







# Breaking the cycle: Identifying key symptom pathways of eating disorders and the influence of childhood maltreatment

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## Abstract

**Background:** Most network analyses on central symptoms in eating disorders (EDs) have been cross-sectional. Longitudinal within-person analyses of therapy processes are scarce. Our aim was to investigate central change processes in therapy in a transdiagnostic sample, considering the influence of childhood maltreatment.

**Method:** We employed dynamic time warping analyses to identify clusters of symptoms that tended to change similarly across therapy on a within-person level. Symptoms were measured by a 28-item Eating Disorder Examination Questionnaire (EDE-Q). Furthermore, we examined the temporal direction of symptom change to identify symptoms that tended to precede and predict other symptoms. Finally, we estimated two directed, temporal networks in patients with and without a history of childhood maltreatment.

**Results:** Our analysis included 122 ED patients (mean age = 30.9,  $SD = 9.7$ ; illness duration = 14.2 years,  $SD = 8.9$ ; prior treatment = 5.6 years,  $SD = 5.1$ ). The initial network revealed three robust clusters of symptoms over time: (1) ED behavior, (2) inhibition, and (3) cognitions and feelings about body and weight. Overvaluation of shape had the highest out-strength preceding and predicting other symptoms. Dissatisfaction with weight preceded and predicted other symptoms in the maltreatment network. The non-maltreatment network showed a similar structure to the transdiagnostic network.

**Conclusion:** Targeting and monitoring feelings and cognitions related to shape may be crucial for achieving lasting symptom improvement in a transdiagnostic sample. Furthermore, our findings highlight the need for further investigation into the different processes driving EDs based on maltreatment status.

**Public significance:** There is limited understanding of the processes that occur for patients with eating disorders between admission and discharge in therapy, especially for patients with a history of childhood maltreatment. Our analyses suggest that changes in cognitions regarding shape precede and predict changes in cognitions

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about weight. Different processes may be driving the eating disorder according to maltreatment status, which might further illuminate the riddle of dropout and relapse in therapy for patients with a history of childhood maltreatment. These findings suggest the need for further investigation into the specific dynamics occurring during therapy for individuals with a history of childhood maltreatment.

#### KEYWORDS

childhood maltreatment, dynamic time warp, eating disorders, network analysis, process data, trauma

A significant challenge in the field of eating disorder (ED) research is the limited understanding of the processes that occur for patients between admission and discharge in therapy. This may be a contributing factor to the relatively low success rate of approximately 50% in the treatment of EDs, such as cognitive-behavioral therapy (CBT) (Keel & Brown, 2010; Monteleone et al., 2022; Wilson et al., 2007). Most studies on ED treatment have investigated pre-post on a group level (between-person level). Outcome studies that solely report pre-post-treatment data fail to inform clinical practice about how patients change during therapy (Kazdin, 2007, 2009). To optimize treatment outcomes, it is important to investigate which symptoms might be central to change processes, also known as mechanisms of change (Hoffart & Johnson, 2020; Kazdin, 2007, 2009).

The increasingly applied network approach in psychopathology conceptualizes symptoms as mutually interacting, often reciprocally reinforcing elements of a complex network (Borsboom & Cramer, 2013; McNally, 2016). In network theory, symptoms are interconnected components of a disorder (Borsboom, 2017; Borsboom & Cramer, 2013). These connections represent the probability that one symptom's activation is linked to other connected symptoms (McNally, 2016). In temporal networks, we examine whether the (de)activation of one symptom precedes the (de)activation of other symptoms later in time. Most network studies performed thus far, although cross-sectional, found that symptoms related to weight and shape concerns were most central in the network (Christian et al., 2020; Forrest et al., 2018; Monteleone & Cascino, 2021), in line with Fairburn and colleagues' transdiagnostic model (Fairburn et al., 2003). Since cross-sectional network analyses are based on group-level (between-person) analyses, translating these findings to individual-level (within-person level) analyses remains uncertain (Fisher et al., 2018). Thus, there is a need for within-person longitudinal network analyses (Hekler et al., 2019).

The within-person network studies that have been conducted have identified different central symptoms between individuals when tracking changes in eating disorder symptoms over time (Levinson et al., 2022, 2023; Levinson, Vanzhula, & Brosf, 2018). However, the studies by Levinson et al. (2022) concentrated on patients undergoing therapy in specific segments rather than throughout the entire observation period. Levinson et al. (2023) adopted a pre-, mid-, and post-therapy approach, while Levinson, Vanzhula, Brosf, et al. (2018) focused on post-discharge observations. Furthermore, the longitudinal network analyses applied by Levinson and colleagues (multilevel vector autoregressive model)

estimated partial correlations between all symptoms. This method requires a high number of repeated measures per patient assuming a linear relationship between symptoms and that these relationships and the levels of symptoms stay the same over the observation period (assumption of stationarity). Additionally, this method can be sensitive to multicollinearity. Multicollinearity is a concept in statistics if several independent variables are highly correlated, it can bias the analysis or make statistical models hard to converge. Weekly measurements in therapy may remain stable at certain points and fluctuate at others. To overcome these limitations of the traditional longitudinal network analyses, and to enable insight into the dynamics of the eating disorder symptoms during treatment the non-linear dynamic time warp approach was used.

Dynamic time warp analysis helps us find the best way to compare these progress patterns, considering the variations in symptom change from admission to discharge. This method can estimate both undirected and directed networks. An undirected network looks at the cooccurrence of symptoms over time (clusters). This informs us of which symptoms are associated with each other, for example, if a change in purging is associated with a change in bingeing. A directed network investigates the direction of the pattern of symptoms across time, for example, whether a change in a symptom score tends to be followed by a similar change in another symptom score during therapy. This can in turn inform clinicians of how and when symptoms change over therapy (if they tend to change first (high out-strength) or last (high in-strength)) and therefore which symptoms should be targeted first in therapy. Thus, directed networks have the highest clinical value, as symptoms that precede and predict other symptoms are viewed as influential and possible treatment targets in therapy. Dynamic time warp analyses have the potential to unravel the riddle of nonresponse in therapy. The method may be an important tool to identify symptoms that can be experimentally manipulated in different contexts in order to fully establish the causal relationships between symptom changes.

To date, only one previous study in the ED field has used dynamic time warp (Slof-Op 't Landt et al., 2022). This study analyzed 22 of the 28 symptoms in the ED examination questionnaire (EDE-Q) in 255 patients during treatment (4 measurements), yielding an undirected symptom network. They found four robust clusters of ED symptoms over time: (1) restraint/rules, (2) secret eating/fasting, (3) worries/preoccupation, and (4) weight and shape concern. Guilt and fear of weight gain acted as bridge nodes responsible for the strongest connections between the clusters. In our study we can

construct a directed network due to having more measurements compared to (Slof-Op 't Landt et al., 2022), which provides us with a more comprehensive grasp of the directional aspects of symptom changes. Additionally, our study specifically examines weekly processes within a (inpatient) therapy context, diverging from Levinson's investigations, which included either individuals not exclusively undergoing therapy (Levinson et al., 2022) or followed a pre, mid, and post-therapy approach (Levinson et al., 2023), or post-discharge observations (Levinson, Vanzhula, & Brosf, 2018; Levinson, Vanzhula, Brosf, et al., 2018). Collectively, these studies can bridge a crucial knowledge gap on within-person change, thereby enhancing the potential for precision treatment.

Trauma exposure and other severe adverse childhood experiences (such as emotional abuse) are heavily associated with EDs and can profoundly affect patients throughout the lifespan (Brewerton, 2007, 2022; Burdo et al., 2023; Trottier & MacDonald, 2017). Recent meta-analyses by Convertino and Mendoza (2023) and Day et al. (2023) suggest a high likelihood of dropouts and relapse within this patient population. These findings indicate that patients with a history of childhood maltreatment might display different patterns of change in therapy than other patients, highlighting the critical need to examine how symptoms interact throughout the course of therapy for these individuals.

This is the first network analysis looking at the directed pattern of ED symptoms across therapy for patients with and without a history of childhood maltreatment, enabling a unique understanding of symptom change. This can help us develop more accurate and potent treatment for patients with EDs, as we gain more knowledge on how symptoms change, and which symptoms seem to be driving change in the overall network and the network with or without maltreatment. Our aims were to (1) investigate the cooccurrence (clusters) of ED symptoms in individuals of a transdiagnostic inpatient sample over the course of therapy, and compare the identified clusters in this study with the ones previously found by Slof-Op 't Landt et al. (2022), (2) investigate the relationships between symptom changes and identify the most influential symptoms in the directed network that precede and predict other symptoms, and (3) compare the directed network structure between patients with and without childhood maltreatment.

## 1 | METHOD

### 1.1 | Treatment setting

Participants were referred to treatment at the Department of Eating Disorders at Modum Bad psychiatric hospital in Norway from a local general practitioner's office or a local psychiatric hospital. This nationwide, specialized hospital provides an inpatient treatment program for patients with longstanding EDs and a history of nonresponse to treatment in local treatment facilities. The department treats anorexia nervosa, bulimia nervosa, and other feeding and EDs and offers two therapy models: CBT (Fairburn et al., 2003; Waller et al., 2007) and compassion-focused therapy (CFT-E) (Goss & Allan, 2014). Our study

**TABLE 1** Sample and group characteristics at pre-treatment.

Characteristics	Total (N = 122)
Age, years (M ± SD)	30.8 (9.6)
Ethnicity	
Caucasian n (%)	115 (98.3)
Others n (%)	2 (1.7)
Gender (as assigned by birth)	
Female n (%)	118 (96.7)
Male n (%)	4 (3.3)
Childhood maltreatment	
Emotional neglect n (%)	81 (66.4)
Emotional abuse n (%)	40 (32.8)
Physical neglect n (%)	103 (84.4)
Physical abuse n (%)	13 (10.7)
Sexual abuse n (%)	22 (18.0)
Duration of illness, years (M ± SD)	14.3 (9.0)
Treatment	
Duration of treatment, years (M ± SD)	5.9 (6.0)
Previous inpatient treatment n (%)	74 (60.7)
Eating disorder	
Bulimia nervosa	51 (40.2)
Anorexia nervosa	31 (24.6)
Other specified eating disorder	40 (41.8)
BMI (M ± SD)	21.4 (5.5)
EDE (M ± SD)	4.3 (1.2)
Bingeing n (%)	66 (54.4)
Vomiting n (%)	72 (59.8)
Self-mutilation n (%)	53 (44.3)

Abbreviations: BMI, body mass index; EDE, Eating Disorder Examination global score.

is part of a larger randomized controlled trial (RCT) where patients with and without childhood maltreatment were block randomized to these two treatment groups (i.e., 50% had childhood maltreatment and 50% did not in each treatment group). The main outcome of our RCT found no difference in the outcome of ED symptoms between patients with and without childhood maltreatment at the end of therapy (Vrabel, [In review](#)).

### 1.2 | Procedures

All patients participated in a preadmission evaluation week for diagnostic evaluation. After identifying eligibility (see the inclusion and exclusion criteria), written informed consent was obtained. A total of 122 patients were included in the analysis. The patients had a mean of 2.1 DSM IV Psychiatric axis-1 ( $SD = 1.6$ ) diagnoses, including their ED. For more demographic information, please consult Table 1. The patients were admitted for 13 weeks of inpatient treatment. Data was collected between spring 2014 and fall 2018. No financial

compensation was offered to the participants. For information regarding the overarching RCT, please consult (Vrabel et al., 2019).

To be eligible to participate in this study, individuals had to meet the following criteria: (1) adult inpatient (18 years or older) with an ED diagnosis, such as anorexia nervosa, bulimia nervosa, and atypical variants (other specified feeding and eating disorders), according to the EDE-Interview (Fairburn & Beglin, 2008), (2) nonresponse to outpatient treatment, (3) no need for immediate additional treatment (see exclusion criteria), and (4) the provision of informed consent. Individuals who met any of the following criteria were excluded from participation in the study: (1) current suicidal risk or psychosis necessitating extensive care, (2) serious substance abuse interfering with treatment, or (3) ongoing trauma (current involvement in an abusive relationship).

### 1.3 | Instruments

ED symptoms were measured weekly using the Norwegian Eating Disorder Examination Self-Report Questionnaire 6.0 (EDE-Q) (Fairburn et al., 1993; Rø et al., 2015). The EDE-Q is a 28-item questionnaire that measures food restriction, fear of weight gain, fear of shape and fear of eating. The 28 symptoms assessing psychopathology are rated on 7-point forced-choice scales (0–6), with higher scores reflecting greater severity or frequency. The questionnaire was adapted to repeated measures in therapy, and the questions asked for symptoms the *last 7 days* instead of 28, as in the original questionnaire. The EDE-Q was shown to be reliable and valid in assessing EDs (Berg et al., 2012).

The Childhood Trauma Questionnaire (CTQ) was used to assess childhood maltreatment (Bernstein et al., 1998). To identify possible cases of childhood maltreatment and differentiate between no maltreatment and maltreatment, we used the CTQ as a categorical measure with the recommended scoring cutoff scores by Walker et al. (1999). We applied a cutoff of 8 on sexual abuse and physical neglect and a cutoff of 15 on the rest of the subscales. In our study, 41% of patients had a history of childhood maltreatment, and 58% did not. The specific types of childhood maltreatment are presented in Table 1.

### 1.4 | Statistical analysis

Several analyses were performed to investigate how ED symptoms cluster together in individuals over the course of treatment and which symptoms had high influence in the network, both overall and with the influence of childhood maltreatment. First, the group-level mean values of EDE-Q scores over time were analyzed to investigate average symptom changes in the overall group. We investigated whether there were any changes between treatment or maltreatment status to inform further analyses. Second, we conducted undirected dynamic time warp analyses to investigate which EDE-Q symptoms tended to covary and change similarly over time. Third, we conducted directed (temporal) analyses to examine whether changes in specific EDE-Q symptoms tended to precede similar changes in other EDE-Q

symptoms. We also examined which symptoms were most central and influential in the network. In this context, the most influential symptoms in the network have the highest *out-strength*, indicating that they precede and influence other symptoms, whereas symptoms with high *in-strength* are symptoms that are mostly influenced by other symptoms. Fourth, we repeated the directed analyses in two groups: patients with or without a history of childhood maltreatment.

### 1.5 | Group-level mean effects in time

First, we wanted to examine the overall change in symptoms on a group level to investigate the raw data. This was done to investigate whether there were any differences over the course of therapy for any of the treatment groups when investigating raw data, to further illuminate the change processes. We used mixed models to estimate the average effects of the 28 symptoms measured by the EDE-Q over time. We included a random intercept for each patient to account for individual differences. The purpose was to determine whether these average effects of symptom change differed and clustered differently when compared to the undirected dynamic time warp analysis, which is based on individual change profiles that are later aggregated to a group level. We investigated raw scores of the group-level means for all four treatment groups in the RCT: compassion focused therapy with and without a history of childhood maltreatment and cognitive behavioral therapy with and without childhood treatment.

### 1.6 | Undirected dynamic time warp analysis

To answer the question of which symptoms tended to change similarly in clusters in therapy, we examined the patterns of the EDE-Q symptoms for each individual. Dynamic time warp was used to calculate the distance between the EDE-Q symptom pairs for each of the 122 patients. The dynamic time warp analyses were performed in R (R Core Team, 2019). For a complete explanation of the dynamic time warp analysis of pairs of symptoms in one individual, please see Slof-Op 't Landt et al. (2022). All EDE-Q symptoms were standardized before the dynamic time warp analysis. The smaller the distance between two symptoms, the more they co-occur (similarly) in time. The thickness of the edges indicates the similarity of the changes over time in item scores, and the size of each node is proportional to the connectiveness to other nodes. We proceeded to analyze the symptoms in a hierarchical cluster analysis to identify the dimensions of symptoms with similar change profiles. The identified clusters were then color coded in the figures.

### 1.7 | Directed dynamic time warp analysis

Directed dynamic time warp allows us to identify patterns and connections between different symptoms, understanding how one symptom may influence or lead to another. This analysis can uncover the

directional relationships of symptoms throughout the therapy process and answer the following question: Which symptoms tended to precede and predict changes in other symptoms? We performed directed (temporal) dynamic time warp analysis with the window type using the Sakoe-Chiba band (Murtagh & Legendre, 2014), which was specified as being asymmetric. (For further explanation and graphic illustration of the directed time warp, please consult Figure S3.) This means that the dynamic alignment was constrained to only one direction (later in time) to investigate the directionality. The Sakoe-Chiba is a method for measuring the similarity between two temporal sequences that may vary in speed. This method accounts for symptom change that happens at different times during therapy. By constraining the comparison to only one direction, the analysis is easier to run while still maintaining accuracy (Murtagh & Legendre, 2014).

More specifically, Granger causality (Granger, 1969) is a statistical method used to examine whether the values in one time series (A) at a particular time point ( $t - 1$ ) can predict the future values in another time series (B) at a different time point ( $t$ ) while accounting for the autocorrelation in series B between time points ( $t - 1$ ) and ( $t$ ). By applying Granger causality analysis in both directions (A predicting B and B predicting A), we can determine whether the predictive relationship between time series A and B is one-way or two-way. This approach allows us to assess whether the influence between the two time series is unidirectional or bidirectional. This is an essential distinction in psychotherapy research. If we can establish directionality, we can screen for symptoms to experimentally manipulate in therapy to move closer to causality. Causal connections between symptoms are, in turn, important to inform treatment planning. A goal in psychotherapy research is to determine whether targeting a symptom in therapy results in change. This is often referred to as mechanisms of change (Kazdin, 2007, 2009).

For each of the 122 patients, a directed distance matrix was estimated. Subsequently, the mean distances for each item pair were calculated, and significant differences from zero (by  $t$ -tests) were determined for each of the item pairs. Only when the directed distance (at the group level) was significantly larger than zero ( $p = .05$ ) an arrow was shown in the directed network plot. Subsequently, all 122 distance matrices were combined to yield standardized out-strength and in-strength centrality values, for which the confidence intervals were assessed through 5000 bootstraps. Finally, patients were categorized into two groups according to childhood maltreatment exposure status. All directed analyses were repeated in the two groups. The “dtw” (version 1.23-1) (Giorgino, 2009), “parallelDist” (version 0.2.9) (Eckert, 2022a), “DistatisR” (version 1.1.1) (Eckert, 2022b), and “qgraph” (version 1.9.6) (Epskamp et al., 2012) packages for R statistical software were used (v4.2.2, 2022). The sample code is provided in Appendix S1.

## 2 | RESULTS

### 2.1 | Group-level mean effects in time

First, we investigated how the symptoms changed on a group-level mean over time, to compare with the within-person analyses. The

results are depicted in Figure S1. The raw scores indicated that behavioral symptoms (blue) exhibit the least severe level of intensity throughout therapy. The symptoms of fear of losing control, guilt, diet rules, food avoidance, worry about eating in public and exercise (yellow) changed moderately and fluctuated through therapy. Last, feelings and cognitions about shape and weight (red) remained high throughout therapy but had a slight decrease. There were no statistically significant differences between the four treatment categories in the RCT when investigating group-level mean symptom levels across therapy. The results are depicted in Figure S2.

### 2.2 | Symptom network of co-occurring symptoms: Undirected dynamic time warp (Figure 1a,b)

Figure 1a portrays the undirected network, which addresses the aim regarding the similarities in the change patterns of symptoms throughout therapy. It also investigates if certain symptoms change collectively within clusters and whether these cluster resemble the study of Slof-Op ‘t Landt et al. (2022). Hierarchical cluster analysis indicated an optimum of three dimensions which we color coded in all figures. The dimension was named: (1) *ED behavior* (referring to the blue symptoms), (2) *cognitions and feelings about weight and shape* (red symptoms) and finally, cluster (3) which we labeled *inhibition*, containing the symptoms: fear of losing control, guilt, diet rules, food avoidance, worry about eating in public and exercise (yellow symptoms). The standardized centrality is reported in Figure 1b with significance levels and error bars.

### 2.3 | Symptom network of temporal effects: Directed dynamic time warp (Figure 2a,b)

In Figure 2a, we present the directed network, which corresponds to our second objective: identifying which symptoms preceded and predicted other symptoms within the overall network. The arrows represent the statistically significant influences between the symptoms. The thickness of the edges indicated the strength of the connection (all significant edges are reported in a forest plot in Table S1). Out-strength and in-strength are reported in Figure 2b. Our findings indicate that overvaluation of shape, the wish for an empty stomach, preoccupation with body and weight, and dissatisfaction with one's figure are symptoms with high out-strength. These symptoms are central and influential in the network, and changes in these symptoms often precede changes in other symptoms. Binge eating and cognitive symptoms such as the wish for a flat stomach, dissatisfaction when other people see your body, desire to lose weight and overvaluation of shape, had high in-strength, suggesting that they are influenced by other symptoms.



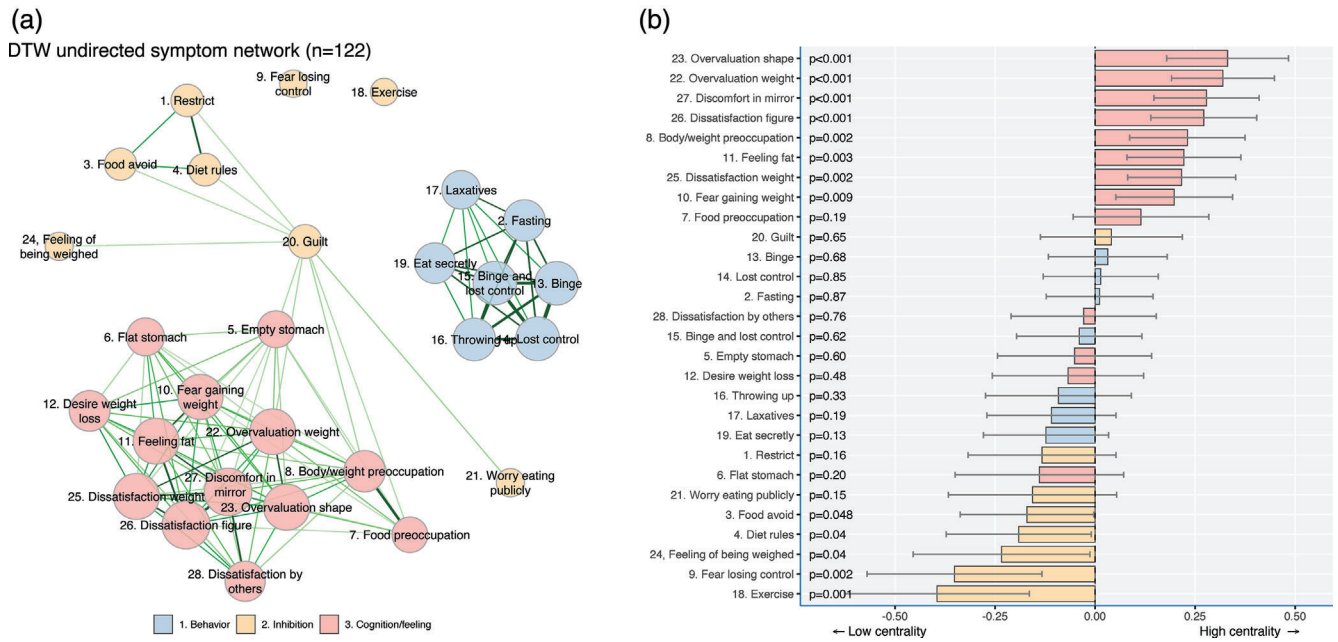


FIGURE 1 (a) Undirected EDE-Q symptom network. (b) Standardized centrality values.

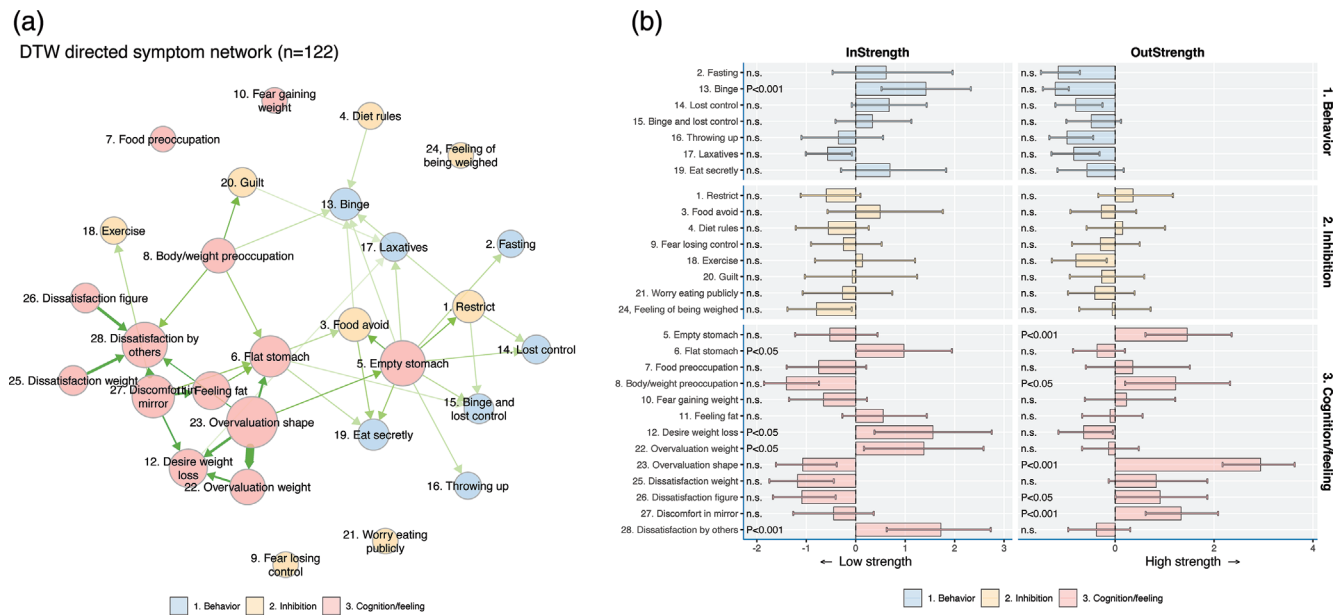


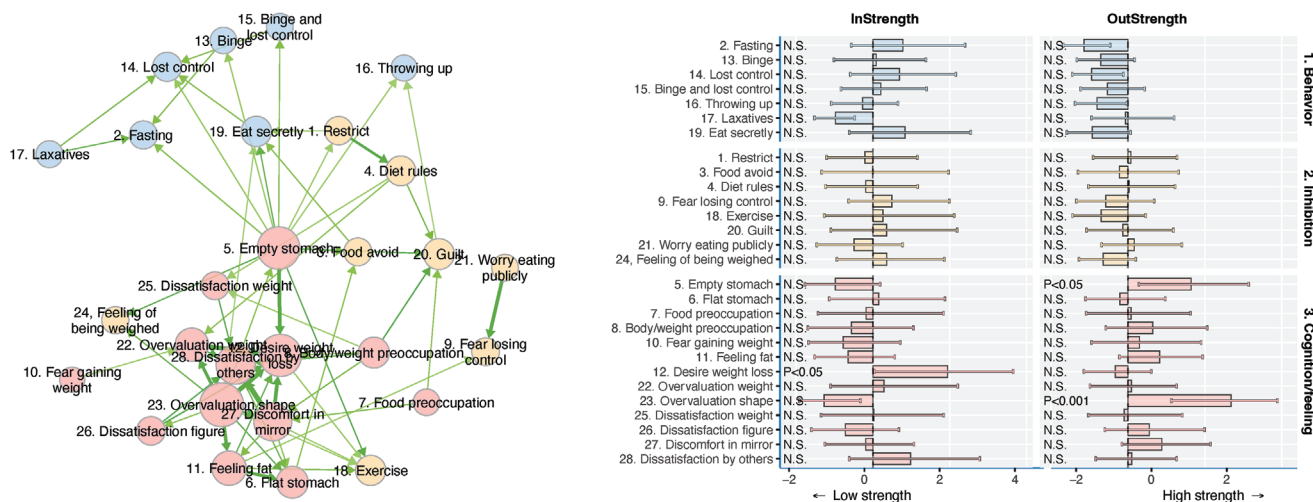
FIGURE 2 (a) Directed EDE-Q symptom network. (b) Standardized centrality values.

## 2.4 | Directed dynamic time warp networks: with and without childhood maltreatment (Figure 3a-d)

Figure 3 shows the directed networks for maltreatment and non-maltreatment which relates to our last aim: compare the directed network structure between patients with and without childhood maltreatment. The results indicated that the symptoms interact in different ways across therapy. When examining the networks, dissatisfaction of weight had high out-strength to other cognitions and

feelings in the maltreatment-network (see Figure 3d), suggesting that dissatisfaction with weight as a central and influential symptom in the network. However, in the non-maltreatment-network (see Figure 3b), it was overvaluation of shape and the wish for an empty stomach that had significant out-strength. Feeling fat, binge eating, and overvaluation of weight showed significant in-strength for patients with a history of maltreatment, indicating that these symptoms are affected by other symptoms (changes). Desire for weight loss had the highest in-strength for patients without a history of maltreatment.

(a) Directed symptom network - No trauma (n=71) (b) In- and OutStrength centrality - No trauma (n=71)



(c) Directed symptom network - Trauma (n=51) (d) In- and OutStrength centrality - Trauma (n=51)

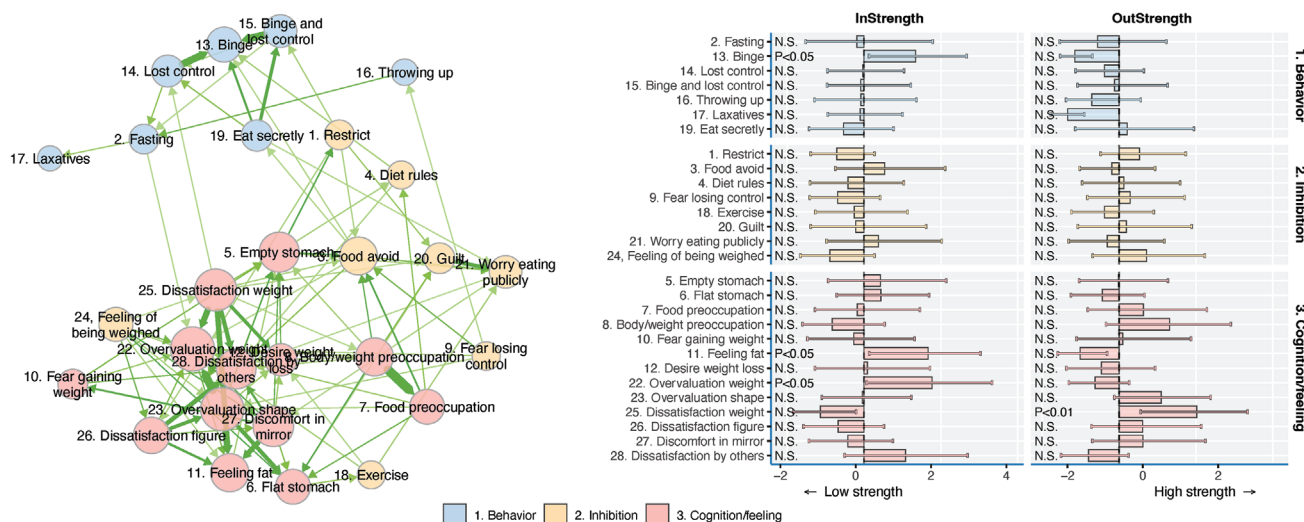


FIGURE 3 (a-d) Directed symptom network for patients with and without childhood maltreatment.

### 3 | DISCUSSION

This is the first directed time warping network analysis investigating ED symptoms, enabling a unique understanding of how symptoms interact and change throughout therapy. The group-level analysis and undirected dynamic time warping analysis revealed clusters in which the symptom severity covaried and changed similarly over time: (1) ED behavior, (2) cognitions and feelings about shape and weight, and (3) inhibition (which refers to the symptoms: fear of losing control, guilt, diet rules, food avoidance, worry about eating in public, and exercise). The directed analysis found evidence that changes in overvaluation of shape (high out-strength) preceded changes in overvaluation of weight (high in-strength) in the overall sample. The wish for an empty stomach preceded the wish for a flat stomach. Body and weight preoccupation, the worry that others will see your body and body dissatisfaction, also had high out-strength, suggesting their

central role in the overall network. In the network for patients with a history of maltreatment, dissatisfaction with weight showed the highest out-strength. However, for patients without a history of maltreatment, overvaluation of shape and the desire for an empty stomach demonstrated the highest out-strength.

The three clusters in the present study are largely consistent with findings from the previous dynamic time warping analysis in patients with EDs (Slof-Op 't Landt et al., 2022). In this study, 22 of the 28 symptoms in the EDE-Q were included, and these clustered within four groups: 1. Restraint/rules, 2. Secret eating/fasting, 3. Worries/preoccupation, and 4. Weight and shape concern (Slof-Op 't Landt et al., 2022). Thus, the clusters tend to overlap, where their second cluster (secret eating/fasting) aligns with our cluster of behavioral symptoms. Furthermore, our feelings and cognitions regarding shape and weight are highly comparable to their weight and shape concern. Thus, the current study supports and extends

findings in that symptoms cluster differently than those suggested by Fairburn et al. (2003). Our group-level mean analysis (Figure S1) was consistent with our undirected analysis, providing further support for the robustness of the three clusters.

Our directed network suggests the symptoms that precede and predict other symptoms (symptoms that are driving change) are feelings and cognitions about shape, suggesting their pivotal role in dissolving the ED network. Accordingly, if a patient reduces his/her ED behavior, the patient might still be vulnerable to relapse if the feelings and cognitions are not properly addressed (and dissolved). One clinical implication of this might be that it is particularly important to target and monitor feelings and cognitions about shape throughout therapy both in relation to assessing symptom improvement but also as a tool to assess when to terminate therapy. Early termination without adequate change in feelings and cognitions about shape might lead to relapse. The directed network also suggests that interventions aimed at the internalization of a body/thinness ideal may be effective in a transdiagnostic inpatient sample as overvaluation of shape has a central role in changing other symptoms.

Our finding that overvaluation of shape *preceded* and *predicted* changes in overvaluation of weight is indeed unexpected, as several previous network analyses has found both overvaluation of weight and shape to be central (Christian et al., 2020; Forrest et al., 2018; Monteleone & Cascino, 2021). These studies could not establish directionality. One study investigated within-person level through panel data, but included both overvaluation of shape and weight together as one construct (Srivastava et al., 2023). They found that overvaluation of shape and weight predicted later reduction of bulimic symptoms and vice versa. In other words, they could not establish the direction of symptom change, and they did not separate the two constructs. Our finding poses a challenge to the transdiagnostic theory and diverges from other studies that suggested substantial influence from overvaluation of both weight and shape (Aardoom et al., 2012; Christian et al., 2020; Fairburn et al., 2003; Forrest et al., 2018; Monteleone & Cascino, 2021). This indicates the necessity to disentangle the overvaluation of shape and weight constructs and investigate them separately.

This study was conducted within the controlled environment of an inpatient facility, where comprehensive attention was directed toward all dimensions of an ED through therapy, meal support, group therapy, and guided physical exercise. In essence, the therapeutic milieu invoked the activation of all symptomatic aspects of an ED, as operationalized through the EDE-Q in this study. It is of note that when concurrently addressing both behavioral and cognitive facets, the alteration in cognitions concerning body shape emerged as a key predictor of change in other symptoms of an ED. The diminished significance of behavioral symptoms could potentially stem from the presence of mandatory and non-negotiable directives within the inpatient environment (Geller & Srikaneswaran, 2006). In this setting, patients might naturally “embrace” treatment, given the absence of opportunities for behaviors such as binge eating, purging, restriction, or excessive exercise. Future studies, especially across diverse treatment contexts and diagnoses, are needed to gain a comprehensive understanding of these dynamics.

Our analysis indicated that for patients with a history of childhood maltreatment, dissatisfaction with weight had the highest influence (out-strength), preceding the symptoms of feeling fat, binge eating, and overvaluation of weight. The non-maltreatment network displayed a different pattern than the maltreatment network, where overvaluation of shape had high out-strength and preceded desire for weight loss. This finding might point to a difference in the direction of symptom change for patients with and without maltreatment.

In the case of patients with a history of maltreatment, our findings may indicate that their ED is not inherently tied to an excessive preoccupation with their body shape or that their body shape relates to their self-worth. Rather, a change in the most central symptom, dissatisfaction with weight, preceded changes in binge eating, overvaluation of weight, and feeling fat. For these patients, it may be necessary to explore whether their ED serves as an outward manifestation of their internal struggle with self-perception, identity, and consciousness, all intricately intertwined with the perception of their physical body. This can also be referred to as embodiment or “the embodied self” (Cassoli et al., 2020; Malecki et al., 2018; Musolino et al., 2020; Young, 1992). ED treatment, especially inpatient treatment, could be an extra trigger for these patients (with a focus on eating, weight normalization, and attachment with the therapist in therapy), which could explain the higher percentage of dropouts (Convertino & Mendoza, 2023; Day et al., 2023; Olofsson et al., 2021). However, there might be aspects central for these patients that are not fully captured by the EDE-Q questionnaire, like the concept of embodiment after childhood maltreatment. Further studies investigating different aspects of ED, attachment and embodiment are warranted.

### 3.1 | Strengths and limitations

Our directed dynamic time warp network analysis of ED symptoms introduces a novel approach to understanding the intricate dynamics of symptom interactions and changes during therapy. While our sample size was relatively large compared to other clinical trials, it had limitations in terms of gender diversity and ethnicity. Additionally, our sample did not include patients diagnosed with binge-eating disorder or avoidant restrictive food intake disorder. Dynamic time warp might be better suited for panel data from naturalistic studies with a limited number of measurements, such as our study. This contrasts with more traditional network approaches like multilevel vector autoregression analysis, which require a greater number of measurements. Dynamic time warp also retains the capability to calculate within-person networks and estimate the temporal direction of symptom change. The analysis cannot, however, consider the predictive standardized effects of previous measurements of the same variable. Studies with more measurements, like ecological momentary assessments across therapy, are warranted.

The EDEQ items were on different scales, most items were from 0 to 6, but the behavioral items could vary in terms of frequency in behavior over the last 7 days. We standardized the items to prevent the different spacing would inflate the correlations. Using the EDEQ



items is always a challenge in research because some items are “heavy tailed”. Nonetheless, network theory posits the investigation of individual items instead of subscales, and our analysis that behavioral items (despite being on different scales) cluster together. The maltreatment network should be considered preliminary, as the sample size was relatively small and needs to be confirmed in future studies.

## 4 | CONCLUSION

This study aimed to use dynamic systems and network theory to be the first study in the ED field to estimate a directed network of ED symptoms to identify the symptoms that precede and predict changes in other symptoms. Our study was performed with a transdiagnostic sample in an inpatient treatment context. The results revealed three robust clusters of symptom change that relate to ED behavior, inhibition (fear of losing control, guilt, diet rules, food avoidance, worry about eating in public and exercise), and cognition and feelings about weight and shape. Overvaluation of shape, weight, and shape preoccupation, the wish for an empty stomach, dissatisfaction with shape and when looking at oneself in the mirror, were found to be the central symptoms preceding and predicting change in the overall sample, potentially serving as mechanisms of change. Furthermore, the study found that patients with childhood maltreatment displayed other central symptoms than patients without maltreatment. This suggests that different processes may be driving the ED depending on maltreatment status, which warrants further investigation. Overall, the study highlights the importance of using dynamic systems and network theory to better understand the complex interactions between symptoms in EDs and the influence of childhood maltreatment.

### AUTHOR CONTRIBUTIONS

**Maren C. G. Kopland:** Conceptualization; data curation; investigation; methodology; project administration; validation; writing – original draft; writing – review and editing. **KariAnne Vrabel:** Conceptualization; investigation; project administration; supervision; validation; writing – original draft; writing – review and editing. **Margarita Slof-Op ‘t Landt:** Conceptualization; methodology; supervision; validation; writing – original draft; writing – review and editing. **Asle Hoffart:** Conceptualization; investigation; methodology; project administration; supervision; validation; writing – original draft; writing – review and editing. **Sverre Urnes Johnson:** Conceptualization; methodology; project administration; supervision; writing – original draft; writing – review and editing. **Erik Giltay:** Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing – original draft; writing – review and editing.

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### CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

### DATA AVAILABILITY STATEMENT

The dataset used in the current study is available from the corresponding author on reasonable request.

### ETHICAL STATEMENT

The study was preregistered in Clinical Trial Registration [ClinicalTrials.gov](https://www.Clinicaltrials.gov), <http://www.Clinicaltrials.gov/ct2/show/NCT02649114>. The study was approved by the Norwegian Regional Committee for Ethics in Medical and Health Research (REK). The project's identification number is 2014/836/REK. Patients were informed of the repeated weekly questionnaire and the purpose. We requested patients' permission to use their data for research. To secure patients' confidentiality, all patient-identifiable data were removed from the database.

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