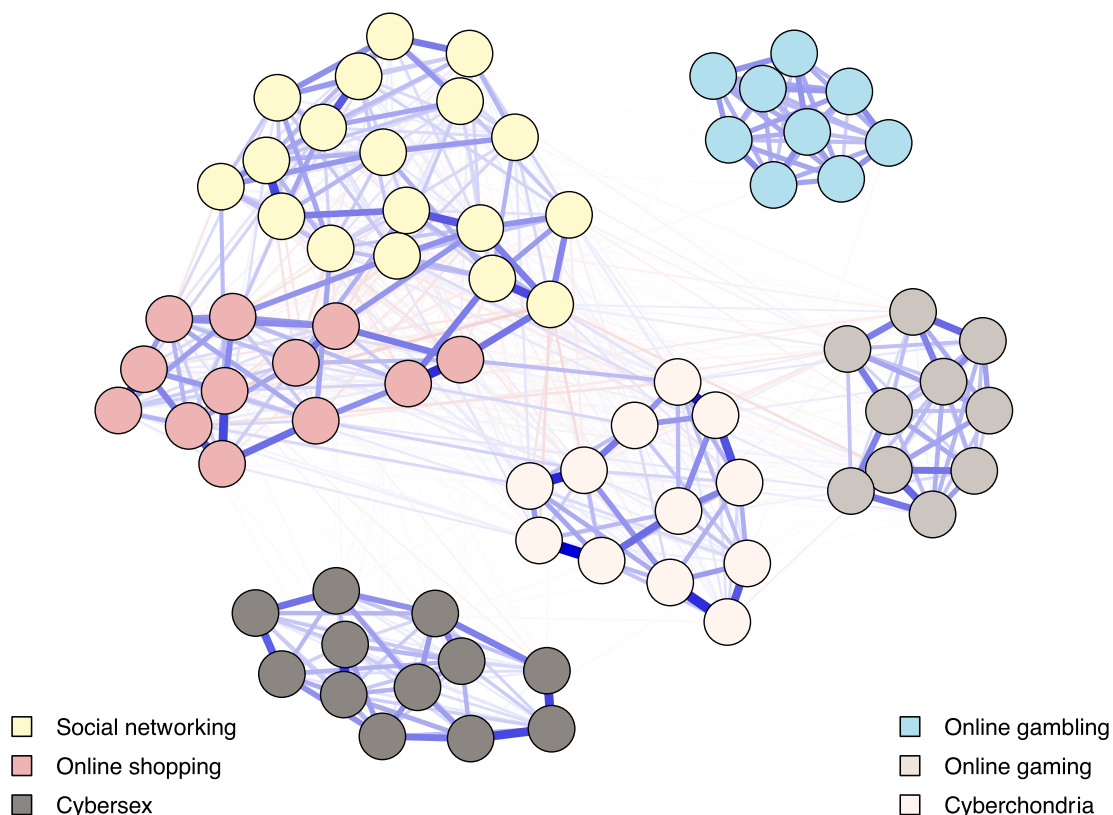


Fig. 1. Network of problematic online behaviors.

● Bootstrap mean ● Sample

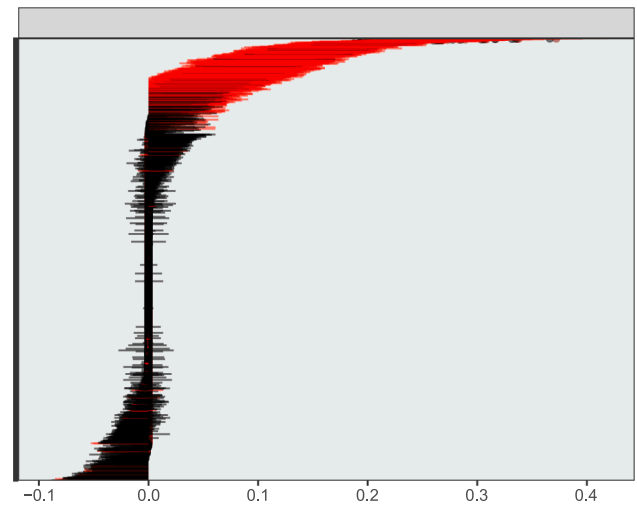


Fig. 2. Edge weights and bootstrapped confidence intervals of the network. Each line represents an edge (red: within-community edges, black: between-community edges), with an area indicating 95 % bootstrapped confidence intervals (1000 estimations, range from the 2.5th to the 97.5th quantiles). Edges are ordered from the lowest to the highest. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

and edges' strength). Fig. 2 shows that the bootstrapped edge-weights overlapped, suggesting that we should avoid interpreting edges' strengths (Epskamp et al., 2018). Consequently, we limited our interpretation to the presence of edges, as it is not affected by large confidence intervals.

Table 3
Percentages of within- and between-communities edges in problematic online behaviors.

	1	2	3	4	5	6
1. Cyberchondria	71.2 %	–	–	–	–	–
2. Problematic cybersex	6.3 %	93.9 %	–	–	–	–
3. Problematic online gambling	0.9 %	2.8 %	100 %	–	–	–
4. Problematic online gaming	13.3 %	6.7 %	7.8 %	93.3 %	–	–
5. Problematic online shopping	18.1 %	8.3 %	3.7 %	12.5 %	87.9 %	–
6. Problematic use of social networking sites	21.8 %	3.7 %	5.6 %	10.6 %	12.0 %	75.2 %

Bold: within-community edges; non-bold: between-community edges.

4. Discussion

The present study tested the spectrum hypothesis of POBs in an Australian community sample using a network analysis approach. This approach has been able to improve understanding of psychiatric disorders (Borsboom, 2017; Schmittmann, Cramer, Waldorp, Epskamp, Kievit, & Borsboom, 2013). To the best of our knowledge, this was the first study that examined a large range of POBs (including cyberchondria) in an age- and gender-balanced community sample of adults.

The results showed that online activities were not highly correlated, with correlations ranging between 0.051 and 0.236. These small correlations indicate that engagement in one online activity was not strongly related to engagement in another. The findings are mostly consistent with those of Rozgonjuk et al. (2021), although they reported slightly higher, but still small to medium correlations between various POBs, ranging from 0.193 to 0.389. Similarly, other studies reported weak correlations between problematic online gaming and “problematic online pornography use” ($r = 0.10$; Pawlikowski et al., 2014) and between problematic online gaming and problematic use of social networking sites ($r = 0.13$; Andreassen et al., 2016).

In the main network analysis, POBs were organized as different communities, which supports the notion that they are distinct constructs. Relationships between POBs existed, but they were fewer compared to relationships within POBs (i.e., lower strength of edges, Fig. 2; and lower proportion of positive edges among all possible edges between questionnaire items, Table 3). Thus, items had stronger relationships when they belonged to the same POB and weaker relationships when they belonged to different POBs. These findings are consistent with the results of two previous studies investigating relationships between POBs in specific populations (young Swiss men, Baggio et al., 2018; mostly male gamers, Rozgonjuk et al., 2021) and using a network analysis approach. In both studies, POBs constituted distinct communities of items.

Taken together, these findings provide further support for the spectrum hypothesis (Billieux, 2012; Starcevic & Aboujaoude, 2017). POBs seem to be organized as distinct activities, which is in agreement with previous theoretical propositions and empirical findings (Baggio et al., 2018; Griffiths, 2000; Griffiths & Szabo, 2014; Lowe-Calverley & Pontes, 2020; Morahan-Martin, 2005; Pontes et al., 2015; Rozgonjuk et al., 2021; Shaffer, Hall, & Vander Bilt, 2000; Starcevic & Aboujaoude, 2017). Moreover, findings of the present study confirm that problematic Internet or smartphone use, as a unitary “umbrella construct”, encompasses vastly different POBs that show little overlap and do not necessarily co-occur. Use of this construct might downplay the differences between POBs. This conclusion is supported by Pawlikowski et al.

(2014) who found that “pathological Internet use” was not a “homogeneous and uniform entity” and by Andreassen et al. (2016) who reported that “Internet use disorder” was not “warranted as a unified construct”. Being too heterogeneous, the construct of problematic Internet or smartphone use reflects a “one-size-fits-all” approach, it is untenable and represents a conceptual impasse. Therefore, future research should abandon it and instead focus on individual POBs. There is no implication that this line of research will inevitably transform POBs into new diagnostic entities, but that possibility remains open. Such efforts are expected to contribute to a better understanding of the psychopathology of addictive and compulsive behaviors related to use of the digital technologies.

This study has several limitations. First, although we have investigated the most relevant POBs, for practical reasons we could not be entirely comprehensive in our coverage, with some POBs (e.g., cyberbullying) not included. In addition, data were collected from an online self-selected sample. Participants were selected to be representative of the Australian population for age and gender, but the sample may have been over- or under-represented in some other respects. For example, there was a large proportion of participants with a tertiary level of education. However, any self-selection bias was unlikely to affect our research question about the relationships between POBs. The study relied on self-report tools for measuring POBs, which can produce biased findings (Parry et al., 2021), and future research should consider clinician-administered interviews. Furthermore, we did not assess the number of participants who performed online health searches because of an assumption that all people engage in this activity. This variable could not be included in the correlation analyses because they are based on the presence/absence of the corresponding behavior. Another limitation was that data were collected during the SARS-CoV-2 pandemic, which could affect the expression and/or severity of some POBs (Masaeli & Farhadi, 2021). However, at the time of data collection, only one Australian state had pandemic-related restrictions in place, with an overall important effect of the pandemic on the relationships between POBs unlikely. Finally, POBs were assessed by different scales, which could have created a method artifact. However, three POBs (problematic cybersex, problematic online shopping and problematic use of social networking sites) were assessed by scales derived from the Short Internet Addiction Test and Internet Addiction Test that used the same Likert scale. If there had been an artifact effect, these three POBs would have clustered in a single community, not in three distinct communities.

In conclusion, our study provides further support for the spectrum hypothesis of POBs, suggesting that POBs occur as distinct but somewhat related entities. Our findings also highlight inadequacy of the construct of problematic Internet or smartphone use. This has implications in terms of our better understanding of POBs and tailoring our approach to their assessment and treatment based on their specific characteristics. Future research should focus on individual POBs, aiming to further investigate their unique and shared features.

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CRediT authorship contribution statement

Stéphanie Baggio: Conceptualization, Formal analysis, Methodology, Writing – original draft. **Vladan Starcevic:** Conceptualization, Data curation, Methodology, Project administration, Supervision, Writing – review & editing. **Joël Billieux:** Conceptualization, Methodology, Writing – review & editing. **Daniel L. King:** Conceptualization, Methodology, Writing – review & editing. **Sally M. Gainsbury:** Conceptualization, Data curation, Methodology, Project administration, Writing – review & editing. **Guy D. Eslick:** Conceptualization,

Methodology, Writing – review & editing. **David Berle:** Conceptualization, Data curation, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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