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Transdiagnostic vulnerability factors in eating disorders: A network analysis

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Abstract

Objective: Eating disorder (ED) symptoms and transdiagnostic vulnerability characteristics play a crucial role in the aetiology and maintenance of EDs. Over the last decade, researchers have started to model complex interrelations between symptoms using network models, but the literature is limited in that it has focused solely on symptoms and investigated-specific disorders while ignoring transdiagnostic aspects of mental health.

Method: This study tackles these challenges by investigating network relations among core ED symptoms, comorbid clinical symptoms (depression and anxiety) and empirically supported vulnerability and protective mechanisms (personality traits, maladaptive cognitive schemata, perfectionism and resilience) in a sample of 2302 treatment-seeking ED patients. We estimated a regularized partial correlation network to obtain conditional dependence relations among all variables. We estimated node centrality (interconnectivity) and node predictability (the overall magnitude of symptom interrelationships).

Results: The findings indicate a central role of overvigilance, excessive focus on inhibiting emotions and feelings, interoceptive awareness and perfectionism.

Conclusions: These results suggest that excessive control of bodily aspects by dietary restraint (possibly through inhibition) and interoceptive awareness may be important constructs that warrant future research in understanding

Abbreviations: AN, anorexia nervosa; Anx, anxiety; Aut, impaired autonomy and performance; Awa, interoceptive awareness; BDI-II, Beck Depression Inventory-II; BED, binge-eating disorder; BMI, Body Mass Index; BN, bulimia nervosa; Bod, body dissatisfaction; Bul, bulimia; CIs, confidence intervals; Coa, cooperativeness; Cri, parental criticism; CS-coefficient, centrality stability coefficient; Dft, drive for thinness; Dir, disconnection and rejection; DSM, Diagnostic and Statistical Manual of Mental Disorders; ED, Eating Disorder; EDI, Eating Disorder Inventory; EDNOS, eating disorder not otherwise specified; EDs, eating disorders; EI, expected influence; Exp, parental expectations; Fea, maturity fear; FMPS, Frost Multidimensional Perfectionism Scale; Har, harm avoidance; Imp, impulse regulation; Ine, ineffectiveness; Inh, overvigilance and inhibition; LASSO, least absolute shrinkage and selection operator; Lim, impaired limits; M, mean; Nov, novelty seeking; OSFED, other specified feeding and eating disorders; Red, reward dependence; Res, resilience; RS-NL, Resilience Scale (Dutch version); SCL-90, Symptom Check-List 90; SD, standard deviation; Sed, self-directedness; Set, self-transcendence; Soc, social insecurity; Sta, personal standards; STAI, State-Trait Anxiety Inventory; TCI-R, Temperament and Character Inventory Revised; TPQ, Tridimensional Personality Questionnaire; YSQ, Young Schema Questionnaire.

vulnerability in EDs. We provide all code and data via the Open Science Framework.

KEYWORDS
eating disorders, inhibition, interoceptive awareness, network analysis, perfectionism

1 | INTRODUCTION

Eating disorders (EDs) are psychiatric illnesses with severe disturbances in people's eating behaviours, emotions and food/body-related thoughts (i.e., preoccupation with food, body weight and shape). Different diagnoses exist within EDs, such as anorexia nervosa (AN), bulimia nervosa (BN), binge-eating disorder (BED) and other specified feeding and eating disorders (OSFED; Diagnostic and Statistical Manual of Mental Disorders [DSM]-V; American Psychiatric Association, 2013). ED diagnoses as categories are faced with numerous challenges, such as high rates of comorbidity with depression and anxiety (Eddy et al., 2008), heterogeneity within these diagnostic categories, poor discrimination, and frequent migration between supposedly distinct diagnoses (Castellini et al., 2011; Eddy et al., 2008), high rates of not otherwise specified diagnoses (Allen, Byrne, Oddy, & Crosby, 2013) and common factors across the diagnoses that influence the maintenance of ED behaviours, emotions, and food-related thoughts (Fairburn, Cooper, & Shafran, 2003). Hence, instead of tailoring treatments only to the symptoms that fall within the boundaries of a specific ED, it is becoming an increasingly common practice to take a transdiagnostic stance (Harvey, Watkins, Mansell, & Shafran, 2004). Klik of tik om tekst in te voeren. The transdiagnostic approach in EDs focuses on identifying the common and core underlying mechanisms that underpin a broad array of diagnostic presentations. Although this approach can be applied to different categories of DSM diagnoses, for the scope of the current study, our transdiagnostic stance refers to a dimensional approach in EDs given that this patient population shares a distinctive core psychopathology not seen in psychiatric disorders (Cooper & Grave, 2017).

A new and fast-moving development in the ED field, which aligns with the transdiagnostic framework, is the conceptualization of ED as networks of related features (Levinson, Vanzhula, Brosof, & Forbush, 2018). From a network perspective, disorders are conceptualized as complex dynamic systems of interacting symptoms, for which some individual symptoms play a unique and central role in relation to other symptoms (Van Borkulo et al., 2015). Klik of tik om tekst in te voeren. The network theory hypothesizes that symptoms influence each other irrespective of traditional diagnosis DSM boundaries (Borsboom, 2017). In network models, ED symptoms such as body checking (Forbush, Siew, & Vitevitch, 2016), fear of weight gain and feeling fat (Christian et al., 2020; Forrest, Jones, Ortiz, & Smith, 2018; Goldschmidt et al., 2018; Levinson, Brosof, Ma, Fewell, & Lenze, 2017) and shape and weight overvaluation (DuBois, Rodgers, Franko, Eddy, & Thomas, 2017; Forrest et al., 2018; Wang, Jones, Dreier, Elliott, & Grilo, 2019; for a review see; Levinson et al., 2018) emerged as the core symptoms with the highest centrality. The authors have interpreted such (statistically) central symptoms as (theoretically) underlying clinical manifestation of ED psychopathology. Other researchers have reported that two ED symptoms, ineffectiveness and interoceptive awareness, are central nodes in ED networks, both at admission and discharge of a psychiatric treatment (Cascino et al., 2019; Monteleone et al., 2019; Olatunji, Levinson, & Calebs, 2018; Solmi et al., 2018). These emerging results point towards the importance of specific food-related and body-related thoughts as transdiagnostic factors in patients diagnosed with ED, as these core ED symptoms have the strongest relations with other nodes and are interpreted by some to potentially maintain ED psychopathology. These cognitive preoccupations also seemed predictive of the post-treatment outcome in

Highlights

- This network analysis revealed a relationship between body dissatisfaction and transdiagnostic vulnerability factors in ED patients
- The results indicate a central role of personal standards (perfectionism), overvigilance and inhibition (maladaptive schemata), and the specific ED symptoms, ineffectiveness and interoceptive awareness
- Using motivational strategies for bridging ED symptoms, adequate methods of self-improvement and adaptive emotion regulation were recommended in the treatment of ED patients

patients with AN Klik of tik om tekst in te voeren (although this might also be due to differences in node variance; Elliott, Jones, & Schmidt, 2020).

What comes out of a statistical model depends on what you put in (Forbes, Wright, Markon, & Krueger, 2019). Additionally, not only ED-related symptoms but also symptoms that are linked to psychopathology in general, such as anxiety and depression, play a key role in network models of EDs. For example, studies examining the interplay between ED-core symptoms and general psychiatric symptoms in patients with AN found that depression and anxiety symptoms were among the most central nodes within the network (Monteleone, Mereu, et al., 2019; Solmi, Collantoni, Meneguzzo, Tenconi, & Favaro, 2019). Interestingly, network theory dictates that in addition to symptom variables, many other variables could play important roles in the complexity of ED (e.g., Fried & Cramer, 2017). As stated by P. J. Jones, Heeren, and McNally (2017), many non-symptom variables play a causal role in the aetiology and maintenance of mental disorders and might enrich a 'symptom network'. Indeed, non-symptom variables such as personality traits, maladaptive schemata, and childhood maltreatment feature prominently in the aetiology, symptomatic expression, and maintenance of EDs (Cassin & Von Ranson, 2005; Farstad, McGeown, & von Ranson, 2016; Monteleone et al., 2019; Pauwels et al., 2018; Pugh, 2015; Rodgers et al., 2019). As such, well-known vulnerability and protective mechanisms in patients diagnosed with ED could be included in network modelling. These vulnerability or protective factors are defined as mechanisms that, respectively, increase or reduce the risk of mental health problems and are rather interrelated (Fritz, Fried, Goodyer, Wilkinson, & van Harmelen, 2018).

As described in the Transtheoretical Model of EDs (Brytek-Matera & Czepczor, 2017), personality plays an important role in the onset and/or maintenance of an ED and is considered an important transdiagnostic vulnerability mechanism. In line with these findings, a meta-analysis by Farstad et al. (2016) revealed that even though personality traits explain variance in ED symptomatic expression and prognosis, some personality traits such as high self-directedness and avoidance motivation are frequent among all ED diagnoses relative to controls. As such, Solmi et al. (2018) included the Tridimensional Personality Questionnaire for personality traits when estimating their network model in patients diagnosed with EDs. Besides personality traits, their recent study also used network psychometrics to model ED symptoms, clinical variables (Body Mass Index [BMI] and duration of illness) and the Symptom Check-List 90. The results showed that, in addition to ED-core symptoms (cognitive features: interoceptive awareness and drive for thinness) and BMI, affective symptoms such as depression and anxiety, interpersonal sensitivity and distrust, and ineffectiveness were highly interconnected in the resulting network of all patients with a diagnosis of ED, and also within each diagnostic subgroup (AN, BN and BED). In line with this reasoning, a network analysis investigating personality characteristics in people seeking bariatric surgery revealed that low self-directedness, a subscale of the Temperament and Character Inventory Revised–was an independent predictor of BMI at follow-up (Monteleone et al., 2019).

Additionally, as another well-known transdiagnostic vulnerability mechanism in EDs, perfectionism has been defined as striving for, and achievement of, personally demanding standards, despite adverse consequences (Shafran, Cooper, & Fairburn, 2002). Studies show that patients diagnosed with an ED experience a sense of ineffectiveness in many areas of their lives (S. Wagner, Halmi, & Maguire, 1987), associated with perfectionistic standards to control eating, shape and weight (Riley & Shafran, 2005). In addition, Wade, Wilksch, Paxton, Byrne, and Austin (2015) found that the relationship between perfectionism and increased risk for EDs was mediated by levels of ineffectiveness (i.e., feelings of inadequacy, insecurity, worthlessness and having no control over one's own life). Finally, Puttevils, Vanderhasselt, and Vervaet (2019) showed that perfectionism was a significant predictor of ED symptoms in a large sample of patients diagnosed with ED (AN, BN, BED and OSFED/EDNOS).

Moreover, maladaptive schemata operate as an important transdiagnostic vulnerability mechanism within the ED. Maladaptive schemata are defined as unconditional, self-defeating emotional and cognitive patterns that result from negative experiences and interactions with significant others during childhood or adolescence and are stable constructs (Young, Klosko, & Weishaar, 2003). A number of empirical studies have indicated that maladaptive schema cognitions play an important role in the development and maintenance of psychopathology, such as EDs (Gongora, Derksen, & Van Der Staak, 2004; Leung, Waller, & Thomas, 1999; Unoka, Tölgyes, & Czobor, 2007; Waller, Ohanian, Meyer, & Osman, 2000) and might act as a vulnerability factor for ED relapse (C. Jones, Harris, & Leung, 2005). For example, Talbot, Smith, Tomkins, Brockman, and Simpson (2015) Klik of tik om tekst in te voeren. reported that AN, BN and OSFED groups each scored significantly higher than a community sample group for the majority of maladaptive schema modes In addition, Boone, Braet, Vandereycken, and Claes (2013) found that maladaptive schemata are positively related to body image concerns in

an ED sample. Furthermore, different aspects of clinical perfectionism are linked to maladaptive schema domains.

Finally, not only vulnerability factors but also protective mechanisms, such as resilience, play an important role within ED. Resilience is frequently defined as the ability to bounce back and adapt in the face of adverse conditions (Kalisch, Müller, & Tüscher, 2015). A study by McGrath, Julie, and Caron (2012) revealed that increased levels of resilience are associated with an improved body image. Research from de Vos et al. (2017) reported that psychological well-being and resilience were found to be fundamental criteria for ED recovery and are associated with a reduction of ED symptoms over time (Calvete, las Hayas, & Gómez del Barrio, 2018). In addition, Ten Ham, Hulsbergen, and Bohlmeyer (2016) indicated that resilience could be a protective factor across EDs.

Overall, the present study aims to use network psychometrics to model the complex interrelations between a selection of constructs derived from a literature review: (1) core ED symptoms and common psychological/behavioral features that are linked with EDs (measured with validated questionnaires); (2) general psychiatric symptoms that are well-known comorbidity factors in EDs (depression and anxiety) and (3) empirically supported vulnerability and protective mechanisms (beyond symptoms) underlying the onset and maintenance of EDs (personality traits, maladaptive cognitive schemata, perfectionism and resilience) in a large sample of treatment-seeking patients diagnosed with an ED (AN, BN, BED and OSFED/EDNOS). We are especially interested in the strongest edges between ED symptoms (most central items) and non-ED symptom variables (i.e., cross-questionnaire edges).

2 | METHOD

The study was conducted according to the principles of the 'Declaration of Helsinki' (as amended in Tokyo, Venice, Hong Kong and Somerset West) and in accordance with the Guideline for Good Clinical Practice (CPMP/ICH/135/95—17th July 1996).

2.1 | Participants

A total of 2302 participants who registered at the Centre of Eating Disorders of the University Hospital of Ghent for ambulant or resident treatments, were asked to complete a series of questionnaires. A total of 2245 patients meeting the criteria of an ED, as defined by the DSM-IV[1] (American Psychiatric Association, 1994), were included in the current study. Due to incomplete data for all the nodes included in the network, 276 individuals were excluded from the sample, leaving 1969 patients—1886 females (95.8%) and 82 males (4.2%)—in the final sample. Missing values were dealt with by using pairwise complete observations (i.e., participants were not deleted listwise, but rather all available information was used to estimate each correlation (cf. Santos, Fried, Asafu-Adjei, & Jeanne Ruiz, 2017). The diagnostic rates are as follows: 831 Anorexia Nervosa (42.2%), 617 Bulimia Nervosa (31.3%), 371 Eating Disorder Not Otherwise Specified (18.8%) and 150 Binge-Eating Disorder (7.6%). The sample members ranged in age from 13 to 67 years ($M = 23.93$, $SD = 8.85$), BMI ranged from 8.79 to 61.67 ($M = 20.1$, $SD = 6.53$) and duration of illness (in years) ranged from 0 to 46 ($M = 5.65$, $SD = 6.72$). Demographics for each ED can be found in Table 1. The study was part of a larger project assessing different questionnaires in patients with ED, and data were collected from 1998 to 2015. All participants provided informed consent for the use of data in an anonymous form.

2.2 | Assessments

For all of the subscales described below, we calculated the subscale scores by summing all the items belonging to a subscale.

2.2.1 | Eating disorder symptoms

The Eating Disorder Inventory (EDI)-II (Garner, 1991) is a self-report measure, which consists of 91 items, with responses on a 6-point Likert scale (ranging from 'never' to 'always'). The EDI-II includes 11 subscales: Drive for Thinness (excessive concern with dieting, preoccupation with weight and fear of weight gain; 7 items), Bulimia (binge eating and purging; 7 items), Body Dissatisfaction (not being satisfied with one's physical appearance; 9 items), Ineffectiveness (feelings of inadequacy, insecurity, worthlessness and having no control over one's own life; 10 items), Perfectionism (not being satisfied with anything less than perfect; 6 items), Interpersonal Distrust (reluctance to form close relationships; 7 items), Interoceptive Awareness (the ability of an individual to discriminate between sensations and feelings, and between the sensations of hunger and satiety; 10 items), Maturity Fears (fear of facing the demands of adult life; 8 items), Asceticism (avoidance of sexual relationships; 8 items), Impulse Regulation (ability to regulate impulsive behaviour such as binge behaviour; 11 items) and Social Insecurity (social fears and insecurity; 8 items).

TABLE 1 Demographics for each eating disorder separately

	Number female *N* (%)	Mean (SD) age	Mean (SD) BMI	Mean (SD) duration of illness (in years)
Anorexia nervosa ($n = 831$)	805 (96.9)	22.33 (8.08)	15.40 (1.60)	4.39 (5.79)
Bulimia nervosa ($n = 617$)	590 (95.6)	23.65 (7.35)	21.84 (3.84)	5.55 (5.67)
Eating disorder not otherwise specified ($n = 371$)	349 (94.1)	24.57 (9.74)	20.88 (5.10)	5.76 (7.30)
Binge eating disorder ($n = 150$)	142 (94.7)	32.38 (11.15)	34.79 (7.29)	11.24 (9.58)

Abbreviations: BMI, body mass index, SD, standard deviation.

2.2.2 | Personality traits

The Temperament and Character Inventory (TCI; Cloninger, Svrakic, & Przybeck, 1993) comprises 240 items with responses in a true/false answer format. The items were divided into seven subscales. Four of them are temperament subscales: novelty seeking (exploratory activity to obtain novel stimulation and impulsive decision making), harm avoidance (excessive worrying and being fearful, doubtful, shy and easily fatigued), reward dependence (depending on signs of reward such as social support and approval) and persistence (perseverance in spite of fatigue or frustration). The other three subscales examine character: self-directedness (ability to regulate and adapt behaviour in order to achieve personal goals and values), cooperativeness (being agreeable in relations with other people) and self-transcendence (experiencing spiritual ideas).

2.2.3 | Maladaptive domains

The Young Schema Questionnaire (YSQ; Young et al., 2003) consists of 205 items, which are divided into 16 subscales corresponding to the 16 early maladaptive schemata (EMS) scales. The items are graded on a 6-point Likert scale ranging from 1 ('Completely untrue of me') to 6 ('Describes me perfectly'). According to Young's schema therapy, the 16 EMS can be grouped into different schema domains. Each of these domains represents one frustration of different core emotional needs during childhood. There are five Schema Domains: Disconnection and Rejection (unmet needs for personal safety and stability), Impaired Autonomy & Performance (inability to function independently), Impaired Limits (inability to respect internal limits and responsibility to others), Other-directness (excessive focus on meeting needs of others at the expense of one's own needs) and Overvigilance & Inhibition (excessive focus on inhibiting one's emotions and feelings in order to avoid making mistakes).

2.2.4 | Perfectionism

The Frost Multidimensional Perfectionism Scale (FMPS; Frost, Marten, Lahart, & Rosenblate, 1990) is a self-report questionnaire that consists of 35 items (rated on a 5-point Likert scale, ranging from 'Strongly Disagree' to 'Strongly Agree'). The FMPS covers six dimensions of perfectionism, namely concern over mistakes (reflecting negative reactions to errors; 9 items), personal standards (setting high standards for evaluation; 7 items), parental expectations (the belief that one's parents set very high standards; 5 items), parental criticism (the belief that one's parents were overly critical; 4 items), doubting of actions (the tendency to doubt about one's ability; 4 items) and organization (the importance placed on orderliness; 6 items).

2.2.5 | Depressive symptoms

The Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996) is a 21-item self-report questionnaire that examines the severity of depressive symptoms (ranging from 0 to 3), with higher scores indicating greater levels of depression.

2.2.6 | Anxiety symptoms

Patients completed the Trait version of the State-Trait Anxiety Inventory (STAI; Spielberger, 1983; Van der Ploeg, 1980), a 20-item self-report questionnaire to measure trait anxiety. All items are rated on a 4-point Likert scale. Scores range from 20 to 80, with higher scores indicating greater anxiety.

2.2.7 | Resilience

To measure resilience, the Dutch version of the Resilience Scale (RS-NL) was used (Portzky, Wagnild, De Bacquer, & Audenaert, 2010; Wagnild, 2009). The RS-NL consists of 25 items rated on a 4-point Likert subscale (ranging from 'strongly disagree' to 'strongly agree').

3 | DATA ANALYSIS

To gain exploratory insights into the structure of mutual dependence relations among the included constructs, we estimated a regularized partial correlation network. Next, we identified the most central nodes, that is, nodes with the highest number of connections, that some interpreted as potentially influencing many other nodes in the network (Bos et al., 2017). In addition to examining the central nodes, we also investigated node predictability, which assesses the overall magnitude of symptom interrelationships as an absolute measure as well as network accuracy and stability (Haslbeck & Fried, 2017; Haslbeck & Waldorp, 2018). Data and analytic codes are available online on the Open Science Framework (https://osf.io/ks85g/). We hope this will enable future analysis of this rich, transdiagnostic ED dataset.

3.1 | Network estimation

Network models were estimated and analysed using the *R*-package *bootnet* (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012; Haslbeck & Waldorp, 2018). In general, a network consists of nodes (variables) and edges (connections between nodes). A main advantage of the network approach is that it estimates and visualizes the multivariate dependencies of the data that otherwise remain hidden. However, the interpretation of network models should be handled with caution since these models do not always match network theory, and the results are equivocal (Forbes et al., 2019; Fried, 2020). We modelled edges akin to partial correlation coefficients, meaning that a connection between nodes A and B is the connection after controlling for all other edges in the network. In order to do so, we computed a Gaussian graphical model (Epskamp & Fried, 2018). With 32 nodes, 496 pairwise association parameters were estimated. Since the estimation of many parameters increases the risk of false positive edges, the least absolute shrinkage and selection operator (LASSO; Tibshirani, 1996) was used, which sets very small edges to zero. The LASSO procedure aims to keep only the relevant edges in order to reveal the underlying structure of the network and usually leads to a sparse structure (Epskamp & Fried, 2018).

3.2 | Centrality estimation

For the 32-item ED network, we were interested in identifying which nodes were most influential. There are numerous graph theoretical measures that can be used for this purpose; however, we opted for expected influence (EI). EI reflects the sum of all edges of a node (Robinaugh, Millner, & McNally, 2016), instead of the *absolute* sum of all edges (node strength). Therewith, both negative and positive edges were considered when estimating centrality.

3.3 | Accuracy and stability estimation

In order to test the stability and accuracy of the estimated network, we carried out the routines described in a tutorial paper by Epskamp, Borsboom, and Fried (2018), using the R-package *bootnet*. First, we used bootstrapping routines for the 95% confidence intervals of the edge weights to estimate the accuracy of edges in the network. Second, we examined the stability of the order of the centrality measures by subsetting bootstrap: if a central node remains central in the estimated network after random participants are dropped, it is considered an indicator of the stability of the order of centrality estimates. Related to this, we estimated the centrality stability coefficient (CS-coefficient) as well as a 'edge stability coefficient' (Epskamp & Fried, 2020), indicating what proportion of participants can be dropped to retain, with 95% probability, a correlation of at least 0.7 between the centrality order in the bootstrapped datasets with the original order of centrality in the full dataset, or for the edge stability coefficient, between the edge weights in the bootstrapped datasets and the original edge weights. The CS-coefficient should be at least 0.25, and preferably above 0.5. Currently, there are no clear thresholds for the edge stability coefficient. Subsequently, we estimated mean explained variance as a measure of node predictability (the degree to which a given node can be predicted by all other nodes in the network). Node predictability is important because while network centrality is a relative measure, node predictability is an absolute measure of potential controllability of a node, and provides the percentage of variance explained by the nodes' neighbours. Generally, predictability is highly related to expected influence, but the former is somewhat more informative since it can give us potential information of the clinical relevance of connections (or edges) between nodes (Haslbeck & Fried, 2017). Finally, we

performed difference tests to compare individual edge weights and to compare individual centrality estimates (see Figure S1 in the supplementary materials). This non-parametric bootstrapping method was used to determine if edges (or centrality values) significantly differed from one another; note that these difference tests are not correct for multiple testing.

3.4 | Visualization

Positive edges are represented by blue lines, while negative edges are printed in red. Thicker and more saturated edges visualize stronger connections. The Fruchterman-Reingold algorithm (Fruchterman & Reingold, 1991) was used, where stronger and/or more connections are placed closer to one another.

4 | RESULTS

4.1 | Estimation of transdiagnostic network model

The 32-item network structure is presented in Figure 1.

Overall, we found more positive (62%) than negative (38%) edges.

The strongest positive associations emerged between Parental Criticism (Cri [nodename; for an overview of full names see legend Figure 1], FMPS [questionnaire]) and Parental Expectations (Exp, FMPS; 0.62), two subscales of the perfectionism questionnaire. Furthermore, there are strong relationships between Drive for Thinness (Dft, EDI) and Body Dissatisfaction (Bod, EDI; 0.43), two core ED symptoms as well as between depression (BDI) and anxiety (Anx, STAI; 0.39).

We also identified some strong negative relations, the strongest being between Harm Avoidance (Har, TCI) and Novelty Seeking (Nov, TCI; −0.28), two personality traits as well as Impaired Limits (Lim, YSQ) and Cooperativeness (Coa, TCI; −0.23), and social insecurity (Soc, EDI) and Resilience (Res, RS; −0.21).

Additionally, we examined which ED symptom variables (as measured by the EDI subscales) are most strongly related to other non-symptom variables. The strongest negative edge is already stated above (social insecurity and resilience [−0.21]), while the strongest positive edge occurs between impulse regulation (Imp, EDI) and novelty seeking (Nov, TCI; 0.13).

Node predictability (degree to which a node can be predicted by all the other nodes in the network).

The five nodes with the highest and lowest predictability were overvigilance and inhibition (Ihn, YSQ; pred = 0.79), disconnection and rejection (Dir, YSQ pred = 0.77), impaired autonomy & performance (Aut, YSQ pred = 0.77), anxiety (Anx, STAI pred = 0.71), personal standards (Sta, FMPS pred = 0.69), novelty seeking (Nov, TCI pred = 0.41), reward dependence (Red, TCI pred = 0.38), maturity fear (Fea, EDI-II pred = 0.36), bulimia (Bul, EDI-II pred = 0.34) and self-transcendence (Set, TCI, pred = 0.152), respectively, from highest to lowest.

5 | CENTRALITY ESTIMATION

Figure 2 shows the standardized EI estimates, that is interconnectedness of all nodes. We list the five most and least connected nodes below. Overvigilance and Inhibition (Inh, YSQ; EI = 1.50) as maladaptive schemata, interoceptive awareness, core ED symptoms (Awa, EDI; EI = 1.40) and personal standards, as characteristic of perfectionism (Sta, FMPS; 1.40), serve as core features in the transdiagnostic network. Ineffectiveness (Ine, EDI; 1.30), Impaired Autonomy and Performance (Aut, YSQ; both = 1.10) also show moderately high indices of centrality. The two least central nodes are Resilience (Res, RS; −0.42) and Harm Avoidance (Har, TCI; −0.40). Other nodes with low interconnectedness are Novelty Seeking (Nov, TCI; −0.32), self-directedness (Sed, TCI; −0.25) and weakened limits (Lim, YSQ; 0.11).

Given that the main analyses—consistent with prior studies—identified expected influence as the most stably estimated centrality metric, we present the difference test for expected influence. Figure 3 represents significant differences between centrality estimates as black boxes; of note, the test does not correct for multiple testing.

5.1 | Network accuracy and stability

We estimated the accuracy and stability of the transdiagnostic ED network (available at https://osf.io/ks85g/). The results from the edge weight bootstrap show that the network model was fairly accurately estimated (however, note that clear benchmarks to interpret the CIs are as yet missing in the literature). The stability analysis for the centrality resulted in a CS-coefficient of 0.75, which can be considered a highly stable order of centrality (Epskamp, Borsboom, & Fried, 2018). The stability analysis for the edge weights resulted in an ES-coefficient of 0.75. The network has a mean explained variance (a measure of node predictability) of 0.60, which is considered a high percentage of node predictability with regard to other network

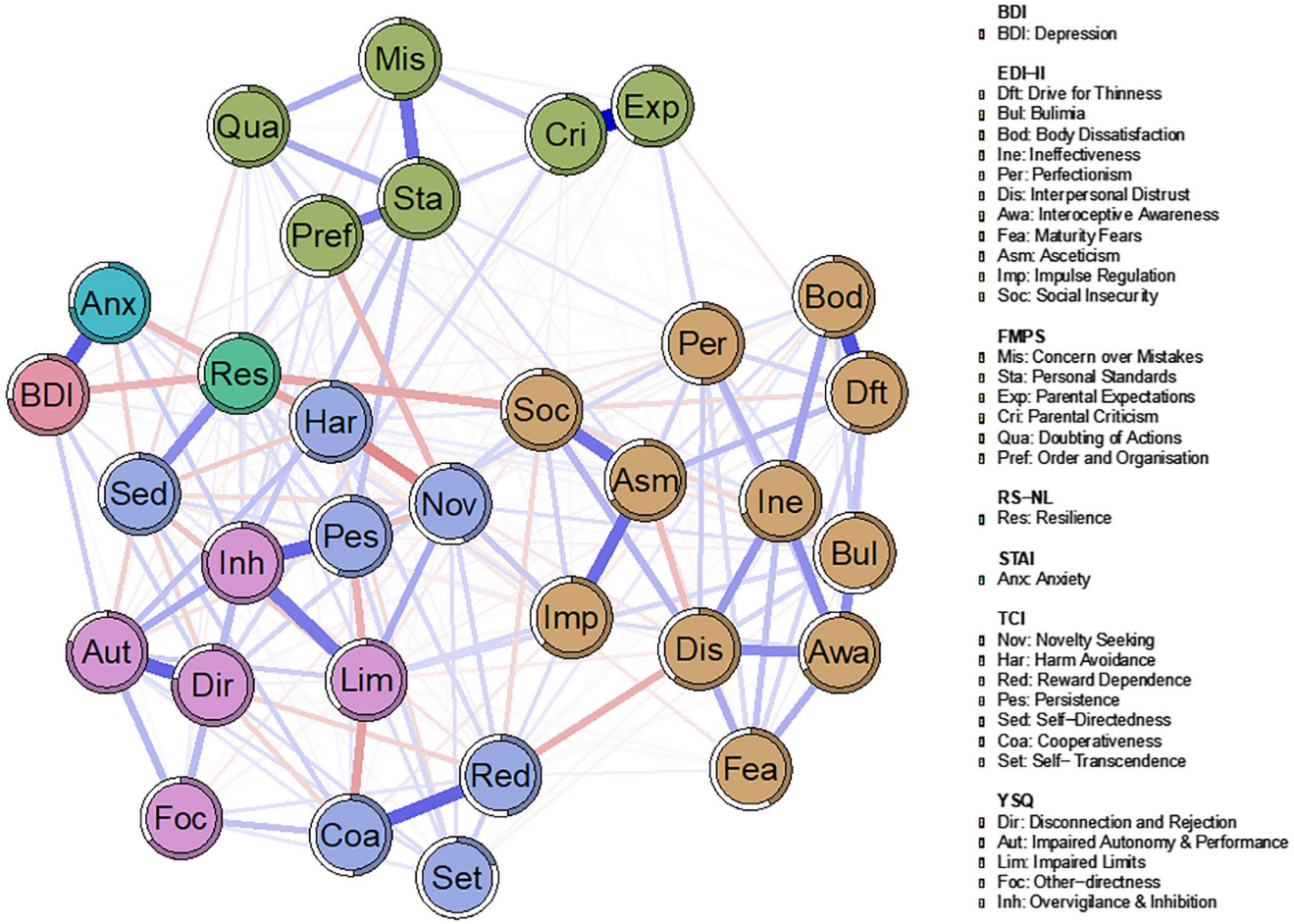

FIGURE 1 Transdiagnostic eating disorders network. Nodes represent eating disorders core features, whereas edges represent the regularized partial correlation between any two nodes

papers investigating psychopathology (Haslbeck & Fried, 2017). Results from the centrality difference test show that EI significantly differs for most nodes from each other. The node with the largest expected influence overvigilance and inhibition (Inh, YSQ; EI = 1.50) is significantly larger than most of the other nodes, with the exception of interoceptive awareness (Awa, EDI; EI = 1.40), Personal Standards (Sta, FMPS; 1.40), and Ineffectiveness (Ine, EDI; 1.30). Further accuracy and stability analyses for this network are available at https://osf.io/ks85g/, including edge weight significance tests (testing for significant differences for all edges) and centrality difference tests (testing for centrality differences for all nodes).

6 | DISCUSSION

We estimated a network model based on (1) core ED symptoms and common psychological/behavioural features that are linked with EDs; (2) comorbid clinical symptoms (depression and anxiety) and (3) well-known and general/transdiagnostic vulnerability mechanisms beyond symptoms (personality traits, maladaptive cognitive schemata, perfectionism and resilience) in a large sample of treatment-seeking patients with an ED (AN, BN, BED and OSFED/EDNOS). The study results identify *maladaptive schemata* with hypervigilance and excessive focus on inhibiting emotions and feelings in order to avoid mistakes (inhibition), *interoceptive awareness*, regulation of feelings of ineffectiveness, and high personal standards (*perfectionism*) as key characteristics in ED patients in the estimated network.

'Hypervigilance/Inhibition' is defined as 'excessive emphasis on suppressing one's spontaneous feelings, impulses and choices or on meeting rigid, internalized rules and expectations about performance and ethical behaviour, often at the expense of happiness, self-expression, relaxation, close relationships or health' (Young et al., 2003), whereas 'interoceptive awareness' measures the ability of an individual to discriminate between sensations and feelings, and between the

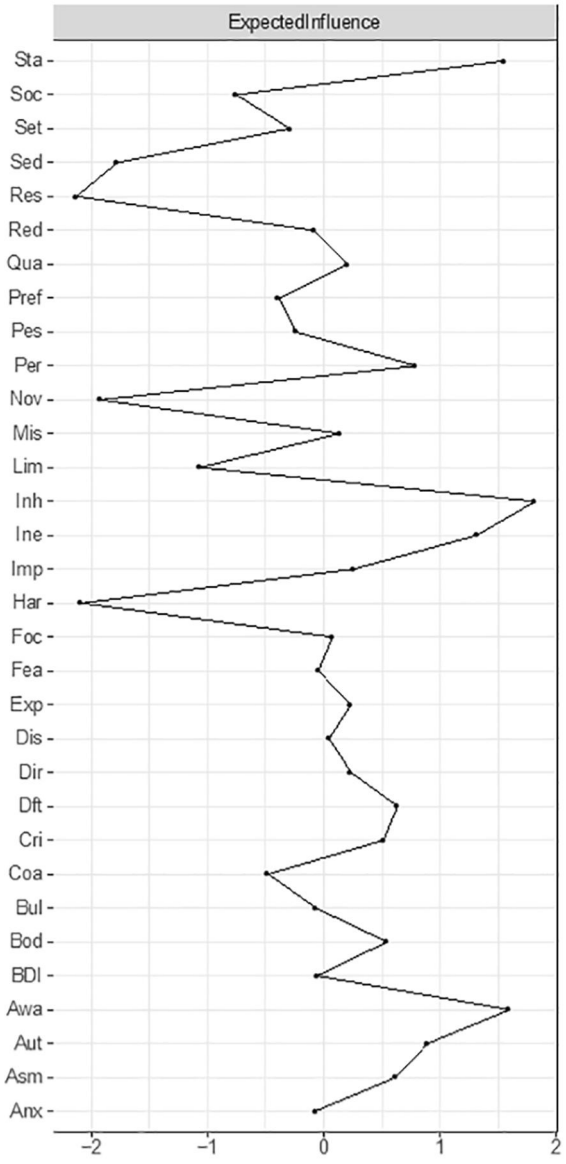

FIGURE 2 Expected Influence for the transdiagnostic eating disorders network. Larger numbers indicate that the item is more central to the network

sensations of hunger and satiety (Garner, Olmstead, & Polivy, 1983). Personal standards, as a measure of perfectionism, involve the setting of high standards and goals for oneself (Frost et al., 1990). High standards perfectionism can become maladaptive and evolve as an important risk and maintenance factor for EDs (Boone, Claes, & Luyten, 2014; Dimaggio et al., 2018; Duffy et al., 2019; Flett & Hewitt, 2002; Slof-Op't Landt, Claes, & van Furth, 2016). In addition, this attitude serves as a predictor of body dissatisfaction, an excessive fear of gaining weight and a preoccupation to be thinner, even in healthy controls (Dickie, Wilson, McDowall, & Surgenor, 2012; Rivière & Douilliez, 2017). Hypervigilance or overcontrol as a schema mode is associated with negative social outcomes, including reduced spontaneity, avoidance, social withdrawal, aversion to novel situations and lack of assertiveness (Cole, Michel, & Teti, 1994; Young et al., 2003).

The high centrality of inhibiting emotions and feelings in EDs is in line with recent studies in AN patients (Oldershaw, Lavender, & Schmidt, 2018; Oldershaw, Startup, & Lavender, 2019). The highly interconnected 'ineffectiveness' and 'interoceptive awareness', as found in their analysis, may also explain experienced feelings of inadequacy, insecurity, worthlessness and a perceived lack of control (McLaughlin, Karp, & Herzog, 1985). Probably because of disturbances in 'Interoceptive awareness', ED patients lose or miss the recognition and accurate identification of appetite signals and emotional cues (Garner et al., 1983), which may not only contribute to dysregulation of food intake, but also to the inhibition of emotion and feelings as described above. Restrictive eating suppresses emotions (primary avoidance behaviour), while binge eating and purging are primarily aimed at weakening emotions (secondary avoidance), and these eating behaviours are an expression of maladaptive emotion regulation as a transdiagnostic factor across EDs. Given the major role that emotions play in signalling, motivating, and communicating, ED patients may lose contact with themselves and the outside world and try to steer their mood according to certain (eating) rules. Because of this, they do not learn to use social, cognitive, and physical strategies that help them deal with negative events.

Furthermore, looking for the most important relationships between ED symptoms and non-symptom variables in this network, the strongest negative association was found between resilience, as a protective factor in mental health, and the core EDI symptom, social insecurity. Prior studies have shown that resilience factors predict improvements in psychological health and social relationship domains of quality of life and a reduction of ED symptoms over time (Calvete et al., 2018). Additionally, the strongest positive connection occurs between the EDI symptom, Impulse Regulation, and the temperament dimension, Novelty Seeking. Several research results indicate that temperamental features could be considered predictors of specific associations between emotions and the tendency to eat (Atiye, Miettunen, & Raevuori-Helkamaa, 2015; Rotella et al., 2018; Vervaet, Van Heeringen, & Audenaert, 2004).

Finally, another interesting result of this study was based on measuring the node predictability. The five nodes with the highest and lowest predictability were overvigilance and inhibition, disconnection and rejection, impaired autonomy and performance, anxiety, personal standards, novelty seeking, reward dependence, maturity fear, bulimia and self-transcendence, respectively, from

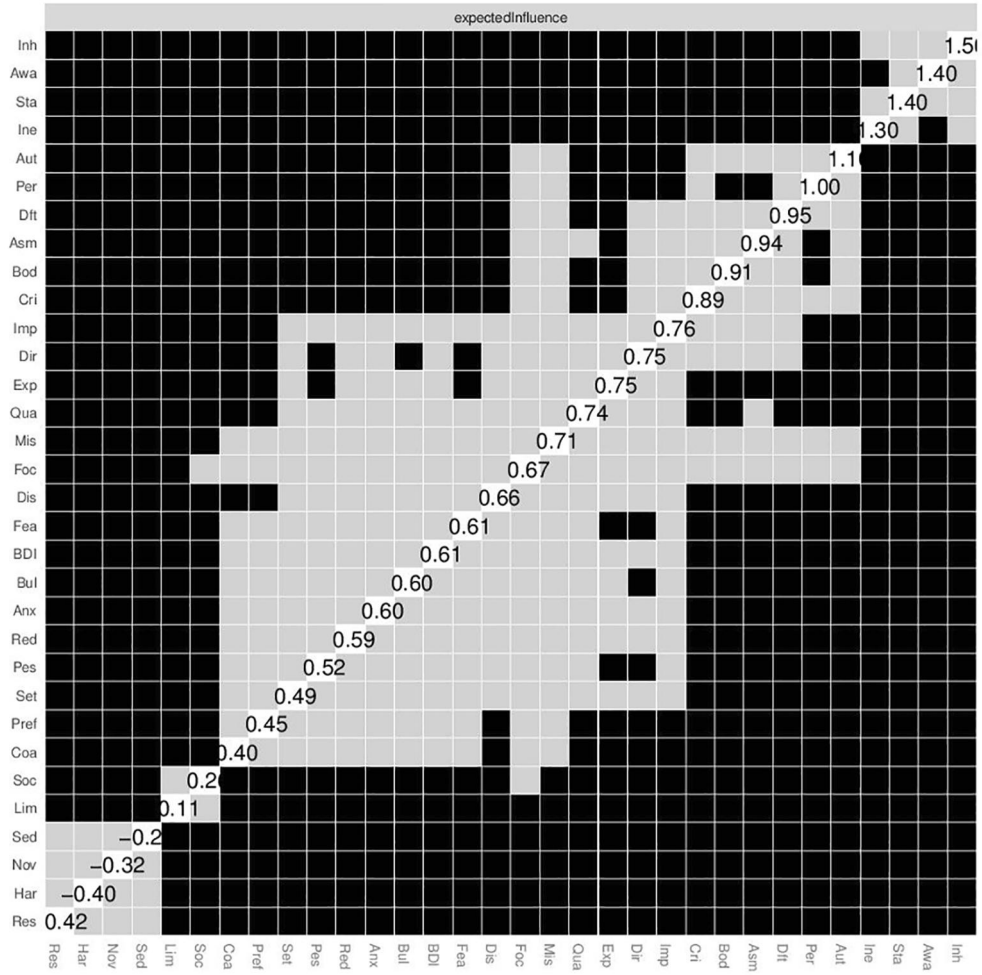

FIGURE 3 Degree centrality difference test for the 32-item eating disorders network. Grey boxes indicate nodes or edges that do not differ significantly from one-another and black boxes represent nodes or edges that do differ significantly from one-another and white boxes in the centrality plot show the value of node strength

highest to lowest. As described earlier (Haslbeck & Fried, 2017), node predictability can provide information on the clinical relevance of connections (or edges) between nodes. This analysis shows again that overvigilance and inhibition, disconnection and rejection, impaired autonomy, anxiety and perfectionism (personal standards) might be clinically relevant constructs (as they are most predicted by all other nodes in the network) that could be taken into account when designing an intervention. Yet, because node predictability informs about shared variance between nodes, and does not give any information on the direction of causation, future research should further investigate these predictions by conducting a study with time-series data to examine the direction of influence of the highly central nodes from the current study. If it could be established that these nodes have temporal precedence, these results could be a first step towards identifying potential intervention targets. The current findings are relevant for the treatment of EDs by elucidating potential mechanisms of behavioural change. The central features of the described network are in line with the transdiagnostic factors of Fairburn's model of ED (Fairburn et al., 2003), that is, perfectionism, low self-esteem, mood intolerance and interpersonal difficulties. Moreover, the findings indicate that ED patients may benefit from treatments designed to enhance cognitive flexibility, combined with self-compassion techniques (Pullmer, Coelho, & Zaitsoff, 2019; A. F. Wagner & Vitousek, 2019). For example, compassion focused therapy (Gilbert, 2009) learns patients to become milder to themselves instead of their extreme perfectionism, which provokes constant negative emotions and thus maintains the ED. Thus, the drive to excel in a valued domain and their strength in top-down regulation strategies can be a powerful attribute when redirected to serve recovery. The harsh self-criticism that accompanies their perfectionistic striving can be diminished by rewarding efforts by directing them to other more efficient goals as an adaptive emotional regulation strategy.

Without any doubt, motivational strategies need to precede every intervention in bridging symptoms related to fear of forming close relationships with those related to feelings of adequacy and perceived lack of control.

Despite some important strengths of the study (including the large, transdiagnostic study sample of patients from all ED-categories with various levels of symptom severity, and the measurement of both ED-specific symptoms and general psychiatric symptoms, and vulnerability factors), a number of methodological issues need to be addressed. Limitations include the cross-sectional nature of the analysed data and the absence of data on potential medical comorbidities, cognitive performance and social functioning that may play important roles (Blinder, Cumella, & Sanathara, 2006; Setia, 2016). Another limitation is that no additional network models were estimated for each ED diagnosis separately, as has been done by previous network studies (e.g., Solmi et al., 2018). Additionally, a statistical limitation is that the current study included a patient sample in a hospital setting (in- and outpatients) that can lead to Berkson's bias (selecting a population based on scores of diagnostic criteria such as symptoms) when using statistical models such as structural equation models that are estimated based on the correlation matrix of items (de Ron, Fried, & Epskamp, 2019). Moreover, current network models are based on pairwise, linear relationships, which should be seen as a lower bound on the true complexity of the modelled system. Therefore, they will not successfully recover more complicated relationships between variables such as non-linear effects, higher-order interactions or threshold effects such that A only starts influencing B when A is at a certain minimum or quadratic correlations among others. Furthermore, network models, such as any statistical model, can only explore variance between items included in the model, and it is not a trivial question which variables should be considered to be part of a complex system. This means that future investigations should examine how replicable the centrality results of the present study are to variations of included items. Related to this issue, it is also very important to focus more on item selection when creating a network model, since centrality measures take items into account, but this implies that constructs that hold more items (and therefore are represented by more nodes in the network) will benefit from intra-measure correlations compared to constructs with only a single node. Bridge symptoms would help account for this issue because they only include associations between clusters; however, this only makes sense with clearly defined constructs and communities in the network, which is not the case in our current network model. Finally, the model is a between-subjects model, and how well the results will generalize to individual patients will have to be studied empirically, for instance by collecting and analysing time-series data (Epskamp, van Borkulo, et al., 2018).

7 | CONCLUSION

This study aimed to explore the link between core ED symptoms and comorbid clinical symptoms and transdiagnostic vulnerability mechanisms in a large sample of treatment-seeking patients with an ED. The results indicate a central role of personal standards (a dimension of perfectionism), overvigilance and inhibition (a maladaptive schemata with excessive focus on inhibiting one's emotions and feelings in order to avoid making mistakes), and ED symptoms (ineffectiveness and interoceptive awareness). These findings may suggest that over controlling bodily aspects by dietary restraint (through inhibition) and interoceptive awareness as a maladaptive regulation of feelings of ineffectiveness are key characteristics in ED patients. Probably, based on their extreme personal standards with severe and rigid rules, they continuously try to improve their control efforts instead of changing their method in order to develop a more adaptive and effective emotion regulation. These findings are relevant for the understanding and treatment of ED by underlining the importance of using motivational strategies in bridging ED symptoms, adequate methods of self-improvement and adaptive emotion regulation.

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ENDNOTE

[1] As data collection started 20 years ago, an older version of the DSM is used for the diagnosis of eating disorders. As the new DSM-5 criteria are more sensitive to capture individuals within specified diagnoses, as compared to other or unspecified diagnoses, we decided to focus our analyses on all patients diagnosed with EDs, without making a differentiation per category.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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