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Symptomatology, risk, and protective factors of gaming disorder: A network analytical approach

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ABSTRACT

Research has identified various cognitive risk and protective (CRP) factors that contribute to gaming disorder (GD), but it remains unclear how GD symptoms are differentially related to specific CRP factors. To fill the gap, this study used network analysis to identify the most central components in the connections between CRP factors and GD symptoms, shedding light on the most important factors for the development and maintenance of GD. The participants of this study were 3002 adult online gamers (49.8% men, mean age = 36.3 years). Two unregularized Gaussian graphical models were estimated, one that only included GD symptoms and another that included both GD symptoms and CRP factors. The findings showed that "cognitive flexibility", "gaming self-esteem", and "loss of control" were the most central cognitive protective factor, cognitive risk factor, and GD symptom, respectively. Moreover, the GD symptom of "escape", the cognitive risk factor of "loss sensitivity", and the cognitive protective factor of "cognitive flexibility" were most prominent in bridging different constructs, reflecting two mechanistic clusters of GD: escapism and reward-seeking. The findings further revealed that the cognitive risk factor of "maladaptive gaming cognition" was closely connected to GD symptoms, indicating its influential role as a harmful mechanism underlying GD. Overall, our network analysis indicates that having secure self-beliefs and situation-based flexibility may be crucial for healthy gaming.

1. Introduction

Problematic gaming has emerged as a global issue with increasing prevalence worldwide (Oka et al., 2021; Stevens et al., 2021; Wang & Cheng, 2021). In 2013, Internet gaming disorder was recognized as a condition in need of further research by the Diagnostic and Statistical Manual of Mental Disorder (DSM-5; American Psychiatric Association, 2013). More recently, gaming disorder (GD) has been categorized as a type of behavioral addiction in the 11th revision of the International Classification of Diseases (ICD-11; World Health Organization, 2019). Despite these developments, there is still controversy surrounding the diagnostic criteria and underlying mechanisms of GD (Stavropoulos et al., 2019; Wang & Cheng, 2020). To address these challenges, the present study used a sophisticated statistical approach called network analysis to explore the interrelationships between GD symptoms and cognitive risk and protective (CRP) factors. This approach can shed new light on the mechanisms involved in the development and maintenance of GD, as well as identify the functional role and relative importance of the associations between GD symptoms and CRP factors in the networks.

1.1. Symptomatology of GD

According to the framework of GD as stated in the DSM-5, nine symptoms indicative of GD were proposed: (a) preoccupied thoughts revolving around gaming (i.e., "salience"); (b) feelings of irritability and restlessness when not gaming ("withdrawal"); (c) need to spend greater and greater amounts of time on gaming ("tolerance"); (d) unsuccessful attempts to stop gaming ("loss of control"); (e) giving up other leisure activities for gaming ("loss of interest"); (f) continued excessive gaming despite experiencing significant undesirable outcomes ("continuation"); (g) lying to other people for concealing ones excessive gaming ("deception"); (h) gaming to evade emotional problems ("escape"); and (i) putting significant social relations or work at risk due to gaming ("functional impairment").

While there is relative agreement on the definition of GD, some experts have raised concerns that the current diagnostic criteria may

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pathologize common behaviors (Kardefelt-Winther et al., 2017). This issue is particularly relevant in the context of studies assessing GD, as most of them have utilized a sum-score approach that aggregates all nine symptoms to form a composite score. However, this approach may not provide a complete understanding of the disorder, especially as some GD symptoms may not be equally predicted by the same event, may have different impacts on psychological and interpersonal outcomes, and may have direct causal links with other symptoms (Fried & Nesse, 2015). To address this issue, the present study studied GD at the level of individual symptoms, providing a more fine-grained understanding of its symptomatology and associated mechanisms.

1.2. Theoretical background

A comprehensive literature review reveals several theoretical models that explain the mechanisms contributing to GD, many of which highlight the pivotal role of cognitive factors in the development and maintenance of GD (Brand et al., 2016; Dong & Potenza, 2014). Among these theoretical models, the Interaction of Person-Affect-Cognition-Execution (I-PACE) model has been the most widely cited and offers the most compelling explanation of GD that integrates multiple psychological aspects of this emergent disorder (Brand et al., 2016).

According to the I-PACE model, the exacerbation and mitigation of GD symptoms are influenced by the complex interplay of multiple factors with cognitive, affective, and behavioral factors. Cognitive protective factors refer to cognitive processes or tendencies that can act as a safeguard against the development of GD, whereas cognitive risk factors refer to cognitive processes or tendencies that can elevate the probability of developing GD. Guided by this comprehensive model, the present study investigated the cognitive mechanisms underlying GD by examining five major CRP factors. Among the cognitive protective factors examined are perceived self-competence and executive functioning, whereas the cognitive risk factors examined include motivational sensitivity and maladaptive gaming cognition. As emotional regulation is a highly complex process that involves both adaptive and maladaptive strategies (e.g., Aldao et al., 2014), it includes both cognitive protective and risk factors. Table 1 provides an outline of the components of these five CRP factors and their definitions.

As shown in Table 1, perceived self-competence represents a cognitive protective factor that assists individuals in resisting excessive gaming (e.g., Kavanagh et al., 2023). This broad construct comprises self-esteem and self-efficacy, with the former reflecting individuals' overall sense of self-worth while the latter reflecting individuals' beliefs in their capability of successful task completion or goal attainment (Tesser, 2004; Van der Bijl & Shortridge-Baggett, 2002). Such perceived self-competence has been consistently found to influence individuals' ability to regulate their gaming behavior. For example, robust findings have shown that GD symptoms have negative associations with favorable self-views or evaluations (e.g., Cudo et al., 2019; Kavanagh et al., 2023).

Executive functioning is a set of cognitive processes involved in goal-directed and planful actions, such as cognitive flexibility and inhibitory control (e.g., Moss & Moss-Racusin, 2021). These processes are crucial for regulating behavior and adapting to changing environmental demands, thus enhancing an individual's ability to balance gaming activities with other important life activities and to prevent excessive gaming. In line with these postulations, studies have demonstrated that individuals with higher levels of executive functioning are less vulnerable to GD symptoms (Argyriou et al., 2017; Cheng et al., 2015).

Emotional regulation is conceptualized as the ability to monitor, evaluate, and alter emotional reactions in response to changing situational demands (e.g., Koole, 2009). Applying this construct to the context of gaming, this set of cognitive processes fosters the management of unpleasant emotions that may arise in life stressors, and individuals lacking emotional regulation skills turn to gaming as a means of escape from real-life problems (Kwon et al., 2011). As noted above, emotional regulation includes both adaptive strategies (e.g., blunting, positive reappraisal) and maladaptive strategies (e.g., catastrophizing, blaming others; Aldao et al., 2014; Cheng et al., 2014). Previous findings indicate that individuals with GD are more inclined to use maladaptive emotional regulation strategies, while displaying a lower tendency to utilize adaptive strategies to modify their unpleasant affect (e.g., Lin et al., 2020; Yen et al., 2018).

Motivational sensitivity is a construct that reflects an individual's sensitivity to both reward and punishment (e.g., Eitam et al., 2013). In the gaming context, this construct refers to the tendency to pursue gaming rewards and avoid poor gaming results by selectively attending to different types of gaming-related cues (Wang & Cheng, 2022). This construct is classified as a cognitive risk factor for GD due to evidence that individuals with GD often indulge in risky decision-making, which can lead to overvaluing the rewards associated with gaming while underestimating the undesirable consequences of excessive gaming (e.g., Dong & Potenza, 2016; Li et al., 2020).

Table 1
Cognitive protective and risk factors of GD and the variables related to each factor.

Label	Variable/Node	Definition
		Cognitive Protective Factors
Perceived self-competence		
PS1	Global self-esteem	Overall positive evaluations of oneself, including self-worth and recognition of socially desirable attributes and abilities in oneself
PS2	Self-efficacy	Generalized sense of personal ability or agency in managing or changing events in the environment
Executive functioning		
EF1	Cognitive flexibility	Ability to shift between mindsets in response to the changing environment
EF2	Working memory	Ability to hold and monitor information in memory while performing other tasks
EF3	Inhibitory control	Ability to suppress or stop impulsive or automatic responses
Emotional regulation		
ER1	Blunting	Thoughts of alternative positive experiences instead of current stressful or undesirable events
ER2	Positive reappraisal	Reinterpretation of undesirable events to give a positive meaning
ER3	Putting into perspective	Downgrading the importance of events or comparing them with other events
		Cognitive Risk Factors
ER4	Catastrophizing	Thoughts of exaggerated threat or adverse effects
ER5	Blaming others	Attribution of undesirable outcomes to others
Motivational sensitivity		
MS1	Reward sensitivity	Tendency to approach or pursue reinforcements
MS2	Loss sensitivity	Tendency to avoid aversive consequences and punishment
Maladaptive gaming cognition		
MC1	Reward overvaluation	Beliefs about the value and tangibility of gaming rewards, activities, and identities over other activities
MC2	Maladaptive gaming rules	Justifications of continued gaming despite adverse consequences
MC3	Gaming self-esteem	Compensating negative core beliefs about oneself with the expectations and experiences related to gaming
MC4	Gaming for social acceptance	Beliefs about gaming achievements to raise social status, relatedness, and sense of belonging

Maladaptive gaming cognition, another cognitive risk factor, encompasses explicit and implicit false beliefs that minimize or ignore the problems associated with excessive gaming, such as distorted thoughts and justifications for continuing to play games despite facing devastating outcomes (e.g., Forrest et al., 2017). The immediate rewards and reinforcement provided by gaming, such as excitement and social connectedness, may lead individuals to prioritize gaming over other important activities in life. Studies have identified positive associations of GD symptoms with a range of maladaptive gaming cognition, which make it difficult for individuals to recognize and rectify their additive behavioral problems (e.g., Bodi et al., 2021; Király et al., 2023).

1.3. Network analytical approach to GD

To advance the studies of GD, Stavropoulos et al. (2019) advocated using a new approach called network analysis for providing a more complete understanding of the disorder and its underlying mechanisms. The network approach to psychopathology research was originally developed by (Borsboom, 2008) to study mental health disorders, which are proposed to arise from interactions among an array of symptoms (Borsboom, 2017; Jones et al., 2017).

The use of network analysis in the context of GD can help identify CRP factors associated with the disorder, as well as which symptoms of the disorder are most important to target in GD treatment (Holman & Williams, 2020). In a network structure, variables are represented as nodes, and the connections between them are represented as edges. The direction of the associations is indicated by the color of the edges, while the thickness and color saturation of the edges indicate the strength of the association. Communities can be identified within the network structure, which are clusters of nodes that are more interconnected with each other than with other nodes in the network. Nodes that bridge different communities can provide valuable information about how activations spread across communities within a network system of behavior.

Centrality measures are tools used in network analysis to identify the nodes that are most "central" or important in a network based on their connections with other nodes (McNally, 2021). By applying centrality measures to a network analysis of GD, researchers can identify which CRP factors and GD symptoms have the most influence in the network and act as bridges between different clusters of nodes. Centrality measures can help researchers understand how the different aspects of GD are interconnected and how they contribute to the development and maintenance of the disorder. Such advancement in the understanding of GD is a crucial step towards identifying new patterns of importance and uncovering mechanisms that can be targeted in interventions to treat or prevent the disorder.

1.4. Overview of present study

Despite the many advantages offered by network analysis, there is a paucity of research examining the network structure of GD symptoms. As reviewed above, various theoretical frameworks and studies have identified a number of CRP factors that are crucial to the development of GD (e.g., Dong & Potenza, 2014; Wei et al., 2017), but little is known about how these factors are related to specific GD symptoms. To address these knowledge gaps, the present study used network analysis to gain a more comprehensive understanding of the connections between CRP factors and GD symptoms. This study aimed to (a) examine how multiple GD symptoms are related to each other, (b) identify the patterns of association between CRP factors and GD symptoms, and (c) identify the most central CRP factors and GD symptoms in the network.

The study used a two-step approach, first estimating a network of all nine GD symptoms and then including CRP factors in the network (e.g., Skjerdingstad et al., 2021). Through the analysis of connections between CRP factors and GD symptoms, the findings may elucidate the underlying mechanisms of GD and enhance our understanding of the disorder. Moreover, by identifying communities and clusters within the network, the findings may offer valuable insight into the different components of GD and their related factors.

2. Method

2.1. Participants

This study adopted a cross-sectional design in obtaining survey data through Prolific Academic (Oxford, United Kingdom), a crowdsourcing platform that provides access to large and diverse samples with high data quality suitable for academic research (e.g., Peer et al., 2021). Eligible participants were adults aged between 18 and 60, who had played video games in the past month, and had a work history of good-quality responses on Prolific Academic (i.e., an approval rate of ≥90% in previous surveys). A sample of 3002 gamers took part in an online survey. The demographic characteristics of the sample are presented in Table 2.

2.2. Procedures

The study protocol was pre-registered on the Open Science Framework website (https://osf.io/zt5s7/) and was approved by the Human Research Ethics Committee of the University of Hong Kong before conducting the study. The study involved collecting data through a survey questionnaire that was launched on the Qualtrics software (Qualtrics, Provo, UT). Participants were recruited from Prolific Academic and had to meet specific eligibility criteria in order to take part.

All eligible participants underwent the same procedures, including providing informed consent before starting the survey. The survey questions were presented in a randomized order, and no attention checks were used. After completing the survey, participants were thanked, debriefed, and compensated for their participation.

Table 2
Demographic characteristics of the sample ($n = 3002$).

Age (*M*)	36.3 (*SD* = 12.4)	
Gender	*N*	%
Male	1495	49.80
Female	1429	47.60
Transgender male	10	0.33
Transgender female	5	0.17
Gender variant/unknown	54	1.80
Other	5	0.17
Prefer not to say	4	0.13
Race		
White or Caucasian	2292	76.35
Hispanic or Latino	332	11.06
Black or African American	144	4.80
Native American or American Indian	5	0.17
Asian	148	4.93
Other	81	2.69
Education		
Less than high school diploma	100	3.33
High school diploma	1088	36.24
Higher diploma	322	10.73
Associate degree	1053	35.08
Bachelor's degree	394	13.12
Master's degree	45	1.50
Professional degree	0	0
Doctoral degree	0	0
Marital Status		
Single	1127	37.54
In a relationship	837	27.88
Married	876	29.18
Divorced	146	4.86
Widowed	16	0.53
Others	0	0

2.3. Measures

Table 3 summarizes a set of validated measures that was used in this study. The sum scores of each measure or subscale were included as a node in the network analysis, except for the GD symptoms that used a single-item score.

2.3.1. Global self-esteem

The Rosenberg Self-Esteem Scale (Rosenberg, 1965) is a 10-item measure widely used to assess the unidimensional construct of global self-esteem. The participants were instructed to rate on a Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*) regarding their feelings toward themselves in general. The sum score ranges from 10 to 40, in which a higher score indicates a higher level of global self-esteem.

2.3.2. Self-efficacy

The Generalized Self-Efficacy Scale (Schwarzer & Jerusalem, 1995) is a measure consisting of 10 items that assess an individual's perceived level of self-efficacy. The participants rated each item on a Likert scale, ranging from 1 (*not at all true*) to 4 (*exactly true*) regarding their competence to cope with a broad range of stressful or challenging demands. The sum-score ranges from 10 to 40, in which a higher score indicates a higher level of self-efficacy.

2.3.3. Cognitive flexibility

The Cognitive Flexibility Inventory (Dennis & Vander Wal, 2010) is a 20-item measure that assesses an individual's ability to identify alternative explanations in a situation and to generate multiple solutions. Participants were asked to rate on a Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*) regarding the extent to which they agree or disagree with each of self-referent statement. The sum-score ranges from 20 to 140, in which a higher score indicates a higher level of cognitive flexibility.

2.3.4. Executive functioning

The Adult Executive Functioning Inventory (Holst & Thorell, 2017) consists of 14 items that measure working memory and inhibitory control of executive functions. The participants gave ratings on a Likert scale (1 = *definitely not true*; 5 = *definitely true*) regarding how well the statements describe them as a person. The working memory and the inhibition subscales consist of 9 items and 5 items, respectively. Originally, a higher score yielded from the inventory indicates greater difficulties in executive functioning, but reverse scoring was adopted in this study for ease of interpretation. As such, the sum-score of the working memory and inhibition subscale ranges from 9 to 45 and 5 to 25, respectively. A higher score indicates a higher level of working memory or inhibitory control.

2.3.5. Emotional regulation

The short form of the Emotional Regulation Questionnaire (Garnefski & Kraaij, 2006) is a measure comprising 18 items that assess nine distinct strategies of emotional regulation. In this study, five subscales—positive reappraisal, putting into perspective, blunting (also known as positive refocusing), catastrophizing, and blaming others—were included. The participants were asked to rate on a Likert scale from 1 (*almost never*) to 5 (*almost always*) regarding how they usually reacted under threatening or stressful situations. Each subscale has a range of 2–10, with a higher score indicates a higher tendency to deploy a particular kind of emotional regulation strategy.

Table 3
Summary of measures used in this study.

Measure	Subscale	Node	α	Sample item
Rosenberg Self-Esteem Scale	Full scale	PS1	.93	"I feel that I'm a person of worth."
Generalized Self-Efficacy Scale	Full scale	PS2	.90	"I can usually handle whatever comes my way."
Cognitive Flexibility Inventory	Full scale	EF1	.91	"I consider multiple options before making a decision."
Adult Executive Functioning Inventory	Working memory	EF2	.76	"I have difficulties with tasks or activities that involve several steps."
	Inhibitory control	EF3	.45	"I have a tendency to do things without first thinking about what could happen."
Emotional Regulation Questionnaire-Short-form	Blunting	ER1	.76	"I think of something nice instead of what has happened."
	Positive reappraisal	ER2	.76	"I think I can learn something from the situation."
	Putting into perspective	ER3	.65	"I tell myself that there are worse things in life."
	Catastrophizing	ER4	.82	"I continually think how horrible the situation has been."
	Blaming others	ER5	.78	"I feel that others are responsible for what has happened."
Sensitivity to Punishment and Sensitivity to Reward Questionnaire	Reward sensitivity	MS1	.78	"Do you often do things to be praised?"
	Loss sensitivity	MS2	.89	"Are you often worried by things you said or did?"
Internet Gaming Cognition Scale	Reward overvaluation	MC1	.70	"Playing Internet games has many other benefits in my life."
	Maladaptive gaming rules	MC2	.78	"When I make mistakes, lose progress, or fail in a game, I must reload and try again."
	Gaming self-esteem	MC3	.75	"I am proud of my gaming achievements."
	Gaming for social acceptance	MC4	.69	"Other players admire and respect my gaming achievements."
Internet Gaming Disorder Scale-Short-Form	Salience	GD1	N/A	"Do you feel preoccupied with your gaming behavior?"
	Withdrawal	GD2	N/A	"Do you feel more irritability, anxiety or even sadness when you try to either reduce or stop your gaming activity?"
	Tolerance	GD3	N/A	"Do you feel the need to spend increasing amount of time engaged gaming in order to achieve satisfaction or pleasure?"
	Loss of control	GD4	N/A	"Do you systematically fail when trying to control or cease your gaming activity?"
	Loss of interest	GD5	N/A	"Have you lost interests in previous hobbies and other entertainment activities as a result of your engagement with the game?"
	Continuation	GD6	N/A	"Have you continued your gaming activity despite knowing it was causing problems between you and other people?"
	Deception	GD7	N/A	"Have you deceived any of your family members, therapists or others because the amount of your gaming activity?"
	Escape	GD8	N/A	"Do you play in order to temporarily escape or relieve a negative mood?"
	Functional impairment	GD9	N/A	"Have you jeopardized or lost an important relationship, job or an educational or career opportunity because of your gaming activity?"

Note. α = Cronbach's alpha. N/A = not applicable.

2.3.6. Loss-reward sensitivity

The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (Torrubia et al., 2001) is a 48-item measure of loss sensitivity and reward sensitivity. Each of these subscales consists of 24 items. The participants were asked to indicate "*yes*" or "*no*" to the statements regarding their thoughts and behaviors. Each subscale was ranging from 0 to 24, with a higher score indicates greater sensitivity.

2.3.7. Maladaptive gaming cognition

The Internet Gaming Cognition Scale (King & Delfabbro, 2016) is a measure comprising 24 items that assess four related variables: reward overvaluation, maladaptive gaming rules, gaming self-esteem, and gaming for social acceptance. The participants rate each item on a 3-point scale (0 = *no agreement*; 2 = *strongly agree*) regarding a series of self-referent statements. A higher score indicates a stronger maladaptive cognition. The reward overvaluation subscale scores range from 0 to 10; maladaptive gaming rules subscale scores range from 0 to 16; gaming self-esteem subscale scores range from 0 to 12; and gaming for social acceptance subscale scores range from 0 to 10.

2.3.8. GD symptoms

The Internet Gaming Disorder Scale-Short-Form (Pontes & Griffiths, 2015) consists of 9 items that assess all nine criteria for GD as listed in the DSM-5. These criteria include salience, withdrawal, tolerance, loss of control, loss of interest, continuation, deception, escape, and functional impairment. Participants gave ratings to each item on a Likert scale from 1 (*never*) to 5 (*very often*) regarding their gaming activity during the last 12 months, in which a higher score indicates greater severity. A cut-off score of 32 was adopted to classify participants as meeting criteria for GD (e.g., Qin et al., 2020).

2.4. Statistical analyses

All of the statistical analyses were conducted using R (Version 4.1.0; R Core Team, 2021). The complete R-codes are available in the Supplementary Materials.

2.4.1. Data preparation

To ensure the accuracy of the network analytic results in this study, nonparanormal transformations were applied to handle skewed data, following the guidelines for network analysis in psychology research (Epskamp & Fried, 2018). The function *huge.npn* in the R package *huge* was used for this purpose (see Supplementary Table S1 for the skewness of the data).

To prevent the problem of topological overlap that can lead to inaccurate inferences (Burger et al., 2022), a data-driven method was used to identify potential redundant nodes in the data (see Blanchard et al., 2021). This method involved first verifying the positive definiteness of the correlation matrix for all variables in the network, and then used a function called *goldbricker* in the R package *networktools* to search for potential pairs of redundant variables. The results showed no redundant variables in the data that needed to be removed from the analysis, providing support for the validity of the methods used to avoid topological overlap and ensure empirical accuracy.

2.4.2. Network analysis

In this study, two network structures were created to explore the connections between GD symptoms and CRP factors. The GD network included only the nine GD symptoms, while the CRP-GD network included both CRP factors and GD symptoms. Blue edges in each network indicate positive connections, red edges indicate negative connections, and the thickness and color saturation of the edges represent the strength of the connections.

The unregularized Gaussian Graphical Model (GGM) was used to estimate the network structures due to the large sample size of over 3000 participants (Isvoranu & Epskamp, 2021). This method establishes the unique connection between two nodes (variables) in the network after accounting for the effects of all other nodes. This creates a sparser network that captures only the unique, direct connections between nodes.

The *ggmModSelect* function from the R package *qgraph* (Epskamp et al., 2012) was used to perform the unregularized GGM. The algorithm generated 100 regularized network structures with different levels of penalization to reduce the number of edges in the network. Each of the 100 estimated network structures was then re-estimated without penalization through maximum likelihood estimation, retaining only statistically significant edges from the regularized networks. This stepwise process optimized the network structure to improve model selection.

The best-fitting network structure was identified using the Bayesian Information Criterion (BIC). The network structure with the lowest BIC was selected as the final network structure, indicating that no edges could be further added or removed to optimize the model. Finally, the Fruchterman-Reingold algorithm was used to visualize the networks, minimizing the number of crossing edges and drawing more highly connected nodes closer together (Fruchterman & Reingold, 1991).

2.4.3. Community detection and centrality analyses

To investigate the community structure of the CRP-GD network, the spinglass algorithm from the R package *igraph* was applied (Csardi & Nepusz, 2006). This algorithm assigned weights to both existing and missing links in the network to find groups of connected nodes, or communities. Links between nodes were weighted based on their strength, with stronger links receiving greater weights and vice versa. Missing links were also given weights based on the probability of a connection existing between two nodes if they were to belong to the same community. The algorithm considered these weights when grouping nodes into communities, with nodes having a higher probability of being connected to each other being more likely to belong to the same community. This process was repeated 1000 times to ensure the reliability of the findings. As a result, each community contained a group of nodes that were more closely related to each other than to other nodes in the network, thus revealing how CRP factors and GD symptoms were connected to each other.

The strength centrality of each node in the GD network and CRP-GD network was computed using the R package *qgraph* (Epskamp et al., 2012). This measure captured the total absolute edge weights to which a node was directly connected, revealing nodes with greater importance in the network (Bringmann et al., 2019). This metric was used to identify central or key nodes that played critical roles in the network's structure and function.

The bridge expected influence (BEI) of each node in the CRP-GD network was calculated using the R package *networktools* (Jones et al., 2019). This metric measured a node's total connectivity with other community structures in the network, revealing nodes that played a significant role in connecting different communities together (Jones et al., 2017). This provided information about the extent to which nodes acted as bridges between different communities, and was used to identify key nodes critical for maintaining communication between disconnected parts of the network.

2.4.4. Network stability

The robustness of the networks was examined by the nonparametric and case-dropping bootstrapping tests using the R package *bootnet* (Epskamp et al., 2018). These tests were used to assess the stability of the edge weights, strength centrality, and BEI metrics. To assess the stability of the edge weights, nonparametric bootstrapping with 1000 iterations was used to construct 95% confidence intervals, and bootstrapped difference tests were computed (Epskamp et al., 2018). This approach helps to quantify the extent to which the edge weights are stable and can be interpreted as reliable measures of the strength of the connections between nodes.

The robustness of the networks was examined using nonparametric and case-dropping bootstrapping tests with the R package *bootnet* (Epskamp et al., 2018). These tests assessed the stability of the edge weights, strength centrality, and BEI metrics in the network.

For assessing the stability of the edge weights, nonparametric bootstrapping with 1000 iterations was used to construct 95% confidence intervals, and bootstrapped difference tests were computed (Epskamp et al., 2018). This approach quantified the extent to which the edge weights were stable and could be interpreted as reliable measures of the strength of the connections between nodes.

To assess the stability of the strength centrality and BEI metrics, case-dropping subset bootstrapping with 1000 iterations was used. The stability of these metrics was quantified using correlation stability coefficients, which should not be below 0.25 and preferably be 0.5 or higher (Epskamp et al., 2018). This approach ensured that the strength centrality and BEI metrics were reliable and stable, and could be used to identify key nodes in the network.

3. Results

3.1. Sample characteristics

The present sample consisted of 3002 online gamers. According to the cut-off criterion by Qin et al. (2020), a composite score of 32 or higher on the IGDS9-SF questionnaire indicates a positive diagnosis of GD. In this study, 139 participants (4.6% of the sample) were classified as belonging to the GD group, based on this criterion.

3.2. Network structure of GD symptoms

3.2.1. Network estimation

Fig. 1a presents the unregularized GGM network structure of the GD symptoms. All symptoms in the GD network were positively correlated. As shown in this figure, the strongest edge in the network appeared between "deception" and "functional impairment",[1] and the next strongest edge was between "deception" and "continuation". The dense connections between "deception", "functional impairment", and "continuation" appear to be the manifestations of overt problematic behaviors related to GD.

On the other side of the network, "withdrawal" had the strongest connections with "loss of control" and "tolerance". "Salience" had the strongest connections with "tolerance", "loss of control", and "escape". The relatively dense connections between "withdrawal", "loss of control", "tolerance", "salience", and "escape" appear to be the manifestations of cognitive symptoms.

3.2.2. Strength centrality

The strength centrality for nodes in the GD network were inspected to examine their relative importance (see Fig. 1b). The symptom of "withdrawal" had the highest strength centrality, followed by "continuation" and "salience". The results suggested that these three are key symptoms that may play pivotal roles in the development and maintenance of GD. However, "escape" was the node with the lowest centrality in the network, suggesting that this symptom may play a relatively less important role than others in the GD network.

3.2.3. Network stability

The stability and accuracy of the edge weights and centrality indices were reported in the Supplementary Materials (see Figure S1 to S4). The correlation stability coefficient of strength centrality was 0.75, indicating a good stability of the centrality indices.

3.3. Network structure of the CRP-GD network

3.3.1. Network estimation

The structure of the CRP-GD network is presented in Fig. 2. The blue edges represented positive partial connections, whereas red edges represent negative partial connections.

The spinglass community analysis identified five clusters, including dysfunctional motivational-affective processing, maladaptive gaming cognition, meaning-focused coping, executive functions, and GD symptoms cluster. As depicted in Fig. 2, the eight cognitive risk factors were split into two distinct clusters, namely dysfunctional motivational-affective processing and maladaptive gaming cognition. The former cluster consisted of two variables of motivational sensitivity ("reward sensitivity" and "loss sensitivity") and two variables of maladaptive emotional regulation ("catastrophizing" and "blaming others"). This grouping represents a combination of general risk factors that is applicable to functioning problems commonly found in other types of behavioral addiction. The latter cluster consisted of all four variables of maladaptive gaming cognition ("reward overvaluation", "maladaptive gaming rules", "gaming self-esteem", and "gaming for social acceptance"). It is noteworthy that these four variables were cognitive risk factors specifically associated with GD, and the network analysis indicated that they were distinct from the cognitive risk factors common to other behavioral addictions as previously discussed.

Similar to the cognitive risk factors, the eight cognitive protective factors were also split into two distinct clusters, namely meaning-focused coping and executive functions. Specifically, the former cluster comprised two variables of perceived self-competence ("global self-esteem" and "self-efficacy"), three variables of adaptive emotional regulation ("blunting", "positive reappraisal", and "putting into perspective"), and a variable of executive functioning ("cognitive flexibility").

The executive functions cluster comprised only two variables, namely "working memory" and "inhibitory control." Interestingly, the cognitive protective factor of "cognitive flexibility" is grouped into the meaning-focused coping cluster instead of the executive functions cluster. A potential explanation is that the manifestation of putatively adaptive cognitive emotional regulation strategies requires a considerable level of cognitive flexibility to perceive situations in a flexible manner (Cheng & Cheung, 2005; Ghosh & Halder, 2020), and cognitive flexibility is essential for problem-solving and adaptability that facilitate self-beliefs through mastery experiences (Cañas et al., 2003; Morton & Montgomery, 2011). Lastly, the nine GD symptoms were grouped together to form their own cluster.

3.3.2. Strength centrality

The strength centrality indexes and the BEI for each node in the CRP-GD network are presented in Fig. 3. The strength centrality indexes of nodes in the network were first inspected to examine their relative importance. As shown in Fig. 3b, the five most central nodes in the network were: "cognitive flexibility", "gaming self-esteem", "loss sensitivity", "self-efficacy", and "global self-esteem". "Cognitive flexibility" was the most central node across the entire network, reflecting the important role of this cognitive protective factor in influencing the entire GD-related network structure. "Gaming self-esteem" was the most central cognitive risk factor, revealing its pivotal role in the development and maintenance of GD symptoms. Lastly, "loss of control" was the GD symptom that had the greatest strength centrality, indicating its significant role in the GD symptomatology. On the other hand, "blunting" and "blaming others" were less important, as they had the lowest strength centrality. These findings revealed that they had a smaller role in the network.

The strength centrality indexes of nodes within each cluster were then inspected. In the dysfunctional motivational-affective processing cluster, "loss sensitivity" had the highest strength centrality. In the maladaptive gaming cognition cluster, "gaming self-esteem" had the

[1] Quotation marks are used to distinguish between concepts or terms that have been specifically measured or tested in this study, as opposed to those that are generally used in everyday language.

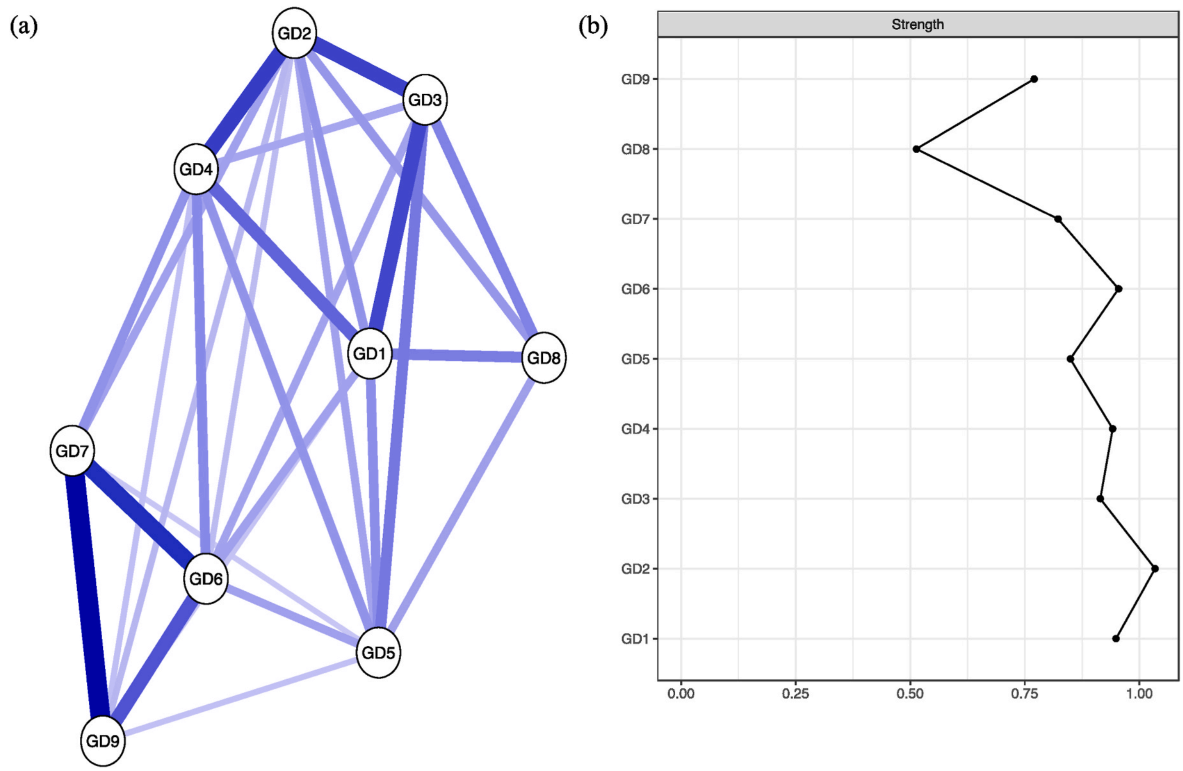

Fig. 1. Network structure of GD symptoms (a) and strength centrality of each node in the GD network (b). *Note*: GD1 = Salience; GD2 = Withdrawal; GD3 = Tolerance; GD4 = Loss of control; GD5 = Loss of interest; GD6 = Continuation; GD7 = Deception; GD8 = Escape; GD9 = Functional impairment. Blue edges represent positive connections between the nodes (variables). Both thickness and color saturation of the edges reflect the strength of the connection, in which edges with greater thickness and color saturation indicate stronger connections.

highest strength centrality. In the meaning-focused coping cluster, "cognitive flexibility" had the highest strength centrality. In the executive functions cluster, "inhibitory control" had the highest strength centrality. Lastly, in the GD symptoms cluster, "loss of control" had the highest strength centrality. Taken together, the influence of these five variables tended to be larger than the other variables in their respective clusters, implying their more critical role in GD through affecting other variables of their own cluster.

3.3.3. Inter-cluster connections

Fig. 3a shows the BEI for each node, which showed which nodes were involved in connecting different clusters within the CRP-GD network. The nodes with the highest BEI index were "escape", "loss sensitivity", and "cognitive flexibility," indicating that these variables played the most important role in activating and deactivating CRP factors and GD symptoms across clusters. The nodes with the second highest BEI index were "reward sensitivity", "maladaptive gaming rules", and "inhibitory control," also showing their importance in spreading activations across clusters of CRP factors and GD symptomatology. On the other hand, "salience" and "deception" had the lowest BEI index, reflecting their less important role in connecting CRP factors and GD symptoms across clusters in the network.

It is also noteworthy that several connections between nodes severe to bridge different CRP factors and GD symptom communities. Specifically, the findings revealed a negative association between "global self-esteem" and "escape" that served as a bridge between the meaning-focused coping and the GD symptoms clusters. These new findings suggest the benefits of self-esteem in coping with life stress that reduces the likelihood of relying on gaming as an avoidant coping strategy. Moreover, there was also a negative association between "working memory" and "loss of control" that bridged between the executive functions and the GD symptoms clusters. Such results suggest that working memory may be a useful cognitive tool that helps monitor one's gaming behavior and devise plans to exert control over excessive gaming patterns.

However, the findings identified a positive association between "reward sensitivity" and "deception" that bridged between the dysfunctional motivational-affective processing and the GD symptoms clusters, suggesting that the reward-seeking tendency of gaming is especially relevant to the GD symptom of deception. In addition, the positive association between "maladaptive gaming rules" and "tolerance" acted as a bridge between the maladaptive gaming cognition and the GD symptoms clusters, suggesting that the irrational, inflexible cognitive biases play an influential role in the constantly increasing duration of gaming observed in individuals with GD.

3.3.4. Network stability

The figures and information regarding the accuracy and stability of the estimated network, strength centrality, and BEI are provided in the Supplementary Materials (See Supplementary Figure S5 to S9), and the results indicate high accuracy and stability of edge weights and centrality indices. The correlation stability coefficient of strength centrality and BEI was 0.595 and 0.75 respectively, indicating acceptable-to-good stability for both metrics.

4. Discussion

The present study adopted a network analytic approach to investigate the associations between CRP factors and GD symptoms. The findings revealed five distinct communities that map the network of these cognitive factors associated with GD, including dysfunctional motivational-affective processing, maladaptive gaming cognition, meaning-focused coping, executive functions, and GD symptoms. The study also demonstrated how these CRP factors and GD symptoms are

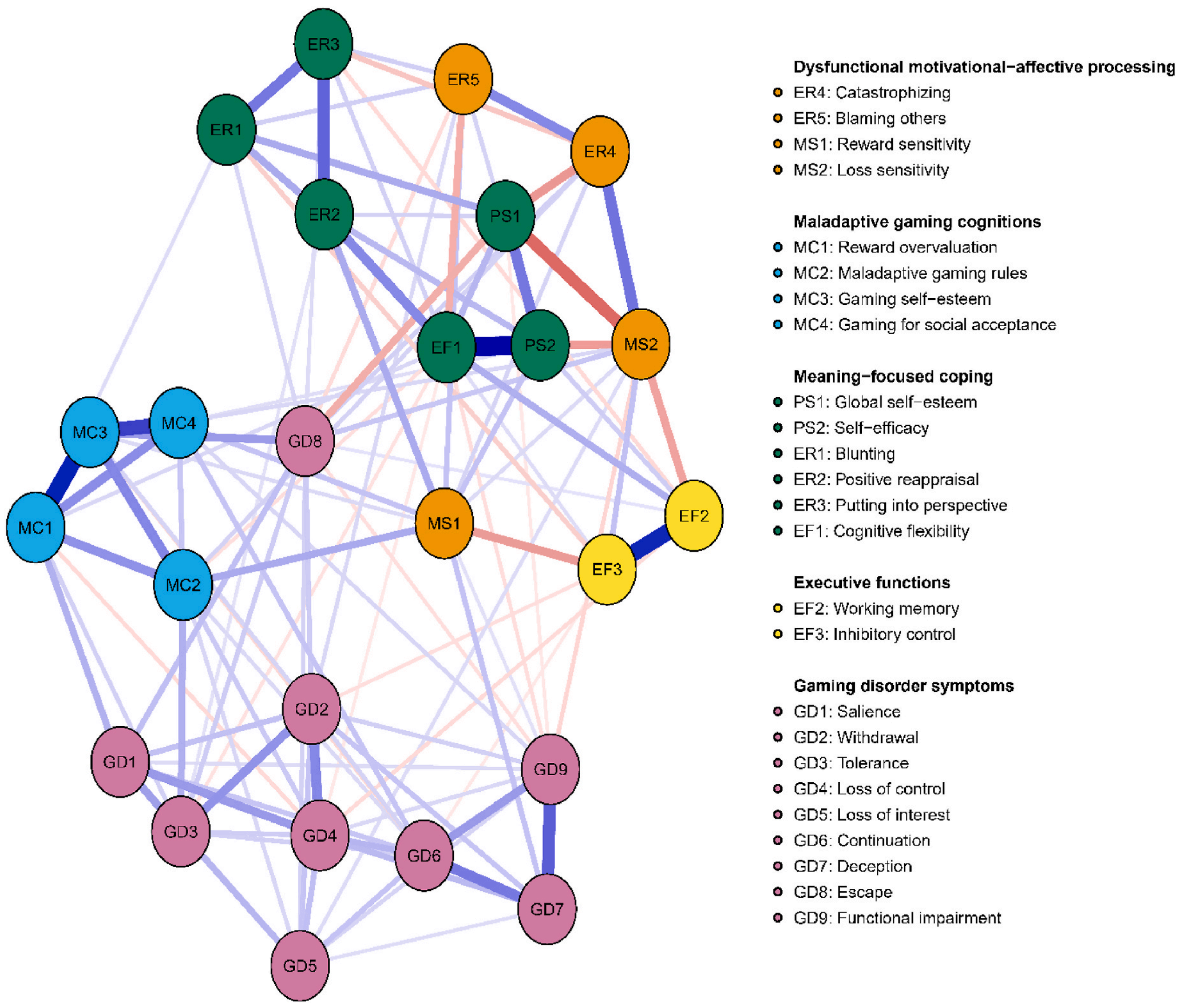

Fig. 2. Network structure of CRP-GD network, regrouping nodes based on spinglass community. *Note.* Blue edges represent positive connections between the nodes (variables), whereas red edges represent negative connections. Both thickness and color saturation of the edges reflect the strength of the connection, in which edges with greater thickness and color saturation indicate stronger connections. Orange nodes indicate dysfunctional motivational-affective processing, blue nodes indicate maladaptive gaming cognition, green nodes indicate meaning-focused coping, yellow nodes indicate executive functions, and purple nodes indicate GD symptoms.

interconnected within and between communities.

The findings identified the most important components of the network, which included three variables that are likely to have the greatest influence on the network's connections: "loss sensitivity", "escape" and "cognitive flexibility". Of these three variables, "cognitive flexibility" had the highest strength centrality, indicating its influence is the strongest within the network. These findings provide an initial understanding of how various GD symptoms are expressed, sustained, and alleviated through interactions with different CRP factors.

4.1. Identification of five clusters and their central nodes

The present network analysis identified five clusters of CRP factors and their central nodes. First, the dysfunctional motivational-affective processing cluster includes four cognitive risk factors: "loss sensitivity", "reward sensitivity", "catastrophizing", and "blaming others". Of these, "loss sensitivity" has the highest strength centrality, indicating its importance in the cluster. This finding is significant because some scholars have posited that decreased loss sensitivity could lead to the development of GD (Dong & Potenza, 2014). However, our results show that loss sensitivity is positively associated with other cognitive risk factors and GD symptoms, making it a risk factor in itself. Our findings further suggest that loss sensitivity plays a role in attentional biases towards negative stimuli and in cooperation with other maladaptive emotional regulation strategies, which may result in the experience of more intense unpleasant emotions. Such intense emotions can lead to a depletion of cognitive resources for problem-focused coping (Plass & Kalyuga, 2019), which can increase the likelihood of deploying emotion-focused avoidant strategies in the form of escape (Bar-Haim et al., 2010).

Second, the maladaptive gaming cognition cluster consists of four variables: "reward overvaluation", "maladaptive gaming rules", "gaming self-esteem", and "gaming for social acceptance". This cluster is spatially closest to the GD construct in the network, indicating its strong association with the disorder. The finding supports the four-factor model of GD, which puts forward that maladaptive gaming cognition forms a solid cognitive profile of individuals with GD (King & Delfabbro, 2014). Among the variables in the maladaptive gaming cognition cluster, "gaming self-esteem" has the highest strength centrality, highlighting its crucial role in persistent gaming-related biases. Therefore, gaming self-esteem should be given greater attention as an essential characteristic of GD, in addition to the diagnostic symptoms.

Third, the meaning-focused coping cluster includes six cognitive protective factors: "global self-esteem", "self-efficacy", "blunting", "positive reappraisal", "putting into perspective", and "cognitive flexibility". This grouping echoes the I-PACE model's proposition that a person's core characteristics and emotional regulation strategies mutually influence each other (Brand et al., 2016). Within the

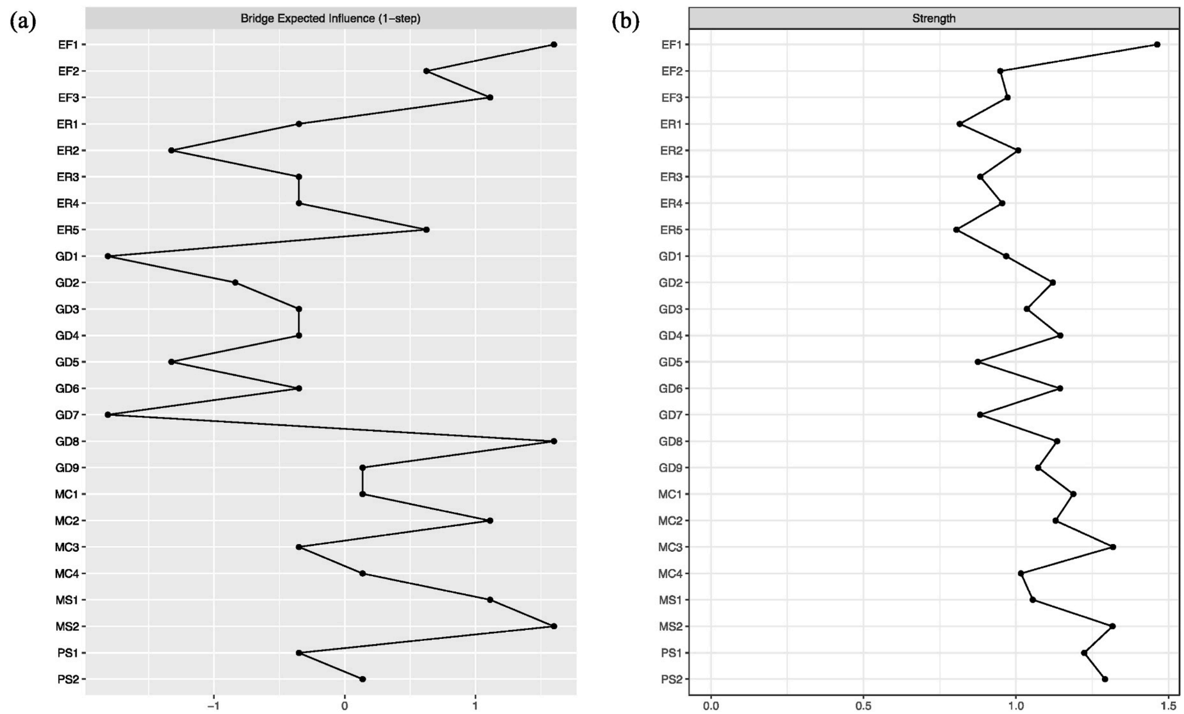

Fig. 3. Bridge expected influence (a) and strength centrality of each node (b) in the CRP-GD network. *Note*. EF1 = Cognitive flexibility; EF2 = Working memory; EF3 = Inhibitory control; ER1 = blunting; ER2 = Positive reappraisal; ER3 = Putting into perspective; ER4 = Catastrophizing; ER5 = blaming others; GD1 = Salience; GD2 = Withdrawal; GD3 = Tolerance; GD4 = Loss of control; GD5 = Loss of interest; GD6 = Continuation; GD7 = Deception; GD8 = Escape; GD9 = Functional impairment; MC1 = Reward overvaluation; MC2 = Maladaptive gaming rules; MC3 = Gaming self-esteem; MC4 = Gaming for social acceptance; MS1 = Reward sensitivity; MS2 = Loss sensitivity; PS1 = Global self-esteem; PS2 = Self-efficacy.

meaning-focused coping cluster, "cognitive flexibility" has the highest strength centrality, indicating its critical role in shaping or maintaining different perceived self-competence and potentially adaptive emotional regulation strategies. According to the cognitive control framework of emotional regulation flexibility (Pruessner et al., 2020), cognitive flexibility is highly involved in shifting between multiple tasks, mindsets, and strategies, highlighting its important role in emotional regulation flexibility and potentially adaptive patterns of gaming behavior.

Fourth, the executive functions cluster has two variables, namely "working memory" and "inhibitory control". The cognitive control framework of emotional regulation flexibility posits that these two variables work collaboratively with "cognitive flexibility" to perform emotional regulation flexibility (Pruessner et al., 2020). However, in this study, "working memory" and "inhibitory control" showed stronger connections to variables related to motivational sensitivity than to those related to emotional regulation strategies. This novel finding suggests that both variables may focus more on monitoring and regulating the perception and processing of external stimuli. Within the executive functions cluster, "inhibitory control" has higher strength centrality, highlighting its substantial role in GD-related constructs. This finding is consistent with previous research on inhibitory control in GD (e.g., Li et al., 2020).

Finally, the cluster of GD symptoms comprises the nine diagnostic symptoms defined in the DSM-5 (APA, 2013). Among these symptoms, "loss of control" has the highest strength centrality, which echoes the results of a recent study (Gomez et al., 2022). Although further research is needed to investigate whether loss of control is the primary driver that activates other GD symptoms, this symptom is crucial for understanding the mechanism underlying GD. Given its central location in the GD symptoms cluster, "loss of control" may serve as a bridge between cognitive symptoms (e.g., withdrawal) and overt problematic behaviors (e.g., functional impairment). This finding suggests that having a loss of control could be a significant characteristic of GD symptomatology.

4.2. Central GD symptoms

In the GD symptoms network, "withdrawal" has the highest strength centrality, suggesting its significant role in the GD symptomatology. Similar to substance addictions, GD is also characterized by abnormal reward processing, which is one of the major mechanisms of this disorder (Raiha et al., 2020). According to the homeostatic principles and the opponent processes theory, withdrawal is a natural response to repeated rewarding stimuli, which causes a drop in dopamine levels in the nucleus accumbens (e.g., Koob et al., 1997; Poulos & Cappell, 1991). It takes time for dopamine levels to return to normal after the rewarding stimulation stops (e.g., Solomon & Corbit, 1974). The study by Holm et al. (2021) showed that nearly 60% of gamers have experienced withdrawal symptoms but, in most cases, these symptoms tend to disappear within 6 h. Such findings imply that most gamers who experience short-term withdrawal symptoms can overcome them without developing problematic gaming patterns. Yet, withdrawal may be an early indicator of developing other GD symptoms in certain cases.

In the CRP-GD network, it is noteworthy that "loss of control" becomes the most central among all of the GD symptoms. According to the allostatic theory of addiction (Koob & Le Moal, 2001), repeated exposure to rewarding stimuli over a long period of time can interfere with the reward processing system, leading to neuroadaptation where normal activity levels cannot be restored. This can elicit compulsive gaming behaviors and loss of control. While healthy gamers may also experience withdrawal symptoms, the presence of loss of control distinguishes heavy gamers from those with GD, as noted by Billieux et al. (2019). The findings suggest that the symptom of loss of control may be a major diagnostic feature that requires more careful attention.

Interestingly, the GD symptom of "escape" shows a unique pattern of connections in the CRP-GD network. Specifically, it has fewer connections within the GD construct and even a small negative association with another symptom of functional impairment. This unexpected finding suggests that escape may be a distinct symptom of GD. In the literature, some scholars have raised concerns about the validity of escape as a GD symptom due to its low centrality in symptom networks and low diagnostic accuracy as identified in their research (Ko et al., 2020; Yuan et al., 2022). Nevertheless, the present network analytic findings show that escape is the third most important symptom within the GD construct and has the highest overall BEI in the CRP-GD network. The new findings suggest that escape plays an influential role in connecting different variables, even if it has low influence among GD symptoms. Like most avoidant coping strategies, escape may not be problematic on its own (Cheng & Chau, 2019). Hence, instead of being classified as a symptom of GD, escape may be more appropriately classified as a risk factor of GD.

4.3. Central cognitive factors of GD

Among the cognitive risk factors, "gaming self-esteem" has the highest strength centrality, reflecting its pivotal role in constructing and maintaining GD's psychological states and excessive gaming patterns. These results are in line with the self-determination theory in showing the tendency of individuals with GD to over-rely on gaming to fulfill their esteem needs (Moller & Deci, 2006; Scerri et al., 2019). Importantly, the GD symptom of "escape" has the strongest association with "gaming self-esteem", further supporting the notion that gratification of fundamental psychological needs is the primary driver of gaming in individuals with GD. The maladaptive gaming cognition cluster, as proposed by King and Delfabbro (2014), forms a cognitive profile of individuals with GD and may act as a bridge between other cognitive constructs and GD symptoms. Each maladaptive gaming cognition has the strongest edge with different GD symptoms, indicating that individuals with different maladaptive gaming cognitions may have distinct key symptoms or initiate a series of GD symptoms. Further time-series network studies are needed to investigate the developmental and transformation processes of maladaptive gaming cognition throughout the continuum of GD.

Among the cognitive protective factors, "cognitive flexibility" has the highest BEI and strength centrality in the network. This pattern of connections highlights its role in shifting perspectives and adjusting behaviors to avoid prolonged unpleasant moods and misuse of maladaptive coping strategies. Cognitive flexibility allows individuals to make alternative solutions and explanations, which is related to an internal locus of control as well as lower levels of perceived stress and aversive emotions (e.g., Cheng & Cheung, 2005; Dennis & Vander Wal, 2010). This cognitive protective factor. This cognitive protective factor may also help gratify esteem needs and reduce the risk of developing GD (Koo, 2009). Interestingly, this cognitive resource factor shows a positive bridging edge with the cognitive risk factor of "reward overvaluation". This may occur when gamers shift their focus to gaming to protect themselves from harm encountered in daily life. The present findings support the importance of inhibitory control in impulse control, resisting gaming distractions, and coping with withdrawal effects. However, "inhibitory control" is positively associated with "gaming self-esteem". This new result suggests that when excessive gaming is shaped by cognitive biases that perceive gaming as highly important to one's self-concepts and self-worth, it may not involve inhibitory control deficits. Instead, inhibitory control may be required to continue gaming despite the perception of high costs and effort.

4.4. Mechanistic clusters of GD

In addition to identifying five clusters and their central nodes, the network analysis further revealed that "escape", "loss sensitivity", and "cognitive flexibility" share the highest BEI index, whereas "reward sensitivity", "maladaptive gaming rules", and "inhibitory control" share the second-highest BEI index in the CRP-GD network. The presence of multiple nodes with high BEI suggests that there may be multiple potential mechanisms contributing to the psychological state related to GD. The study identified two mechanistic clusters of GD, namely escapism and reward-seeking, which align with Dong and Potenza's (2014) cognitive-behavioral model of internet gaming disorder.

The present study indicates that "escape" and "loss sensitivity" play significant roles in bridging all constructs in the network, suggesting the presence of an escapism mechanistic cluster of GD. This cluster resembles the emotionally vulnerable type of GD, as proposed by Lee et al. (2017). The variables of "escape" and "loss sensitivity" are interrelated and share the same bridging edge that connects with "global self-esteem" and "gaming self-esteem". In line with the self-determination theory (Ryan & Deci, E, 2017), these associations reflect that individuals with unfulfilled psychological needs tend to have low self-esteem and be emotionally vulnerable, motivating them to play video games to compensate for their unmet psychological needs.

Similarly, the study revealed that the variables of "reward sensitivity" and "maladaptive gaming rules" had similar patterns of association, suggesting the presence of a reward-seeking mechanistic cluster of GD. This cluster is comparable to the impulsive or aggressive subtype of GD proposed by Lee et al. (2017). The interrelationships among these variables highlight the reward-seeking characteristics of the disorder, with some antisocial manifestations (e.g., "deception") associated with "reward sensitivity". Interestingly, "positive reappraisal" appears to play a role in reframing adverse real-life consequences brought by excessive gaming or justifying biased beliefs about gaming, resembling the characteristics of people with gambling disorder (Ruiz de Lara et al., 2019).

Furthermore, the study reveals rigidity as a defining feature of the reward-seeking mechanistic cluster of GD, characterized by maladaptive gaming rules shaped by aberrant reward-based learning during the course of receiving rewards in gaming. These rules are built upon biased thoughts of reward overvaluation together with low cognitive flexibility, thus elevating reward sensitivity through increased amounts of time and effort spent on gaming (Duven et al., 2015). As a result, maladaptive gaming rules can maintain excessive gaming patterns through the misuse of positive reappraisal and the feedback loop between rigidity and aberrant reward-based learning.

4.5. Practical implications

In addition to the conceptual and research implications previously discussed, our network analysis also has some practical implications. Specifically, our network analysis has identified several cognitive risk factors that are uniquely related to specific GD symptoms. One of the most notable findings is the negative association between inhibitory control and the GD symptom of tolerance. Individuals with lower inhibitory control, and therefore a reduced ability to suppress impulsive behavior, are more likely to have higher tolerance for gaming and engaging in increasingly lengthy gaming sessions. The identification of impulsivity as a key feature in various types of addiction disorders, including substance use disorder and gambling addiction (e.g., Ioannidis et al., 2019; Stevens et al., 2014), highlights the need for clinicians to screen for impulsivity as a risk factor in the assessment of GD. Goal management training has been shown to be an effective intervention in reducing impulsive behavior in various types of behavioral addiction (e.g., Anderson et al., 2021; Valls-Serrano et al., 2016). In this light, interventions that target impulsivity may show promise in mitigating GD symptoms, such as tolerance and uncontrolled gaming behavior. However, further studies with multiple time points, which examine longitudinal changes over time, are needed to validate these proposals before implementing them in the interventions.

The tendency to use gaming as a form of escapism to avoid real-world problems is identified as one of the most prominent factors bridging cognitive risk factors and GD symptoms. This new finding highlights the need to screen for the cognitive risk factor of escapism in the assessment of GD. Goal management training may be a suitable intervention to explore further in reducing symptoms of this disorder, as it focuses on improving self-control and helping individuals find alternative behaviors instead of engaging in harmful activities (Robertson, 1996). In addition, goal management training emphasizes managing emotions effectively (Robertson, 1996), which is crucial in decreasing the tendency to use gaming as a form of escapism. This new finding presents an opportunity for future to check whether goal management training can be an effective intervention for mitigating GD symptoms. Similar interventions have been effective in reducing symptoms of other types of behavioral addiction, such as substance abuse and gambling disorder (e.g., Anderson et al., 2021; Valls-Serrano et al., 2016). Further work is needed to more thoroughly evaluate the effectiveness of this intervention in the treatment of GD.

Reward sensitivity is found to be uniquely connected to two GD symptoms—tolerance and salience—in this network analysis. This new result highlights the role of sensitivity to rewards as a significant risk factor of GD. This particularly strong connection suggests that screening for reward sensitivity may be useful in identifying individuals who are more likely to experience preoccupied thoughts about gaming compared to their peers. Cognitive-behavioral interventions have been found to be effective in treating GD and other behavioral addictions (e.g., Han et al., 2020; Petry et al., 2006). One promising type of intervention that may be investigated in future studies is cognitive restructuring with individuals who are prone to reward sensitivity and report high levels of recurrent and preoccupied thoughts about gaming. It is noteworthy that reward sensitivity is among the strongest factors bridging cognitive risk factors and GD symptoms. This new result highlights the importance of clinicians being attentive to reward sensitivity when screening for potential susceptibility to GD.

The tendency to justify continued gaming despite undesirable consequences (i.e., the factor of maladaptive gaming rules) is shown to be strongly associated with multiple GD symptoms. The new finding is consistent with previous research on permissive beliefs and addiction (e.g., Ryan, 2022; Wright et al., 1993), emphasizing the significance of screening for cognitive beliefs related to gaming. Cognitive-behavioral interventions have been shown to be effective in addressing these beliefs and mitigating GD symptoms (Han et al., 2020). Therefore, it is crucial for clinicians to be aware of these maladaptive gaming rules and to consider using cognitive-behavioral interventions as a possible approach to challenge and intervene on these maladaptive thoughts in individuals with GD.

Finally, this network analysis has unveiled cognitive flexibility as a protective factor against the development of GD. Specifically, the findings indicate that this cognitive factor has a protective association with the tolerance and loss of control GD symptoms. This implies that training individuals to flexibly switch their focus away from gaming when necessary could be an effective protective measure against GD symptoms. Our new finding thus highlights the need for further investigation of cognitive flexibility in intervention studies with longer time frames.

4.6. *Research caveats and future research directions*

Despite the implications drawn to inform the research and treatment of GD, there are several research caveats in our study. With a cross-sectional design, directionality cannot be drawn in this study, which does not allow drawing firm conclusions regarding how CRP factors increase or mitigate GD symptoms. Although several CRP factors and GD symptoms are reported to be highly central in the network, it is unclear whether they exert high influence or being highly influenced by other nodes in the network. However, the present new findings contribute to the literature in identifying several CRP factors as core characteristics of GD, and be able to furnish hypotheses about possible mechanistic relationships that may benefit future research on GD. Thus, future studies adopting dynamic networks are needed to reveal substantial etiology for demonstrating GD symptom development, and the beneficial effects of various protective factors over time.

This study estimated interindividual network at a group level, but there may be potential differences across age groups, gender, cultural groups, and gaming genres. Although our findings have captured the general patterns across demographic backgrounds, the pattern of findings may not be identical at an intraindividual level. Therefore, future studies can replicate our study with samples of different demographical backgrounds, as well as employing dynamic network analysis to reveal the GD's etiology, and protective effects against GD at an intraindividual level. Moreover, this study includes participants along the entire continuum of GD symptom severity, ranging from average individuals without GD to those with probable GD. Given that there may be substantial differences between non-clinical and clinical populations, replicating the current results with a clinical sample is highly recommended in future studies.

In addition, the internal consistency of the scale measuring "inhibitory control" was poor, in which significant improvement in reliability cannot be made even if some of the items of the scale are dropped. Such reliability problem in "inhibitory control" measures from the Adult Executive Functioning Inventory (Holst & Thorell, 2017) can reduce the power of the results, in which the role of "inhibitory control" may be undermined in our analysis. Given that "inhibitory control" is an important construct in GD, this variable was included in current study, but it warrants special attention when interpreting the results, especially those related to "inhibitory control".

As aforementioned, maladaptive gaming cognition may play a substantial role in GD symptom development and maintenance. Since maladaptive gaming cognition are made up of different gaming-related cognitive biases, it is worthwhile to investigate how GD symptoms arise from the interactions between different types of cognitive bias throughout the course of gaming in future research. In addition, given the similarities among some information technology addictions (Sigerson et al., 2017), future research can investigate how different cognitive processes bridge between various types of information technology addictions to better understand the shared etiological mechanisms.

Credit author statement

Ming-Chun Tang: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing- Original draft preparation, Writing- Reviewing and Editing. Omid Ebrahimi: Validation, Methodology, Writing- Reviewing and Editing. Cecilia Cheng: Conceptualization, Methodology, Software, Supervision, Writing- Original draft preparation, Writing- Reviewing and Editing.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2023.107899.

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