

Mindfulness and Eating Disorders: A Network Analysis

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Higher trait mindfulness may be protective against eating disorder (ED) pathology. However, little is understood about which specific mindfulness processes connect to specific ED symptoms. This study ($N = 1,056$ undergraduates) used network analysis at the symptom/process level to identify: (1) central nodes, or symptoms/processes with the greatest collective connection with all other symptoms/processes; and (2) bridge nodes, or symptoms/processes driving interconnection between mindfulness processes and ED symptoms. We conducted analyses both with and without food- and body-related mindfulness items. Central nodes included: *describing how one feels in detail, expressing how one feels in words, and feeling guilty about eating due to shape/weight*. Bridge nodes connecting higher mindfulness processes with lower ED symptoms included: *the eating disorder symptom, being uncomfortable about others seeing one eat, and the mindfulness process, not criticizing oneself for having irrational/inappropriate emotions*. Bridge nodes connecting higher mindfulness processes with higher ED symptoms included: *noticing sensations of the body moving when walking and noticing how food/drinks affect thoughts, bodily sensations, and emotions*. Findings suggest that future research should explore whether mindfulness-based interventions for EDs may be more effective by targeting mindfulness processes related

to describing, expressing, and accepting emotions, accepting discomfort when eating with others, and reducing hyper-focus on and reactivity to food-and-body related sensations.

Keywords: mindfulness; acceptance; anorexia nervosa; bulimia nervosa; binge eating disorder

MINDFULNESS INVOLVES THE ABILITY to direct one's awareness to the present moment with an attitude of acceptance and nonjudgment (Bishop et al., 2004). Mindfulness-based treatments have been successfully applied to a wide range of psychiatric conditions, such as depression (Goldberg et al., 2018, 2019), anxiety (Evans et al., 2008; Vøllestad et al., 2011), chronic pain (Chiesa & Serretti, 2011; Goldberg et al., 2018), substance use disorders (Goldberg et al., 2018; Grant et al., 2017; Li et al., 2017), attention-deficit/hyperactivity disorder (Cairncross & Miller, 2020), and schizophrenia (Goldberg et al., 2018; Hodann-Caudevilla et al., 2020). Most recently, research also suggests that mindfulness-based treatments may also be efficacious for eating disorders (Eds) (Barney et al., 2019; Godfrey et al., 2015; Turgon et al., 2019).

Higher trait mindfulness (i.e., the general tendency to be mindful in situations) may be protective against ED pathology (Sala et al., 2019; Sala & Levinson, 2017) by influencing constructs that are relevant to EDs, such as improving emotion

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regulation and reducing engagement with maladaptive cognitions (Sala et al., 2020; Vanzhula & Levinson, 2020). Indeed, individuals with EDs are less mindful than healthy individuals (Compare et al., 2012; Sala et al., 2019). Furthermore, a recent meta-analysis reports that trait mindfulness has a moderate inverse associations with ED pathology in both individuals with EDs and healthy individuals (Sala et al., 2020).

Trait mindfulness has been conceptualized as a multifaceted construct with five facets: (1) *observing*, or noticing internal and external sensations; (2) *describing*, or labeling one's thoughts, emotions, and physical sensations; (3) *acting with awareness*, or consciously attending to and engaging in present-moment activities; (4) *nonjudging*, or accepting thoughts and feelings as they are; and (5) *nonreactivity*, or letting thoughts and feelings come and go without getting caught up in them (Baer et al., 2006). Interestingly, these distinct facets of mindfulness appear to be differentially associated with psychopathology. For example, studies have found that the observing facet of mindfulness is either unrelated to health outcomes (Mattes, 2019) or positively associated with psychopathology. On the other hand, the other facets of mindfulness (describing, acting with awareness, nonjudging, and nonreactivity) have generally been found to be associated with lower psychopathology and better health outcomes (Mattes, 2019). The Monitor and Acceptance Theory (MAT) of mindfulness posits that heightened mindful observation alone, without other qualities of mindfulness (e.g., nonjudgment), may increase affective reactivity and be maladaptive for some individuals (Lindsay & Creswell, 2017).

Research on facets of mindfulness among samples with ED pathology appears consistent with MAT and prior empirical work. For example, a recent meta-analysis found that the acting with awareness and nonjudging facets of mindfulness were most strongly negatively associated with ED pathology (Sala et al., 2020). In contrast, the observing facet of mindfulness has been found to be positively associated with ED pathology (Lattimore et al., 2011; Levin et al., 2014; Prowse et al., 2013). Higher attentional monitoring alone may be indicative of maladaptive hyperawareness among individuals with high levels of ED pathology. Although preliminary work has shed light on the extent to which facets of mindfulness are related to ED pathology as a whole, more *precise* work in this area is needed. For example, there is a need to understand which *specific* mindfulness processes (e.g., observing of sounds or smells vs. observing body sensations vs. observing

while eating) are most strongly linked with *specific* ED symptoms (e.g., weight dissatisfaction, eating in secret, restriction, etc.). Importantly, clarifying the dynamic links between specific mindfulness processes and specific ED symptoms has the potential to inform the refinement and precision delivery of mindfulness-based interventions for EDs. That is, the efficiency and efficacy of mindfulness-based interventions can be enhanced if they target specific deficits in mindfulness skills that play the largest role in maintaining an individual's presenting ED symptomology. For example, if findings reveal that a lack of emotion awareness bridges mindfulness processes and ED symptoms, mindfulness-based intervention for EDs could focus on enhancing emotion awareness as a mechanism to disrupt the associations among ED symptoms.

Network analysis may be a useful analytic approach to elucidate the links between specific mindfulness processes and ED symptoms. Network analysis is a novel methodology that is rooted in the theory that psychological disorders are maintained by dynamic relations between symptoms (Borsboom, 2017; Cramer et al., 2010), and stands in contrast to a classical view that describes symptoms as passive indicators of an underlying (i.e., latent) syndrome. A network analysis approach allows for the examination of the complex dynamic interplay among psychological constructs in one network (Epskamp et al., 2012) and can facilitate the understanding of how protective factors (e.g., mindfulness) and symptoms of psychopathology are dynamically related to each other. Network analysis enables the identification of central nodes, which exhibit a large number of connections in the network and are theorized to be the most influential symptoms within the network (Borsboom & Cramer, 2013; McNally, 2016). In network theory, switching a central symptom on versus off would likely have a high impact on all symptoms in the network. Network analysis also enables the identification of bridge symptoms, which link two distinct symptom clusters (e.g., mindfulness processes and ED symptoms). Network theory posits that targeting bridge pathways should help to disrupt the connection between symptom networks (i.e., dismantling the connection between low mindfulness and high ED symptoms). Therefore, treatments should target mindfulness processes that connect most strongly to ED symptoms.

Recent research within both the ED (DuBois et al., 2017; Forbush et al., 2016; Forrest et al., 2018, 2019; Levinson et al., 2017, 2018; Vanzhula et al., 2019) and mindfulness

(Bronchain & Chabrol, 2020; Medvedev et al., 2021; Rowland & Wenzel, 2020) fields has begun to apply network analytic methods. Research on the ED symptom network has identified that symptoms related to weight/shape concern are central to the ED symptom network (DuBois et al., 2017; Forbush et al., 2016; Forrest et al., 2018, 2019; Levinson et al., 2017; Sala et al., 2019, 2020; Vanzhula et al., 2019). Research on mindfulness networks has mostly examined facets (subscales rather than individual processes), and has found that the acting with awareness, nonjudging, and nonreactivity facets act as important bridge nodes between protective (e.g., positive affect) and maladaptive factors (e.g., depression, anxiety) (Medvedev et al., 2021). However, to our knowledge, no study to date has used network analysis to examine mindfulness within an ED symptom network. Furthermore, most mindfulness networks to date have not examined item-level data (Medvedev et al., 2021; Rowland & Wenzel, 2020). Examining item-level data is more consistent with network theory than the use of subscales and may enable identification of more precise pathways that connect specific mindfulness processes and ED symptoms (e.g. identifying the specific aspects of non-judgment that connect mindfulness and ED pathology).

The current study used network analysis to test links between specific mindfulness processes and ED symptoms. We aimed to identify central (i.e., most densely connected) and bridge (i.e., link) processes/symptoms within a mindfulness process and ED symptom network. We also aimed to examine whether network structure and connectivity differed between individuals with high levels of ED symptoms and the general sample. First, based on previous research, we hypothesized that central symptoms would be ED symptoms related to weight/shape concern (DuBois et al., 2017; Forbush et al., 2016; Forrest et al., 2018, 2019; Levinson et al., 2017; Vanzhula et al., 2019), and mindfulness processes related to emotion awareness (Brown et al., 2020; Davies et al., 2011, 2013; Haynos & Fruzzetti, 2011). Second, based on theory (Vanzhula & Levinson, 2020) and previous research (Lattimore et al., 2011; Levin et al., 2014; Prowse et al., 2013; Sala et al., 2020), we hypothesized that bridge processes/symptoms would be *elevations* in observing one's body and what one is eating, and *deficits* in the ability to notice and accept challenging thoughts and emotions. Because strong interconnections between mindfulness and ED symptoms through food and body items in mindfulness

measures (e.g., "I notice how foods and drinks affect my thoughts, bodily sensations, and emotions") could obscure other findings and because analyses showed that this was the case in the current sample, we made the post-hoc decision to conduct networks analyses both with and without items related to food and body in order to fully understand potential dynamic interconnections among mindfulness processes and ED symptoms that may or may not be related to food and one's body. Based on previous research (DuBois et al., 2017; Liebman et al., 2020; Vanzhula et al., 2019), we hypothesized that the networks would be more densely connected in individuals with high levels of ED symptoms than the general sample, but that there would be no differences in network structure.

Methods

PARTICIPANTS

Participants were 1,056 undergraduate students from a university in the United States who completed both trait mindfulness and ED assessments. Data were collected in 2018–2020 as part of ongoing data collection (Christian et al., 2020; Cusack et al., 2021; Levinson et al., 2019; Levinson & Williams, 2020). All study procedures were approved by the Institutional Review Board, and all participants provided informed consent. Participants were primarily female ($n = 791$; 75.3%), and Non-Hispanic White ($n = 723$, 68.5%). Other reported races/ethnicities were Black ($n = 148$; 14.0%), Asian ($n = 63$; 6.0%); Multiracial ($n = 59$; 5.6%), Hispanic ($n = 35$; 3.3%), American Indian ($n = 8$; 0.8%) and Other ($n = 20$, 1.9%). The average age was 19.65 (Range = 17–70, $SD = 3.75$). Participants were recruited from undergraduate psychology classes using an online system. There were no exclusion criteria, and anyone who signed up for a psychology course was eligible to participate. The mean Eating Disorder Examination Questionnaire (EDE-Q) global score was 1.72 ($SD = 1.25$, Range = 0.00–5.90) and 28.9% of the sample had an EDE-Q global score above the 2.4 clinical cut-off level indicating there was a significant percentage of individuals who would likely meet criteria for an ED.

PROCEDURES

Participants were asked to complete the measures described below, as a part of a larger online study. The study was conducted through the Redcap Secure Survey System, and participants received course credit for their participation.

MEASURES

Five Facet Mindfulness Questionnaire (FFMQ);
Baer et al., 2006)

Trait mindfulness was measured with the FFMQ. The FFMQ measures trait mindfulness and its five facets: (1) observing (“I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing”), (2) describing (“I am good at finding the words to describe my feelings”), (3) acting with awareness (“I find it difficult to stay focused on what’s happening in the present”), (4) nonjudgment (“I think some of my emotions are bad or inappropriate and I shouldn’t feel them”), and (5) nonreactivity (e.g., I perceive my feelings and

emotions without having to react to them). Items are rated on a scale of 1 (*never or very rarely true*) to 5 (*very often or always true*). All 39 items in the FFMQ were used for the first network model (see [Table 1](#)). For the second network model, we used all mindfulness items of the FFMQ except for noticing sensations of the body moving when walking (*WlkNotice*), noticing how food/drinks affect thoughts, bodily sensations, and emotions (*Food*), and staying alert to sensations of water on the body when showering (*Shower*). Items were coded in such a way that higher scores indicate higher mindfulness. The FFMQ has excellent psychometric properties ([Baer et al., 2006](#)). In the cur-

Table 1
Mindfulness Network Nodes Included

Node	Description
WlkNotice	Noticing sensations of the body moving when walking
DescFeel	Ability to find words to describe feelings
CritEmot*	Criticizing oneself for having irrational or inappropriate emotions
FeelReact	Perceiving feelings and emotions without having to react to them
MdWander*	When doing things, having one’s mind wander and being easily distracted
Shower	Staying alert to sensations of water on the body when showering
WordBelief	Ability to easily put beliefs, opinions, and expectations into words
Attention*	Not paying attention to what one is doing
WatchFeel	Ability to watch feelings without getting lost in them
NoFeel*	Telling oneself one shouldn’t be feeling a certain way
Food	Noticing how food/drinks affects thoughts, sensations, and emotions
DescThink*	Difficulty finding the words to describe what one is thinking
Distract*	Being easily distracted
ThoughtAbn*	Believing some of one’s thoughts are abnormal or bad
Sensations	Paying attention to sensations
WordFeel	Expressing how one feels in words
JudgThoughts*	Making judgments about whether one’s thoughts are good or bad
Focus*	Difficulty staying focused on what is happening in the present
StepBack	When having distressing thoughts or images, ability to “step back”
Sounds	Paying attention to sounds
Pause	In difficult situations, ability to pause before immediately reacting
DescSensat*	Difficulty describing sensations in the body
NoAware*	Running on automatic without much awareness of what one is doing
Calm	Feeling calm soon after having distressing thoughts
ShldntThink*	Telling self one shouldn’t be thinking what one is thinking
Smell	Noticing smells and aromas of things
WordUpset	Even feeling upset, being able to put it into words
Rush*	Rushing through activities without being really attentive to them
DistNotice	When having distressing thoughts, ability to notice them without reacting
ShldntFeel*	Thinking some of one’s emotions are bad, and one shouldn’t feel them
Notice	Noticing visual elements in art or nature
WordExp	Natural tendency to put experiences into words
NoticeLetgo	When having distressing thoughts, ability to notice them and let them go
TaskAutom*	Doing tasks automatically without awareness of what one is doing
DistJudge*	Judging self for having distressing thoughts or images
EmotThought	Paying attention to how one’s emotions affect one’s thoughts and behavior
DescDetail	Describing how one feels in detail
NoAttention*	Doing things without paying attention
Dissapprove*	Disapproving of self when having irrational ideas

Note: * denotes that the item was reverse coded such that a higher score represented higher mindfulness.

rent study, internal consistency was excellent ($\alpha = .95$).

EDE-Q (Fairburn & Beglin, 1994)

Eating disorder symptoms were measured with the EDE-Q Version 6.0. We used all continuously rated items of the EDE-Q, excluding count items (see Table 2). These 25 items are rated on a scale of 0 (*not at all*) to 6 (*markedly*). Higher values indicate more severe ED symptoms. The EDE-Q has good psychometric properties (Berg et al., 2012). In the current study, internal consistency was excellent ($\alpha = .96$).

DATA ANALYSES

Glasso Networks

Networks were estimated with the GLASSO estimator using the *bootnet* package in R. Correlations among nodes in GLASSO networks represent partial correlations in the network while accounting for other symptoms. Additionally, GLASSO networks estimate edges that are likely to be spurious as zero, therefore resulting in a more parsimonious and accurate network (Epskamp & Fried, 2018). The initial network, estimated using polychoric correlations, was densely connected. Thus, per recommendation of Epskamp and Fried (2018), we used Spearman

correlations in our final analysis. We ran two sets of networks. Model 1 contained all mindfulness items, whereas Model 2 contained all mindfulness items except for noticing sensations of the body moving when walking (*WlkNotice*), noticing how food/drinks affect thoughts, bodily sensations, and emotions (*Food*), and staying alert to sensations of water on the body when showering (*Shower*).

Network Stability

To assess network accuracy, we computed: (1) a strength centrality stability coefficient [CS-coefficient]; (2) an edge stability correlation coefficient [ES-coefficient], and (3) bridge strength stability coefficient [BS-coefficient]. Coefficients reflect the maximum proportion of cases that can be dropped such that the correlation between original centrality indices and the reduced sample is at least .70. Coefficients between .20 and .50 are considered acceptable, coefficients above .50 and below .70 are considered good, and coefficients above .70 are considered excellent (Epskamp et al., 2018). We used the *bootnet* package to estimate network stability (Epskamp et al., 2018).

Centrality Indices

Central nodes represent nodes that exhibit the greatest collective strength of connections with

Table 2
Eating Disorder Network Nodes Included

Node	Description
Restrict	Tried to limit the amount of food eaten for shape or weight concerns
NotEat	Gone for long periods of time without eating for shape or weight concerns
AvoidEat	Avoiding eating specific foods one likes to influence shape/weight
Eatrules	Tried to follow food rules for shape or weight concerns
Emptstom	Definite desire to have an empty stomach
Flatstom	Definite desire to have a flat stomach
FoodConc	Thinking about food, eating, or calories made it difficult to concentrate
WtShpConc	Thinking about shape or weight made it difficult to concentrate
StopFear	Fear of not being able to resist or stop eating
NoControl	Experiencing a sense of loss of control over eating
Binge	Having had episodes of binge eating
Feargain	Fear of gaining weight
Feelfat	Feeling fat
WantLose	Having a strong desire to lose weight
ThinDesire	Desire for thinness
Secreteat	Eating in secret
WtShpGuilt	Feeling guilty about eating due to shape/weight
SeeEat	Concerns about others seeing one eat
WtThink	Weight influencing how one thinks about oneself
ShpThink	Shape influencing how one thinks about oneself
WeightDis	Distress regarding weighing
WtDiss	Weight dissatisfaction
ShpDiss	Shape dissatisfaction
SeeBody	Discomfort with seeing one's body
OtherSee	Concerned about other people seeing one eat

all other nodes in the network. Central nodes were identified by calculating strength centrality (i.e., the sum of the absolute values of the connections between one node and all other nodes) (Epskamp & Fried, 2018). We performed node centrality difference tests to determine whether nodes with higher centrality statistics were significantly different from nodes with lower values (Epskamp et al., 2018). We used the *centralityPlot* and *centralityTable* functions in the *qgraph* package in R (Epskamp et al., 2012).

Bridge Symptoms

Bridge nodes represent nodes that link two distinct symptom clusters. Bridge nodes between mindfulness and ED psychopathology were identified by calculating bridge strength centrality. Bridge strength centrality is defined as the sum of the absolute values of the connections that exist between a node and all nodes that are not in the same cluster. For this set of analyses, all FFMQ items were designated as one cluster, and all EDE-Q items were designated as another cluster. We used the *bridge* function of the *networktools* package in R (Jones, 2017). We performed bridge strength centrality difference tests to determine

whether nodes with higher bridge strength statistics were significantly different from nodes with lower values using the *bootnet* package in R (Epskamp et al., 2018).

Network Comparisons

Network comparisons compare whether networks differ in structure (i.e., the way that the nodes are connected within the network) and global strength (i.e., connectivity, or the sum of the strength of all edges). For this set of analysis, we compared a subsample of individuals with clinically significant EDE-Q scores (>2.4; 28.9% of the general sample; *n* = 305) to the general sample. We used the *nct* function of the *NetworkComparisons* R package (van Borkulo et al., 2017).

Results

MODEL 1: MINDFULNESS-ED NETWORK USING ALL ITEMS

Strength Centrality

Network stability was excellent (CS coefficient = .75; ES coefficient = .75). Please see Figure 1 for the mindfulness and ED symptoms network. The items with the highest strength centrality

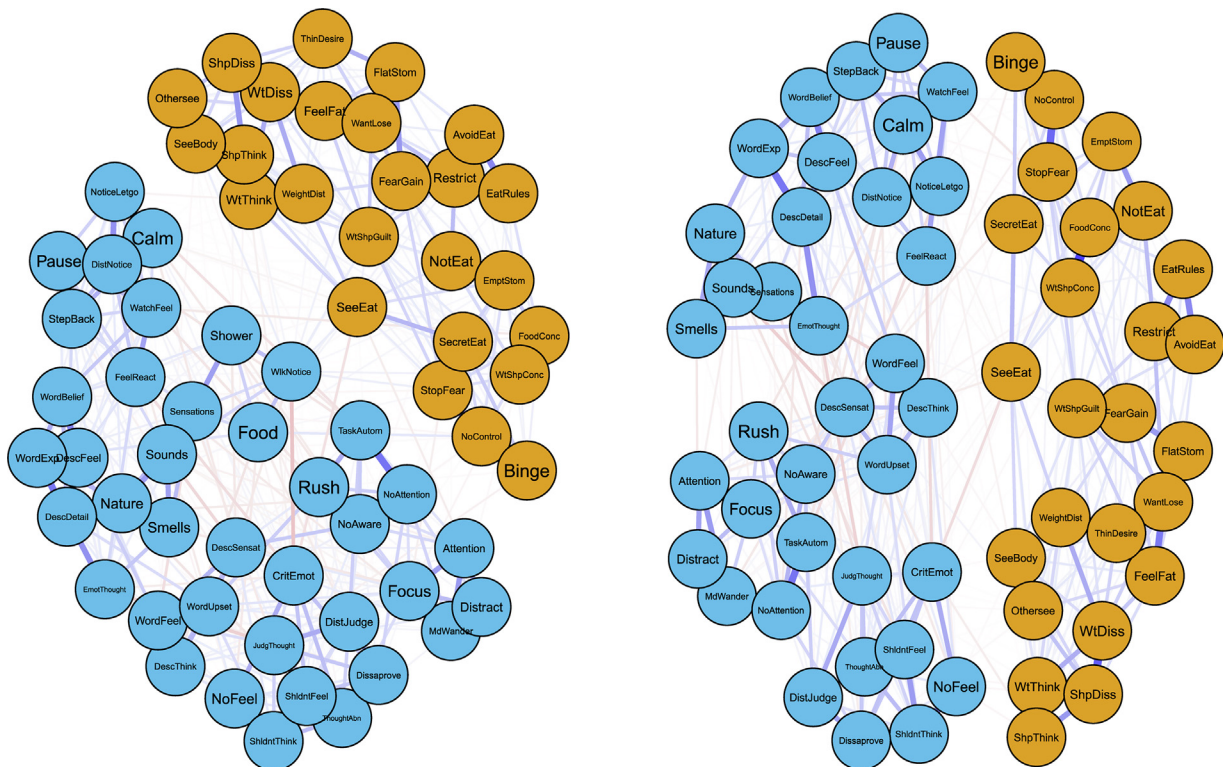


FIGURE 1 Mindfulness and eating disorder (ED) symptom network. The first network represent a network of all items, whereas the second network represents a network of all items except for Food, WikNotice, and Shower: Mindfulness is in blue and ED symptoms are in orange. Thicker lines represent stronger relationships.

(i.e., items that were core to the ED-mindfulness network) were describing how one feels in detail (*DescDetail*, mindfulness, strength = 2.63), feeling guilty about eating due to shape/weight (*WtShpGuilt*, eating disorder symptom, strength = 1.68), and expressing how one feels in words (*WordFeel*, mindfulness, strength = 1.57). See Figure 2 for the strength centrality plot and Supplemental Figure 1 for the strength centrality difference graph.

Bridge Symptoms

Bridge strength stability was good (BS coefficient = .67). The node with the highest bridge strength centrality (i.e., node linking mindfulness processes and ED symptoms) was the mindfulness item, noticing sensations of the body moving when walking (*WlkNotice*, mindfulness, bridge strength = .24). This item had significantly higher bridge strength centrality than 97% of other items in the network, and had positive connections with ED symptoms (see Supplemental Table 1). It was most strongly positively connected with the ED symptoms of concerns about others seeing one eat (*SeeEat*, part $r = .04$), fear of not being able to resist or stop eating (*StopFear*, part $r = .04$), and feeling guilty about eating due to shape/weight (*WtShpGuilt*, part $r = .04$). The second mindfulness item with the highest bridge strength centrality was noticing how food/drinks affect thoughts, bodily sensations, and emotions (*Food*, mindfulness, bridge strength = .15). This item had significantly higher bridge strength centrality than 86% of other items in the network, and had positive associations with ED symptoms (see Supplemental Table 1). It was most strongly positively connected with experiencing a sense of loss of control over eating (*NoControl*, part $r = .05$), feeling guilty about eating due to shape/weight (*WtShpGuilt*, part $r = .03$), and avoiding eating specific foods one likes to influence shape/weight (*AvoidEat*, part $r = .03$). The eating disorder item with the highest bridge strength centrality was concerns about others seeing one eat (*SeeEat*, ED symptom, bridge strength = .20). This item had significantly higher bridge strength than 92% of other items in the network. It was most strongly positively connected (i.e., higher ED symptoms being associated with higher mindfulness) with noticing sensations of the body moving when walking (*WlkNotice*, part $r = .04$), and most strongly negatively connected (i.e., higher ED symptoms being associated with lower mindfulness) with not criticizing oneself for having irrational/inappropriate emotions (*CritEmot*, part $r = -.07$), and paying attention to what one is doing (*Attention*, part $r = -.04$). See Supple-

mental Table 1 for a list of edges between ED and mindfulness items, Figure 3 for the bridge strength centrality graph, Figure 4 for the visualization of bridge pathways, and Supplemental Figure 2 for the bridge strength difference graph.

Network Comparison

The general sample network had higher global strength than the network of the sample with high levels of ED symptoms (General sample = 31.20, ED sample = 21.65). There were no significant differences in network structure ($p = .22$).

MODEL 2: MINDFULNESS-ED NETWORK WITHOUT FOOD AND BODY MINDFULNESS ITEMS

Strength Centrality

Network stability indicated excellent model accuracy (CS coefficient = .75; ES coefficient = .75). Please see Figure 1 for the mindfulness and ED symptoms network. The items with the highest strength centrality were describing how one feels in detail (*DescDetail*, mindfulness, strength = 2.67), expressing how one feels in words (*WordFeel*, mindfulness, strength = 1.82), and feeling guilty about eating due to shape/weight (*WtShpGuilt*, eating disorder symptom, strength = 1.50). See Figure 2 for the strength centrality plot and Supplemental Figure 1 for the strength centrality difference graph.

Bridge Symptoms

Bridge strength stability was acceptable (BS coefficient = .44). The node with the highest bridge strength was the eating disorder item concerns about others seeing one eat (*SeeEat*, ED symptom, bridge strength = .18). This item had significantly higher bridge strength than 97% of the items in the network, and had negative associations with ED symptoms (see Supplemental Table 1). This item was most strongly negatively connected (such that higher ED symptoms was associated with lower mindfulness) with not criticizing oneself for having irrational/inappropriate emotions (*CritEmotion*, part $r = -.07$) and paying attention to what one is doing (*Attention*, part $r = -.04$). The second item with the highest bridge strength was the mindfulness item, not criticizing oneself for having irrational/inappropriate emotions (*CritEmot*, mindfulness symptom, bridge strength = .14). This item had significantly higher bridge strength than 80% of other items in the network, and had negative associations with ED symptoms (see Supplemental Table 1). This item was most strongly negatively connected (such that higher mindfulness was associated with lower ED symptoms) with concerns about others seeing one eat (*SeeEat*, part

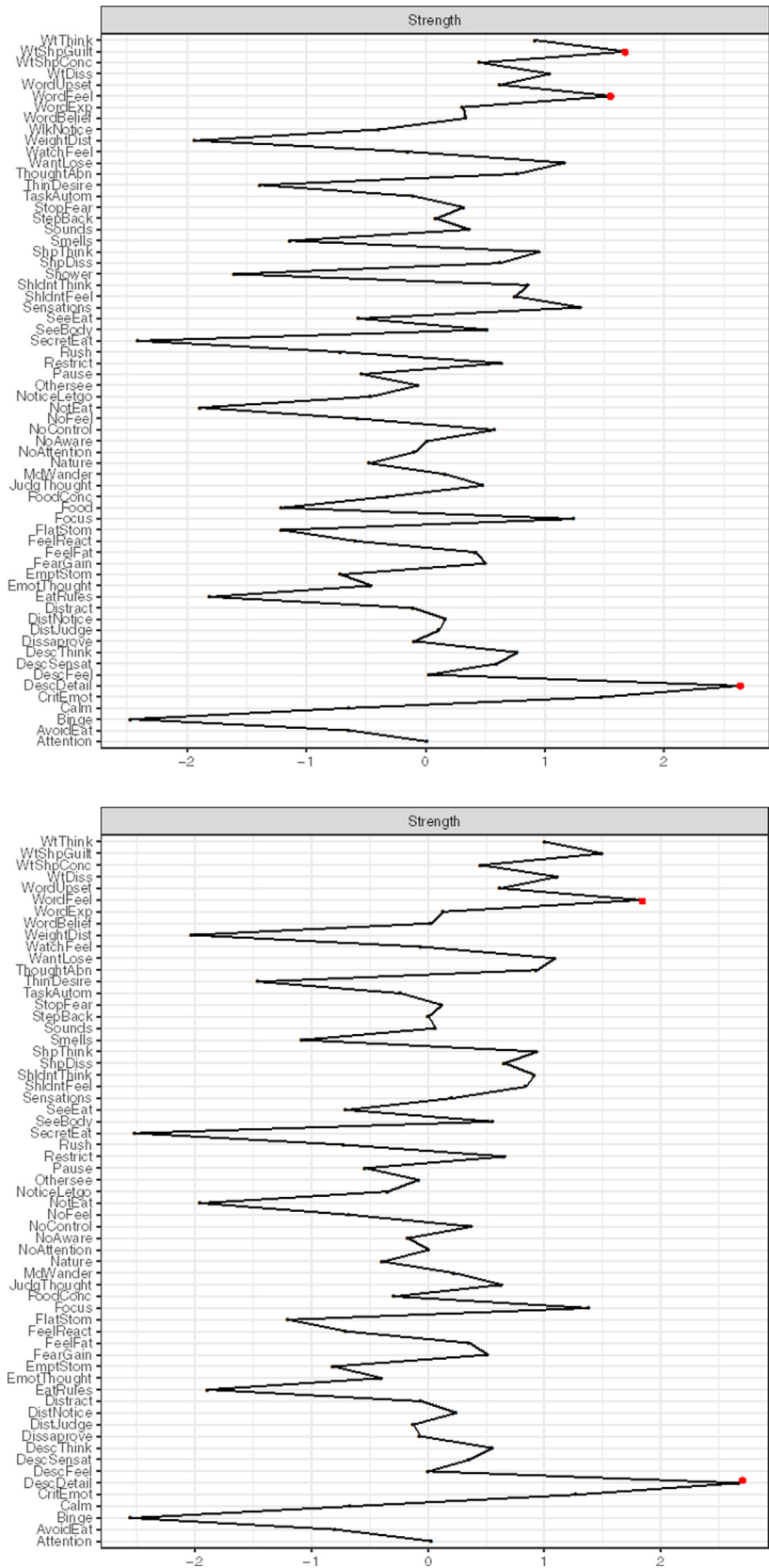


FIGURE 2 Network strength plot for the mindfulness and eating disorder (ED) symptom network. The first plot represents a network of all items, whereas the second plot represents a network of all items except for Food, WkNotice, and Shower.

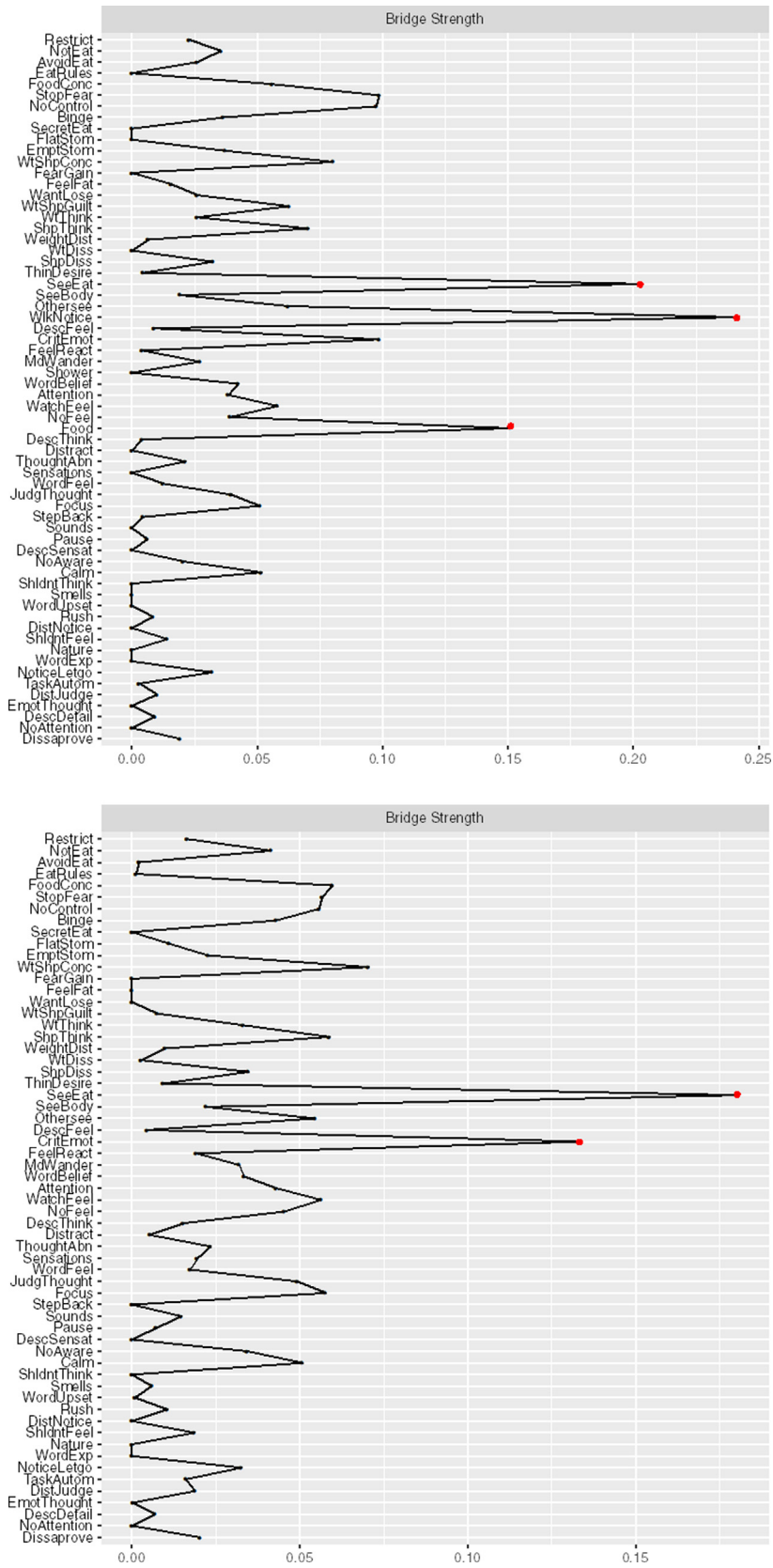


FIGURE 3 Bridge strength plot for mindfulness and eating disorder (ED) symptoms. The first plot represents a network of all items, whereas the second plot represents a network of all items except for Food, WlkNotice, and Shower.

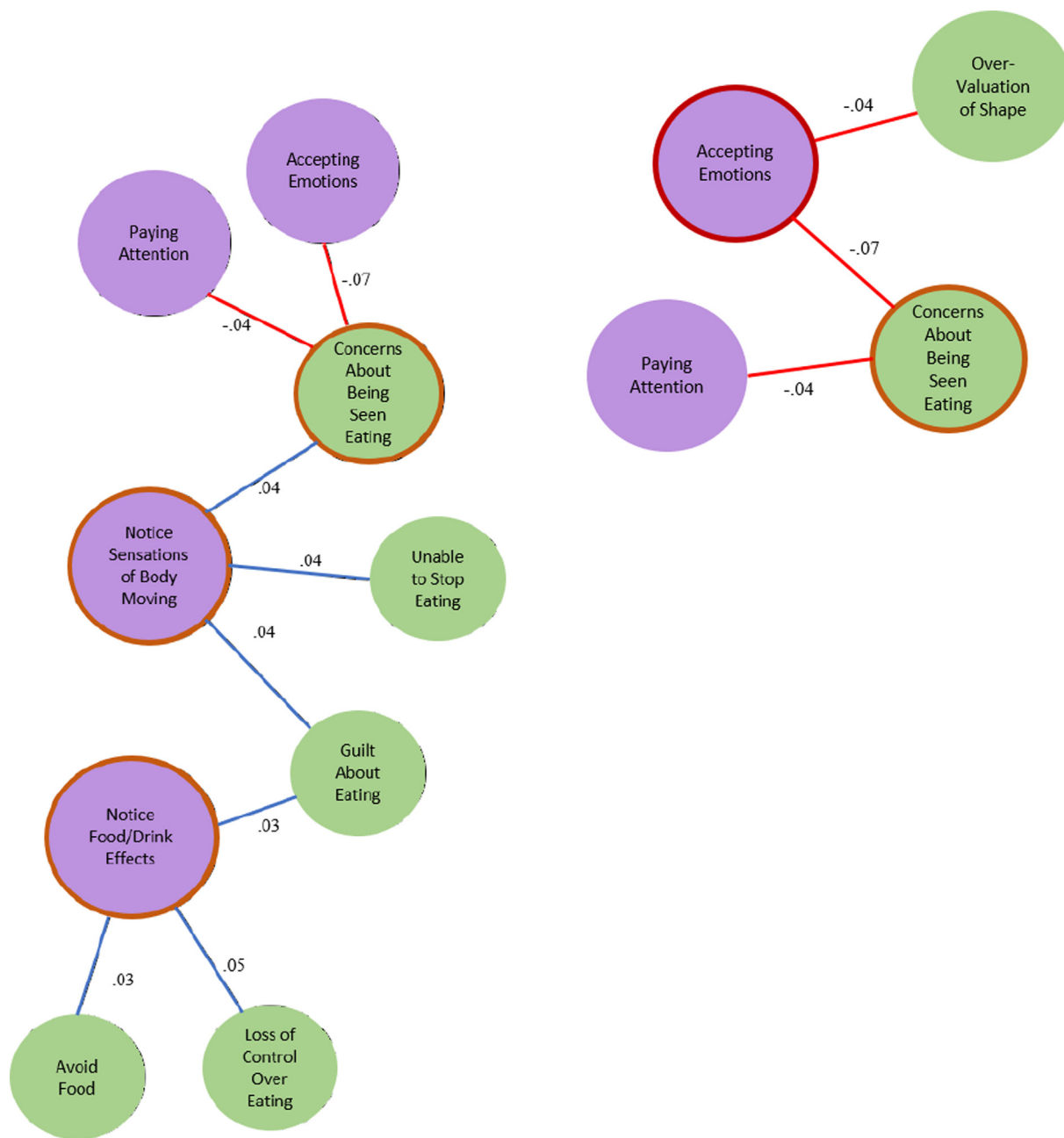


FIGURE 4 Bridge pathways between mindfulness and ED network. The first network represent a network of all items, whereas the second network represents a network of all items except for Food, WikNotice, and Shower. Purple represents mindfulness items, and green represents ED items. Blue lines indicate positive correlations; Red lines indicate negative correlations; Nodes highlighted in red = nodes with highest bridge centrality.

$r = -.07$) and one's shape influencing how one thinks about oneself (*ShpThink*, part $r = -.04$). See Figure 3 for the bridge strength centrality graph, Figure 4 for the visualization of bridge pathways, and Supplemental Figure 2 for the bridge strength difference graph, and Figure 4 for the visualization of bridge pathways.

Network Comparison

The general sample network had higher global strength than the network of the sample with high levels of ED symptoms (General sample = 29.80, ED sample = 20.58). There were no significant differences in network structure between the two samples ($p = .18$).

Discussion

We used network analysis to identify how mindfulness processes were interconnected with ED symptoms. The most central processes/symptoms in the network included the mindfulness process of describing and expressing emotions, and the ED symptom of guilt over eating. Bridge analysis revealed that both body/eating-related mindfulness processes as well as general mindfulness process are relevant to ED symptoms, but in different ways. Higher sensitivity to body sensations and food intake were linked to higher ED symptoms. In contrast, when we re-ran the model without body- and food-related items, higher general mindfulness processes (acceptance of emotions) were linked with lower ED symptoms (social eating anxiety). Of note, the network structure did not differ among individuals with higher ED symptomatology and the general sample.

CORE SYMPTOMS OF THE MINDFULNESS-ED NETWORK

Consistent with the study hypothesis, the most central item in the network was the mindfulness process *describing how one feels in detail*. Additionally, the mindfulness process *expressing how one feels in words* was the third most central process in the network. These findings suggest that mindfulness processes related to describing and expressing emotions may be the most relevant aspects of mindfulness for understanding EDs, and are in line with an extensive body of literature that suggests that difficulty with identifying one's feelings (Nowakowski et al., 2013) and emotion expression (Davies et al., 2011, 2013) are implicated in EDs. These findings are also similar to research by Brown et al. (2020), which found that an emotion-related process (listening for information from the body about one's emotional state) was central to the eating disorder and interoceptive awareness network. Of note, it was interesting that two processes from the describing facet of mindfulness were identified as central symptoms, given that previous eating disorder research has showed that the facets of acting with awareness, nonjudging, and nonreactivity (rather than the describing facet) are most strongly associated with ED symptoms (Sala et al., 2020; Sala et al., 2019). Network analysis thus revealed that specific aspects of the describing facet of mindfulness may be important in understanding the relationship between mindfulness and eating disorder symptoms—a finding that has not been captured by other statistical methods which examined the overall construct of describing.

Consistent with the study hypothesis, *feeling guilty about eating due to shape/weight* was the third most central symptom, further supporting the CBT model of eating disorders, which suggests that overvaluation of weight and shape is core to EDs (Fairburn, 2008; Fairburn et al., 2003). This finding is also consistent with several other network studies that have shown that weight and shape concerns are core to ED networks (DuBois et al., 2017; Forbush et al., 2016; Forrest et al., 2018, 2019; Vanzhula et al., 2019). However, previous networks had shown that other aspects of weight and shape concerns (other than eating-related to guilt) are core to ED networks (DuBois et al., 2017; Forbush et al., 2016; Forrest et al., 2018, 2019; Vanzhula et al., 2019). Guilt related to eating due to weight and shape concerns may be particularly central to the ED-mindfulness network because eating-related guilt may function to mask primary emotions in individuals who are low in mindfulness. For example, for individuals who are low in mindfulness/high in avoidance, guilt related to eating may function as a form of distraction or avoidance from unpleasant primary emotions (e.g., sadness, loneliness, etc.).

PATHWAYS BETWEEN MINDFULNESS PROCESSES AND ED SYMPTOMS

Consistent with the study hypothesis, bridge analysis revealed that two mindfulness bridge processes were positively connected with ED symptoms: *noticing sensations of the body moving when walking* and *noticing how food/drinks affect thoughts, bodily sensations, and emotions*. These findings are in line with the Monitor and Acceptance Theory of mindfulness (Lindsay & Creswell, 2017), research showing that observing is positively correlated with ED psychopathology (Lattimore et al., 2011; Levin et al., 2014; Prowse et al., 2013), emerging research that interoceptive abnormalities contribute to abnormal perceptions of hunger and satiety in EDs (Jacquemot & Park, 2020), and research showing that observing is higher in individuals with EDs than healthy controls (Sala et al., 2019). The findings from this study add to the literature by suggesting that observation of sensations related to eating and the body may explain why observing may not always be helpful in individuals with EDs. These findings raise the possibility that although trait mindfulness is protective to EDs, observing food- and body-related sensations specifically may not always be beneficial for individuals with ED pathology, and may be indicative of a maladaptive hyper-focus on sensations related

to weight and shape. These possibilities should be explored in further research. Alternatively, these two mindfulness processes may have been highly positively correlated with ED symptoms due both measures having a strong overlap on food and body items. Future researchers exploring the associations between trait mindfulness and ED symptoms should consider excluding body- and food-related items in mindfulness scales, or investigating observing of food and bodily sessions separately from observing other sensations.

In particular, the mindfulness process *noticing sensations of the body moving when walking* was connected to EDs through the following pathways: being uncomfortable about others seeing one eat, fear of not being able to resist or stop eating, and feeling guilty about eating due to shape/weight. These findings lead to the hypothesis that hypersensitivity of bodily sensations might be linked with discomfort, fear, and guilt related to eating. The second strongest linked mindfulness process was *noticing how food/drinks affect thoughts, bodily sensations, and emotions*, and it was connected to EDs through the following pathways: experiencing a sense of loss of control over eating, feeling guilty about eating due to shape/weight, and avoiding eating specific foods one likes to influence weight and shape. These findings lead to the hypothesis that a hyperfocus on one's internal experiences while eating may be associated with unhelpful eating-related emotions and thoughts (e.g., guilt about eating, feeling out of control), as well as the avoidance of specific foods (potentially related to avoiding unpleasant emotions). It may be that general mindfulness processes are first needed before body-related mindfulness processes can be applied effectively.

The eating disorder symptom with high bridge centrality in both models with and without body- and food-related items was *concerns about others seeing one eat*. This finding is consistent with several other findings showing that social eating anxiety bridges eating disorders with other forms of psychopathology and processes that impact psychopathology (Forrest et al., 2019; Levinson et al., 2018). Social eating anxiety was linked to mindfulness processes through the following pathways: higher criticizing of oneself for having irrational/inappropriate emotions and lower paying attention to what one is doing. These findings suggest that discomfort with others seeing one eat may be linked with lower present-moment awareness as well as lower emotion awareness/acceptance, perhaps related to a hyperfocus on how one is perceived while eating. The dynamic link between discomfort with others seeing one eat

and deficits in the mindfulness processes of lack of acceptance of emotions and awareness of actions may be a potential link to target in clinical interventions. For example, future research should test if present-moment awareness and nonjudgment of emotions while eating may be mindfulness skills that could be targeted for potentially weakening this link.

Consistent with the study hypothesis, when we reestimated the model without body- and food-related items, *criticizing oneself for having irrational/inappropriate emotions* was the mindfulness item with the strongest bridge centrality. This finding is consistent with a large body of literature that shows that ED symptoms are associated with self-criticism (Duarte et al., 2016; Dunkley & Grilo, 2007; Fennig et al., 2008; Zelkowitz & Cole, 2020). Acceptance of emotions may be particularly protective to ED pathology, as many ED behaviors function to regulate emotions (Haynos & Fruzzetti, 2011). This finding is consistent with research that suggests that the nonjudging/acceptance aspect of mindfulness has particularly strong links with ED pathology (Butryn et al., 2013; Sala et al., 2019, 2020; Sala & Levinson, 2017), and adds to the literature by highlighting that deficits in the acceptance of emotions in particular may be critical in maintaining ED pathology. This item was connected to ED symptoms through the following pathways: higher concerns about others seeing one eat and higher levels of one's shape influencing how one thinks about oneself. The connection between criticizing oneself for having rational or inappropriate emotions and higher concerns about others seeing one eat suggests that nonjudgment of emotions may be particularly critical while eating with others. The connection between criticizing oneself for having rational or inappropriate emotions and levels of one's shape influencing how one thinks about oneself suggests that acceptance of emotions may be most relevant to ED symptoms, as shape and weight concerns are core to ED psychopathology (DuBois et al., 2017; Fairburn, 2008; Fairburn et al., 2003; Forbush et al., 2016; Forrest et al., 2018, 2019; Levinson et al., 2017; Vanzhula et al., 2019).

NETWORK COMPARISONS

Network comparisons revealed that the general sample had higher global strength than the high ED symptoms sample. This finding is inconsistent with several prior ED network studies (DuBois et al., 2017; Liebman et al., 2020; Vanzhula et al., 2019), but consistent with another ED network research study (Forrest et al., 2019). This finding could suggest that mindfulness and ED

symptoms may be more strongly related in a general undergraduate sample than a clinical sample. However, an alternative potential explanation for this finding is that the sample with high ED symptoms was smaller, which could have pulled more edge weights to zero. Most important, the structures were similar in both groups, suggesting that nodes in this network interact similarly regardless of ED severity.

CLINICAL IMPLICATIONS

Taken together, the current findings suggest that future research should examine whether mindfulness processes related to describing, expressing, and accepting emotions may be important aspects to target in mindfulness-based interventions for EDs. Current mindfulness-based interventions for EDs use mindfulness practice to build awareness and acceptance of emotions (Godfrey et al., 2015). Furthermore, other third-wave treatments also have strong components focused on describing, expressing, and accepting emotions. For example, Dialectical Behavior Therapy (DBT) for EDs (Telch et al., 2001) includes a strong focus on emotional eating, emotion regulation, and distress tolerance, and Acceptance and Commitment Therapy (ACT) for EDs (Juarascio et al., 2013) has a strong emphasis on emotion acceptance. Future research should test whether third-wave interventions for EDs may potentially be improved by having a stronger emphasis on the labeling, expressing, and accepting emotions and the reduction of emotion avoidance.

Findings also suggest that the describing facet of mindfulness may be a potentially more important to target in ED treatments than previous research had suggested. Mindfulness-Based Relapsed Prevention (MBRP; Bowen et al., 2010), Mindfulness-Based Stress Reduction (MBSR; Kabat-Zinn, 2003), and Mindfulness-Based Cognitive Therapy (MBCT; Segal & Teasdale, 2002) are treatments that have a strong focus on describing via the inquiry process (e.g., asking participants to describe in words the sensations, emotions, and thoughts that came up during a meditation practice), and thus should be examined as interventions for EDs.

Given that a hyper-focus on food- and body-related sensations appears to maintain ED symptoms, future research should explore if teaching all mindfulness-based skills in mindfulness-based interventions results in better outcomes. Consistent with the Monitor and Acceptance Theory of mindfulness (Lindsay & Creswell, 2017), teaching only observing one's sensation while eating or noticing one's body alone without teaching other

mindfulness skills may be harmful. Future research should examine if mindfulness-based interventions for EDs might also focus on helping individuals notice and accept certain food- and body-related sensations without becoming overwhelmed by them, particularly when eating. Mindfulness-based interventions for EDs during eating might also focus on redirecting attention to other aspects of the present moment as needed (e.g., bringing curiosity to the sight of food and how it tastes, rather than hyper-focusing on sensations of fullness).

Finally, findings suggest that interventions may need to more precisely focus on eating around others and related nonacceptance of emotions. Imaginal or in-vivo exposure exercises and/or intentional practice of mindfulness skills when eating around others may be a potential avenue to help individuals cope with discomfort with eating around others. Future research should explore these possibilities.

STRENGTHS AND LIMITATIONS

The present study had numerous strengths, including the large sample and examination of network and bridge stability. There were also several limitations. First, this study was conducted in an undergraduate, primarily female and Caucasian sample. It is unclear if these results would replicate in different samples. However, the current research as well as previous eating disorder network research has shown that eating disorder network structures do not differ among clinical vs. nonclinical samples (Forrest et al., 2019), which is consistent with dimensional models of EDs (Wildes & Marcus, 2013). Furthermore, ED network structures do not appear to differ between genders (Perko et al., 2019) and age groups (Brown et al., 2020; Calugi et al., 2020). Second, bridge stability for the second model was only acceptable. Third, these models are limited by the measures that we used. It is possible that different results would have emerged with different measures of mindfulness and/or eating disorder symptoms. Relatedly, because we had a higher number of mindfulness items than ED items, it is likely that centrality results favor mindfulness processes. Fourth, the network was cross-sectional, and we can therefore not make any directional claims.

CONCLUSIONS

The present study used network analysis to characterize the associations between mindfulness processes and ED symptoms. Results suggest that emotion labeling and expression as well as guilt

about eating due to shape/weight are central to the ED-mindfulness network. Processes related to noticing the body and how food affects internal experiences appear to maintain a positive association between mindfulness processes and ED symptoms. In contrast, emotion acceptance and social eating anxiety are two factors that maintain negative associations between trait mindfulness and ED symptoms. Findings suggest that future research should explore if mindfulness-based interventions for EDs could potentially be improved by (a) enhancing emotion labeling and expression; (b) reducing hyper-awareness to food-and body-related sensations; and (c) enhancing emotion acceptance, particularly when eating.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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