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A longitudinal analysis of the network structure of internet gaming disorder and its associations with distress

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ABSTRACT

Concerns have arisen regarding the possible addictive nature of videogames, resulting in the provisional recognition of internet gaming disorder (IGD) as a behavioural addiction. However, this classification remains controversial, with arguments abounding regarding its structure and nature. Therefore, the present study examined the network structure/characteristics of nine IGD symptoms and three distress behaviours (i.e. depression, anxiety, and stress). A sample of 462 adults ($M_{age} = 30.8$. [$SD_{age} = 9.23$]; 320 males [69.3%]) were surveyed regarding their experience of IGD symptoms and distress behaviours using the Internet Gaming Disorder Short Form (IGDS9-SF) and the Depression, Anxiety and Stress Scale (DASS21) respectively. Subsequently, a network analysis was undertaken using R. IGD symptoms were found to be stable both cross-sectionally and over time. They were associated with, yet distinct, from, depression, anxiety, and stress. The most central symptoms within the network in terms of expected influence were tolerance, persistence, and stress. With a pathway between depression and mood modification providing the 'bridge' between IGD and Distress. The findings support the conceptualisation of IGD as a distinct construct (i.e. behavioural addiction). Further implications for the identification and treatment of IGD are discussed.

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KEYWORDS
Internet gaming disorder; behavioural addiction; psychological distress; network analysis; longitudinal

1. Introduction

Given the increasing proliferation of gaming into everyday life, concerns have arisen regarding the potential impact of gaming. A complex relationship exists between gaming and wellbeing, with both positive and negative outcomes. For some individuals, gaming can reduce stress (Desai et al. 2021; Pine et al. 2020), enhance cognition (Nuyens et al. 2019; Özçetin et al. 2019), aid in treating affective disorders (Griffiths, Kuss, and de Gortari 2020), encourage physical activity (Pallavicini, Pepe, and Mantovani 2022), alleviate PTSD symptoms (Butler et al. 2020), and foster social connections (Pallavicini, Pepe, and Mantovani 2022). Conversely, a minority of gamers exhibit problematic gaming behaviours, showing addiction-like symptoms (Pontes et al. 2022; Scerri et al. 2019; Stavropoulos, Gomez, and Motti-Stefanidi 2019), and neglecting real-world interactions in favour of gaming, leading to negative health outcomes (Byeon et al. 2022), impaired sleep (Wong et al. 2020), mood disruptions (Byeon et al. 2022; Ostinelli et al. 2021), cognitive decline (Nuyens et al. 2019; Özçetin et al. 2019), lowered educational and employment performance (Byeon et al. 2022; Marraudino et al. 2022), and increased risk of other addictions (Byeon et al. 2022; Marraudino et al. 2022). This has prompted the classification of problematic gaming as a behavioural addiction due to its significant adverse effects.

In 2013, the American Psychiatric Association (APA) recognised internet gaming disorder (IGD) as a provisional mental health disorder (APA and APA 2013). Characterised by a deep fixation on gaming, IGD comprises nine symptoms: (i) preoccupation with gaming, (ii) withdrawal symptoms in the absence of gaming, (iii) tolerance (increasing gaming needed for mood modification), (iv) inability to cease gaming despite attempts to stop, (v) loss of interest/participation in previously enjoyed activities aside from gaming, (vi) persistence in gaming even when adversely affecting the gamer's life, (vii) deception to others about their gaming habits, (viii) use of gaming to escape/manage negative moods, and (ix) gaming results in the loss of (educational/occupational) opportunities or relationships (APA and APA 2013). However, the APA's 'behavioural addiction' conceptualisation has faced criticisms

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regarding its accuracy, criticisms labelling it a premature pathologisation of ordinary behaviours (Pontes et al. 2019), lacking in diagnostic validity (Kardefelt-Winther et al. 2017; van Rooij et al., 2018), a potential secondary symptom of affective disorders such as depression or anxiety (Griffiths et al., 2014; Kardefelt-Winther et al. 2017). Moreover, the literature suggests that IGD is overly influenced by criteria for substance addictions (Kardefelt-Winther et al. 2017).

While the current literature highlights several convergent and divergent views on IGD's classification, there remains a lack of clarity on how individual IGD symptoms evolve and interrelate alongside psychological distress over time. Addressing this gap is essential for determining whether certain symptoms are primary drivers of problematic gaming or, conversely, if broader effective processes shape the manifestation and persistence of IGD. Moreover, internet gaming behaviours, and their psychological impacts may change over time, and in doing so offer insights into their nature (Schivinski et al. 2018). Therefore, longitudinal analysis serves as a pivotal tool, enabling an understanding of IGD's intricate structure and temporal stability. Unlike cross-sectional studies, a longitudinal approach allows for the examination of how interactions between IGD symptoms and associated comorbidities evolve, offering insights into causal pathways and mechanisms underpinning these relationships (Borsboom et al. 2021; Fried 2020).

Therefore, the present study addresses these knowledge gaps by clarifying the temporal nature of IGD. It examines the relative importance of each symptom and the relationships of these symptoms with well-researched comorbidities, which are theoretically and empirically associated with gaming disorder (i.e. depression, anxiety, and stress) (Blanchard et al. 2023; Montag et al. 2019). In doing so, it elucidates whether IGD can be considered a unique disorder or is better understood as a secondary symptom of broader affective conditions.

1.1. IGD and longitudinal network analysis

One method that could investigate the aforementioned areas, but which has never been attempted with IGD, is longitudinal network analysis (LNA; Blanchard et al. 2023). LNA is an exploratory approach which allows unique relationships between variables to be observed with standard liner modelling. In line with the network approach to psychopathology (Borsboom and Cramer 2013), this study conceptualises IGD as an emergent phenomenon arising from dynamic interactions among its symptoms, thereby providing the theoretical rationale for employing LNA to examine these processes. In this sense, LNA explores the patterns of the data and creates a graphical 'network' of the relationships between these variables and testing the network changes over time. Therefore, allowing for the examination of symptom centrality (relative influence on symptoms for each symptom) rather than symptom severity, it can be understood which symptoms have the largest influence on the others, and consequently which should be targeted for intervention, or which define the disorder (Mullarkey, Marchetti, and Beevers 2019). The relationships between distinct clusters of symptoms (i.e. subnetworks) can be examined, giving an indication as to which symptoms bind distinct disorders together. Additionally, by testing successive networks (at different timepoints) against one another, LNA can identify any significant differences between them in terms of basic network structure and centrality (Tullett-Prado et al. 2023).

In the present study, LNA's value lies in its ability to verify the validity of models, like IGD's nine symptoms (APA and APA 2013), by examining symptom relationships and cluster formations. If symptoms do not correlate or form distinct clusters, or if they align more closely with symptoms of another disorder, it may indicate that there are an incorrect number of symptoms or that IGD is a secondary symptom of another condition (Elliott, Jones, and Schmidt 2020). Moreover, evaluating the stability of these symptom networks over time with LNA can show whether IGD represents a transient or persistent condition, and observe any changes that could inform the understanding of IGD and its underlying risk factors (Beard et al. 2016).

Despite the recognised potential of network analysis, no study has applied LNA to IGD. Six cross-sectional studies have however investigated the IGD symptom model, primarily within Chinese populations, examining the network structure of IGD and its associations with psychological factors and comorbidities (Gomez et al. 2022; Li et al. 2023; Liu et al. 2022; Tang, Ebrahimi, and Cheng 2023; Yang et al. 2023; Yuan et al. 2022). Liu et al. (2022) examined the IGD network in isolation, focusing on determining the basic structure of the IGD network. Whereas Gomez et al. (2022) and Yuan et al. (2022) furthered this foundation by adding motivation types and coping styles respectively to the IGD network, examining both the basic structure of IGD and its association with these psychological factors. Tang, Ebrahimi, and Cheng (2023) examined the centrality of the 9 IGD symptoms in a network that included a number of mental health risk factors and measures of wellbeing. Whereas Yang et al. (2023) and Li et al. (2023) both examined networks made up of IGD symptoms alongside a comorbid disorders

symptoms, Anxiety and PTSD respectively, assessing both the network structure of IGD, and the ways in which IGD symptoms interacted with outside networks of symptoms.

However, the results of these studies offer very little in the way of a holistic understanding of the IGD network and its associations with comorbidities. Yang et al. (2023) was very selectively focused on the bridges between IGD and Anxiety symptoms, identifying escapism as the symptom via which IGD and anxiety interacted. And while the other studies would examine both the network structure of IGD and its bridges with comorbidities where possible, the produced results often varied. Li et al. (2023) and Tang, Ebrahimi, and Cheng (2023) both found withdrawal to be the most central symptom. However, Yuan et al. (2022), Liu et al. (2022) and Gomez et al. (2022) found preoccupation, negative life consequences and the inability to stop the most central symptoms respectively. Results were equally varied in terms of edge strengths, with no agreement between these published papers on which edges may have been the strongest. Though escapism/mood modification consistently served as the bridge between IGD and affective disorders in studies that examined this interaction (Li et al. 2023; Tang, Ebrahimi, and Cheng 2023; Yang et al. 2023).

The sheer variation in these results makes it difficult to conclusive read into the nature of IGD based off these few results, a problem exacerbated by a number of statistical oversights and methodological restrictions inherit in these studies. Three of these studies focused solely on young Chinese students (Li et al. 2023; Yang et al. 2023; Yuan et al. 2022), and some lacked stability analyses, relied on visual inspections of the network without conducting statistical significance tests, or applied such tests inconsistently (Gomez et al. 2022; Liu et al. 2022; Yang et al. 2023; Yuan et al. 2022). Only two studies have employed both stability and difference testing comprehensively (Li et al. 2023; Tang, Ebrahimi, and Cheng 2023).

Given these research gaps, there is a need for studies that (i) apply rigorous statistical processes to examine the IGD symptom network, (ii) investigate these networks longitudinally, (iii) include diverse sample populations, and (iv) integrate risk factors or outcomes of interest to elucidate the impact of individual symptoms on well-being and assess IGD's status as a secondary symptom. The present study addressed these needs by employing LNA to examine IGD symptoms alongside a related covariate condition, to further validate the IGD construct and identify key symptoms and pathways for prevention, identification, and treatment.

1.2. Internet gaming disorder and psychological distress

Given criticisms that IGD may represent a secondary symptom (Griffiths et al., 2014; Kardefelt-Winther et al. 2017), and the many comorbidities related to IGD (Stavropoulos, Gomez, and Motti-Stefanidi 2019; Byeon et al. 2022), investigation of the structure of IGD and its relationships with separate comorbidities is essential. Psychological distress is one such comorbidity.

Characterised by depression, anxiety, and stress, psychological distress is a broad state of emotional suffering (Drapeau, Marchand, and Beaulieu-Prévost 2012). Each of these subtypes reflects a distinct aspect of mental health impairment. Depression typically involves persistent low mood, hopelessness, and a diminished interest or pleasure in activities, often accompanied by cognitive impairments and fatigue. Anxiety, in contrast, is marked by excessive worry, nervousness, and physiological symptoms such as increased heart rate or restlessness, reflecting a heightened sensitivity to perceived threats. Stress, while often overlapping with anxiety, specifically relates to a sense of being overwhelmed or unable to cope with external pressures, which can be acute or chronic in nature. As distress is commonly used as a general indicator of mental health (Drapeau, Marchand, and Beaulieu-Prévost 2012), investigating the ways in which IGD interacts with distress provides a potential baseline understanding for how mental health is affected by the separate symptoms of IGD.

Numerous studies and reviews have found IGD symptom severity to be positively associated with depression, anxiety, and stress (González-Bueso et al. 2018; Marraudino et al. 2022; Montag et al. 2019; Ostinelli et al. 2021; Wong et al. 2020). However, this relationship is not necessarily the product of gaming itself, with recent research suggesting it exists independent of game time (Burkauskas et al. 2022; Pontes et al. 2022), and that gaming itself can reduce distress in certain cases (Imperato et al. 2023). Therefore, indicating that a problematic mode of gameplay characterised by the symptoms of IGD, is what influences distress. This relationship appears bidirectional, with stressful circumstances, inherit traits or improper coping styles, and declines in mental health increasing the severity of IGD symptom experience as those effected seek to cope using gaming to compensate for basic psychological needs (Imperato et al. 2023; Marraudino et al. 2022; Ostinelli et al. 2021; Wang et al. 2022). Subsequently, the same IGD symptoms contributing to behavioural disturbances and poor

productivity prompt further stresses and negative feelings (González-Bueso et al. 2018; Wong et al. 2020; Ostinelli et al. 2021; Marraudino et al. 2022). However, research has yet to explore the disparate effects of individual IGD symptoms on psychological distress, or how they evolve over time.

Given prior criticisms that IGD may represent a secondary symptom (Kardefelt-Winther et al. 2017), and the strong body of research associating IGD and psychological distress as well as psychological distress subtypes with eachother (González-Bueso et al. 2018; Marraudino et al. 2022; Ostinelli et al. 2021; Wong et al. 2020). There are multiple purposes a simultaneous examination of the nine IGD symptoms and three distress subtypes would serve. Firstly, such an examination would allow for both the satisfaction of the above listed research gaps and contribute to the debate regarding IGD's potential status as a secondary symptom. Moreover, it would do so with a high degree of rigour. Depression, anxiety and stress, as components of distress, all display significant relationships with IGD and eachother, thus assessing these all together allows for a more complex and clear examination that captures direct and indirect pathways between the distress subtypes and IGD. Furthermore, in real world addiction scenarios, depression, anxiety and stress don't often present in isolation, but rather tend to form complex loops or comorbid presentations (McNicol and Thorsteinsson 2017; Pontes, Taylor, and Stavropoulos 2018). Thus, examining the network associations of all three subtypes with IGD symptoms is more likely to accurately present how addiction symptoms interact with distress in real life. In particular, by examining the bridges between IGD symptoms and distress, insights can be gleaned as to how these two conditions affect each other and the routes by which they do so, aiding in potential prevention/treatment of comorbid distress and IGD.

1.3. The present study

Given the need both for further validation/clarification of IGD symptoms, and to longitudinally examine how IGD interacts bidirectionally with psychological distress, the present study employed LNA among a sample of English-speaking gamers to (i) examine the network structure of the nine IGD symptoms and three distress subtypes (depression, anxiety, and stress); (ii) examine the specific interactions between the subnetworks of IGD and distress; and (iii) compare the differences between the network of IGD symptoms and psychological distress subtypes at two timepoints separated by twelve months.

Advancing current understandings of IGD in this way may help clarify ongoing debates about the nature of IGD (Sun and Zhang 2020). Furthermore, in a more practical sense, a more precise grasp of IGD's properties and the individual importance/influence of each symptom will help supports the development of targeted assessment, treatment, and prevention strategies (Sun and Zhang 2020; Pellegrino, Stasi, and Bhatiasevi 2022).

2. Method

2.1. Participants

English-speaking gamers aged 18–64 years were assessed across two timepoints (T1 and T2), 12 months apart: 968 at T1 (M_{age} = 29.5 years [SD_{age} = 9.36]; 622 males [64.3%]), and 462 at T2 [M_{age} = 30.8 years [SD_{age} = 9.23]; 320 males [69.3%]). To accurately estimate the edge weights of a network with a high degree of accuracy and specificity, the sample size exceeded the recommended minimum size of 350 for sparse networks (Constantin and Cramer 2020). Moreover, a sample error of 4.56% was identified, satisfying Hill (1998) recommendation that sampling error is acceptable up to 10%. While there was significant participant attrition from T1 to T2 (53.27%), a missing completely at random (MCARS) test of the attrition found no significant associations found among individuals who dropped out, $\chi^2_{(64)} = 83.10$, $p = .0543$. Thus indicating that time point 2 was still a random sample. For participants' sociodemographic information, see Table 1.

2.2. Measures

Aside from collecting socio-demographic information (ethnicity, sex, sexuality, employment status, level of education), the following instruments were employed:

2.2.1. Internet Gaming Disorder Scale-Short Form (IGDS9-SF; Pontes & Griffiths, 2015)

The IGDS9-SF measures the severity of IGD symptom experience via nine items asking about the rate at which the symptoms are experienced (e.g. '*Do you feel more irritability, anxiety or even sadness when you try to either reduce or stop your gaming activity?*'). Items are rated on a five-point scale ranging from 1 (*never*) to 5 (*very often*). Higher scores indicate greater risk of IGD. In the present study, Cronbach's α = .88 and McDonalds ω = .89 (T1); α = .87 and ω = .88 (T2). This measure can be found in the appendix as 'Appendix A'.

2.2.2. Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995)

The DASS assesses psychological distress, comprising 21 items divided into three subscales (depression, anxiety,

Table 1. Socio-demographic and characteristics of participants.

Sociodemographic variables		Male		Female		Non-binary /Other	
		n	%	*n*	%	*n*	%
White /Caucasian		321	69.5	132	28.6	9	1.9
Ethnicity	Black/African	202	43.7	77	16.7	7	1.5
	American	17	4.7	12	2.6	1	0.2
	Asian	66	14.3	26	5.6	0	0.0
	Hispanic/Latino	15	3.2	4	0.9	0	0.0
	Other (Aboriginal, Indian, Pacific Islander, Middle eastern, Mixed, other)	21	5.8	13	2.8	1	.2
Sexual Orientation	Heterosexual /Straight	267	57.8	92	19.9	1	.2
	Homosexual/ Gay	20	4.3	7	1.5	1	.2
	Bisexual	29	8.0	25	5.4	4	.9
	Other	5	1.1	8	1.7	3	.6
Employment status	Full Time	144	31.2	43	9.3	1	.2
	Part Time/ Casual	44	12.2	20	4.3	1	.2
	Self Employed	48	10.4	17	3.7	2	.4
	Unemployed	68	18.8	33	7.1	3	.6
	Student/Other	53	11.5	32	6.9	4	.9
Level of Education	Elementary /Middle school	4	0.9	0	0.0	0	.0
	High School or equivalent	76	21.0	31	6.7	5	1.1
	Vocational/ Technical School/Tafe	31	6.7	14	3.0	0	.0
	Some Tertiary Education	55	11.9	26	5.6	2	.4
	Bachelor's Degree (3 years)	68	18.8	27	5.8	1	.2
	Honor's Degree or Equivalent (4 years)	46	10.0	15	3.2	1	.2
	Master's Degree (MS)	25	5.4	9	1.9	0	.0
	Doctoral Degree (PhD)	3	.8	2	.4	0	.0
	Other/Prefer not to say	13	2.8	8	1.7	0	.0

stress) of seven items. Items inquire into the degree to which certain distress related statements apply to the respondents (e.g. '*I found it hard to wind down*'), rating responses on a four-point scale ranging from 0 (*did not apply*) to 3 (*applied most of the time*). Higher scores indicate greater psychological distress. In the present study for depression, anxiety and stress respectively: Cronbach's $\alpha = .94$, $\alpha = .85$ and $\alpha = .88$, and McDonalds $\omega = .94$, $\omega = .86$, $\omega = .88$ (T1); Cronbach $\alpha = .93$, $\alpha = .85$ and $\alpha = .86$, and McDonalds $\omega = .93$, $\omega = .86$, $\omega = .86$ (T2). This measure can be found in the appendix as 'Appendix B'.

2.3. Procedure

Approval was received from the Victoria University Human Research Ethics Committee (HRE20-169) for a study assessing various addictive behaviours and common risk factors/comorbidities that may be contributing to them, and data for both time points was collected between 2020 and 2022. At T1 data were collected using an online survey distributed via social media (e.g. *Facebook, Instagram,* and *Twitter*), digital forums (e.g. *Reddit*) and the university learning management system. This link first took potential participants to the Plain Language Information Statement (PLIS), which provided the study requirements, guaranteed anonymity, and their withdrawal rights (Clark 2006). Participants were asked to voluntarily provide their email address for prospective data collection waves, and to digitally sign the consent form. Twelve months later (August 2021–August 2022), follow-up emails with an identical survey were sent out to those interested in participating in the second wave (T2). From the gathered dataset, data relating to IGD and distress were employed for this study.

2.4. Statistical analyses

A network model involving the nine IGD symptoms and three DASS subscales was estimated for the two time-points using the *qgraph* and *networktools* packages in *R* (Epskamp et al. 2012; Jones and Jones 2018). Network models involve the use of zero order correlations (i.e. no control for the influence of any other variables) combined with a graphical Least Absolute Shrinkage and Selection Operator algorithm (g-lasso; Tibshirani 1996) to identify the correlations/connections between a number of variables and shrink any partial correlations to zero. In the process of generating these correlations, pairwise deletion is employed to exclude any missing datapoints the analysis (Christensen 2018). These accumulated correlations between the selected variables create a network of nodes and edges, where nodes represent considered variables/observations and edges the relationships between them (Borgatti 2005). Stronger relationships/edges are represented by thicker, darker lines with the distance between variables/nodes indicating their relevance/association (closer = higher relevance).

2.5. Cross-sectional network stability

Once network models were estimated across timepoints, their respective centrality, edge weights and bridge centrality values were assessed (Levinson et al. 2018; Opsahl, Agneessens, and Skvoretz 2010). Briefly, edge weights represent a quantitative indication of the strength of each connection showed in the network. Centrality refers to the 'importance' or 'influence' of a node on the network. There are several centrality measures used in network analysis. The present study employed expected influence (the sum of the magnitudes of edges leading to/from a node) due to its accounting for negative influences/edges and general high level of stability in generated networks (Elliott, Jones, and Schmidt 2020; Levinson et al. 2018; Robinaugh, Millner, and McNally 2016). Finally, bridge centrality values represent the 'importance' of any given node in terms of how they serve as connections between distinct clusters in the network. These were measured using the same indices as for standard network centrality, and for the same reasons outlined above, expected influence was employed (Elliott, Jones, and Schmidt 2019; Jones, Ma, and McNally 2021; Levinson et al. 2018).

However, before these values can be estimated, the stability/accuracy of these indices at each timepoint must be calculated using the *botnet* package via case dropping bootstrapping and represented with calculated stability coefficients. Stability coefficients denote the correlation between indices results when progressively more cases are dropped. Correlations of > .5 are considered sufficient (Epskamp, Borsboom, and Fried 2018). Further stability coefficients are generated for the edges of the network, with the same rules regarding the ranges within which a stability coefficient is considered sufficient applying (Epskamp, Borsboom, and Fried 2018).

2.6. Cross-sectional network characteristics

Once network stability was confirmed, the *networktools* package estimated the centrality, edge weight, and bridge indices, and graphs the network. Judgements regarding differences in centrality across nodes or in the strength of edges were made using the centrality/edge difference tests via the *bootnet* package (Epskamp, Borsboom, and Fried 2018). These were used to construct a confidence interval between the two results, deeming the difference to be non-significant if the points were within it.

2.7. Stability of the network across time

To compare network stability across timepoints, the *NetworkComparisonTest* package was employed to estimate their variance in terms of the global network structure, the global strength of the nodes, edges, and centrality. Each test was carried out in succession, with the latter two only being conducted by the package if the first two detected significant differences (van Borkulo et al. 2015). A *p*-value less than .05 was used to indicate significant differences.

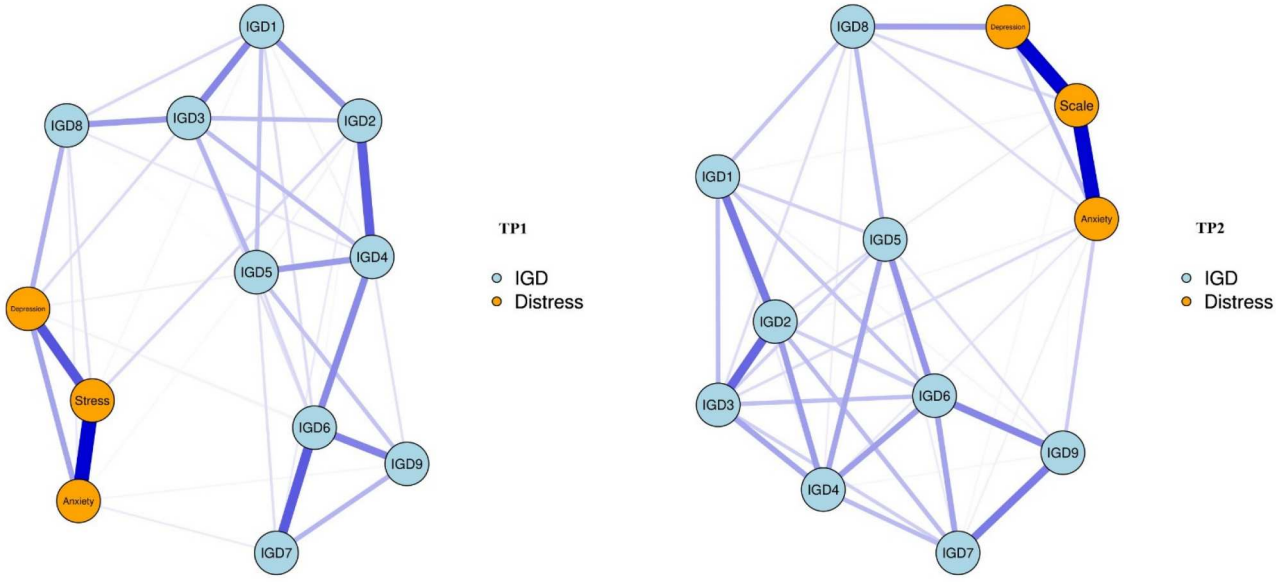

Figure 1. Network of the IGD symptoms and DASS subscales at T1 and T2.

Table 2. Descriptive statistics for time point 1.

	IGD1	IGD2	IGD3	IGD4	IGD5	IGD6	IGD7	IGD8	IGD9	Depression	Anxiety	Stress
N	460	460	460	459	460	458	460	460	459	452	459	455
Missing	2	2	2	3	2	4	2	2	3	10	3	7
Mean	2.78	1.89	2.15	1.73	2.11	1.63	1.33	3.15	1.33	7.94	4.25	6.81
Median	3.00	2.00	2.00	1	2.00	1.00	1.00	3.00	1	7.00	3	6
Standard deviation	1.19	1.05	1.12	1.02	1.17	1.06	0.805	1.24	0.781	5.94	4.07	4.72
Minimum	1	1	1	1	1	1	1	1	1	0	0	0
Maximum	5	5	5	5	5	5	5	5	5	21	21	21

Table 3. Descriptive statistics for time point 2.

	IGD1	IGD2	IGD3	IGD4	IGD5	IGD6	IGD7	IGD8	IGD9	Depression	Anxiety	Stress
N	461	461	461	459	460	460	459	460	460	293	292	292
Missing	1	1	1	3	2	2	3	2	2	169	170	170
Mean	2.52	1.82	1.85	1.65	1.96	1.64	1.32	3.14	1.30	7.18	4.23	6.41
Median	2	2	2	1	2.00	1.00	1	3.00	1.00	6	3.00	6.00
Standard deviation	1.07	0.974	1.04	0.942	1.06	1.00	0.756	1.16	0.723	6.10	4.22	4.72
Minimum	1	1	1	1	1	1	1	1	1	0	0	0
Maximum	5	5	5	5	5	5	5	5	5	21	19	21

Table 4. Edge strengths across the network at T1.

	IGD1	IGD2	IGD3	IGD4	IGD5	IGD6	IGD7	IGD8	IGD9	Depression	Anxiety	Stress
IGD1	0	0.218	0.254	0.025	0.132	0.071	0	0.081	0	0	0	−0.015
IGD2	0.218	0	0.141	0.347	0.024	0.008	0.039	0	0	0	0	0.082
IGD3	0.254	0.141	0	0.140	0.156	0.065	0	0.212	0	0.073	0	0
IGD4	0.025	0.347	0.140	0	0.214	0.247	0.088	0.047	0.06	0	0	0
IGD5	0.132	0.024	0.156	0.214	0	0.08	0.065	0.002	0.127	0.026	0.007	0
IGD6	0.071	0.008	0.065	0.247	0.08	0	0.351	0	0.266	0.022	0	0
IGD7	0	0.039	0	0.088	0.065	0.351	0	0	0.156	0	0.035	0
IGD8	0.081	0	0.212	0.047	0.002	0	0	0	0	0.170	0.043	0.063
IGD9	0	0	0	0.06	0.127	0.266	0.156	0	0	0.021	0.018	0
Depression	0	0	0.073	0	0.026	0.022	0	0.17	0.021	0	0.191	0.361
Anxiety	0	0	0	0	0.007	0	0.035	0.043	0.018	0.191	0	0.548
Stress	−0.015	0.082	0	0	0	0	0	0.063	0	0.361	0.548	0

Table 5. Edge strengths across the network at T2.

	IGD1	IGD2	IGD3	IGD4	IGD5	IGD6	IGD7	IGD8	IGD9	Depression	Anxiety	Scale
IGD1	0	0.246	0.122	0.035	0.08	0.103	0	0.105	0.016	0	0	−0.013
IGD2	0.246	0	0.277	0.178	0.063	0.078	0.119	0	0.087	0	0.01	0
IGD3	0.122	0.277	0	0.161	0.082	0.115	0.087	0.059	0.000	0	0.063	0
IGD4	0.035	0.178	0.161	0	0.163	0.173	0.123	0.027	0.012	0	0.039	0
IGD5	0.080	0.063	0.082	0.163	0	0.191	0.031	0.124	0.061	0	0	0.025
IGD6	0.103	0.078	0.115	0.173	0.191	0	0.164	0	0.217	0	0	0
IGD7	0	0.119	0.087	0.123	0.031	0.164	0	0	0.237	0	0.023	0.013
IGD8	0.105	0	0.059	0.027	0.124	0	0	0	0	0.174	0.062	0.067
IGD9	0.016	0.087	0	0.012	0.061	0.217	0.237	0	0	0	0.093	−0.005
Depression	0	0	0	0	0	0	0	0.174	0	0	0.119	0.467
Anxiety	0	0.01	0.063	0.039	0	0	0.023	0.062	0.093	0.119	0	0.464
Scale	−0.013	0	0	0	0.025	0	0.013	0.067	−0.005	0.467	0.464	0

3. Results

3.1. Network generation and stability

Network analyses generated two networks, one for each timepoint, showed in Figure 1. Descriptive statistics for all employed variables are displayed in Tables 2 and 3 for time points 1&2 respectively. Edge strengths for T1 are shown in Table 4, and T2 in Table 5. Table 6 shows the calculated centrality statistics (expected influence) for both timepoints across all IGD symptoms and distress subtypes. To enhance readability, only the most relevant results are discussed here. The detailed results are shown in Tables 4–6 and Figures 2–9.

Both networks showed excellent cross-sectional stability in terms of their basic structure. In general, stability coefficients of .25 and higher are deemed acceptable for use, with coefficients of .5 or higher deemed to have 'good' stability (Epskamp, Borsboom, and Fried 2018).

Table 6. Centrality statistics across all nodes at T1 and T2.

Node	T1 expected influence	T2 expected influence
IGD1	−0.623	1.387
IGD2	−0.104	0.752
IGD3	0.924	0.365
IGD4	1.636	−0.249
IGD5	−0.253	1.267
IGD6	1.309	−0.405
IGD7	−0.804	−1.636
IGD8	−1.457	−0.954
IGD9	−1.283	−0.655
Depression	−0.066	0.129
Anxiety	−0.193	1.122
Stress	0.915	1.387

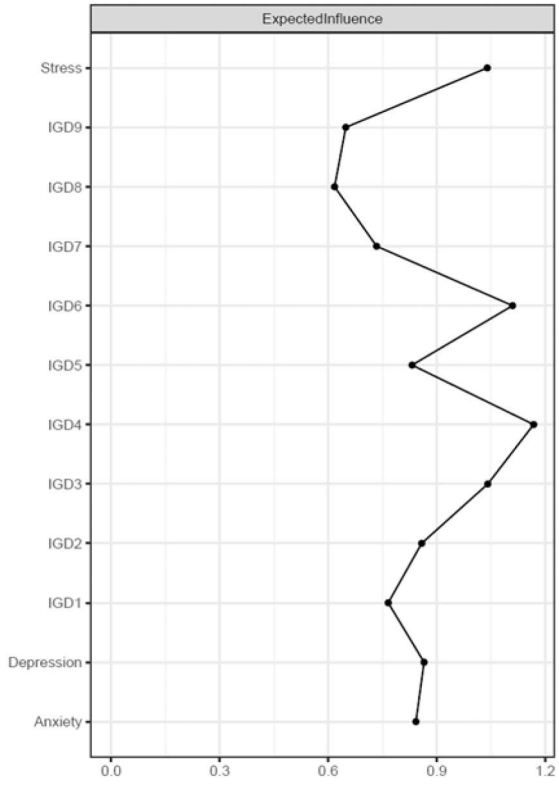

Figure 2. Expected Influence across all nodes at time point 1.

These values were well exceeded by stability coefficients at T1 (edge stability coefficient = .75, expected influence centrality stability coefficient = .67, bridge expected influence centrality stability coefficient = .67) and T2 (edge stability coefficient = .75, expected influence centrality stability coefficient = .60, bridge expected influence centrality stability coefficient = .67). With all necessary structural measure's stability within acceptable limits, further analysis of the network structures and network comparison was undertaken.

3.2. Network characteristics at T1

The expected influence centrality of all nodes at T1, and centrality difference tests showing which nodes had significantly greater expected influence than the others are shown in Figures 2 and 3 respectively. In terms of the overall importance of each node, the IGD symptoms of inability to stop, persistence, and tolerance (IGD4, IGD6, and IGD3) had the highest centrality, forming a plateau of nodes with significantly greater centrality than all others except for stress. Stress showed expected influence centrality significantly greater than any distress subtype, and the majority of IGD symptoms. Escapism/mood modification (IGD8) showed the least centrality.

Figure 4 shows edge difference tests regarding the significance of differences in the strength of individual connection edges. These indicated that the edges between (i) anxiety and stress, (ii) depression, and stress, (iii) IGD symptoms of persistence and deception (IGD6, IGD7), and (iv) withdrawal and the inability to stop (IGD2, IGD4) were significantly stronger than those between almost all other nodes. Forming a second plateau beneath these in which edges were significantly stronger than most other edges were those between (i) persistence and negative life consequences (IGD6, IGD9), (ii) preoccupation and tolerance (IGD1, IGD3), (iii) inability to stop and persistence (IGD4. IGD6) and (iv) preoccupation and withdrawals (IGD1, IGD2). The only edge with any kind of strength between the subnetworks of IGD symptoms and distress subtypes was that between escapism/mood modification (IGD8) and depression.

3.3. Bridge characteristics at T1

Figure 5 shows the bridge expected influence between the nodes of the IGD and distress subnetworks at T1. With regards to the IGD symptoms, only escapism/mood modification showed a markedly high level of bridge expected influence. It was also found that (i) inability to stop had no impact on the distress subnetwork, (ii) preoccupation had a negative relationship with the distress subnetwork, and (iii) rises in preoccupation were associated with a decline in distress. In terms of distress, only depression showed a high bridge expected influence.

3.4. Network characteristics at T2

Figures 6 and 7 show the expected influence centrality of all nodes at T2 and centrality difference tests regarding which nodes had significantly greater expected influence than the others respectively. In terms of the overall importance of each node, the IGD symptoms of withdrawal and persistence (IGD2, IGD6) were significantly stronger than many other nodes in the network, with tolerance (IGD3) and stress forming a lower, slightly less influential plateau of influence over the other

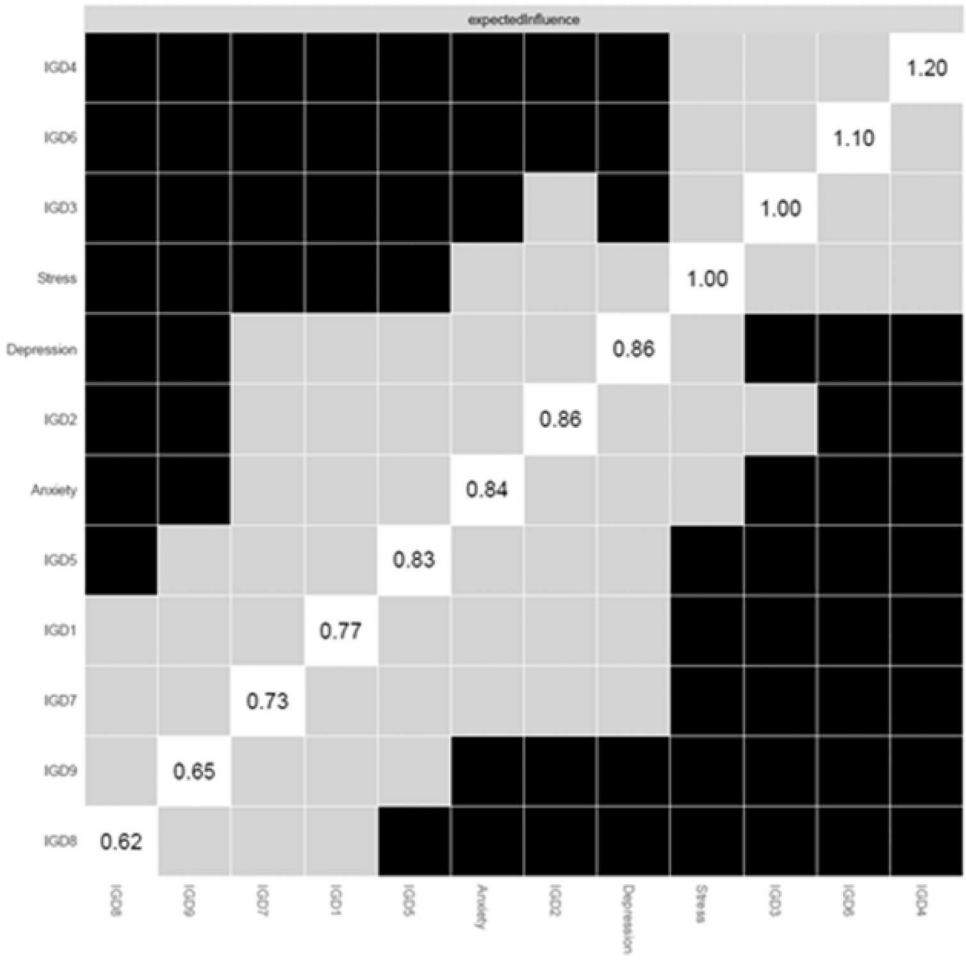

Figure 3. Centrality difference tests regarding the Expected Influence of nodes at time point 1.

nodes which had the highest centrality, with the exception of stress. Escapism/mood modification (IGD8) showed the least centrality.

Figure 8 shows significance tests regarding differences in the strength of individual edges at T2. These indicated that the edges between anxiety and stress, and between depression and stress were significantly stronger than any other edges in the network. Moreover, the edges between the IGD symptoms of withdrawal and tolerance (IGD2, IGD3) and between preoccupation and withdrawal (IGD1, IGD2) formed a second plateau of strength being significantly stronger than most edges in the network. Finally, the edges between deception and negative life outcomes (IGD7, IGD9), persistence and negative life consequences (IGD6, IGD9), loss of interest and persistence (IGD5, IGD6), withdrawal and the inability to stop (IGD2, IGD4), and between escapism/mood modification (IGD8) and depression formed a third, lower plateau of edges, that were significantly greater in strength than approximately a quarter of the edges in the network.

3.5. Bridge characteristics at T2

Figure 9 shows the bridge expected influence between the nodes of the IGD and distress subnetworks at T2. With regards to the IGD symptoms, again, only escapism/mood modification showed a markedly high level of bridge expected influence. With persistence having no impact on the distress subnetwork, and preoccupation having a negative relationship with the distress subnetwork, rises in preoccupation were associated with a decline in distress. In terms of distress, anxiety and depression showed high bridge expected influence.

3.6. Longitudinal network comparison

Finally, a network invariance test between the two networks showed no significant differences between the network at T1 and T2 in terms of global network invariance ($p = .27$) and global strength invariance ($p = .52$). Therefore, no significant differences were detected between the two time-points, indicating stability in the network over time.

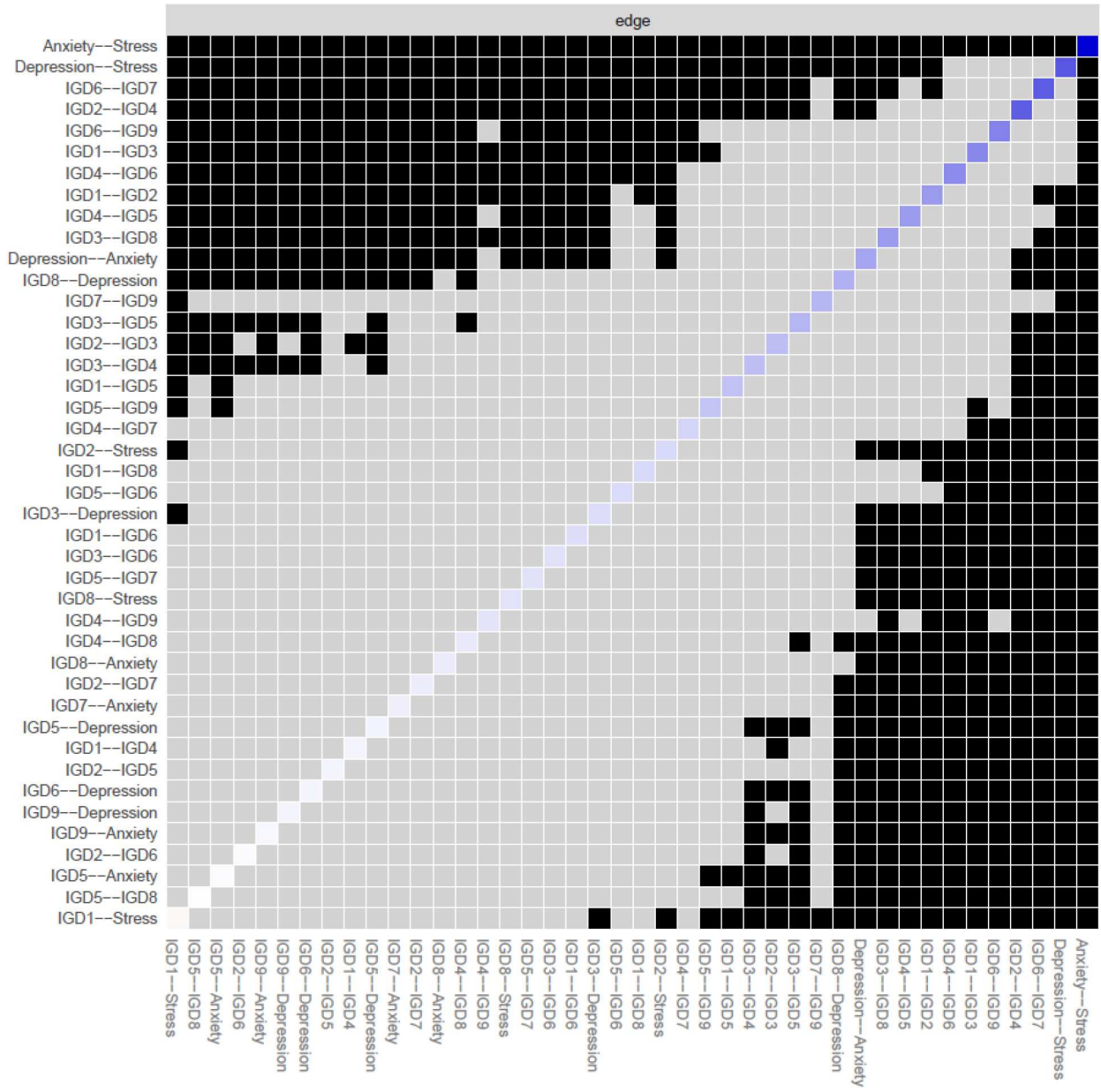

Figure 4. Edge difference tests regarding the edges between nodes at time point 1.

4. Discussion

Through the innovative use of longitudinal network analysis (LNA), the present study longitudinally examined the relationships between the IGD symptoms and the three psychological distress subtypes by comparing the differences between the network of IGD symptoms and psychological distress subtypes at two timepoints separated by twelve months. Two stable networks were identified at both timepoints, with no significant differences found between them, indicating the network was stable over time. Therefore, only the similarities between these networks are considered below.

Regarding network characteristics, tolerance and persistence were the IGD symptoms with the greatest centrality, and stress was the distress subtype with the greatest centrality. The associations within the IGD and distress subnetworks were significantly greater than those between the two, indicating a separation, with the edges joining stress with anxiety, and depression presenting significantly stronger than all other associations in the network. Among the IGD symptoms, the strongest associations were between withdrawal and the inability to stop (IGD2, IGD4), persistence and negative life consequences (IGD6, IGD9), and preoccupation and withdrawal (IGD1, IGD2). The IGD and distress subnetworks were associated via the bridging symptom of escapism/mood modification (IGD8) and distress subtype depression. These findings are therefore discussed.

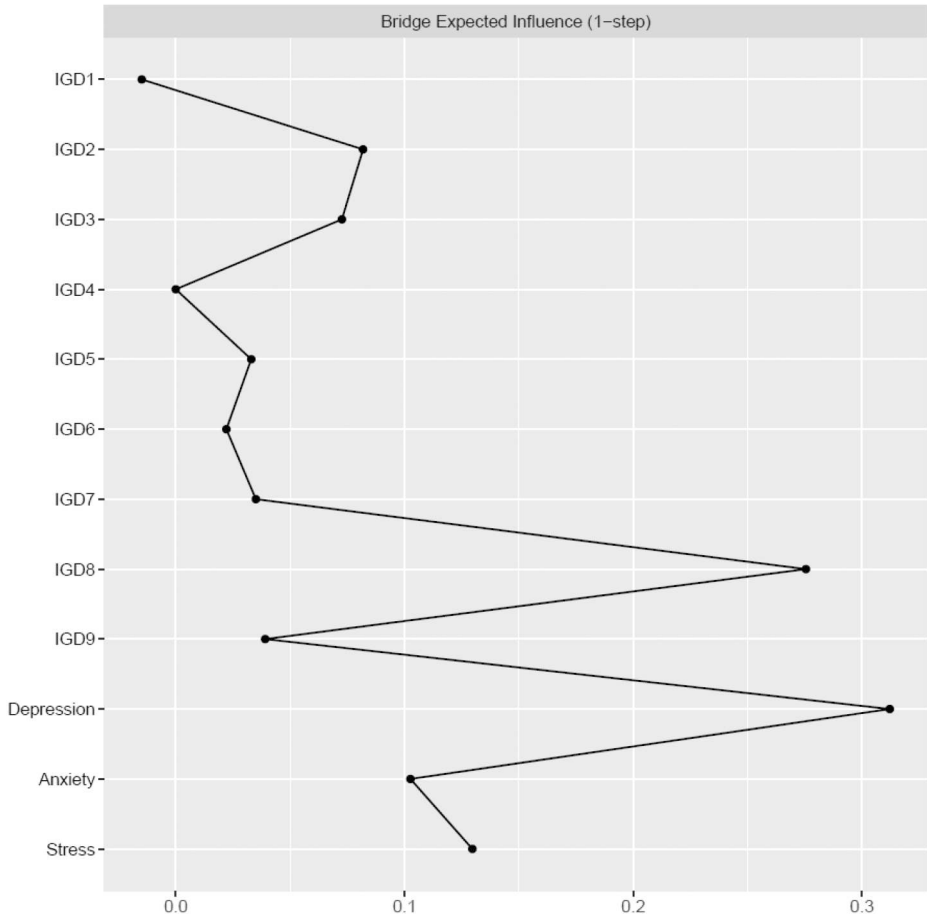

Figure 5. Bridge Expected Influence Centrality across all nodes at time point 1.

4.1. The IGD and distress network – primary characteristics

Where Li et al. (2023) and Tang, Ebrahimi, and Cheng (2023) both found withdrawal to be the most central symptom, and Yuan et al. (2022), Liu et al. (2022) and Gomez et al. (2022) found preoccupation, negative life consequences and the inability to stop the most central symptoms of IGD respectively. Contrary to the previus studies, the present findings indicated that tolerance was the most central symptom in the IGD network, closely followed by persistence. In terms of stress subtypes, Stress was the most central. One possible explanation for this discrepancy, is the more rigorous methodology applied here when compared to prior network analyses. The analysis conducted in the present study examined stability and only considered results with acceptable levels and differences in centrality which were determined through statistical means rather than by reading them off a graph and which held consistency over a six-month period. Therefore, the results of this analysis can be treated with a considerably higher degree of confidence than those of prior network analyses.

Nevertheless, these results suggest that tolerance and persistence may influence the other symptoms and cause the experience of IGD. This may take a form like that seen in drug addiction, in which the development of a tolerance for a drug (a need for its presence in ever increasing amounts to achieve homeostasis) prompts other symptoms such as increased use, more negative life consequences, and stronger withdrawals when attempting to stop (Siegel 2005; Everitt and Robbins 2016). This process takes the form of a cause and effect chain, where the development of a tolerance both necessitates greater use for the same result, but also indicates greater biological dependence and, therefore stronger withdrawals if use is ceased (Siegel 2005; Everitt and Robbins 2016). This dual effect usually results in greater use, even while experiencing negative consequences such as career damage, causing more negative consequences to accrue, necessitating more gaming to cope/reduce stress. All these factors together can cause addiction to resemble a self-fulfilling cycle that circles ever deeper into addiction (Koob and Volkow 2016). The finding that stress was the most central distress subtype in the network may reinforce this

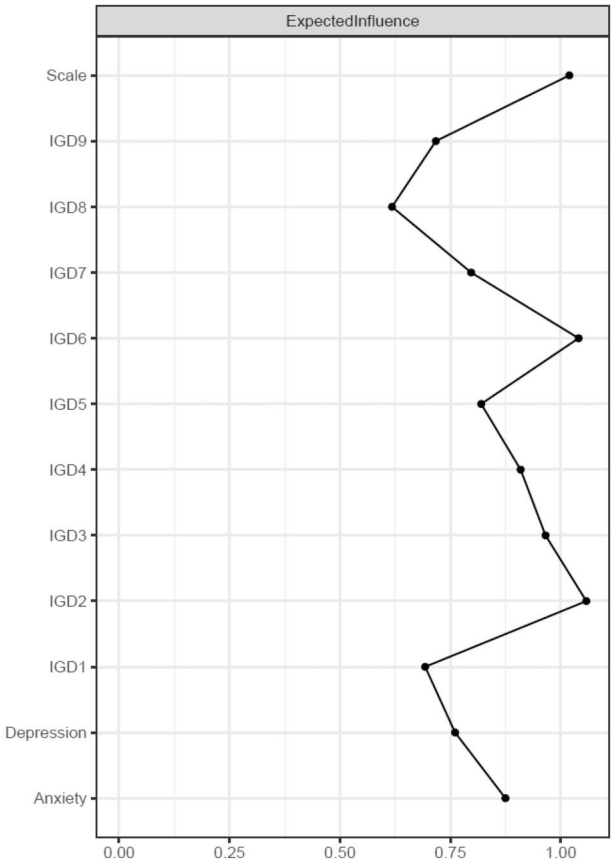

Figure 6. Expected Influence across all nodes at time point 2.

potential. As one of the more central nodes in the network, stress might act as a precursor oramplifier of distress and IGD, and if it's centrality represents more of an influence by other nodes, then it may represent an important indicator of the severity of an IGD/distress presentation.

It is thus likely that treatments that target client stress levels, the development of a tolerance and the persistence of use will see a greater impact than more general treatments. Furthermore, the development of IGD may be identified early on via the more focused examination of a clients tolerance and persistence symptoms. Though care must be taken to acknowledge that the direction of influence while inferable, is not conclusively displayed in network analysis (McNally 2021). Thus, it is possible that rather than holding great influence, tolerance and persistence may in fact be the most influenced by other symptoms, in which case these would serve as a sign the disorder has fully manifested rather than an early warning signal of its development (McNally 2021).

In terms of the validity of the IGD model, the results were mixed. Consistent with the only other network analyses covering similar topics (Tang, Ebrahimi, and Cheng 2023; Yang et al. 2023), IGD presented as distinct from distress, the connections within the IGD subnetwork significantly stronger than those between the IGD symptoms and distress subtypes. Given that psychological distress serves as a general indicator of mental health illness (Drapeau, Marchand, and Beaulieu-Prévost 2012), and that the results of the present study are the product of a rigorous statistical analysis undertaken across two timepoints, these results strongly indicate that critics asserting that IGD is a secondary symptom are incorrect. However, the presence of significantly stronger edges in the network among manifestations of addiction (salience, withdrawal, tolerance) and 'sequelae' caused by addiction (persistence, negative life outcomes) first identified by Liu et al. (2022) may indicate that the distinctions between these symptoms in these clusters are not as strong as previously thought. A possibility that would not discredit the behavioural addiction model of IGD, but that would present the possibility that the IGD framework requires adjustment, perhaps via the compression of certain symptom sets into one, such as salience and tolerance, or even the compression of all symptoms into two, 'sequalae' and the 'manifestations'.

In terms of assessment, prevention and treatment these results primarily confirm the use of the IGD model and assessments like the IGD-SF9 to assess problematic video game use.

4.2. The IGD and distress network – bridges and routes of influence

Supporting prior research, IGD was positively associated with distress, though there are several peculiarities to note. Rather than all symptoms of IGD associating with all symptoms of distress, most symptoms associated with distress only very weakly with preoccupation appearing to have a negative effect on distress reducing the experience of the stress subtype. In contrast escapism/mood modification were found to 'bridge' the gap between the two subnetworks, displaying the most influence of any IGD symptom on distress. Results consistent with prior network analyses examining the associations of IGD with other risk factors (Tang, Ebrahimi, and Cheng 2023), Anxiety (Yang et al. 2023) and PTSD (Li et al. 2023). This implies a more complicated relationship between excessive gaming and distress than 'higher level of IGD implies more distress'.

Rather, it appears there is a route of influence that links the experience of IGD with distress. Previously, it was theorised in this paper that a source of stress may cause an increase in gaming to compensate, a theory perhaps reinforced by the finding that preoccupation with gaming can cause a reduction in. Initially,

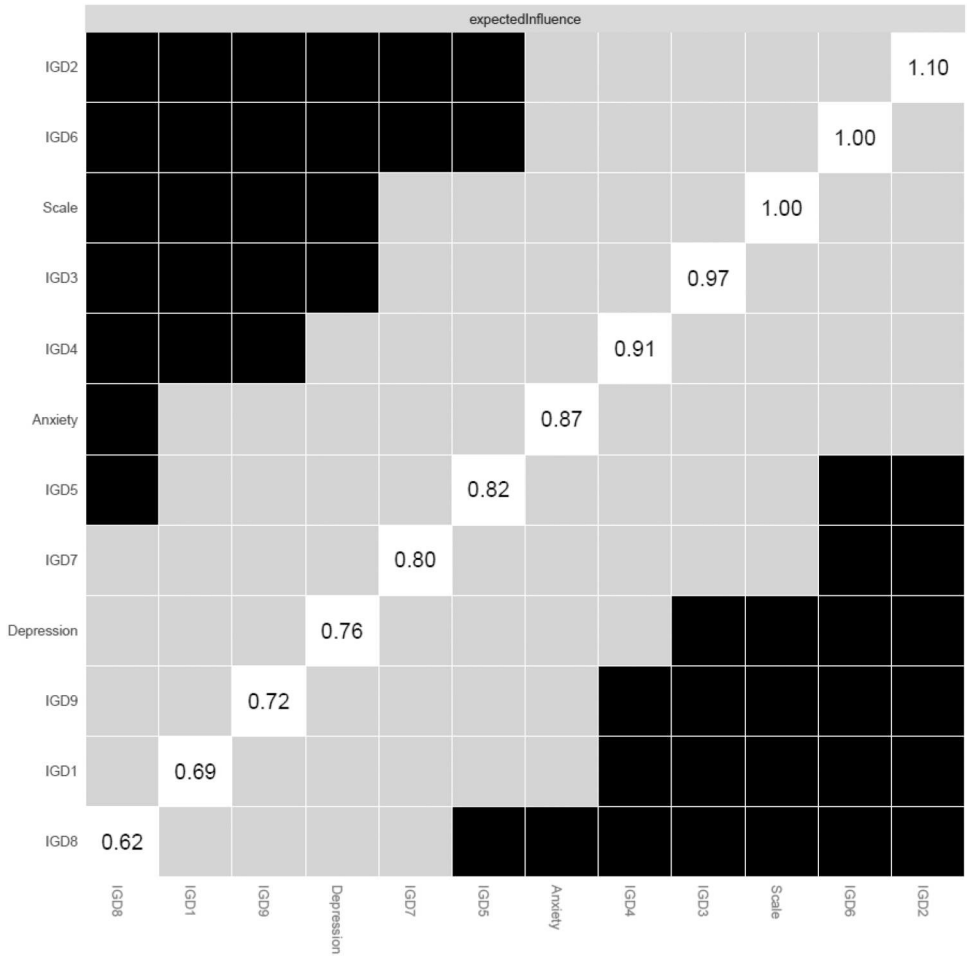

Figure 7. Centrality difference tests regarding the Expected Influence of nodes at time point 2.

this may even work. However, as tolerance increases, and more gaming is needed, and perhaps even a more intensive style of gaming, negative consequences accrue which the individual persists through, prompting more negative life consequences. These bridging results may provide the final step in this loop, the connection between the initial theorised stressor and tolerance.

Prior research has indicated that using gaming to make up for missing life circumstances may predict the development of a gaming disorder (Anderson, Steen, and Stavropoulos 2017; Marraudino et al. 2022). Here, stress did not appear to have a direct influence on IGD. However, it very strongly predicted depression and anxiety, which link to IGD via mood modification. It may be that when stressful circumstances reach the point that depression or anxiety symptoms develop, individuals who use gaming to escape those feelings, build up tolerance, causing stacking social and economic stressors that prompt increased negative feelings, potentially creating a bidirectional feedback loop, similar to that observed in social media (Tullett-Prado et al. 2023). This theorised route is unlikely to be the only explanation for IGD, but it's likely a strong factor in individuals who suffer both IGD and psychological distress and one that should be targeted. Treatments that target this maladaptive coping style (the use of gaming to control for negative moods), are likely to halt this cycle if it exists in an individual. This implies that DBT in particular (Cavicchioli et al. 2019; Southward, Howard, and Cheavens 2023), or aspects of CBT based on building effective coping strategies (Chettiar and De Terte 2022) should be explored as potential targeted treatments for IGD.

4.3. Limitations and future research

While the present study attempted to be as rigorous as possible in its methodology, several limitations remain. Firstly, the sample was heavily skewed both towards males who made up 70% of the sample and towards Caucasians who made up 62% of the sample. Therefore, generalisations to non-female and non-Caucasian populations are more difficult. Secondly, and building off of the first flaw, while mostly Caucasian males

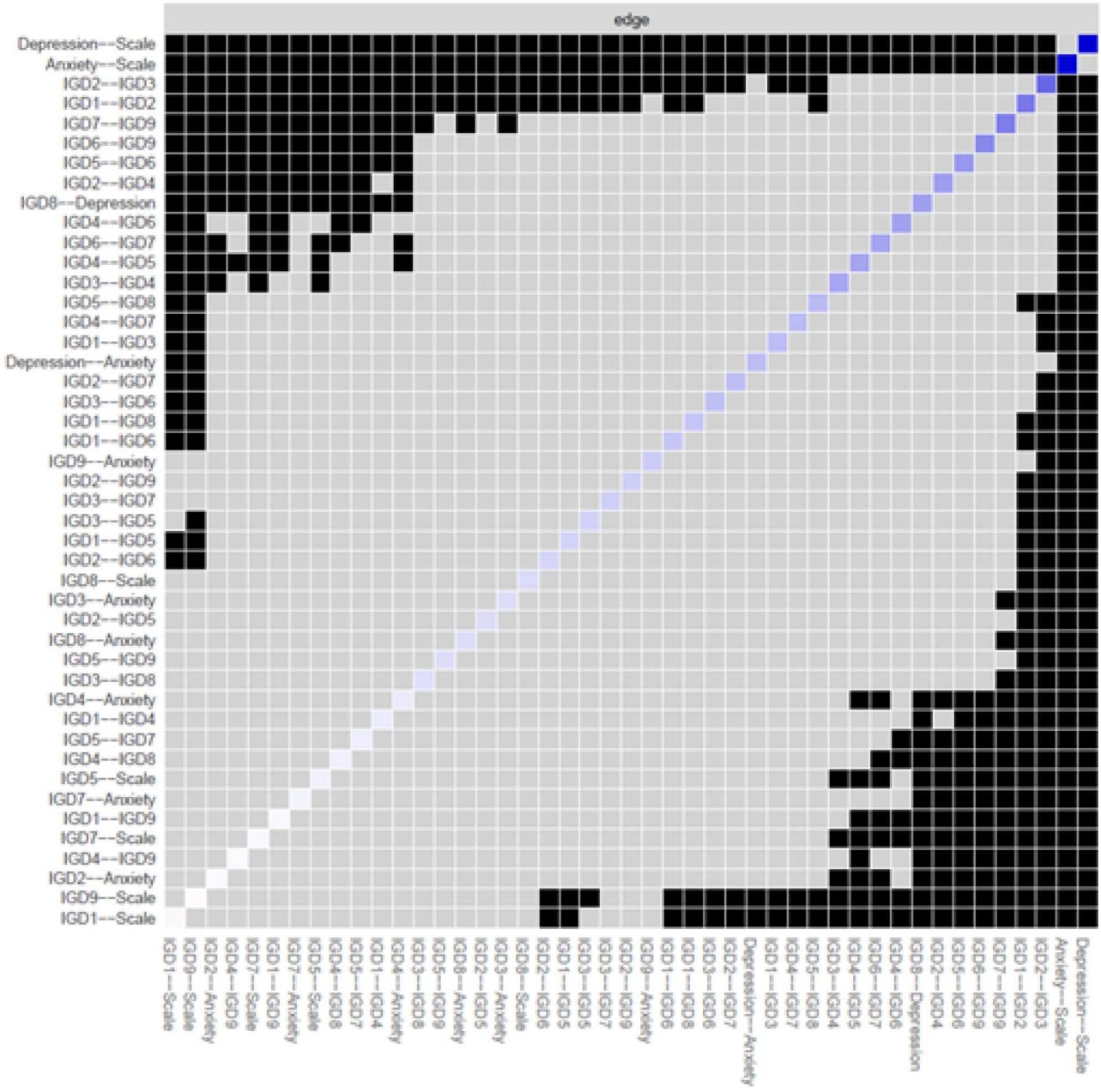

Figure 8. Edge difference tests regarding the edges between nodes at time point 2.

were assessed, these participants did originate from a variety of western nations, however no examination of cultural differences affect on IGD has taken place. Given that strong cultural effects have been found on the way IGD is expressed (Stavropoulos et al. 2021), this represents a missed opportunity to explore the way a significant factor impacts the IGD network. Thirdly, the present study faces the common problems inherent to self-report research, in which there is always the possibility that participant responses are not truthful, whether due to an active desire to appear desirable or undesirable, or due to a participant's own implicit memory biases (Hoerger and Currell 2012). Fourthly, while signifigance testing was employed to check differences between individual edge weights, and importantly, to identify whether the connections within the two subnetworks were greater than those between the subnetworks, there are more specific ways to do so that might have proven more robust. There are methods which might have provided a more unbiased assessment of which subnetworks were present and which were distinct. Exploratory Graph Analysis (EGA), which start from zero looking for communities of nodes (subnetworks) in a set of data, rather than starting with

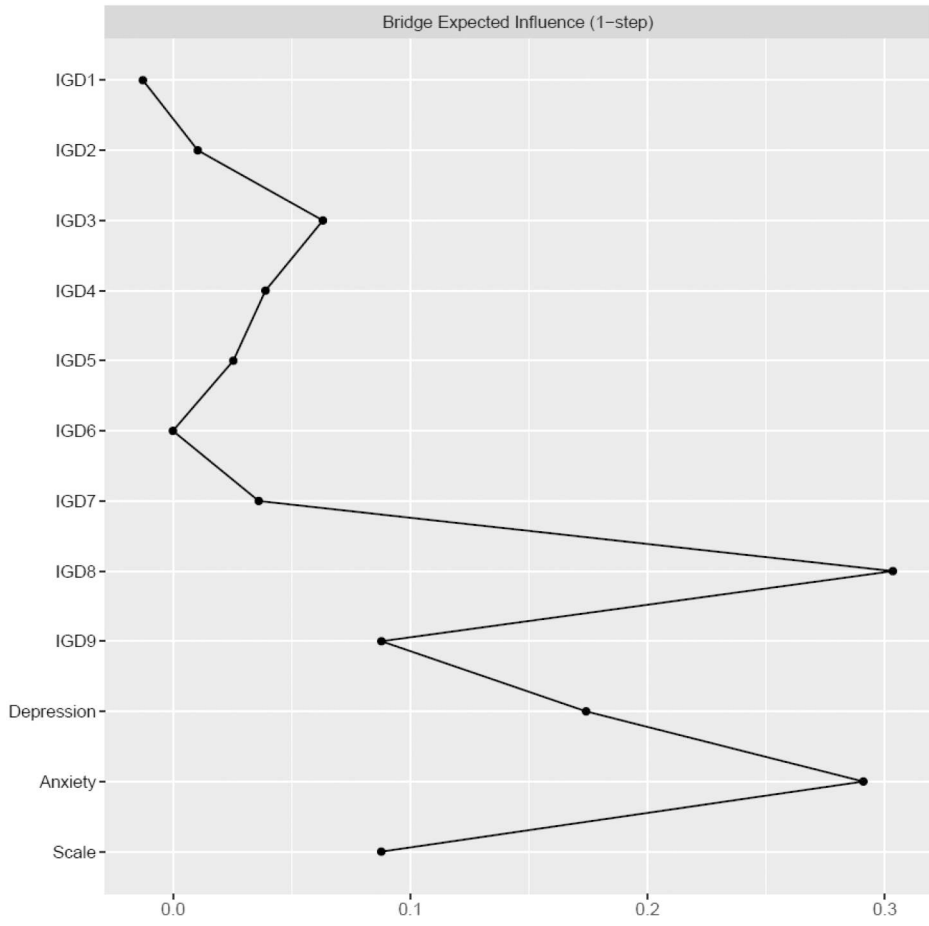

Figure 9. Bridge Expected Influence Centrality across all nodes at time point 2.

assumed subnetworks (Golino and Epskamp 2017), is one such possible candidate. Finally, the wide scope of this network analysis, though necessary to capture as much information about as many different associations and pathways as possible, does leave something to be desired in terms of specific detail regarding the relationships between individual symptoms and subtypes. An analysis more specifically tailored to identifying movements and the cause of changes over time, such as growth mixture modelling, might have provided more specific information on that topic for example.

Future research seeking to build on the present study should focus on two possible pathways. The first being to replicate the present study while addressing its flaws, assessing different populations and different sample proportions, perhaps with social desirability/sincerity scales to check the honesty of participants or by employing more exploratory methods such as EGA. The second is to explore the relationships identified here in finer detail using different study designs. Topics raised requiring more finely detailed examinations are the (i) order in which IGD symptoms arise among problematic gamers, (ii) effect of increases and decreases in persistence and tolerance on other IGD symptoms, (iii) role of mood modification, depression, and anxiety as pathways between distress and IGD, and (iv) potential stress relieving aspect of preoccupation.

4.4. Conclusion

The present study has significant implications for our understanding of the behavioural addiction model of IGD and how it interacts with psychological distress. The IGD model was both supported and weakened, with significant covariance identified between IGD symptoms on the one hand, particularly between the symptoms of preoccupation and withdrawal, and persistence and negative life consequences, and on the other hand, a distinction observed between psychological distress and IGD symptoms that was stable cross-sectionally and longitudinally.

Persistence and tolerance were found to be the most 'formative' symptoms in the IGD network, with (i) stress offering the most centrality in terms of distress, and (ii) anxiety, depression, and mood modification presenting

the route by which distress and IGD interacted. These results have several important implications for the treatment of IGD and distress: (i) treatment should focus on the symptoms of persistence and tolerance with regards to IGD, (ii) that distress should be tested for among clients who use online games problematically, and (iii) interventions among gamers with IGD who show distress symptoms should target the relationship between negative emotions and gaming in which gamers compensate for negative moods with gaming.

Statements and declarations

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Disclosure statement

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Ethical standards – animal rights

All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors. Thus, the present study was approved by the Human Ethics Research Committee of Victoria University (Australia).

Informed consent

Informed consent was obtained from all individual participants included in the study.

Confirmation statement

Authors confirm that this paper has not been either previously published or submitted simultaneously for publication elsewhere.

Publication

Authors confirm that this paper is not under consideration for publication elsewhere. However, the authors do disclose that the paper has been considered elsewhere, advanced to the pre-print stage and then withdrawn.

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Availability of data and materials

The datasets generated by the survey research during and/or analysed during the current study are available in the following Github repositories, as is the Syntax and Raw Results obtained during the course of analysis.

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Appendix

Appendix A: Internet Gaming Disorder Scale-Short Form (IGDS9-SF; Pontes and Griffiths 2015)

Internet Gaming Disorder Scale–Short-Form (IGDS9-SF) (Pontes & Griffiths, 2015)

Instructions: These questions will ask you about your gaming activity during the past year (i.e., last 12 months). By gaming activity we understand any gaming-related activity that has been played either from a computer/laptop or from a gaming console or any other kind of device (e.g., mobile phone, tablet, etc.) both online and/or offline.

	Never	Rarely	Sometimes	Often	Very Often
1. Do you feel preoccupied with your gaming behavior? (Some examples: Do you think about previous gaming activity or anticipate the next gaming session? Do you think gaming has become the dominant activity in your daily life?)	○	○	○	○	○
2. Do you feel more irritability, anxiety or even sadness when you try to either reduce or stop your gaming activity?	○	○	○	○	○
3. Do you feel the need to spend increasing amount of time engaged gaming in order to achieve satisfaction or pleasure?	○	○	○	○	○
4. Do you systematically fail when trying to control or cease your gaming activity?	○	○	○	○	○
5. Have you lost interests in previous hobbies and other entertainment activities as a result of your engagement with the game?	○	○	○	○	○
6. Have you continued your gaming activity despite knowing it was causing problems between you and other people?	○	○	○	○	○
7. Have you deceived any of your family members, therapists or others because the amount of your gaming activity?	○	○	○	○	○
8. Do you play in order to temporarily escape or relieve a negative mood (e.g., helplessness, guilt, anxiety)?	○	○	○	○	○
9. Have you jeopardized or lost an important relationship, job or an educational or career opportunity because of your gaming activity?	○	○	○	○	○

Scoring information:

Total scores can be obtained by summing up all responses given to all nine items of the IGDS9-SF and can range from a minimum of 9 to a maximum of 45 points, with higher scores being indicative of a higher degree of Internet Gaming Disorder. In order to differentiate disordered gamers from non-disordered gamers, researchers should check if participants have endorsed at least five criteria out of the nine by taking into account answers as '5: Very Often', which translates as endorsement of the criterion.

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Appendix B: Depression, Anxiety and Stress Scale (DASS-21; Lovibond & Lovibond, 1995)

DASS 21 NAME _____ DATE _____

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you over the past week. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all - NEVER

1 Applied to me to some degree, or some of the time - SOMETIMES

2 Applied to me to a considerable degree, or a good part of time - OFTEN

3 Applied to me very much, or most of the time - ALMOST ALWAYS

		N	S	O	AA	FOR OFFICE USE D	A	S
1	I found it hard to wind down	0	1	2	3			
2	I was aware of dryness of my mouth	0	1	2	3			
3	I couldn't seem to experience any positive feeling at all	0	1	2	3			
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3			
5	I found it difficult to work up the initiative to do things	0	1	2	3			
6	I tended to over-react to situations	0	1	2	3			
7	I experienced trembling (eg, in the hands)	0	1	2	3			
8	I felt that I was using a lot of nervous energy	0	1	2	3			
9	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3			
10	I felt that I had nothing to look forward to	0	1	2	3			
11	I found myself getting agitated	0	1	2	3			
12	I found it difficult to relax	0	1	2	3			
13	I felt down-hearted and blue	0	1	2	3			
14	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3			
15	I felt I was close to panic	0	1	2	3			
16	I was unable to become enthusiastic about anything	0	1	2	3			
17	I felt I wasn't worth much as a person	0	1	2	3			
18	I felt that I was rather touchy	0	1	2	3			
19	I was aware of the action of my heart in the absence of physicalexertion (eg, sense of heart rate increase, heart missing a beat)	0	1	2	3			
20	I felt scared without any good reason	0	1	2	3			
21	I felt that life was meaningless	0	1	2	3			
	TOTALS					0	0	0