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Technology-mediated addictive behaviors constitute a spectrum of related yet distinct conditions: A network perspective

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ABSTRACT

An important ongoing debate in the addiction field is whether certain technology-mediated behaviors constitute tenable and independent constructs. This study investigated whether problematic technology-mediated behaviors could be conceptualized as a spectrum of related, yet distinct disorders (spectrum hypothesis), using the network approach that considers disorders as networks of symptoms. We used data from the Cohort Study on Substance Use and Risk Factors (C-SURF), with a representative sample of young Swiss men (subsample of participants engaged in technology-mediated behaviors, n=3,404). Four technology-mediated addictive behaviors were investigated using symptoms derived from the DSM-5 and the component model of addiction: Internet, smartphone, gaming, and cybersex. Network analyses included network estimation and visualization, community detection tests, and centrality indices. The network analysis identified four distinct clusters corresponding to each condition, but only Internet addiction had numerous relationships with the other behaviors. This finding, along with the finding that there were few relationships between the other behaviors, suggests that smartphone addiction, gaming addiction, and cybersex addiction are relatively independent constructs. Internet addiction was often connected with other conditions through the same symptoms, suggesting that it could be conceptualized as an "umbrella construct," i.e., a common vector that mediates specific online behaviors. The network analysis thus provides a preliminary support to the spectrum hypothesis and the focus on the specific activities performed online, while showing that the construct of "Internet addiction" is inadequate.

Keywords: Cyberaddiction; cybersex addiction; Internet addiction: gaming addiction; network analysis; smartphone addiction

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INTRODUCTION

Internet and smartphone use has become a worldwide phenomenon. Progress in digital technologies has led to a wide range of positive applications, such as promoting communication, health, education, or leisure (e.g., video games). Yet, in the last two decades, there has been a growing recognition of an association between problematic use of digital technologies and psychological distress, health problems, and functional impairment (Kuss, Griffiths, Karila, & Billieux, 2014; van den Brink, 2017). Crucially, the number of treatment-seeking cases whose online behaviors are of a functionally impairing nature is increasing worldwide (Billieux et al., 2017), and several cases of death have been related to "prolonged sitting at computer" (Saunders et al., 2017).

Behaviors related to the problematic use of digital technologies are generally conceptualized within a biomedical framework as genuine addictive disorders (Block, 2008; Chóliz, 2010; Petry & O'Brien, 2013), although alternative conceptual hypotheses have also been formulated, e.g., as a maladaptive coping strategy, impulse-control disorders, or disorders related to obsessive-compulsive disorder (Kardefelt-Winther et al., 2017; Starcevic & Aboujaoude, 2017).

Initial work in the field introduced terms such as "Internet addiction" (Griffiths, 1996; Young, 1998) and "mobile phone dependence" (Bianchi & Phillips, 2005; Billieux, Van der Linden, d'Acremont, Ceschi, & Zermatten, 2007) to describe these emerging problems. However, these terms are now considered misleading by many authors. "Internet addiction" and "smartphone addiction" may be umbrella constructs, subsuming a variety of problematic behaviors (Andreassen et al., 2016; Billieux,

Maurage, Lopez-Fernandez, Kuss, & Griffiths, 2015; Király et al., 2014; Yellowlees & Marks, 2007) for which the Internet or the smartphone is the common vector or "delivery mechanism" (Griffiths, 2000; Shaffer, Hall, & Vander Bilt, 2000; Starcevic & Aboujaoude, 2017). Examples of problematic behaviors mediated by the Internet and/or smartphone include (video) gaming (Saunders et al., 2017), various sexual activities (Wéry & Billieux, 2017), gambling (Gainsbury, 2015), and to a lesser degree, social networking (Carbonell & Panova, 2017).

Crucially, only problematic (video) gaming, named Internet gaming disorder, is currently considered a potential technology-mediated psychiatric condition. It is listed in the "Emerging Measures and Models" (Section III) of the last *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) (American Psychiatric Association, 2013), which suggests that it is a condition for further study. The proposed diagnostic criteria for Internet gaming disorder have been adapted from those for substance use disorders. There have been similar developments in the work on the beta draft of the *11th Revision of the International Classification of Diseases* (ICD-11) (World Health Organization, 2017), except that the condition is named gaming disorder, described differently and not proposed as a provisional diagnosis. Both the DSM and ICD systems propose to conceptualize gaming disorder as an addictive behavior. Furthermore, the DSM-5 and ICD-11 working groups both concluded that evidence was still too scarce to include as distinct psychiatric disorders other problematic online behaviors, such as problematic cybersex or use of social networking sites.

Solid and definitive data-driven approaches are needed to test whether Internet and smartphone addictions are tenable constructs or whether specific technology-mediated addictive activities constitute distinct conditions. This is required to advance the field beyond theoretical debates about Internet and smartphone addiction versus

disorders characterized by the specific online addictive behaviors (Kuss, Griffiths, & Pontes, 2016).

Spectrum hypothesis and network analysis

It has been hypothesized that technology-mediated addictive behaviors could be conceptualized within a *spectrum* of related, yet relatively distinct disorders that may be associated with both common and unique etiological factors (Billieux, 2012; Starcevic & Billieux, 2017). However, the spectrum hypothesis has not yet undergone empirical testing. Classic data analytic strategies used in psychopathological research such as structural equation modeling, cluster analysis, or latent class analysis can test the spectrum hypothesis indirectly and only to some extent. For reasons stipulated below, the network perspective is better placed to test this hypothesis directly.

The network analysis conceptualizes disorders as complex networks, i.e., as sets of symptoms directly interacting with one another (Borsboom, 2017; Schmittmann et al., 2013). Symptoms are considered as separate "nodes" that are related to other nodes via "edges". The latter reflect the relationships between nodes and have different weights (strengths). Therefore, a strong edge between two nodes means that the symptoms are likely to co-occur. Accordingly, symptoms that are strongly related to other symptoms may be more central to the construct, whereas symptoms that are weakly connected to others are more peripheral. This approach addresses the complexity and dynamic nature of mental disorders and is especially useful to study relations between disorders (Cramer, Waldorp, van der Maas, & Borsboom, 2010). Furthermore, traditional methods such as factor analysis are not appropriate to identify umbrella constructs, because these constructs are not considered unique underlying factors and may overlap with other factors. As such, the network analysis can test the

spectrum hypothesis. In addition, the network analysis makes it possible to explore whether some symptoms constitute "bridge symptoms," which create a path between two relatively distinct disorders (Baggio, Gainsbury, Berchtold, & Iglesias, 2016; Cramer et al., 2010). Such bridge symptoms may represent common etiological factors, and their identification may contribute to the testing of the spectrum hypothesis.

Current study

The current study aimed to test the spectrum hypothesis in a representative sample of males from the community using a network analysis. This testing pertained to the links between the two umbrella constructs (Internet addiction and smartphone addiction) and two specific technology-mediated conditions (gaming addiction and cybersex addiction). We decided, for the sake of hypothesis testing, to rely on the addiction model as a theoretical framework in the current study. However, we are mindful that caution is needed when using the term "addiction" and considering these behaviors as genuine addictive disorders (Aarseth et al., 2016; Kardefelt-Winther et al., 2017). Accordingly, and in line with the DSM-5 approach (American Psychiatric Association, 2013) and the component model of addiction (Brown, 1993), modified by Griffiths (2005), the symptoms considered in the network analysis were taken from substance use disorders (e.g., loss of control, continued use, mood modification).

Based on the spectrum hypothesis (Billieux, 2012; Starcevic & Billieux, 2017), we formulated two study hypotheses. First, we expected that the symptoms of gaming addiction and cybersex addiction would form relatively distinct clusters (i.e., gaming addiction would be relatively unrelated to cybersex addiction). Second, we postulated that the umbrella constructs of Internet addiction and smartphone addiction would not constitute discrete or specific disorders. If the network analysis supported these study hypotheses, that would also provide a strong support to the spectrum hypothesis.

METHODS

Participants and procedure

Data were collected in the third wave of the Cohort Study on Substance Use and Risk Factors (C-SURF). The C-SURF is a longitudinal study designed to assess addictive behaviors and associated consequences among a representative sample of Swiss young men. Participants were enrolled in 2010-2011 during the conscription in three Swiss national military recruitment centers (21 out of 26 cantons of the country). The representativeness of the sample was ensured by the fact that the conscription process is mandatory in Switzerland for all men around the age of 20. At baseline, of 7,556 conscripts who gave written consent to participate, 5,987 (79.2%) completed the questionnaire.

The present study is based on the data collected during the third wave (April 2016 - June 2017), because data on technology-mediated addictive behaviors were not collected in previous waves. In total, 5,214 men participated in the third wave. Of these, 94.8% used the Internet, 86.6% played video games, 95.5% used a smartphone, and 77.9% visited pornography websites. A total of 3,428 (65.7%) reported the four technology-mediated behaviors. Twenty-four (0.7%) participants were excluded because they did not provide complete data, with a final sample of 3,404. The mean age of participants was 25.4 ± 1.2 years (age range: 23-33.5). Participants were either French-speaking (55.5%) or German-speaking (44.5%). Previously published results derived from the baseline sample of the C-SURF reported a small non-response bias

(Studer et al., 2013). Other findings of the C-SURF are available elsewhere (Gmel et al., 2015).

Measures

The four self-report instruments were administered to assess Internet addiction, gaming addiction, smartphone addiction, and cybersex addiction.

Internet addiction. The Compulsive Internet Use Scale (CIUS: Meerkerk, Van Den Eijnden, Vermulst, & Garretsen, 2009; German version: Bischof, Bischof, Meyer, John, & Rumpf, 2013; French version: Khazaal et al., 2012) was used to assess symptoms of addictive use of the Internet. It consists of 14 items using a five-point scale coded "never", "rarely", "sometimes", "often", and "very often". The CIUS demonstrated high Cronbach alpha ($\geq$ .89) and a one-factor model (RMSEA $\leq$ .08 and CFI $\geq$ .984; Meerkerk, Van Den Eijnden, Vermulst, & Garretsen, 2009). Similar psychometric properties were reported for the French version of the CIUS (Cronbach alpha = .91, one-factor model with RMSEA = .08 and CFI = .920; Khazaal et al., 2012). The ability of the CIUS to identify Internet addiction was also compared to a clinical interview based on the DSM-5 criteria for Internet gaming disorder, which was adapted for Internet use (Besser et al., 2017); area under the curve was 0.968 and a cut-off score of 20 exhibited acceptable sensitivity (0.954) and specificity (0.942).

Gaming addiction. The seven items of the Game Addiction Scale (GAS: Lemmens, Valkenburg, & Peter, 2009; French and German versions: Khazaal et al., 2016) were used. Responses were registered on a five-point scale coded "never", "rarely", "sometimes", "often", and "very often". The GAS demonstrated high Cronbach alpha values (original version: .82; Lemmens, Valkenburg, & Peter, 2009; French version:

.86; German version: .85, Khazaal et al., 2016). A one-factor structure was reported for the French and German versions (RMSEA = .02 and .04, and TLI = .990 and .940, respectively; Khazaal et al., 2016).

Smartphone addiction. The ten items of the Smartphone Addiction Scale (SAS: Kwon et al., 2013; German version: Haug et al., 2015) were used to measure addictive use of smartphone. Responses were recorded on a six-point scale coded "strongly disagree", "disagree", "not completely agree", "somewhat agree", "agree", and "strongly agree". High Cronbach alpha values were reported for both the English (.97; Kwon et al., 2013) and German version of the scale (.91; Haug et al., 2015).

Cybersex addiction. The six items pertaining to online sexual compulsive behavior were selected from the Internet Sex Screening Test (ISST: Delmonico & Miller, 2003). Reponses were provided on a binary scale ("no" versus "yes"). The original English version of the ISST was demonstrated to have a high Cronbach alpha value (.86; Delmonico & Miller, 2003).

Some scales were not translated into French and/or German prior to conducting the present study (German: ISST, French: SAS and ISST). The translation process of these scales into French/German was as follows: (1) the C-SURF-team translated the scales from the original English into French/German; (2) persons bilingual in English and French/German translated the French/German version back into English; and (3) all discrepancies between the original English scales and their French/German translations were discussed until a consensus was reached and all matters were resolved.

Correspondence between scale items and addiction symptoms

To test the spectrum hypothesis and to have comparable symptoms for each technology-mediated behavior, the first and the last author linked each scale item with the following "classical" addiction symptoms: continued use, mood modification, loss of control, preoccupation, withdrawal, and consequences (see Supplementary Table A1 and Table 1). The theoretical frameworks for linking scale items with the specific symptoms were the DSM-5 Internet gaming disorder criteria (American Psychiatric Association, 2013) and the component model of addiction (Brown, 1993; Griffiths, 2005). When more than one scale item corresponded to the same symptom (in case of the CIUS, GAS, and SAS), a mean score of these items was used.

Statistical analysis

First, descriptive statistics were considered regarding the symptoms of the four technology-mediated behaviors. We also tested the reliability of each scale using confirmatory factor analyses with Maximum Likelihood Robust Estimation and robust Cronbach alphas. Furthermore, we computed an additional exploratory factor analysis with weighted least-squares estimation including the four conditions. These results are reported in the Supplementary Material. Second, we estimated the symptoms network. In this network, each symptom is a node and the relationships between nodes are edges. Edges represent conditional pairwise relationships, controlling for all other nodes of the network. We used a pairwise Markov Random Field model (the Gaussian graphical model) to estimate the symptoms network. In this model, edges are interpreted as partial correlation coefficients between nodes. Since the data were not normally distributed, we used a nonparanormal transformation (Liu, Han, Yuan, Lafferty, & Wasserman, 2012) before estimating the Gaussian graphical model. Our model also applied a penalty parameter based on sample size to shrink small edges to zero using the least

absolute shrinkage and selection operator (LASSO), which minimized the Extended Bayesian Information Criterion (Kossakowski & Cramer, 2017). Therefore, only sufficiently strong edges were retained in the network (Epskamp, Borsboom, & Fried, 2016). Next, we tested whether the four technology-mediated conditions formed distinct clusters in the network using a community detection analysis. Clusters of symptoms in the network were detected using the spinglass algorithm (Traag & Bruggeman, 2009).

In addition to the edges, the model allowed computing two indices of nodes' centrality. The first one is the strength of the node, which is defined as the sum of the absolute values of the edges connecting a node to all the other nodes. The second index is the betweenness of the node, which is defined as the number of the shortest paths between two nodes that go through the node in question. Thus, the strength of the node provides information on the extent to which a symptom is central to the network, whereas the betweenness of the node is crucial to detect bridge symptoms, i.e., symptoms that connect with other symptoms and in some case, across different conditions. Each symptom has its own strength and betweenness. Finally, we checked our model's accuracy, as recommended in the literature on network estimation (Epskamp et al., 2016). Details are reported in the Supplementary material.

As we focused on a subsample of participants engaged in all four activities, we also ran sensitivity analyses in participants engaged in three of the four activities to test the specificity of our findings. We computed networks for two additional subsamples: for participants using the Internet, having a smartphone, and playing video games (n=4,155) and for participants using the Internet, having a smartphone, and being involved in cybersex (n=3,816). We found distinct clusters of symptoms corresponding to each technology-mediated addictive behaviors, and similar between-condition

relationships as those presented in the Results section for participants engaged in all four activities.

We used R 3.3.2 for all analyses, with the package bootnet 1.0.0 to estimate the network (default = "huge") and for bootstrap estimations, the package qgraph 1.4.2 to visualize the network, and the algorithm "cluster_spinglass" from the igraph 1.0.1 package to detect community. The package lavaan 0.5-23.1097 was used to perform confirmatory factor analyses, the package coefficientalpha 0.5 was used to compute robust Cronbach alphas, and the package psych 1.7.8 was used for the exploratory factor analysis.

Ethics

The study procedures were carried out in accordance with the Declaration of Helsinki. The Lausanne University Medical School's Clinical Research Ethics Committee approved the study protocol (No. 15/07). All participants were informed about the study and provided informed consent.

RESULTS

Descriptive statistics are reported in Table 1. The symptoms having the highest means were "*continued use*" for Internet addiction (standardized mean = 2.61), "*loss of control*" for gaming addiction (standardized mean = 2.89), "*withdrawal*" for smartphone addiction (standardized mean = 0.36). and "*continued use*" and "*mood modification*" (standardized means = 0.81 and 0.83, respectively) for cybersex addiction.

The network of technology-mediated addiction symptoms is depicted in Figure 1. Overall, the symptoms of the four conditions (Internet addiction, smartphone

addiction, gaming addiction, and cybersex addiction) formed distinct clusters, as identified by the community detection analysis. Regarding the relationships between them, only the cluster of Internet addiction symptoms presented a substantial number of positive edges with other conditions: it had 11 positive edges with gaming addiction symptoms (30.6% of all possible edges between these disorders), 13 positive edges with smartphone addiction symptoms (43.3%), and 14 positive edges with cybersex addiction symptoms (38.9%). In contrast, there were only three positive edges between cybersex addiction and smartphone addiction symptoms (10.0%), one positive edge between cybersex addiction and gaming addiction symptoms (2.8%), and one positive edge between gaming addiction and smartphone addiction symptoms (2.8%). Interpretation of differences in edges' strength should be done cautiously because their confidence interval overlap (see Supplementary material).

Between-conditions edges often connected the same symptoms through Internet addiction symptoms. For example, Internet addiction *withdrawal* symptoms were connected with *withdrawal* symptoms of all other conditions (gaming addiction, smartphone addiction, and cybersex addiction) and adverse *consequences* of Internet addiction were also connected with adverse *consequences* of all other conditions. In contrast, there were no connections between *withdrawal* symptoms of other (non-Internet addiction) conditions (e.g., between gaming addiction and smartphone addiction). *Mood modification* symptoms of Internet addiction were connected with *mood modification* symptoms of gaming and cybersex addiction (note that this symptom was missing for smartphone addiction). Other symptoms of Internet addiction connected with the corresponding symptoms of only one or two other conditions: *continued use* of Internet addiction was connected with *continued use* of smartphone and cybersex addiction; *preoccupation* of Internet addiction was connected with

preoccupation of gaming and smartphone addiction; and *loss of control* of Internet addiction was connected with *loss of control* of smartphone addiction.

Centrality indices are reported in Table 1. The symptoms with the highest betweenness for most conditions were related to adverse *consequences* (86 for Internet addiction, 50 for gaming addiction, and 21 for smartphone addiction [second highest betweenness]) and *continued use* (83 for Internet addiction, 46 for cybersex addiction, and 29 for smartphone addiction). Adverse *consequences* also had the highest strength (1.28 for Internet addiction, 0.99 for gaming addiction, 1.12 for smartphone addiction, and 0.59 for cybersex addiction [second highest strength]). The stability of centrality indices was high and therefore, the results can be considered reliable (see Supplementary material for more details). No clear bridge symptom between the conditions was identified.

DISCUSSION

This study was an attempt to empirically test whether technology-mediated addictive behaviors could be conceptualized within a spectrum of related, yet distinct disorders, using the network model, a symptom-based approach that has recently received growing attention in the conceptualization of mental disorders (Borsboom, 2017; Schmittmann et al., 2013). Overall, the network analysis revealed four distinct clusters of symptoms, which correspond to the four technology-mediated problematic behaviors: Internet addiction, smartphone addiction, gaming addiction, and cybersex addiction.

The network analysis largely supports the spectrum hypothesis (Billieux, 2012; Starcevic & Billieux, 2017), implying that the construct of "technological addiction" as a discrete syndrome is untenable and further emphasizing the focus on the specific

technology-mediated behaviors. The same conclusion was reached through a conceptual analysis (Morahan-Martin, 2005; Shaffer et al., 2000) and indirectly arrived at by previous empirical reports showing that specific online activities exist as latent constructs (Pontes, 2017). Results of the network analysis clearly supported our first hypothesis, identifying gaming addiction and cybersex addiction as clusters distinct from each other and also distinct from Internet addiction and smartphone addiction. This may suggest that gaming addiction and cybersex addiction are relatively independent psychopathological entities, as suggested by previous researches (Pawlikowski, Nader, Burger, Stieger, & Brand, 2014).

Our second hypothesis that the umbrella constructs of Internet addiction and smartphone addiction did not represent specific disorders was not unequivocally supported because these conditions did constitute relatively distinct clusters. However, the network analysis showed that symptoms of Internet addiction were largely connected with the symptoms of other three addictive behaviors, whereas the reverse was not the case. Moreover, Internet addiction was connected with other conditions through the same symptoms, including *withdrawal* and adverse *consequences*. These findings are in line with the idea that the Internet itself is not addictive, but acts as a medium through which certain behaviors may become addictive (Shaffer et al., 2000; Starcevic & Billieux, 2017).

A finding that Internet addiction and smartphone addiction constituted relatively distinct, but also related clusters, calls for an explanation. Their relatedness could be due to the specific online behaviors that were associated with both Internet addiction and smartphone addiction. However, these behaviors were not assessed in this study. They may include addictive use of social networking sites (e.g., Facebook, Instagram), which have been increasingly studied (Andreassen et al., 2016; Carbonell

& Panova, 2017; Pontes, 2017) and may account, at least in part, for the relatively strong interconnections between Internet addiction and smartphone addiction (43.3% of positive edges). Other online activities that could also explain the links between Internet addiction and smartphone addiction include instant access messaging (e.g., WhatsApp), video sharing websites (e.g., Youtube), and streaming media websites (e.g., Netflix).

Distinctions between Internet addiction and smartphone addiction remain to be better understood, especially in light of their strong relationships in the network. These distinctions are unlikely to be related to online content because such content can be accessed by smartphones as well as various other devices. The way smartphones are used and misused may help account for the relative distinctness of smartphone addiction (De-Sola Gutiérrez, Rodríguez de Fonseca, & Rubio, 2016). For example, some individuals show strong attachment patterns vis-à-vis their smartphones as objects of such an importance that any physical separation from them is vehemently resisted (Kuss, Harkin, Kanjo, & Billieux, 2018). Moreover, use of smartphones can be dangerous in situations such as driving (Delgado, Wanner, & McDonald, 2016), and individuals with smartphone addiction may thus be at risk for traffic accidents. Another phenomenon that has been specifically linked to addictive mobile phone use is "phubbing", which denotes snubbing someone in a social setting by using one's phone instead of interacting with them (Chotpitayasunondh & Douglas, 2016).

Although the present study provides a preliminary support to the spectrum hypothesis, we acknowledge that its findings are based on the model of behavioral addiction that relies heavily on the conceptualization of substance addictions (e.g., Billieux, Schimmenti, Khazaal, Maurage, & Heeren, 2015; Kardefelt-Winther et al., 2017) and the corresponding assessment instruments. However, we were guided by

pragmatic considerations and the fact that alternative models of behavioral addiction are much less developed and have not led to an introduction of the relevant assessment tools. Advances in the field and further testing of the spectrum hypothesis can be expected from qualitative and phenomenological studies conducted in individuals who are highly engaged in technology-mediated behaviors (e.g., Colder Carras et al., 2018) and assessment instruments derived from such research.

Our study has several limitations. The most important limitation pertains to the psychometric properties of the instruments used in the study. Only some indices of reliability (e.g., internal consistency) and validity (e.g., convergent validity with similar self-reported scales and factor structure) have been reported, and not for all instruments. Other psychometric properties, such as test-retest reliability and indices of discriminant and construct validity, have not been reported. Therefore, reliability and validity of these measures are yet to be firmly established. Moreover, validity of the constructs that are purported to be measured by the instruments has been a subject of controversy. No "gold standard" assessment tools have been developed to date for various addictive behaviors, although some instruments have been tested against a clinical interview (CIUS against a clinical interview based on an adapted version based of the DSM-5 criteria for Internet gaming disorder: Besser et al., 2017; smartphone addiction against a clinical global impression for the presence of smartphone addiction: Lin et al., 2016). These considerations mandate a cautious use of instruments used in this study as screening tools for technology-mediated addictions.

Another limitation is that one of the scales used in the study (SAS) did not allow assessment of a relevant symptom (mood modification), whereas other scales had more than one item assessing certain symptoms. This might have limited our ability to identify the potential bridge symptoms, i.e., symptoms that could reflect common

etiological factors. Furthermore, items of the scale assessing cybersex addiction (ISST) only allowed dichotomous responses, in contrast to all the other measures used in the study. However, additional sensitivity analyses yielded similar results (see Supplementary material), thus supporting the findings of our network analysis. We also tested alternative models using binary scale responses (symptom considered as "present" or "absent", or symptom occurring "rarely" or "frequently"). We performed these analyses to ascertain whether the differences in scale responses (i.e., considering in the same network Likert-scale and binary scale responses) had an effect. The results were similar to those obtained from the original instruments and presented in the paper. However, further studies are required to test the spectrum hypothesis using the same scale responses in instruments assessing various conditions. Yet another measurement-related limitation in the present study was the use of self-report assessment tools, known to be influenced by responses biases (e.g., lack of introspection, social desirability). Future studies should rely on clinical interviews. This would contribute to ascertaining the validity of the underlying constructs, i.e., technology-mediated addictions.

In addition, our study only included males. Addictive patterns are different in females and males (Blais-Lecours, Vaillancourt-Morel, Sabourin, & Godbout, 2016; Greenberg, Lewis, & Dodd, 1999), and testing the spectrum hypothesis in a female cohort is needed to compare the findings with those of the present study. Finally, further studies of technology-mediated addictive behaviors using the network model should also consider the etiological or underlying variables (e.g., personality aspects such as impulsivity or self-esteem) that may account for the symptoms. This approach has recently been suggested in relation to the psychopathology-focused network research (Jones, Heeren, & McNally, 2017), but findings of the present study should not be used to make any inferences about the causal relationships between the symptoms.

Conclusion

Despite these limitations, the current study represents the first empirical investigation of the spectrum hypothesis using the network approach, capitalizes upon a large and representative community-based sample and has important theoretical and practical implications. Our findings highlight deficiencies of the umbrella constructs such as Internet addiction and provide further support to the focus on the specific Internet- and technology-mediated addictive behaviors. At a broader level, this study is one of the first testing the relevance of the network analysis in relation to addictive disorder symptomatology, as most of the studies conducted to date have examined depressive disorder, anxiety disorders, and post-traumatic stress disorder. Future studies should differentiate between the various facets of technology-mediated addictions instead of considering Internet addiction as a unitary syndrome and ascertain the associations between the specific online activities and constructs such as smartphone addiction and Internet addiction. Therapeutic interventions should also target problematic use of the Internet for the specific purposes (e.g., cybersex, online gaming, but also online gambling and use of social networking sites) rather than focusing on the broad and misleading notion of "Internet addiction."

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Table 1. Descriptive statistics for symptoms

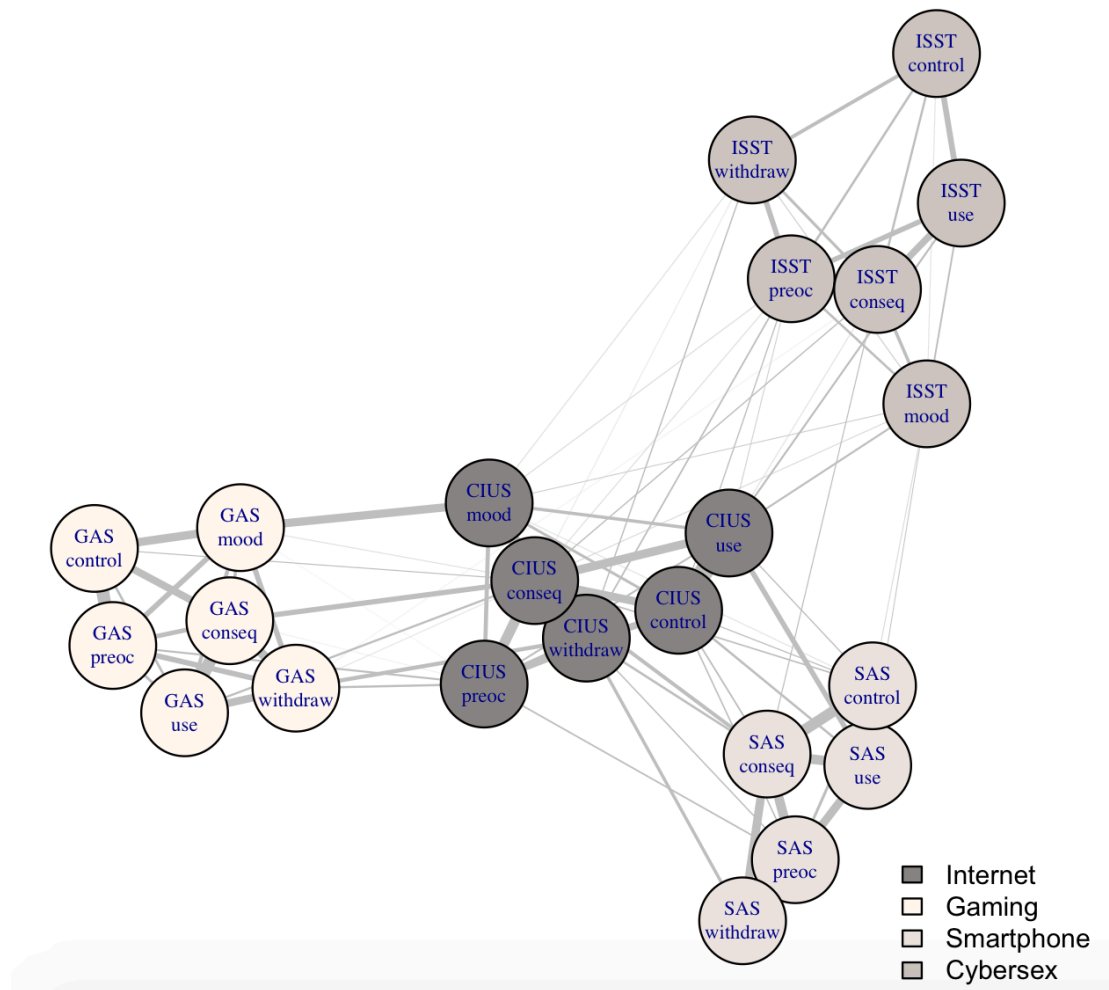| Conditions	Symptoms	Mean[1]	Strength[2]	Betweenness[3]
Internet addiction	Continued use	2.61	1.03	83
	Mood modification	1.23	0.87	27
	Loss of control	0.85	1.05	0
	Preoccupation	-1.24	0.77	0
	Withdrawal	-2.39	0.83	31
	Consequences	-1.05	1.28	86
Gaming addiction	Continued use	-1.14	0.74	0
	Mood modification	0.32	0.82	12
	Loss of control	2.89	0.76	15
	Preoccupation	0.58	0.78	0
	Withdrawal	-1.46	0.80	6
	Consequences	-1.20	0.99	50
Smartphone addiction	Continued use	0.25	0.83	29
	Mood modification	-	-	-
	Loss of control	-0.11	0.57	0
	Preoccupation	-0.21	0.88	8
	Withdrawal	0.36	0.64	6
	Consequences	-0.29	1.12	21
Cybersex addiction	Continued use	0.81	0.50	46
	Mood modification	0.83	0.30	0
	Loss of control	-0.89	0.34	0
	Preoccupation	-0.05	0.63	15
	Withdrawal	-0.83	0.34	0
	Consequences	0.14	0.59	2

CIUS: Compulsive Internet Use Scale, GAS: Gaming Addiction Scale, SAS: Smartphone Addiction

Scale, ISST: Internet Sex Screening Test.

[1] Means are standardized within each condition.

[2] Sum of the absolute values of the positive edges that connected a symptom to all the other symptoms.

[3] Number of the shortest paths connecting two symptoms that go through the symptom in question.

Figure 1. Symptom network of Internet addiction, gaming addiction, smartphone addiction, and cybersex addiction

CIUS: Compulsive Internet Use Scale, GAS: Gaming Addiction Scale, SAS: Smartphone Addiction Scale, ISST: Internet Sex Screening Test (see Table 1 for codes).

Thicker edges indicate a stronger relationship between symptoms.

Node colors are defined according to the community detection analysis.