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Personalizing Eating Disorder Treatment Using Idiographic Models: An Open Series Trial

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Objective: Treatments for adults with eating disorders (EDs) only work in about 50% of individuals, and for some diagnoses (e.g., anorexia nervosa; atypical anorexia nervosa), there are no existing evidence-based treatments. Part of the reason that treatments may only work in a subset of individuals is because of the high heterogeneity present in the EDs, even within diagnoses. Manualized treatments delivered in a standard format may not always address the most relevant symptoms for a specific individual. ***Method:*** The current open series trial recruited participants with transdiagnostic ED diagnoses (N = 79) to investigate the feasibility, acceptability, and initial clinical efficacy of a 10-session network-informed personalized treatment for eating disorders. This treatment uses idiographic (i.e., one-person) network models of ecological momentary assessment symptom data to match participants to evidence-based modules of treatment. ***Results:*** We found that network-informed personalized treatment was highly feasible with low dropout rates, was rated as highly acceptable, and had strong initial clinical efficacy. ED severity decreased from pre- to posttreatment and at 1-year follow-up with a large effect size. ED cognitions, behaviors, clinical impairment, worry, and depression also decreased from pre- to posttreatment. ***Conclusions:*** These data suggest that network-informed personalized treatment has high acceptability and feasibility and can decrease ED and related pathology, possibly serving as a feasible alternative to existing treatments. Future randomized controlled trials comparing network-informed personalized treatment for ED to existing gold standard treatments are needed. Additionally, more research is needed on this type of personalized treatment both in the EDs, as well as in additional forms of psychopathology, such as depression.

What is the public health significance of this article?
This study shows that network-informed personalized treatment for eating disorders is feasible, acceptable, and decreases eating disorder symptom severity and depression and worry. This type of personalized treatment may be a feasible alternative to existing evidence-based treatments for eating disorders.

Keywords: eating disorders, personalized treatment, network theory, CBT

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Eating disorders (EDs) are serious mental illnesses, with the second-highest mortality rate of any psychiatric disorder, after opioid use disorder (Chesney et al., 2014). Despite the high death toll, impairment, and societal costs, there are no evidence-based treatments for adults with anorexia nervosa (AN) and other specified feeding and eating disorder (OSFED)–Atypical AN, and evidence-based treatments for bulimia nervosa (BN) and binge eating disorder (BED) are only effective in ~50% of individuals (Atwood & Friedman, 2020;

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There are currently no published or in press articles from this data set. The idiographic networks that were used to personalize treatment have been partially published in Levinson et al., 2021.

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This trial was preregistered at https://clinicaltrials.gov NCT04183894.

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Murray et al., 2019). This low response rate is due, in part, to the fact that EDs are heterogeneous conditions, even within the same diagnosis (Beltz et al., 2018; Forbush et al., 2017; Levinson et al., 2021; Mallorquí-Bagué et al., 2018).

These diverse symptom presentations (i.e., varied comorbid conditions, different ED symptom patterns, individual personality characteristics) are not adequately addressed in current "one-size-fits-all" evidence-based psychotherapies. Existing evidence-based treatments are developed based on averages and delivered in a standardized order. As such, clinicians often need to modify treatment for it to be applicable to individual patients, relying on "guesswork" to determine which targets should be addressed in treatment (Moskowitz & Young, 2006; Spengler et al., 2009). To make such modifications, clinicians are left to use clinician judgment to decide which maintaining symptoms (i.e., mechanisms) to target in treatment, despite a large body of research showing clinician judgment is biased (Spengler et al., 2009). Clinicians need a personalized evidence-based treatment that uses data-based targeted treatment plans, which will ultimately prevent harmful ED behaviors and promote long-term recovery.

In response to this need, researchers and granting institutes have called for the development of evidence-based precision interventions (Purgato et al., 2021; Wright & Woods, 2020). Proponents of the precision medicine initiative cite research showing large variability in symptoms of psychiatric illness between persons and that tailored treatment produces longer lasting and more effective outcomes (Fernandes et al., 2017; Lenze et al., 2021; Oslin et al., 2021). To date, precision interventions that exist focus heavily on subgroups of individuals matched to specific treatments known to be more effective for certain personal patient characteristics (Lenze et al., 2021). This type of research is a significant step toward evidence-based precision treatments. However, a truly personalized-to-the-individual treatment would not focus solely on subgroups, but on personalization based on the one individual presenting for treatment. This type of personalization has been difficult to develop because such idiographic methodologies had not been developed for and applied to psychopathology until recently (Brandt & Williams, 2022; Epskamp et al., 2018, p. 2018; Kim et al., 2007). With the advent of network science, novel idiographic methodologies, and ecological momentary assessment (EMA) researchers are now able to develop personalized treatments without heavy clinician or patient burden. Ultimately, the implementation of this type of methodology could serve as a roadmap for additional development and utilization of evidence-based personalized treatment for a range of psychiatric illnesses, in addition to EDs.

This type of personalization method is based heavily on theory. Specifically, network theory of psychopathology proposes that symptoms of psychiatric illness have dynamic interactions that ultimately maintain an active illness state (For more discussion please see: Borsboom & Cramer, 2013). Network analysis is the analytic extension of network theory, which quantifies both central symptoms (symptoms with the most relations to other symptoms in the network often considered "most important" symptoms) and pathways among symptoms (Epskamp et al., 2018). Network analysis, combined with EMA (i.e., multiple daily assessments of symptoms) delivered directly to patients' smartphones, is a methodology that can be used to personalize treatment (see Levinson, Hunt, Cusack, et al., 2022, for a discussion). One of the core tenets of network *theory* is that central "trigger" symptoms should be reasonable intervention targets that produce maximal change in the entire network of psychopathology (Borsboom & Cramer, 2013). As such, theory suggests that intervention on central symptom targets (or mechanisms) that are highly related to the most other symptoms in the network should maximize the impact of the intervention and improve treatment outcomes (Borsboom & Cramer, 2013; McNally, 2016). This theoretical proposition, one of the core tenets of network theory, is supported by empirical evidence across several fields, with research from our team and others showing that central symptoms are predictive of clinical and treatment outcomes in obsessive compulsive disorder, social anxiety disorder, as well as the EDs (Elliott et al., 2019; Levinson et al., 2020, 2021; Olatunji et al., 2018; Rodebaugh et al., 2018). Most importantly, recent developments in network analysis provide a statistical approach to identify specific core "trigger" symptoms and symptom pathways for each individual and how these symptoms differ from the average (i.e., idiographic network analysis; Epskamp & Fried, 2018). In other words, we can build idiographic network models for each person and use these data to identify central symptoms to then decide which symptoms should be targeted in a "network-informed personalized treatment."

To date, only one small trial has applied idiographic network analyses to treatment, finding that data-based treatment outperformed treatment based on clinician judgment when applied to mood and anxiety disorders (Fisher et al., 2019). However, this method has not yet been applied to the EDs. EDs represent the ideal disorder to pilot the feasibility, acceptability, and initial clinical efficacy of such a methodology for personalizing treatment, given the high heterogeneity present and lack of evidence-based treatments (Beltz et al., 2018; Forbush et al., 2017; Levinson et al., 2021; Murray et al., 2019; Riesco et al., 2018). For example, recent research using idiographic network analysis has found that while ~50% of individuals with EDs and those at risk for EDs endorse central symptoms consistent with overvaluation of weight and shape, about 50% do not. Instead, 50% of individuals endorse central symptoms consistent with targets such as shame, worry, and additional nontraditional cognitive–affective mechanisms (Levinson et al., 2019, 2021; Levinson, Hunt, Christian, et al., 2022). Network-informed personalized treatment for EDs can address such heterogeneity by tailoring interventions to individual therapy targets and then matching these targets to existing or adapted evidence-based treatment modules.

As such, in the present study, we sought to pilot network-informed personalized treatment for eating disorders. The present study used an open series trial design, in alignment with the National Institute of Health stage model of treatment building, which recommends strategic, stepped trials to guide efficacy evaluation (Onken et al., 2014).We created this treatment by collecting EMA data from patients ($N = 79$) with EDs, modeling idiographic networks of each persons' symptoms, and matching the two most central symptoms to existing or modified treatment modules from cognitive behavioral therapy (CBT) and third-wave evidence-based treatments (see more details on the treatment in *treatment procedure* and for more details on each idiographic network applied to treatment, please see Levinson et al., 2021). We hypothesized that network-informed personalized treatment for eating disorders would be feasible, with high retention. We also hypothesized that the treatment would be rated as acceptable by participants. In terms of clinical change, our primary outcome was overall ED symptom

severity, and our secondary outcomes were ED behaviors (restriction, binge eating, excessive exercise, purging), anxiety, worry, and depression. We hypothesized that overall, ED symptom severity, restriction, binge eating, excessive exercise, purging (all measured by the Eating Disorder Examination Questionnaire [EDE-Q]; Fairburn & Beglin, 1994), anxiety, depression, and worry would decrease with moderate effect sizes. We also tested the same outcomes with a second measure (Eating Pathology Symptom Inventory [EPSI]; Forbush et al., 2013) to test if our results replicated beyond a single ED measure, especially given that many of the behavioral items on the EDE-Q are one item. We hypothesized that we would observe similar results regardless of outcome measure used. We also tested these analyses in both Intent to Treat (ITT) and As-Treated (see Supplemental Material) samples. Finally, in post hoc analyses, we tested if any of our outcomes differed by diagnosis.

Method

Data Transparency and Openness

This trial was preregistered at https://clinicaltrials.gov. All analyses code and data are available via reasonable request of the first author and data will be posted on Git-hub.

Participants

Participants were 79 individuals with a current ED diagnosis, with 75 entering treatment (see Figure 1). Exclusion criteria were active suicidal intent, mania, or psychosis. For demographic and diagnostic information, please see Table 1. Participants were recruited from across the United States using advertisements and referrals from ED clinics. All participants provided informed consent and all procedures were approved by the institutional review board.

Diagnostic Measures

The Structured Clinical Interview for DSM-5

The Structured Clinical Interview for *Diagnostic and Statistical Manual, fifth edition* (SCID-5-RV; First et al., 2015) is a semistructured interview for making standardized *Diagnostic and Statistical Manual, fifth edition* (*DSM-5*) diagnoses. This study used the ED modules to determine ED diagnoses.

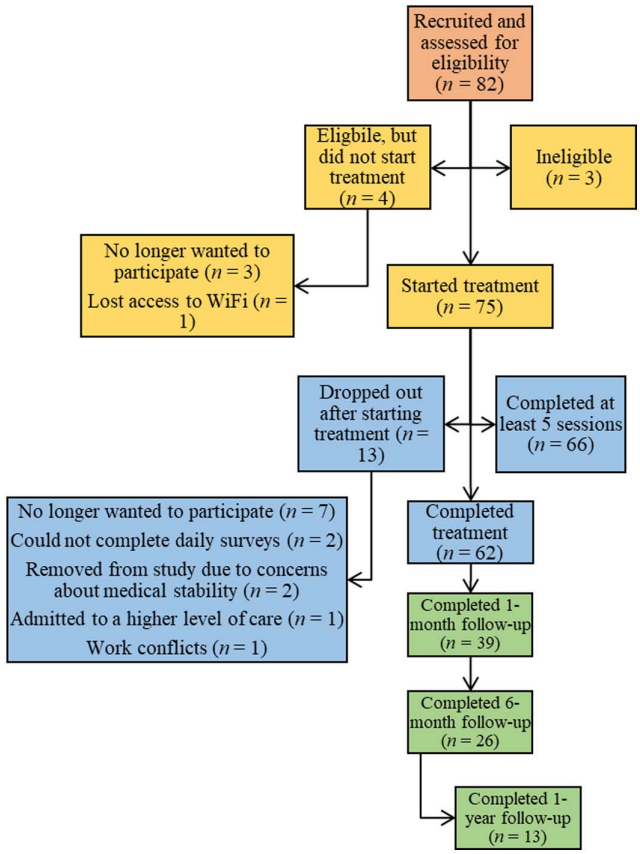
The Eating Disorder Diagnostic Interview

The Eating Disorder Diagnostic Interview (EDDI; Stice et al., 2000) is a semistructured interview for making ED diagnoses. The measure assesses frequency of ED behaviors and severity of ED cognitions. EDDI diagnoses have shown good interrater agreement and test–retest reliability based on the full interview for *DSM-5* ED diagnoses (Krabbenborg et al., 2012; Stice et al., 2000). This measure was used as a supplement to the SCID-5-RV to confirm diagnoses.

The Mini-International Neuropsychiatric Interview 5.0

The Mini-International Neuropsychiatric Interview 5.0 (Sheehan et al., 1998) is a semistructured interview to assess for *DSM-5* diagnoses, with excellent interrater and test–retest reliability, and good convergent validity (Sheehan et al., 1998). We used the suicidality, mania/hypomania, and psychosis modules to exclude participants with active suicidal intent, active mania, or psychosis.

Figure 1
Participant Flowchart



Note. See the online article for the color version of this figure.

Acceptability and Outcome Measures

Adapted Client Satisfaction Questionnaire

The Client Satisfaction Questionnaire (CSQ; Attkisson & Zwick, 1982) is an eight-item self-report measure aimed at measuring participant satisfaction with treatment. The CSQ has demonstrated strong psychometric properties (Attkisson & Greenfield, 2004). In the present study, the researchers adapted the CSQ to include one additional question to measure satisfaction with online-based treatment (e.g., If you received part or all of your treatment online: how satisfied were you with the online treatment program you received?), as treatment moved online in response to the COVID-19 pandemic.

EDE-Q

The EDE-Q Version 6.0 (Fairburn & Beglin, 1994) is a 28-item self-report questionnaire adapted from Eating Disorder Examination Interview (Fairburn & Cooper, 1993) that is designed to assess ED behaviors and cognitions over the last 28 days. The EDE-Q has four subscales: Eating Concern (e.g., Have you had a definite fear

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Table 1
Diagnostic and Demographic Information

$N = 79$	Diagnostic and demographic info	n (%)	M (SD)	Range
Age			31.69 (10.60)	18–64
Gender	Male	5 (6.3)		
	Female	67 (84.8)		
	Gender variant/ nonconforming	3 (3.8)		
	Not reported	4 (5.1)		
Ethnicity	White	63 (79.7)		
	Asian or Pacific Islander	4 (5.1)		
	Hispanic	2 (2.5)		
	Black	1 (1.3)		
	Biracial/multiracial	1 (1.3)		
	Not reported	8 (10.1)		
Broad Dx	AN	16 (20.2)		
	BN	15 (19.0)		
	BED	15 (22.8)		
	OSFED	45 (38.0)		
Specific Dx	AN-R	11 (13.9)		
	AN-BP	5 (6.3)		
	BN	15 (19.0)		
	BED	18 (22.8)		
	Atypical AN	18 (22.8)		
	Atypical BN	6 (7.6)		
	Atypical BED	2 (2.5)		
	Purging disorder	1 (1.3)		
	USFED	3 (3.8)		

Note. Dx = diagnosis; AN = anorexia nervosa; R = restricting subtype; BP = binge/purge subtype; BN = bulimia nervosa; BED = binge eating disorder; OSFED = other specified feeding or eating disorder; USFED = unspecified feeding or eating disorder.

of losing control over eating?), Shape Concern; for example, Has your shape influenced how you think about (judge) yourself as a person?, Weight Concern; for example, Has your weight influenced how you think about (judge) yourself as a person?, and Restraint (e.g., Have you been deliberately trying to limit the amount of food you eat to influence your shape or weight?). The global score of the EDE-Q can be calculated by summing the subscale totals and dividing by the number of subscales to measure overall eating symptomatology/severity and has been shown to have the best psychometric properties. As such, we used the global score as a measure of ED severity and as our primary outcome measure. The EDE-Q has demonstrated excellent test–retest reliability and internal consistency (Luce & Crowther, 1999), and acceptable to good criterion validity and concurrent validity (Mond et al., 2004). We used the EDE-Q frequency items (restriction, binge eating, purging) to measure ED behaviors. Internal consistencies for the EDE-Q global score at all time points were excellent (αs = .92–.95).

The Clinical Impairment Assessment

The Clinical Impairment Assessment (CIA; Bohn & Fairburn, 2008) is a 16-item self-report measure designed for use in conjunction with the EDE-Q to measure psychological and social impairment related to an ED. Items ask about ED impairment on mood, cognitive functioning, interpersonal functioning, and work performance (e.g., over the past 28 days, to what extent have your eating habits, exercising, or feelings about your eating, shape or weight made you upset). We used the global score of the CIA, calculated by summing the item totals as a measure of clinical impairment. The CIA has demonstrated high internal consistency and test–retest reliability, and good construct and criterion validity (Vannucci et al., 2012). Internal consistencies for the CIA at all time points were excellent (αs = .95–.98)

EPSI

The EPSI (Forbush et al., 2013) is a 45-item measure used to assess ED symptoms. The EPSI has eight scales to assess different aspects of eating pathology: Body Dissatisfaction, Binge Eating, Cognitive Restraint, Excessive Exercise, Restricting, Purging, Muscle Building, and Negative Attitudes Toward Obesity. The present study did not use the Muscle Building and Negative Attitudes Towards Obesity subscales as we were only interested in ED specific behaviors and cognitions. The EPSI has been shown to have excellent convergent and discriminant validity, as well as excellent test–retest reliability ($r = .73$; Forbush et al., 2013). Internal consistencies at all time points for the EPSI Body Dissatisfaction subscale were excellent (αs = .90–.93), Binge Eating subscale were excellent (αs = .93–.95), Cognitive Restraint subscale were acceptable to good (αs = .68–.78), Excessive Exercise subscale were very good to excellent (αs = .88–.91), and Restricting subscale were very good to excellent (αs = .88–.91), Purging subscale were acceptable to good (αs = .68–.79). We used this measure in addition to the EDE-Q because it provides dimensional indices of specific symptom behaviors, as well as a cognitive restraint and body dissatisfaction subscale, which are not included in the EDE-Q. We also sought to test if our outcome results generalized across two common ED symptom assessments.

The Penn State Worry Questionnaire

The Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990) is a 16-item self-report questionnaire that measures worry. The PSWQ has been demonstrated to be valid and reliable in clinical and nonclinical samples (Meyer et al., 1990) and is considered to be a gold standard measure of worry. Internal consistencies for the PSWQ were acceptable to good (αs = .75–.82).

The Anxiety Sensitivity Index

The Anxiety Sensitivity Index (ASI-3; Taylor et al., 2007) is an 18-item self-report measure that assesses sensitivity to anxiety. The ASI-3 has three subscales: Physical Concerns (e.g., It scares me when my heart beats rapidly), Cognitive Concerns, (e.g., When my thoughts seem to speed up, I worry that I might be going crazy), and Social Concerns (e.g., I worry that other people will notice my anxiety). In the present study, the total ASI-3 score was used as a measure of overall anxiety sensitivity. The ASI-3 has demonstrated good psychometric properties, including convergent discriminant, and factorial validity (Taylor et al., 2007). Internal consistencies for the ASI-3 were excellent (αs = .93–.96).

The Beck Depression Inventory-2

The Beck Depression Inventory-2 (BDI-2; Beck et al., 1996) is a 21-item self-report measures that assesses depression. The BDI-2 has shown strong psychometric properties among both clinical and nonclinical samples (Beck et al., 1996; Steer et al., 1997). Internal consistencies for the BDI-2 were excellent (αs = .90–.92).

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EMA

We used a 56-item EMA measure that sought to encompass all symptoms of EDs, including ED behaviors (e.g., restriction), cognitions (e.g., overvaluation of weight), affect (e.g., shame), as well as co-occurring issues (e.g., anxiety, posttraumatic stress disorder; Levinson et al., 2021). This EMA was used to develop idiographic network models for each patient, more details on these models and the EMA measure can be found in Levinson et al. (2021).

Procedure

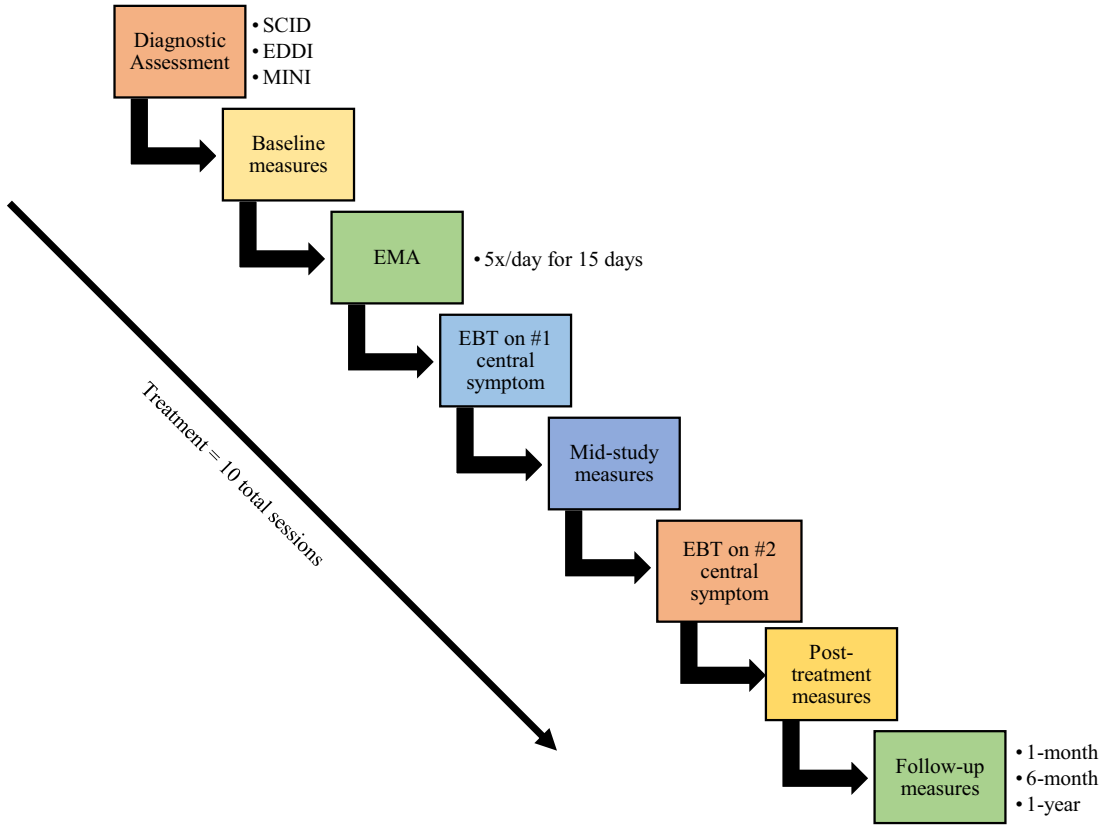
Data Collection Procedures

The network-informed personalized treatment for eating disorders protocol consists of 10 weekly sessions with a therapist (see Figure 2). All therapists were PhD or masters students in clinical or counseling psychology with 0–4 years of treatment experience and were supervised by the senior author. Sessions were conducted either in-person or via Zoom (starting in March 2020; there were no significant differences on outcomes between those in-person or zoom; *p*s > .685). In Session 1, participants completed semistructured interviews (see measures above) to determine eligibility (e.g., at least 18-years old, current ED diagnosis) and exclusion criteria (e.g., current suicidal intent, current manic or hypomanic episode, current psychosis). Upon determining eligibility, participants completed baseline questionnaires (outcome measures). Participants were then trained on the EMA procedure and signed up to receive the EMA five times a day for the next 15 days, which were used to model an idiographic network for each participant. Participants were informed that their EMA data would be used to help personalize treatment. In Session 2, participants completed a semistructured intake, similar to an initial assessment that would be completed in most clinical settings (Fairburn, 2008) with the goal to establish rapport while participants continued to complete EMA measures. Participants were compensated up to 60 dollars for completing pre-, mid-, posttreatment and follow-up assessments. Participants were not specifically reimbursed for participation in EMA. However, participants were informed that completion of the EMA would inform their personalized treatment, which served as motivation to complete the surveys.

Treatment Procedures: Network-Informed Personalized Treatment for Eating Disorders

In Session 3, the participant was provided with psychoeducation on network theory, as has been done prior (Meier et al., 2022), as

Figure 2
Study Procedure



Note. SCID = Structured Clinical Interview for *Diagnostic and Statistical Manual, fifth edition*; EDDI = Eating Disorder Diagnostic Inventory; MINI = Mini-International Neuropsychiatric Interview; EMA = ecological momentary assessment; EBT = evidence-based treatment. See the online article for the color version of this figure.

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well as psychoeducation on how EDs differ based on the individual, why we personalize ED treatment, and how treatment targets would be selected via their EMA measures and matched to evidence-based treatment. Upon completion of the EMA (which was finished before Session 3), the participants' networks were modeled, and the top two treatment targets, selected via their top two central symptoms, were matched to existing modules of evidence-based treatments (see Table 2 for a full list of targets assessed and matched treatments). Matched treatments were selected a-priori from a review of the literature to determine what evidence-based treatments existed for each symptom assessed and translated into EMA items. If a symptom did not have an existing evidence-based treatment specifically for EDs, we adapted existing treatments or, in some cases, developed novel modules based on CBT theory. For more

Table 2

Mechanisms (Most Central Symptoms) Assessed via EMA With Matched Evidence-Based Treatment Modules and Number of Participants Who Were Assigned Each Module

Type of symptom	Construct	Corresponding evidence-based treatment module	*n*
Cognitions	Drive for thinness	CBT—self-monitoring, thought challenging, core beliefs, behavioral experiments	12
	Body dissatisfaction	CBT—thought challenging Mirror exposure	10
	Fear of weight gain	Imaginal exposure	8
	Worry	Mindfulness for worry	8
	Overvaluation of weight/shape	CBT—self-monitoring, thought challenging ACT—values and goal setting	5
	Fear of rejection	Social exposure	5
	Social appearance anxiety	Social exposure	5
	Self-criticism	Mindful self-compassion	5
	Feeling ineffective	CBT—self-monitoring, thought challenging, core beliefs, behavioral experiments	5
	Fear of losing control	DBT—mindfulness	4
	Concern over mistakes perfectionism	CBT perfectionism modules	3
	Obsessions	ERP	3
	Cognitive restraint	Regular eating	3
	Intolerance of uncertainty	CBT—psychoeducation Exposure to sit with uncertainty	2
	Rumination	CBT for rumination	2
	Repetitive thoughts about food	CBT for rumination	2
	Meal rumination	CBT for rumination	2
	High standards	CBT perfectionism modules	1
	Feeling fat	Exposure	1
Behaviors	Eating rules	CBT—adjusting rules and assumptions, behavioral experiments	3
	Body checking	ERP	3
	Excessive exercise	CBT—self-monitoring, thought challenging	2
	Difficulty eating in public	Food exposure	2
	Food avoidance	Food exposure	2
	Objective binge eating	Regular eating	1
Affect	Shame	DBT—emotion regulation; shame/guilt modules	8
	Guilt	DBT—emotion regulation; shame/guilt modules	5
	Emotional avoidance	DBT—emotion regulation; what emotions do for you Emotion exposures	3
	Anxiety about eating	Food exposure	3
	Emotions as overwhelming	DBT—emotion regulation; what emotions do for you, myths about emotions, ways to describe emotions, check the facts, opposite action	1
Physiological symptoms	Feared concerns about eating	Interoceptive exposure	3
	Interoceptive awareness	Interoceptive exposure	2
	Difficulty relaxing	CBT—self-monitoring Relaxation training	1
	Hunger anxiety	Mindful eating	1
Comorbid conditions	Generalized anxiety disorder	Mindfulness	4
	Depressive symptoms	Behavioral activation	3
	Sleep difficulties	CBT-I	2
	Social interaction anxiety	Social exposure	2
	Social appearance anxiety	Social exposure	2
	Posttraumatic stress disorder	Prolonged exposure	1
	Impulsivity	DBT—distress tolerance; STOP skill, pros and cons, TIP skills	1

Note. CBT = cognitive behavioral therapy; ACT = acceptance and commitment therapy; DBT = dialectical behavior therapy; ERP = exposure and response prevention; CBT-I = cognitive behavioral therapy for insomnia; EMA = ecological momentary assessment. Each participant was assigned two modules corresponding to their top two central symptoms. Some participants did not complete both modules due to dropout.

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information on the modeling technique and our treatment module selection, please see Levinson et al. (2021), which shows idiographic networks for these participants and discussed treatment development and matching.

In Session 4, the therapist showed the participant their network and discussed the most important symptoms identified via their idiographic model. The patient and therapist discussed how their model fit with the participant's perception and conceptualization of their symptoms. Starting in Session 4, the therapist began the first session of personalized treatment, starting the first evidence-based module that was matched to one of the participant's most central symptoms. Sessions 5–6 consisted of completion of the first module of matched treatment. At mid-treatment, participants recompleted outcome measures, except for the CIA. Sessions 7–9 consisted of completion of the second module of matched, personalized treatment. Each treatment session consisted of psychoeducation, learning skills, and homework assignment, based on the specific module assigned. Examples of the modules are presented in the Supplemental Material. There were 24 treatment modules, both consisting of 3–4 sessions each. Treatments were delivered by clinicians in training (MA or PhD students) and supervised by the first author. Most treatment modules were from existing CBT, dialectical behavior therapy, or acceptance and commitment therapy treatments or were adapted based on CBT. There were 58 different combinations of treatment delivered at the modular level.

During Session-10, the therapist and participant reviewed the skills learned throughout the treatment and discussed relapse prevention. Participants also completed posttreatment questionnaires in the last session. Participants completed follow-up questionnaires online at 1-month, 6-month, and 1-year follow-up. We primarily report on pre-, mid-, and posttreatment outcomes because of low current *n*s at follow-ups. We report across 1-year follow-up for our primary outcome: ED symptom severity.

Data Analytic Procedure and Missing Data

Multiple imputation was performed to estimate missing data in R using Multivariate Imputation by Chained Equations Version 3.14.0 (Van Buuren & Groothuis-Oudshoorn, 2011) with five pooled datasets. 35.04% of item-level data were missing, including those in the ITT analyses; with $n = 66$ completers, missing data is 20.92% of item-level data, including follow-ups. We computed repeated-measures analyses of variance (ANOVAs) with time (pre-, mid-, posttreatment, 1-month, 6-month, and 1-year follow-ups) as our primary variable of interest (ED symptom severity). We computed repeated-measures ANOVAs with time (pre-, mid-, posttreatment) on our secondary (ED behaviors, anxiety, depression, worry) outcomes. For ANOVAs, we used η_p^2 as a measure of effect size with ≥.06 defined as medium and ≥.14 defined as large (Richardson, 2011).

Results

Feasibility

Overall, we recruited and screened 82 participants (see Figure 2). Of these 82 participants, 79 were eligible and 75 started treatment. Of these 79, 62 (82.67%) completed all 10 sessions with 66 (88%) completing at least five sessions.

Acceptability of Treatment

Overall, participants reported being mostly-to-very satisfied with the quality and kind of treatment, that they would recommend the treatment to a friend, return to a similar program, and that treatment helped them deal effectively with their problems. Please see Table 3 for means, median, and standard deviations for participant acceptability questions.

Initial Clinical Efficacy

For clinical efficacy analyses (Figures 3–5), we included all participants who entered treatment ($N = 79$) or an ITT sample. We also computed As-Treated ($n = 64$) analyses, which are in the Supplemental Material. We present data from pre- to posttreatment and follow-ups (1-month, 6-month, 1-year) for our primary outcome: ED severity. The remainder of our outcomes we show pre- to mid- to posttreatment, apart from the CIA, which was only collected pre- and posttreatment. Keeping in mind that η^2 of .01 = small effect size, η^2 of .06 is a medium effect size and $\eta^2 > .14$ is a large effect size (Cohen, 1992).

ITT Analyses

ED Severity

ED symptom severity (EDE-Q global: Figure 3) decreased from pre- to posttreatment, as well as from pretreatment to all follow-ups (1-month, 6-month, 1-year) with a large effect size $F(2, 77) = 28.21$, $p < .001$, $\eta^2 = .27$. When these data were analyzed for a sensitivity analysis to include only pre-, mid-, and posttreatment only, the effect remained significant and large $F(2, 77) = 14.43$, $p < .001$, $\eta^2 = .16$. There were no differences between ITT and As-treated analyses for ED symptom severity and effect sizes for both analyses ranged from .16 to .29.

ITT Restriction

Restriction (EDE-Q; Figure 4) decreased from pre- to posttreatment with a large effect size $F(77) = 11.97$, $p < .001$, $\eta^2 = .13$. Restriction (EPSI) decreased from pre- to posttreatment with a medium effect size $F(2, 77) = 4.26$, $p = .016$, $\eta^2 = .05$. There were no differences between ITT and As-Treated analyses for restriction and effect sizes for both analyses ranged from .05 to .17.

ITT Binge Eating

Binge eating (EDE-Q) was not significant ($p = .482$). Binge eating (EPSI; Figure 4) decreased from pre- to posttreatment with a large effect size $F(2, 77) = 8.04$, $p = .005$, $\eta^2 = .07$. ITT analyses binge eating (EDE-Q) was no longer significant, whereas these results were significant in the As-Treated analyses. Effect sizes for significant results ranged from .07 to .16.

ITT Purging

Purging (EDE-Q) was nonsignificant ($p = .230$). Purging (EPSI; Figure 4) decreased from pre- to posttreatment with a medium effect size $F(2, 77) = 4.75$, $p = .010$, $\eta^2 = .06$. There were no differences between ITT and As-Treated, with effect sizes ranging from .06 to .12.

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Table 3
Acceptability Results

Question	Scoring responses	*M* (*SD*)	*Mdn*	Range
How would you rate the quality of treatment you received?	0 = Poor 2 = Fair 4 = Good 6 = Excellent	5.15 (.92)	5	3–6
Did you get the kind of treatment you wanted?	0 = Yes, definitely 2 = Yes, generally 4 = No, not really 6 = No, definitely not	1.70 (1.33)	2	0–5
To what extent has the treatment met your needs?	0 = None of my needs have been met 2 = Only a few of my needs have been met 4 = Most of my needs have been met 6 = Almost all of my needs have been met	3.95 (1.24)	4	1–6
If a friend were in need of similar help, would you recommend this treatment to him or her?	0 = Yes, definitely 2 = Yes, generally 4 = No, not really 6 = No, definitely not	.98 (1.10)	1	0–4
How satisfied are you with the amount of help you have received?	0 = Very satisfied 2 = Mostly satisfied 4 = Indifferent or mildly dissatisfied 6 = Quite dissatisfied	1.58 (1.43)	2	0–6
Has the treatment you received helped you to deal more effectively with your problems?	0 = No, they seemed to make things worse 2 = No, they really didn't help 4 = Yes, they helped somewhat 6 = Yes, they helped a great deal	4.75 (1.07)	5	2–6
In an overall, general sense, how satisfied are you with the treatment you have received?	0 = Quite dissatisfied 2 = Indifferent or mildly dissatisfied 4 = Mostly satisfied 6 = Very satisfied	4.57 (1.43)	5	0–6
If you were to seek help again, would you come back to our program for treatment?	0 = Yes, definitely 2 = Yes, generally 4 = No, not really 6 = No, definitely not	1.32 (1.36)	1	0–6
If you received part or all of your treatment online: how satisfied were you with the online treatment program you received?	0 = Quite dissatisfied 2 = Indifferent or mildly dissatisfied 4 = Mostly satisfied 6 = Very satisfied	4.73 (1.29)	5	0–6

ITT Excessive Exercise

Excessive exercise (EDE-Q) was nonsignificant ($p = .276$). Excessive exercise (EPSI; Figure 4) decreased from pre- to posttreatment but was nonsignificant $F(2, 77) = 2.61$, $p = .076$, $\eta^2 = .03$. There were no differences between ITT and As-Treated, with effect sizes ranging from .03 to .08.

ITT Fasting

Fasting (EDE-Q) decreased but was nonsignificant ($p = .180$, $\eta^2 = .02$). There were no changes between ITT and As-Treated.

ITT Body Dissatisfaction

Body dissatisfaction (Figure 4) decreased from pretreatment to posttreatment with a large effect size $F(2, 77) = 9.91$, $p < .001$, $\eta^2 = .11$. There were no changes between ITT and As-Treated analyses with effect sizes ranging from .11 to .18.

ITT Cognitive Restraint

Cognitive restraint (Figure 4) decreased from pre- to posttreatment with a large effect size $F(2, 77) = 7.03$ $p < .001$, $\eta^2 = .08$. There were no changes between ITT and As-Treated analyses with effect sizes ranging from .08 to .15.

ITT Depression

Depression (Figure 5) decreased from pre- to posttreatment with a large effect size $F(2, 77) = 16.51$, $p < .001$, $\eta^2 = .29$. There were no changes between ITT and As-Treated with effect sizes ranging from .27 to .29.

ITT Anxiety

Total anxiety sensitivity decreased but was nonsignificant ($p = .070$). There were no differences between ITT and As-Treated.

ITT Worry

Worry (Figure 5) decreased from pre- to posttreatment with a large effect size $F(2, 77) = 10.81$, $p < .001$, $\eta^2 = .19$. There were no differences between ITT and As-Treated worry with effect sizes ranging from .15 to .19.

ITT Clinical Impairment

Clinical impairment (Figure 5) was significantly lower at posttreatment than at pretreatment $t(78) = 2.84$, $p = .006$. Clinical

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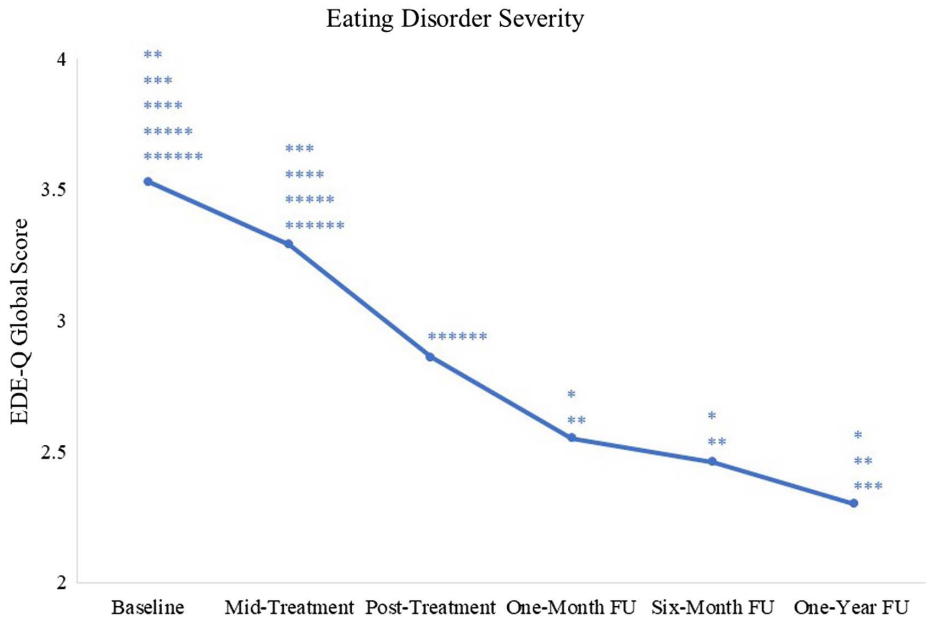
Figure 3
Change in Eating Disorder Severity



Note. EDE-Q = Eating Disorder Examination Questionnaire; FU = follow-up. See the online article for the color version of this figure.
* significantly different than baseline. ** significantly different than mid-treatment. *** significantly different than posttreatment. **** significantly different than 1-month follow-up. ***** significantly different than 6-month follow-up. ****** significantly different than 1-year follow-up. *ps* < .05.

impairment was significantly lower in both ITT and As-Treated analyses.

Post hoc Exploratory Analyses by Diagnosis

We tested for differences between diagnosis (AN [n = 15], BN [n = 15], BED [n = 15], Atypical AN [n = 18], and OSFED [n = 27]). There were no significant time-by-diagnosis differences in change in ED severity (p = .837). There were no significant time-by-diagnosis interactions in any ED behavior (ps > .878) or depression/worry (ps > .935).

Discussion

We conducted an open series trial of network-informed personalized treatment for eating disorders. Participants (N = 79) enrolled in 10 sessions of treatment, which were personalized based on idiographic network models of ED cognitions (e.g., overvaluation of weight), behaviors (e.g., restriction), affect (e.g., hunger anxiety), and co-occurring symptoms (e.g., depression) modeled from EMA data collected across 2 weeks parallel to the first three sessions of treatment. Based on these idiographic models, the top two central symptoms were identified and then matched to corresponding evidence-based treatments (see Levinson et al., 2021, for information on the idiographic models and treatment matching). We found strong support for the feasibility, acceptability, and initial clinical efficacy for network-informed personalized treatment for eating disorders.

Feasibility

Of the 75 eligible individuals who started treatment (79 total were recruited and eligible but four did not elect to start treatment), we had an 88% completion rate through at least five sessions and an 82.67% completion rate for all 10 sessions. These completion rates are extremely high for psychosocial interventions (Cooper & Conklin, 2015; Dixon & Linardon, 2020; Fassino et al., 2009; Stein et al., 2011) and in particular for trials for EDs, which are a notoriously difficult population to recruit and retain in treatment (Agras et al., 2004). For comparison, trials of CBT Enhanced (CBT-E) generally have attrition rates ranging from 20% to 54%, with most trials losing at least 1/3 of participants (Atwood & Friedman, 2020). These rates are also similar to treatment-as-usual adherence rates, which also range around 20%–50%, and are lowest among participants with AN (Allen et al., 2012; Byrne et al., 2011; Wade et al., 2017; Zipfel et al., 2014). Our completion rate was higher than rates that have been documented in the prior literature, and we included 15 (20%) participants with AN, finding no difference in outcomes among diagnoses. The personalized nature of the interventions delivered and relatively short length of the treatment in comparison to other trials in the literature may have contributed to higher than typical adherence. A true comparison of personalized treatment versus treatment-as-usual is needed.

Acceptability

Participants reported that they thought the treatment was of high quality, that they received the type of treatment they wanted, that

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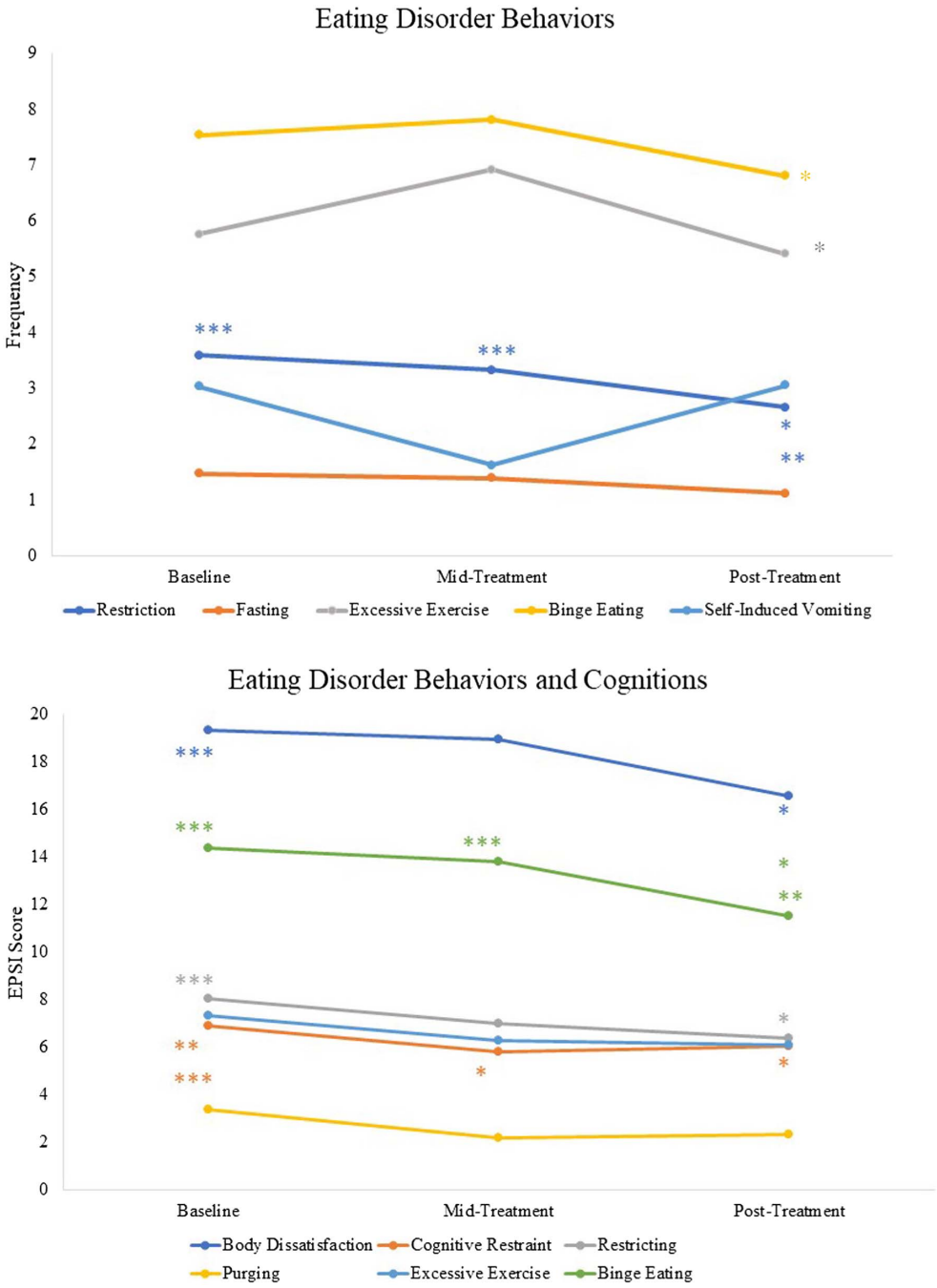
Figure 4

Changes in Eating Disorder Cognitions and Behaviors Measured via the Eating Disorder Examination Questionnaire and the Eating Pathology Symptoms Inventory



Note. EPSI = Eating Pathology Symptom Inventory. See the online article for the color version of this figure. * significantly different than baseline. ** significantly different than mid-treatment. *** significantly different than posttreatment. *p*s < .05.

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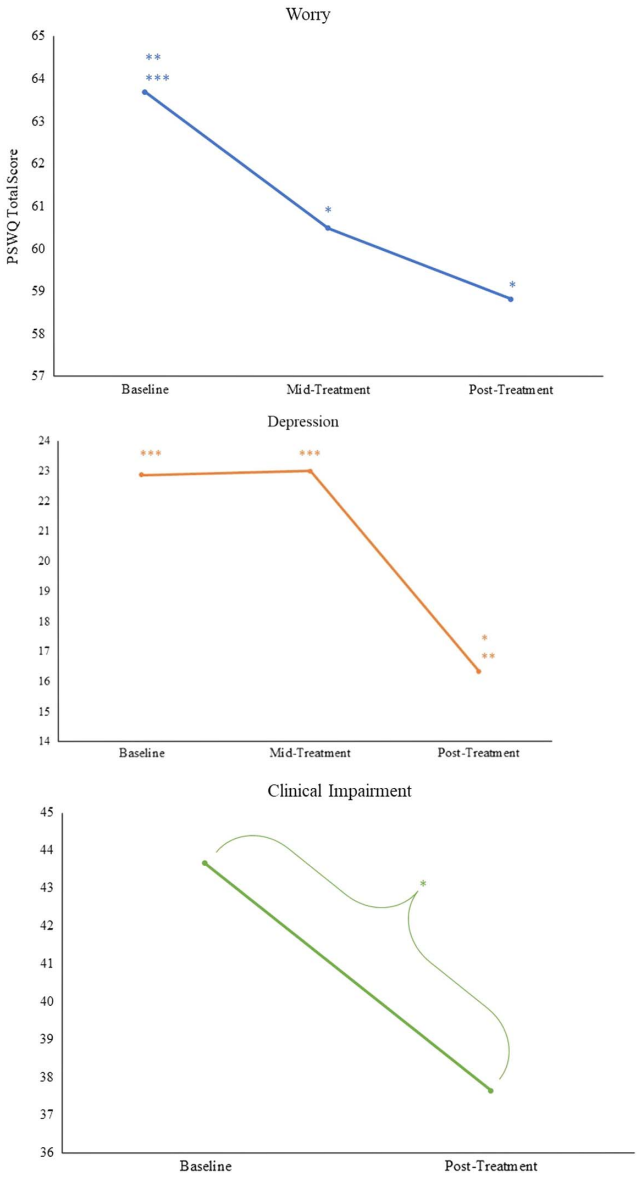
Figure 5

Changes in Worry, Depression, and Clinical Impairment



Note. PSWQ = The Penn State Worry Questionnaire. See the online article for the color version of this figure.
For worry and depression: * significantly different than baseline. ** significantly different than mid-treatment. *** significantly different than posttreatment. For clinical impairment: * significantly difference between baseline and posttreatment. *ps* < .05.

treatment met their needs, that they were satisfied with the treatment, that they would come back to do more treatment, and that they would recommend this type of treatment to a friend. Additionally, participants who received treatment virtually reported satisfaction with the treatment delivered via an online format and there were no differences on outcomes between group. Given the substantial uptick in ED cases (Galmiche et al., 2019; Tavolacci et al., 2021) and the need for treatments that can be disseminated virtually (Andersson et al., 2019; Tavolacci et al., 2021), the fact that participants were satisfied with the virtual format is encouraging. Overall, network-informed personalized treatment for eating disorders were perceived as highly acceptable by participants in its current format.

Initial Clinical Efficacy

ED Symptom Severity, Behaviors, and Cognitions

Our primary outcome was ED symptom severity. We found that ED severity significantly decreased from pre- to posttreatment, as well as at 1-month, 6-months, and 1-year follow-up, with a very large effect size. On average, participants moved from a clinically significant ED to normative levels of ED pathology (Mond et al., 2004). In addition to ED severity, we found that restriction on two ED measures (EDE-Q and EPSI), binge eating on one ED measure, purging, excessive exercise, body dissatisfaction, and cognitive restraint decreased from pre- to posttreatment. Notably, most of these effect sizes were quite large, with all effects either in the medium or large range. We are particularly encouraged by the finding that restriction decreased with a medium to large effect size, as restriction can be an extremely difficult ED behavior to treat (Chapa et al., 2020; Geller et al., 2004).

Co-Occurring Conditions and Impairment

In addition to ED behaviors and cognitions, we found that depression, worry, and clinical impairment decreased from pre- to posttreatment with large effect sizes. Given that 95% of participants with an ED have co-occurring anxiety and/or depression (Pallister & Waller, 2008), the fact that network-informed personalized treatment for eating disorders decreased worry and depression suggests that such a treatment may be transdiagnostic, in that it can target co-occurring ED and affective disorder symptoms. The decrease in depression was specifically notable. On average, participants went from a high moderate level of depression to mild depression over the course of 10 weeks. Future research should test if personalizing treatment with idiographic networks could be helpful for those with primary depressive disorders. Our results suggest that depression may be particularly modifiable via this type of personalized treatment. It may be that participants experienced decreased depression because of the personalized nature of treatment or because we were targeting many transdiagnostic targets (e.g., self-criticism, shame) in treatment, which might otherwise remain untargeted.

Implications for Network-Informed Treatment

Our findings have implications for the field of network science. In particular, network theory proposes that intervention on central symptoms should have maximal input on disruption of the entire network of pathology (Borsboom & Cramer, 2013; Epskamp et al., 2018). Our data do not conclusively show that using idiographic networks can improve treatment, as a randomized controlled trial is needed to convincingly show that network-informed treatment can outperform treatments as usual and/or with other personalization strategies. However, our data do suggest that using idiographic network modeling is an effective strategy for personalizing treatment, such that ED cognitions and behaviors and symptoms of co-occurring conditions decrease. Our results also show that

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such a treatment is feasible and rated as highly acceptable by patients. Of note, we used centrality indices to personalize treatment, of which there has been considerable debate (Bringmann et al., 2019). Our data add to the literature suggesting that central symptoms may be modifiable and improve treatment outcomes (Elliott et al., 2019; Levinson et al., 2020, 2021; Olatunji et al., 2018; Rodebaugh et al., 2018). More data are needed to test this type of personalization; however, this first trial of network-informed personalized treatment for eating disorders is exceedingly promising.

Limitations

There are several limitations of our work. First, this was not a randomized controlled trial, which means we do not know if network-informed personalized treatment will outperform other types of ED treatments. However, we sought to first test an open series trial of such a novel treatment, in alignment with the National Institute of Health stage model of treatment building, which reccomends stategic, stepped trials to guide efficacy evaluation (Onken et al., 2014). This type of strategy recommends first establishing feasibility, acceptability, and initial clinical efficacy, before using resources on fully powered randomized controlled trials. Second, because our sample size was moderate, we could not fully test for differences between diagnostic categories in our post hoc analyses because of low power. Our initial tests show that participants performed similarly, regardless of diagnosis. Given that we included adults with AN and OSFED, for whom there are no effective treatments (Murray et al., 2019), this finding is encouraging, though future research in larger sample sizes is needed. The fact that we found no differences among diagnoses is consistent with our ultimate goal to create a transdiagnostic treatment intervening on personalized mechanisms that regardless of ED diagnosis. Additionally, we had low response rates for our 1-month, 6-month, and 1-year follow-ups for ED symptom severity. However, we chose to present these data because the results were on our primary outcome, (a) the results were extremely promising and (b) due to the fact that many ED trials often do not include any follow-up data even if it exists and it has been recommended to include follow-up data if possible (Kaidesoja et al., 2022). However, in particular, our data on longer term outcomes should be interpreted with caution, given the high amount of missing data, specifically at 1-year follow-up. More research is needed with longer term follow-up in larger samples. Another limitation is that all outcomes were based on self-report questionnaires and that we quantified binge eating and purging in dimensional terms and not by abstinence from the behaviors. Finally, we our sample consisted of primarily White women, with only 20% minority participants. Future research is needed to test this type of treatment in more diverse populations.

Future Research

Future research on network-informed personalized treatment for eating disorders is needed. In particular, current results provide support for a well-powered randomized controlled trial comparing personalized treatment to existing evidence-based treatments. Given that there are no existing evidence-based treatments for AN or OSFED–Atypical AN, it will also be important for future research to test if network-informed personalized treatment for eating disorders outperforms treatment-as-usual. Further, research is needed on each of the specific treatment modules in a larger sample, to test if these modules can be improved or replaced, such that the most effective treatment components are used. We were unable to test that idea here, given the small sample size. Future research is needed to test if an idiographic approach to personalize modules of CBT could improve treatment outcomes, as well as to test if CBT plus additional evidence-based treatments applied in an idiographic manner could improve outcomes. Additionally, we used contemporaneous idiographic networks (i.e., relationships occurring within the same window of measurement; Epskamp et al., 2018) to build our idiographic models and more research is needed to identify the ideal idiographic algorithm. For example, it may be especially useful to test if integration of clinician and patient case conceptualizations into existing algorithms can improve efficacy (Burger et al., 2021). Additionally, more work is needed to identify the ideal dose of treatment and the number of central symptoms that should be matched to treatment modules. More research is needed across the weight spectrum to identify if this treatment works for all presentations of EDs, including those with underweight AN. We could not test this question as our sample of underweight AN was small. Finally, more work is needed to translate these types of personalization into a clinician-friendly software application that can easily deliver treatment recommendations without knowledge of programming or advanced statistical analyses. This type of program could be integrated into community clinical practice and provide a method for guidance to clinicians on what symptoms to focus on and how to treat these symptoms in ED treatment.

Conclusions

We tested a 10-week format of network-informed personalized treatment for eating disorders. We used idiographic network models to personalize treatment to each patient by matching their central symptoms with evidence-based modules corresponding to each symptom. Overall, we found that network-informed personalized treatment was feasible, acceptable and had clinical efficacy, such that ED symptom severity, ED cognitions and behaviors, worry, depression, and clinical impairment all decreased with large effect sizes.

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