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J Abnorm Psychol. 2017 April ; 126(3): 340–354. doi:10.1037/abn0000254.**The Core Symptoms of Bulimia Nervosa, Anxiety, and Depression: A Network Analysis****Cheri A. Levinson^a, Stephanie Zerwas^b, Benjamin Calebs^a, Kelsie Forbush^c, Hans Kordy^d, Hunna Watson^{b,k,l}, Sara Hofmeier^e, Michele Levine^f, Ross D. Crosby^{g,h}, Christine Peat^{b,i}, Cristin D. Runfola^{b,j}, Benjamin Zimmer^d, Markus Moesner^d, Marsha D. Marcus^{f,1}, and Cynthia M. Bulik^{b,m,n,1}**^aDepartment of Psychological and Brain Sciences, University of Louisville, Life Sciences Building, Louisville, KY 40292^bDepartment of Psychiatry, University of North Carolina at Chapel Hill, CB 7160, Chapel Hill, NC 27599^cDepartment of Psychology, The University of Kansas, 1415 Jayhawk Blvd, Fraser Hall, Lawrence, KS 66045-7556^dCenter for Psychotherapy Research, University of Heidelberg, Bergheimer Str. 54, 69115 Heidelberg, Germany^eVeritas Collaborative, 615 Douglas St #500, Durham, NC 27705^fDepartment of Psychiatry, Western Psychiatric Institute and Clinic, University of Pittsburgh Medical Center, 3811 O'Hara Street, Pittsburgh, PA 15213^gNeuropsychiatric Research Institute, 120 Eighth Street South Fargo, ND 58107^hDepartment of Psychiatry and Behavioral Science, University of North Dakota School of Medicine and Health Sciences, Fargo, ND 58102ⁱDepartment of Neurosurgery, University of North Carolina at Chapel Hill, Chapel Hill, NC 27514^jDepartment of Psychiatry and Behavioral Sciences, Stanford University School of Medicine, 401 Quarry Rd., Stanford, CA 94304^kSchool of Paediatrics and Child Health, Faculty of Medicine, Dentistry, and Health Sciences, The University of Western Australia, Stirling Highway, Crawley, Western Australia, Australia 6009^lSchool of Psychology and Speech Pathology, Faculty of Health Sciences, Curtin University, Kent Street, Bentley, Western Australia, Australia 6102

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¹The last two authors contributed equally.**Disclosures**

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Abstract

Bulimia nervosa (BN) is characterized by symptoms of binge eating and compensatory behavior, and overevaluation of weight and shape, which often co-occur with symptoms of anxiety and depression. However, there is little research identifying which specific BN symptoms maintain BN psychopathology and how they are associated with symptoms of depression and anxiety. Network analyses represent an emerging method in psychopathology research to examine how symptoms interact and may become self-reinforcing. In the current study of adults with a DSM-IV diagnosis of BN ($N=196$), we used network analysis to identify the central symptoms of BN, as well as symptoms that may bridge the association between BN symptoms and anxiety and depression symptoms. Results showed that fear of weight gain was central to BN psychopathology, whereas binge eating, purging, and restriction were less central in the symptom network. Symptoms related to sensitivity to physical sensations (e.g., changes in appetite, feeling dizzy, wobbly) were identified as bridge symptoms between BN, and anxiety and depressive symptoms. We discuss our findings with respect to cognitive-behavioral treatment approaches for BN. These findings suggest that treatments for BN should focus on fear of weight gain, perhaps through exposure therapies. Further, interventions focusing on exposure to physical sensations may also address BN psychopathology, as well as co-occurring anxiety and depressive symptoms.

Keywords

Bulimia Nervosa; Anxiety; Depression; Network Analysis

Models based on theories of psychopathology have the ability to enhance our understanding and treatment of mental disorders. The field of clinical psychology has traditionally relied on latent variable theory and has used these models to help understand why mental disorders develop and persist (e.g., Bollen, 2002; Borsboom et al., 2016; Clark & Watson, 1991; Eaton, 2015; Haslam, Holland, & Kuppens, 2012). In latent variable theory it is assumed that symptoms of mental disorders arise from a common cause (e.g., Borsboom et al., 2016; Clark & Watson, 1991). For example, in bulimia nervosa (BN) it is assumed that symptoms such as fear of weight gain, avoidance of food, binge eating, and purging each arise from an underlying latent variable that represents BN. In other words, BN is the *cause* that leads to each of these common symptoms. However, there are additional theories and modeling techniques that are being increasingly applied to psychopathology.

One of these more recent theories is network theory. Network theory proposes that symptoms of disorders cause each other (Borsboom & Cramer, 2010). In other words, symptoms are part of a dynamic network of symptoms, which produce, sustain, and underlie mental disorders (e.g., Kendler, Zachar, & Craver, 2011). For example, in BN, the symptoms *fear of weight gain* and *avoidance of food* may be highly correlated not because they stem from the same latent variable representing ‘bulimia’, but because *fear of weight gain* directly

leads to *avoidance of food* (for additional examples with other disorders please see: Borsboom & Cramer, 2013). These symptoms may then interact with each other to strengthen (or weaken) the disorder. Network *theory* proposes that there are *causal* paths between such symptoms. This type of theory can be tested using network analysis.

Network *analysis* is a methodology drawn from network science that allows for an unprecedented number of interacting factors to be considered at once within a mathematical model (Borgatti, Mehra, Brass, & Labianca, 2009). Applied to the study of psychopathology, network analysis allows for examination of how individual behaviors or symptoms are associated with other behaviors or symptoms (e.g., Borsboom et al., 2010). Further, network analysis allows for the characterization of core symptoms (e.g., central features of the disorder) within networks of psychopathology (using measures of centrality explained further in the analyses section). Thus, network analysis is one step towards understanding causal pathways between symptoms of disorders (pending experimental and longitudinal research testing causal pathways). By analyzing symptoms as a network, we can examine not just how symptoms of disorders are associated with each other, but how they may interact and become mutually reinforcing (e.g., Cramer, Waldorp, van der Mas & Borsboom, 2010).

Most recently in network analysis, methods of using partial correlation networks have been championed as the best way to understand psychopathology (please see McNally, 2016 for a discussion of the different types of network analyses, for a comparison between latent variable analysis and network analysis, as well as limitations and strengths of both methods). Partial correlation networks control for each of the symptoms in the network. If symptoms are overlapping, partial correlation networks account for that overlap. Consider the example of major depressive disorder. A partial correlation network would allow researchers to understand how the symptoms *difficulty sleeping*, *irritability*, and *difficulty concentrating* each uniquely interact with each other, while considering all relationships between these symptoms. For example, irritability and difficulty concentrating may be affected by difficulty sleeping. A partial correlation network explains how these symptoms relate while also considering the impact of difficulty sleeping on both irritability and difficulty concentrating. This methodology provides a way to understand which symptoms uniquely contribute to the development and maintenance of psychopathology.

Network theory has not yet been applied to BN. However, applying network theory to BN may elucidate several important aspects of the illness. Several existing theories propose that symptoms such as overevaluation of weight and shape may be central to BN psychopathology (e.g., Fairburn et al., 1986; Fairburn & Cooper, 1993; Fairburn, Shafran, & Cooper, 2003; Vitousek, & Brown, 2015). Network analysis is a methodology that allows researchers to test if these symptoms are central to BN psychopathology within individuals diagnosed with BN and how such symptoms might interact with other symptoms in a BN psychopathology network. Thus, network analysis provides researchers with a nuanced understanding of how symptoms relate to each other and how they might maintain BN. Network analysis can also establish how symptoms of comorbid disorders interact with symptoms of BN. For example, network analysis can identify which anxiety symptoms are most likely to impact BN symptoms (and vice versa).

A network analysis has clinical utility. First, interventions focusing on alleviating specific central symptoms (symptoms related to the most other symptoms) should theoretically also decrease related symptoms. Second, defining which symptoms lie at the center of a psychopathology network might lead to focused interventions to target these core symptoms (symptoms which have high centrality in the network and may play a crucial role in the network) (Hayes, Yasinski, Barnes, & Bockting, 2015). From a cognitive-behavioral perspective, these core symptoms may be central to the maintenance of the psychopathology network (e.g., Beck, 2011; Clark & Wells, 1995; Fairburn, Cooper, & Shafran, 2003). Therefore, intervening on core symptoms that are highly related to most other symptoms in the network should maximize the impact of the intervention on the other behaviors, thoughts, and emotions related to the core symptom. Third, by identifying the core symptoms of *comorbid* disorders (e.g., comorbid anxiety symptoms), treatments could be refined to focus on these symptoms. Focusing on core comorbid symptoms could disrupt or weaken the cycle between symptoms of multiple psychopathologies (e.g., eating disorder and anxiety disorder symptoms) or weaken the connection between them. Identification of these networks may ultimately lead to interventions that are more finely honed to target core symptoms in the network.

In the current study, in a clinical sample of individuals with BN, we first examined a psychopathology network of BN symptoms to identify which symptoms are most central in a BN psychopathology network (i.e., identification of core symptoms). Next, we examined which symptoms of anxiety and depression are most strongly related to symptoms of BN. This study had two primary aims: (a) to identify which symptoms of BN are central to the disorder and (b) to test which symptoms of anxiety and depression are most strongly related to symptoms of BN. We hypothesized that the hallmarks of BN (binge eating and purging behaviors, as well as the undue influence of body weight or shape on self-evaluation, or overevaluation of weight and shape) would be more central to the BN network than other symptoms. Additionally, we hypothesized that physical sensation symptoms associated with eating and digestion, such as indigestion and appetite, may be bridge symptoms between BN symptoms and associated anxiety and depression.

Methods

Design and Procedure

Data were drawn from a randomized controlled trial conducted at two eating disorder centers, the Center of Excellence for Eating Disorders (CEED) at the University of North Carolina at Chapel Hill and the Center for Overcoming Problem Eating (COPE) at Western Psychiatric Institute and Clinic, University of Pittsburgh Medical Center. The institutional review boards at both institutions approved the trial and all patients provided informed consent. Details regarding the design, methods, and treatment of the study have been published previously and the study is registered at ClinicalTrials.gov ([NCT00877786](https://clinicaltrials.gov/ct2/show/study/NCT00877786)) (Bulik et al., 2012). We used baseline data in the current study. BN, anxiety, and depressive disorder diagnoses were based on the Eating Disorder Examination interview (Fairburn & Cooper, 1993) and the DSM-IV SCID-I/P semi-structured interviews.

Participants

A total of 196 patients participated in the baseline assessment. Participants were primarily female ($n = 187$; 95.4%) and of European ancestry ($n = 165$; 84.2%). Other ancestries reported were: African-American ($n = 11$; 5.6%), Asian ($n = 5$; 2.6%), Native Hawaiian or Pacific Islander ($n = 1$; .5%), and other ($n = 10$; 5.1%). Participants' average age was 28.2 years ($SD = 9.2$; range = 18 to 65). Patients were recruited via clinical referrals and advertisements in university listservs, print, radio, and social media platforms (such as Facebook), and brochures at counseling centers, physician offices, and mental health organizations. Patients completed a telephone screen to assess inclusion and exclusion criteria before an in-person baseline assessment.

Inclusion criteria were DSM-IV diagnosis of BN (American Psychiatric Association, 2000); 18 years; body mass index (BMI) ≥ 18.5 kg/m²; English speaking; and private access to the Internet. Exclusion criteria included any major medical condition that would interfere with treatment (e.g., type 1 diabetes mellitus; $N = 6$); alcohol or drug dependence in the last three months ($N = 11$); psychosis, including schizophrenia, and bipolar I disorder or current significant suicidal ideation reported during the clinical assessment ($N = 10$). A sizable proportion of participants had a lifetime diagnosis of comorbid depression or anxiety, with $n = 136$ (69.4%) meeting criteria for major depressive disorder and $n = 75$ (38.3%) meeting criteria for any anxiety disorder, obsessive-compulsive disorder, or post-traumatic stress disorder.

Measures

Eating Disorder Symptoms—Eating Disorder symptoms (e.g., binge eating, restriction, overevaluation of weight, fears of fatness: for a full list of symptoms assessed please see note for Figure 1) were assessed via the *Eating Disorder Examination* interview (EDE) (Fairburn & Cooper, 1993) and the ADQ (Bauer, Winn, Schmidt, & Kordy, 2005). The ADQ is a follow-up measure developed from the *The Short Evaluation of Eating Disorders* (SEED; Bauer et al., 2005). The SEED is a brief instrument, which assesses eating disorder symptoms on a weekly basis during treatment participation. The ADQ was specifically designed to assess number of days and times a participant engaged in eating disorder behaviors over the previous week. We used the symptoms vomiting, purging, and excessive exercising from the ADQ prior to treatment.

Beck Anxiety Inventory (BAI) (Steer & Beck, 1997)—Anxiety symptoms were assessed via the BAI, a 21-item self-report measure of anxiety. Each symptom is rated for severity on a scale from “not at all” to “severely-it bothered me a lot”. The BAI had excellent internal consistency ($\alpha = 0.90$).

Beck Depression Inventory II (BDI-II) (Beck, Steer, & Brown, 1996)—Depression symptoms were assessed via the BDI-II, a 21-item self-report measure of depression. Each symptom was rated for severity based on endorsement of one of a series of statements arranged in order from least to most symptomatic. The BDI-II has been validated in psychiatric and non-psychiatric samples (Steer, Ball, Ranieri, & Beck, 1997) and has excellent internal consistency.

Network Analyses

In psychopathology networks, edges or ties represent the correlation between two nodes. In the present study, the strength of a tie was operationalized as the partial correlation coefficient between two nodes (i.e., the correlation coefficient for two nodes after controlling for the influence of all other nodes in the network with which they are connected). Networks can be weighted or unweighted. Unweighted networks are those in which the relationship between nodes is either present or not (e.g., McNally, 2016). Weighted networks are those in which some operationalization of the strength of the tie exists (as in a partial correlation network; e.g., McNally, 2016). The operationalization of tie strength as a partial correlation coefficient made the network models in the present study weighted networks.

Network models were constructed and analyzed in *R* (Version 3.2.4) using the *qgraph* package (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012). We used a portion of the script provided in the supplemental materials from Borsboom and Cramer (2013), a script provided by Costantini and colleagues (2015), and a script from Epskamp (2014) to arrive at our network models. We created *graphical lasso* (Glasso) networks using the *glasso* function in *qgraph* (Epskamp et al., 2012). Glasso networks include a least absolute shrinkage and selection operator (i.e., lasso) penalty (Friedman, Hastie, & Tibshirani, 2008; Tibshirani, 1996), which functions to create a more parsimonious network by reducing small correlations to zero.

Additionally, a glasso network arises from a partial correlation network; thus, each pathway is the remaining relationship between two variables after partialling all other relationships, which has been proposed as a means of limiting spurious connections in a network (Costantini et al., 2015). The glasso network is a variant of the general lasso model that calculates differing penalty weights for the various correlation coefficients (Friedman, Hastie, & Tibshirani, 2008). Because the literature suggests that glasso models account for both partial relationships and small relationships between items, we present these models in the current study.

Interpreting the networks—In each visual network, a circle represents an individual *node* or *symptom* (one item from the symptom measures). Associations between nodes are represented with either green or red *lines*, in which green lines represent a positive relationship between the symptoms and red lines represent a negative relationship between symptoms. Strongly related symptoms in the network have thicker lines and items in the center of the network represent items are represented as *core* to the psychopathology network (when centrality networks also support this conclusion). *Bridge nodes* are symptoms that link adjacent symptoms together and are theorized to constitute pathways that could causally connect symptoms or behaviors (pending longitudinal and experimental data analysis). For example, there may be either BN symptoms or anxiety symptoms that connect (bridge) the BN and anxiety psychopathology networks.

Centrality measures—Both tie strength, as well as the position of a node, within the network structure are used to determine the relative importance of the nodes in a psychopathology network. Core nodes are those that are considered most important to the

psychopathology network. To identify which items were at the core of the networks we use statistical indices, called measures of centrality (Freeman, 1979; Opsahl, Agneessens, & Skvoretz, 2010), which quantify certain features of the networks and nodes. These indices were calculated using the centrality function in the qgraph package (Epskamp et al., 2012) for R and include *betweenness*, *closeness*, and *strength* (McNally, 2016). *Strength* centrality refers to the sum of the strengths of the ties between a node and all other nodes to which it is connected. For example, if binge eating had high centrality it would have many strong connections (e.g., indicated by larger partial correlation coefficients) to other symptoms in a network. *Betweenness* centrality typically refers to the number of times that a node lies along the shortest path between two other nodes in the network. For example, if binge eating had high betweenness centrality, binge eating would be passed through many times when moving between symptoms in a network. *Closeness* centrality refers to the inverse sum of the paths between a node and all other nodes in the network. For example, if binge eating has high closeness it would be connected to other symptoms in the network with fewer symptoms between it and all other symptoms.

Opsahl et al. (2010) suggested a way to incorporate both the number of nodes and the strength of the relationship between nodes into centrality indices when working with weighted networks. Opsahl et al. (2010) used Dijkstra's algorithm (Dijkstra, 1959) to identify the least costly path between nodes, which takes into account the number of nodes that are passed through, as well as the strengths of the ties between the nodes that are being passed through (Opsahl et al., 2010). Thus, betweenness and closeness centrality can account for the fact that a path between two nodes that involves a small number of nodes and strong ties will be more important in a network than a path that involves the same number of nodes but weaker ties. The present study used Opsahl and colleagues' (2010) definitions of betweenness and closeness given for weighted networks. Overall, symptoms that have *higher centrality are more central to the network* and have more frequent and stronger relationships with other symptoms than do symptoms with lower centrality. These measures are important for identifying which symptoms may possibly drive the psychopathology network.

Stability Analyses—We also tested the stability of these networks using the R package bootnet (Epskamp, Borsboom, & Fried, 2016). When creating network models, the stability of the measures (e.g., tie strength, centrality) must be considered so that one has adequate support for any inferences made about the networks. To test the stability of the edge weights, confidence intervals were constructed using a non-parametric bootstrapping technique in bootnet as recommended by Epskamp and colleagues (2016). The stability of the order of nodes in terms of centrality was also tested using the nodedropping function in bootnet (Epskamp et al., 2016).

Results

Model 1. Bulimia Nervosa Psychopathology

Fear of weight gain, desire to lose weight, and feelings of fatness fell at the center of the model, suggesting that these symptoms may be core to BN psychopathology (Figure 1). Binge eating and vomiting have a strong relationship with each other, but are located at the

periphery of the network. Similarly, restriction and overeating have a strong relationship with each other but are again, located somewhat at the periphery of the network (Please see Table S1 that reports the partial correlation coefficients between symptoms). The indices of centrality support the finding that fear of weight gain (betweenness = 1.79; closeness = 1.23), desire to lose weight (betweenness = 2.09; closeness = 1.42; strength = 1.45), preoccupation with weight (betweenness = 1.91; strength = 1.57), and overevaluation of weight (closeness = 1.21; strength = 1.22) are central (core symptoms) to this network (Figure 2). Other symptoms with high centrality were dieting rules (betweenness = 1.73), feelings of fatness (closeness = 1.28), and overeating (strength = 1.24).

Model 2. Bulimia Nervosa and Associated Anxiety Psychopathology

There are two clusters of symptoms (anxiety and BN symptoms) that are bridged by several symptoms (Figure 3). The anxiety symptoms that are closest to BN symptoms are as follows [BN symptoms in parentheses]: feelings of wobbliness (located closest to avoidance of eating), fear of losing control (located closest to guilt over eating and eating in secret), feelings of unsteadiness (located close to guilt over eating and avoidance of social eating), and terrified (located close to avoidance of social eating and eating in secret) (Please see Table S2 that reports the partial correlation coefficients between symptoms). The anxiety symptoms with the highest centrality are feelings of choking (betweenness = 2.39; strength = 1.54), unsteady (betweenness = 1.69; closeness = .84; strength = 1.32), terrified (betweenness = 1.89; closeness = .87), and worries about losing control (betweenness = 1.91; closeness = .95), whereas the BN symptoms with the highest centrality are overevaluation of shape (betweenness = 2.03; closeness = .87; strength = 1.30), avoiding eating (betweenness = 1.96; closeness = .64), and preoccupation with weight (betweenness = 1.28; closeness = .65; strength = 1.09) (Figure 4). Other symptoms with high centrality were (anxiety) hands trembling (closeness = .85), dizzy (strength = 1.08), shaky (strength = 1.70), and (BN) fears of weight gain (betweenness = .89), avoidance of social eating (closeness = .63), overevaluation of weight (strength = 1.03), and desire to lose weight (strength = 1.23).

Model 3: Bulimia Nervosa and Associated Depression Psychopathology

There are two clusters of symptoms (depression and BN symptoms) that are bridged by several symptoms (Figure 5). The depression symptoms that fall closest to BN symptoms are feeling like crying, lack of interest in sex, self-dislike, self-criticalness, change in appetite, thinking of suicide, and guilty feelings, falling close to the BN symptoms overevaluation of weight, overevaluation of shape, preoccupation with weight, desire to have an empty stomach, preoccupation with shape, and binge eating (Please see Table S3 that reports the partial correlation coefficients between symptoms). Irritability (betweenness = .81; closeness = .81), feelings of sadness (betweenness = 1.05; strength = 2.14), and concentration difficulties (betweenness = 1.63; closeness = .98; strength = 1.20) were the depression symptoms with the highest centrality, whereas fear of weight gain (betweenness = 2.60; closeness = 1.95), avoiding food (betweenness = 2.52; closeness = 1.47), and preoccupation with weight (betweenness = 2.24; closeness = 1.29; strength = 1.41) were the BN symptoms with the highest centrality (Figure 6). Other symptoms with high centrality were (depression) self-dislike (betweenness = 1.00), agitation (closeness = .75), difficulty sleeping (closeness = .69), loss of interest (strength = 1.00), feelings of worthlessness (strength =

1.35) and (BN) dieting rules (betweenness = 1.96), feelings of loss of control (closeness = 1.36), desire to lose weight (strength = 1.19), dissatisfaction with shape (strength = 1.22), and overeating (strength = .94).

Stability Analyses

The results from the stability analyses showed that the network models were stable. Specifically, the results from the edge weight stability analyses suggested that the tie strengths were reliably estimated. Also, the results from nodedropping stability analyses suggested that the order of the nodes in terms of centrality was stable even after dropping up to 50% of the nodes in each network. Strength centrality appeared to be most stable among the centrality measures. Additionally, the BN network was most stable and the BN and depression network was least stable, though all were overall stable. Depictions of the results from stability analyses are available upon request from the first author.

Supplemental Analyses

In the online supplement we include a fourth model (see Figure S1) that includes all three constructs in one model: BN, anxiety, and depression, as well as the indices of centrality for this model (Figure S2). As can be seen in this supplement, the primary findings remained the same. We also include tables that show the tie strength between each of the related symptoms (partial correlations between symptoms: Table S4).

Discussion

We identified several core symptoms of BN, as well as bridge symptoms between BN and anxiety and depression symptoms. Overall, two common themes emerged in these networks. First, fear of weight gain and overevaluation of weight and shape emerged as core BN symptoms throughout each network. Second, when concentrating on the overlap between BN and anxiety and depression symptoms, physical sensations such as dizziness, wobbliness in legs, changes in appetite, and lack of interest in sex, appear to be possible bridge symptoms that connect anxiety or depression symptoms to symptoms of BN.

BN psychopathology network

Fear of weight gain, overevaluation of weight and shape, and feeling fat were identified as highly central to BN psychopathology in the BN network model. These findings support theory and research that suggest that overevaluation of weight gain and fears of weight gain are central to BN psychopathology (Fairburn et al., 1986; Fairburn & Cooper, 1993; Fairburn, Shafran, & Cooper, 2003; Vitousek, & Brown, 2015). These symptoms anchored the center of the network and had the strongest and most frequent relationships with other symptoms of BN. Interestingly, other symptoms, such as binge eating, vomiting, restriction, and overeating fell on the periphery of the network and had lower centrality. Consistent with research that implicates restriction in a cycle of risk for overeating, restriction was very strongly related to overeating (e.g., Polivy, 1996; Matthes, Brownley, Mo & Bulik, 2009). Similarly, binge eating and vomiting were very highly linked, as found in other research (Striegel-Moore et al., 2005).

Our findings support the importance of overevaluation of weight and shape as central in a cognitive behavioral model of BN (Fairburn et al., 1986; Fairburn & Cooper, 1993; Fairburn, Shafran, & Cooper, 2003; Vitousek, & Brown, 2015). In our data, overevaluation of weight and shape were highly central. Researchers have found that weight and shape concerns do not necessarily decrease after cognitive behavioral therapy (CBT) (for a review please see Anderson & Maloney, 2001). Our findings further support the idea that these are central BN maintaining symptoms and that treatments need to address such concerns.

Our findings help clarify individual differences within individuals diagnosed with BN. While binge eating and purging are important indicator symptoms of BN, our findings show that they are located on the periphery of the BN psychopathology network in individuals with BN and are less highly central. Our findings suggest that while these hallmark symptoms may be critical for diagnosis, binge eating and purging may not play as strong of a *maintaining* role in the disorder as does fear of weight gain. Alternatively, fear of weight gain may be the core maintaining symptom once the disorder develops. In other words, when comparing individuals with and without BN, the symptoms binge eating and purging are highly important. However, our data consisted of individuals who all engaged in binge eating and compensatory behaviors (e.g., purging). Within individuals with BN, fears of weight gain and overevaluation of weight and shape play a key role, rather than binge eating and purging.

Network theory suggests that treatments focused on core maintaining symptoms should have the maximal effect in decreasing all symptoms within a psychopathology network (Borsboom & Cramer, 2013). Therefore our findings using network analysis support the idea that our treatments should focus on targeting shape and weight concerns, as well as fears of weight gain (Fairburn, 2008). Our findings also bring to light several areas that should be tested with future treatment research. In addition to concentrating on balancing eating habits and decreasing episodes of binge eating and purging (Fairburn, 2008), researchers could test if integrating additional and novel specific interventions focused on fears of weight gain into existing treatments would improve treatment outcomes. Interventions specifically enhanced to focus on fears of weight gain (such as routine weighing) may lead to subsequent decline in binge eating and purging episodes, in addition to the traditional focus on binge eating, purging, and restrictive behaviors.

Existing treatments should continue to include components which focus on fears of weight gain. For example, CBT for BN already includes a weekly weighing component (Fairburn, 2008), and this research supports the idea that weighing once weekly may be necessary to combat fears and reactions related to weighing. However, some research suggests that while routine weighing is a widely supported empirical intervention, clinicians often drift away from employing this practice as suggested in most CBT for BN approaches (Waller, Stringer, & Meyer, 2012). Additional research suggests that clinicians who do weigh patients weekly, often practice blind weighing practices (Forbush, Richardson, & Bohrer, 2015). Our findings, which suggest that fear of weight gain is a core symptom of BN and may drive other symptoms in the network, augment the existing literature suggesting the importance of including routine, weekly, open weighing in CBT treatments. It may be that combatting fear

of weight gain through weekly weighing is a central mechanism by which CBT leads to successful treatment outcomes.

Although fear of weight gain is frequently discussed as an important component of CBT for BN, it may be necessary to craft additional interventions (beyond routine weekly weighing) that specifically address this core symptom. For example, it may be useful to integrate imaginal exposures related to fear of weight gain (as described in Levinson, Rapp, & Riley, 2014). Such interventions hold promise for enacting maximal change on the greatest number of BN symptoms, since they exhibit the highest levels of centrality (i.e., they are the most connected symptoms in the network). Research testing exposure therapy with BN has focused on exposing individuals to binge and purge cues (Bulik et al., 1998). This research has suggested that adding this type of exposure component did not lead to better outcomes versus CBT without exposure. It may be that exposures focused on fears of weight gain would produce longer lasting effects than exposures focused on binge eating and purging cues. Our findings suggest that exposures that target fear of weight gain would address core (fear of weight gain) rather than peripheral (binge eating and purging) fears. Further, additional evidence from network analysis suggests that body checking may be a key symptom in eating disorder psychopathology (Forbush, Siew, & Vitevitch, 2016). It is possible that a combination of body checking exposures and imaginal exposures addressing fears of weight gain may be optimal for addressing core symptoms of BN. We, therefore, need further pilot experimental and clinical intervention research testing the theory that including novel interventions focused on fear of weight gain might lead to the greatest change in BN symptomatology.

BN and associated anxiety and depression psychopathology networks

We found that physical sensations may bridge the associations between BN and anxiety/depression symptoms. Specifically, in both the BN and anxiety symptom network and the BN and depression symptom network, forms of sensitivity to physical sensations emerged as the closest connections between BN symptoms and anxiety and depression. For example, in the anxiety and BN network, the anxiety symptoms feelings of wobbliness in one's legs, unsteadiness, and dizziness fell very close to the BN symptoms and were highly central. Similarly, in the depression and BN network, lack of interest in sex and changes in appetite were highly central. These findings are important because they further contribute to our understanding of how anxiety, depression, and BN symptoms might interact with each other. Such identification has the potential to lead to interventions targeted at maintenance symptoms, which could disrupt the link between BN and associated anxiety and depression.

A number of studies have implicated a potential role of the insula in eating disorders specifically in AN, with some research finding an exaggerated insula response in individuals with BN as compared to individuals without the disorder (e.g., Kim et al., 2012; Oberndorfer et al., 2013). The insula is thought to be associated with sensitivity to physical sensations and hyperawareness of interoceptive sensations. Other research has suggested that within BN specifically there may be interoceptive deficits, such as inaccuracies in perceiving the number of heart beats during a specified interval (Fassino, Pierò, Gramaglia, & Abbate-Daga, 2004; Klabunde et al., 2013). Interoceptive exposure has been found to be an effective

transdiagnostic intervention across anxiety disorders (Boswell, Farchione, Sauer-Zavala, & Murray, 2013). It is possible that extending this type of intervention to BN could be helpful in addressing comorbid anxiety and depression, as well as BN symptoms. Of course, it is also possible that BN behaviors themselves may alter such anxiety and depressive symptoms.

Several additional symptoms in the BN and anxiety/depression networks were highly central. In the anxiety and BN network, feelings of choking was a highly central symptom. This finding could be indicative of overall difficulties with physical sensations that occur during eating, the somatization of anxiety in one's throat, and may help explain why individuals with BN often struggle during meals. Additionally, in the depression and BN network, the depression symptom irritability emerged as highly central to the network on all three measures of centrality, meaning that irritability may be an important symptom across disorders. Finally, though appetite dysregulation did not emerge as a central symptom, it was related to symptoms associated with eating, such as binge eating and purging.

Limitations of our data

There are certain limitations of this work that must be considered. First, our data are cross-sectional. Although network theory hypothesizes that these analyses reflect potential dynamic relationships between symptoms, longitudinal and/or experimental data are needed to test if the associations found in the present study affect each other across time and in causal experiments. We cannot make any causal claims about the data presented here. Second, our sample was treatment seeking and therefore we do not know if these results would generalize to non-treatment seeking samples, although we should note that our results are consistent with the one prior paper using network analysis in a non-treatment seeking eating disorder sample (Forbush, Siew, & Vitevitch, 2016). Additionally, although the sample was somewhat representative, it consisted primarily of women of European ancestry and may not generalize to men and other racial and ethnic groups. Finally, because our sample consisted of individuals diagnosed with BN, we had less variance than if a healthy control population was also included. Future research should test these network models in a sample including a range of participants with and without BN.

Limitations of network analysis

Any methodology has inherent limitations, as is true for network analysis. Our data are limited by the symptoms and behaviors we chose to include and to define as BN symptoms in our networks. For example, inclusion of additional symptoms (e.g., body checking) might produce a different psychopathology network. This limitation is especially relevant because binge eating and purging were each measured with only one item. This may limit the reliability of the measurement of these symptoms, and could possibly impact why we found binge eating and purging to be peripheral to the network. We await future research with additional measurement of these symptoms to test if our results replicate. Relatedly, we hope future research will test if these results are stable across samples and to explore which centrality indices are most stable. We also chose to include symptoms and behaviors that are not specific to a DSM diagnosis of BN, given that research has not shown a general convergence between models of DSM symptoms and non-DSM network models (Fried,

Epskamp, Nesse, & Tuerlinckx, 2016). Network analysis as applied to psychopathology is a relatively new enterprise. Therefore, methods such as tests of reliability and establishment of fit indices are still in development. While network analyses may have the ability to lead to important insights in clinical psychology, it is also necessary to consider other traditional methods such as latent variable analysis and multi-dimensional models of psychopathology (e.g., Flett, Vredenburg, & Krames, 1997; Prisciandaro & Roberts, 2009). However, the results presented here demonstrate how network analysis can be used to better define psychopathology and represent a step forward in our understanding of how BN symptoms may interact.

Conclusions

Overall, we found that fear of weight gain was a core symptom of the BN network of psychopathology, whereas binge eating, purging, and restriction were less central symptoms. We also found that physical sensation symptoms might link BN with associated anxiety and depression. Consistent with a CBT framework, fear of weight gain may represent a core belief or fear that in turn engenders subsequent behaviors, thoughts, and emotions, such as binge eating, purging, restriction, and guilt. Future research is needed to test if interventions targeting the core symptom of fear of weight gain may maximize change on other behaviors, thoughts, and emotions. Additionally, further research is needed to test if targeting physical sensation symptoms can disrupt the link between BN and associated anxiety and depression. The development of targeted interventions that augment current treatments for fear of weight gain and physical sensation symptoms should be considered.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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General Scientific Summary

Fear of weight gain is a central symptom in a bulimia nervosa psychopathology network. Sensitivity to physical symptoms connect symptoms of bulimia nervosa with associated anxiety and depression symptoms.

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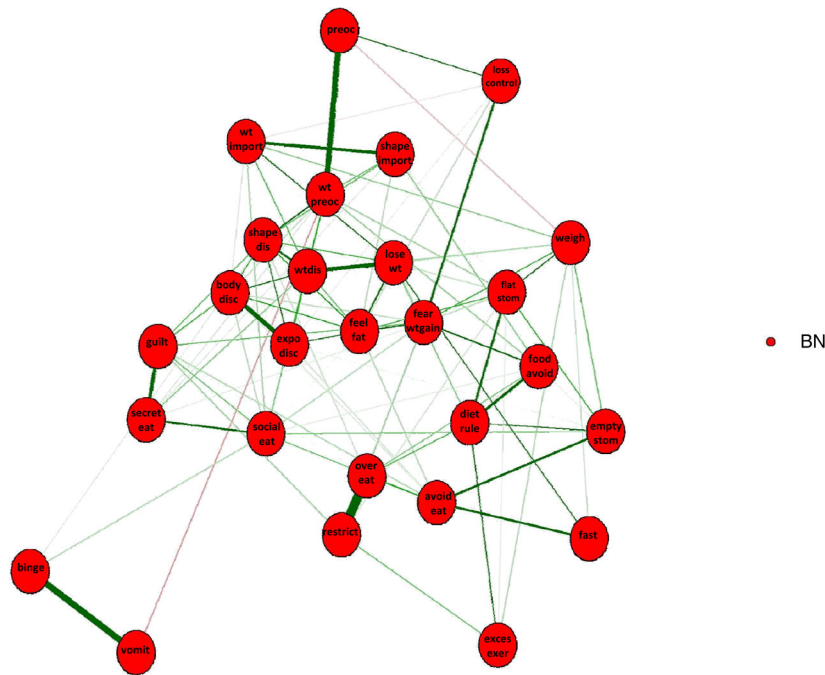


Figure 1.
BN Network.

Note. BN symptom label descriptions: avoideat = avoidance of eating; binge = bingeing; bodydisc = body discomfort; dietrule = dieting rules; emptystom = desire for an empty stomach; excesexer = excessive exercising; expodisc = discomfort with exposure; fast = fasting; fearwtgain = fear of weight gain; feelfat = feelings of fatness; flatstom = desire for flat stomach; foodavoid = food avoidance; guilt = guilt over eating; losewt = desire to lose weight; losscontrol = loss of control over eating; overeat = overeating; preoc = preoccupation with weight/shape; restrict = restriction; secreteat = eating in secret; shapedis = overevaluation of shape; shapeimport = shape importance; socialeat = avoiding eating in social settings; vomit = vomiting; weigh = reaction to prescribed weighing; wtdis = overevaluation of weight; wtimport = weight importance; wtpreoc = preoccupation with weight. Tie strength is indicated by line thickness between nodes with thicker lines representing stronger ties.

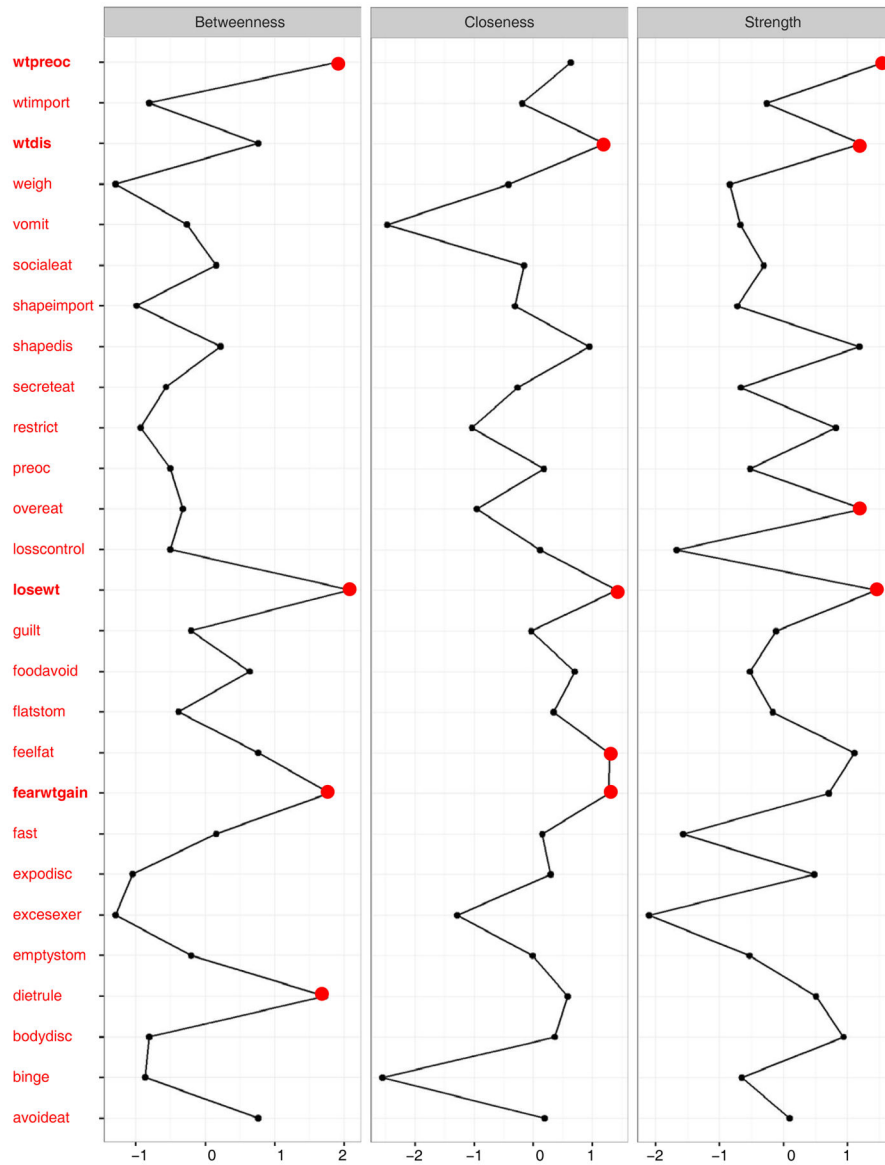


Figure 2. Centrality Indices for BN Network.
Note. Higher numbers indicate that the item is more central to the network; highest four values are indicated within each index by a red dot; symptoms with at least two of the highest centralities are bolded. Values shown on the x-axis are standardized z-scores.

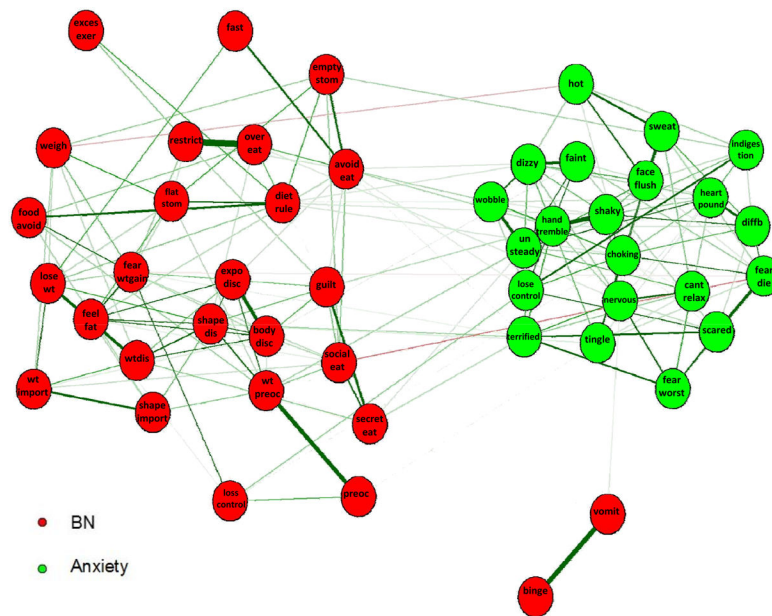


Figure 3.
BN and Anxiety Network.

Note. BN symptom label descriptions: avoideat = avoidance of eating; binge = bingeing; bodydisc = body discomfort; dietrule = dieting rules; emptystom = desire for an empty stomach; excesexer = excessive exercising; expodisc = discomfort with exposure; fast = fasting; fearwtgain = fear of weight gain; feelfat = feelings of fatness; flatstom = desire for flat stomach; foodavoid = food avoidance; guilt = guilt over eating; losewt = desire to lose weight; losscontrol = loss of control over eating; overeat = overeating; preoc = preoccupation with weight/shape; restrict = restriction; secreateat = eating in secret; shapedis = overevaluation of shape; shapeimport = shape importance; socialeat = avoiding eating in social settings; vomit = vomiting; weigh = reaction to prescribed weighing; wtdis = overevaluation of weight; wtimport = weight importance; wtpreoc = preoccupation with weight. Anxiety symptom label descriptions: cantrelax = unable to relax; choking = feeling of choking; diffb = difficulty breathing, dizzy = dizzy or lightheaded; faceflush = face flushed; faint = feeling faint/lightheaded; feardie = fear of dying; fearworst = fear of worst happening; handtremble = hands trembling; heartpound = heart pounding/racing; hot = feeling hot; indigestion = indigestion; losecontrol = fear of losing control; nervous = feeling nervous; scared = feeling scared; shaky = feeling shaky; sweat = hot/cold sweats; terrified = terrified/afraid; tingle = numbness or tingling; unsteady = unsteady; wobble = wobbliness in legs. Tie strength is indicated by line thickness between nodes with thicker lines representing stronger ties.

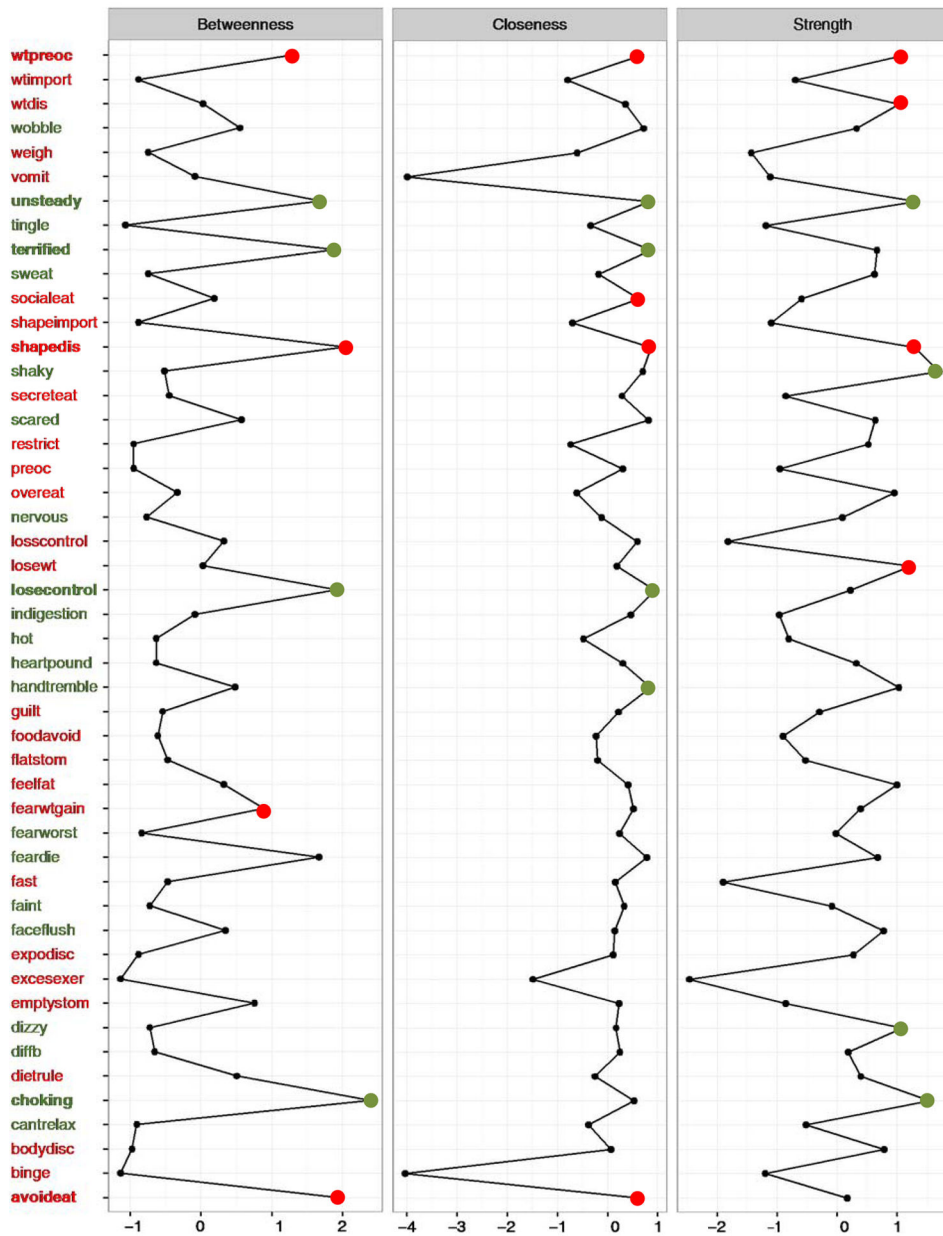


Figure 4. Centrality Indices for BN and Anxiety Network.

Note. BN symptoms are denoted in red and anxiety symptoms in green; higher numbers indicate that the item is more central to the network; highest four values for each disorder are indicated within each index by a red dot for BN and a green dot for anxiety; symptoms with at least two of the highest centralities are bolded. Values shown on the x-axis are standardized z-scores.

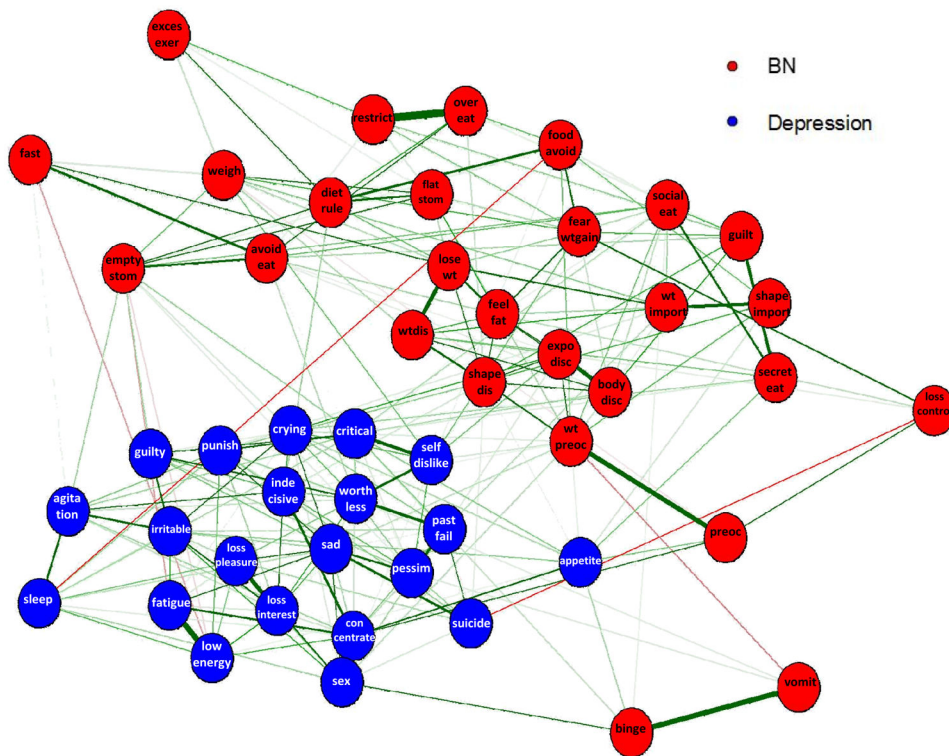


Figure 5.
BN and Depression Network.

Note. BN symptom label descriptions: avoideat = avoidance of eating; binge = bingeing; bodydisc = body discomfort; dietrule = dieting rules; emptystom = desire for an empty stomach; excessexer = excessive exercising; expodisc = discomfort with exposure; fast = fasting; fearwtgain = fear of weight gain; feelfat = feelings of fatness; flatstom = desire for flat stomach; foodavoid = food avoidance; guilt = guilt over eating; losewt = desire to lose weight; losscontrol = loss of control over eating; overeat = overeating; preoc = preoccupation with weight/shape; restrict = restriction; secreateat = eating in secret; shapedis = overevaluation of shape; shapeimport = shape importance; socialeat = avoiding eating in social settings; vomit = vomiting; weigh = reaction to prescribed weighing; wtdis = overevaluation of weight; wtimport = weight importance; wtpreoc = preoccupation with weight. Depression symptom label descriptions: agitation = feeling agitated and restless; appetite = changes in appetite; concentrate = concentration difficulties; critical = self-criticalness; crying = crying too much or too little; fatigue = tiredness or fatigue; guilty = feeling guilty; indecisive = difficulty making decisions; irritable = irritability; lossinterest = loss of interest; losspleasure = loss of pleasure; lowenergy = loss of energy; pastfail = past feels like a failure; pessim = pessimism; punish = punishment feelings; sad = sadness; selfdislike = disliking self; sex = loss of interest in sex; sleep = changes in sleeping pattern; suicide = suicidal ideation; worthless = feelings of worthlessness. Tie strength is indicated by line thickness between nodes with thicker lines representing stronger ties.

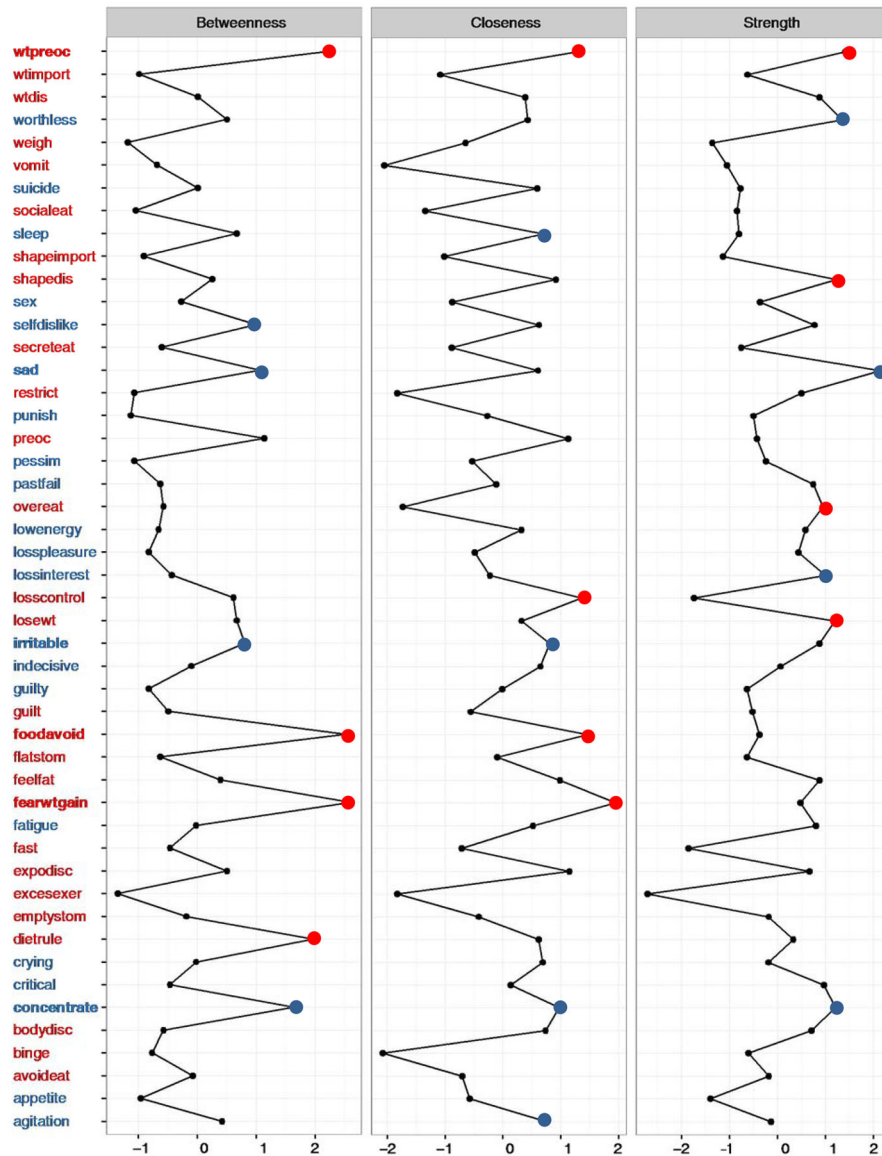


Figure 6.

Centrality Indices for BN and Depression Network.

Note. BN symptoms are denoted in red and depression symptoms in blue; higher numbers indicate that the item is more central to the network; highest four values for each disorder are indicated within each index by a red dot for BN and a blue dot for depression; symptoms with at least two of the highest centralities are bolded. Values shown on the x-axis are standardized z-scores.