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# Depression and eating disorders in early adolescence: A network analysis approach

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**Abstract**

**Objective:** Eating disorders (EDs) and depression are among the most debilitating and pervasive mental illnesses. Although they often co-occur, the relationship between EDs and depression remains poorly understood. This study used network analysis to explore the symptom-level relationship between EDs and depression among a sample of Australian adolescents completing their first year of secondary school.

**Method:** Adolescents ($N$ = 4 421) aged between 10 and 15 years completed the Centre for Epidemiological Depression Scale and the Eating Disorder Examination-Questionnaire. Network structure was estimated using the Gaussian graphical model and node centrality was assessed using one-step expected influence and bridge expected influence.

**Results: '**Depressed', 'lonely' and 'low energy' were identified as core symptoms of depression. 'Shape and weight dissatisfaction', 'desire to lose weight' and 'preoccupation with shape or weight' were identified as core ED symptoms. 'Irritable', 'social eating' and 'depressed' were identified as the most important nodes connecting (i.e., bridging) symptoms of depression and EDs.

**Discussion:** This study provides an important symptom-level conceptualisation of the association between depression and ED symptoms in a community sample of adolescents. This preliminary evidence may guide the development of public health prevention and early intervention programs. Future research should be conducted to address the study limitations (e.g., cross-sectional design).

Keywords: *depression, eating disorders, adolescent, core psychopathology, network analysis, comorbidity.*

Eating disorders (EDs) are among the most enduring and devastating mental illnesses. They are notoriously difficult to treat, and course progression is often chronic (Eddy et al., 2017; Treasure, Duarte, & Schmidt, 2020). Individuals diagnosed with an ED are at increased risk of psychological distress and premature death due to physical health complications and suicide (Lipson & Sonneville, 2020; Treasure et al., 2020; Zerwas et al., 2015).

EDs are often associated with other psychiatric comorbidities including depression (van Alsten & Duncan, 2020). A comorbid diagnosis of depression is often associated with more severe ED symptoms and worse treatment outcomes (Giovanni et al., 2011; Hughes et al., 2013). Given the adverse outcomes of depression in its own right (World Health Organisation, 2020), understanding the structure of these psychopathologies, and the relationship they share, is of clinical significance.

Network theory is an emerging approach to the study of psychopathology and provides a means to understand the relationship between EDs and depression. Network theory, as it relates to psychopathology, posits that mental disorders arise from interactions between symptoms in a network (Borsboom, 2008, 2017). In these networks, nodes represent symptoms and edges represent interactions (e.g., regularised partial correlations) between symptoms (Borsboom & Cramer, 2013; Fonseca-Pedrero, 2017).

Network theory has been applied to the study of several different mental disorders (e.g., anxiety, depression and substance use disorders) (Beard et al., 2016; Rhemtulla et al., 2017) but is particularly suited to the study of EDs. Network theory aligns with several theories of EDs (e.g., Cognitive Behaviour Theory and Transtheoretical Model) that describe how

relations among ED symptoms perpetuate and exacerbate the disorder (Brytek-Matera & Czepczor, 2017; Fairburn, 2008).

There is a growing body of literature using network theory to assess EDs in clinical adult populations. Shape and weight dissatisfaction and overvaluation have been found to be the most central symptoms in clinical populations (Calugi, Sartirana, Misconel, Boglioli, & Dalle Grave, 2020; DuBois, Rodgers, Franko, Eddy, & Thomas, 2017; Forbush, Siew, & Vitevitch, 2016; Forrest, Jones, Ortiz, & Smith, 2018; Goldschmidt et al., 2018; Wang, Jones, Dreier, Elliot, & Grilo, 2018). These findings support the Cognitive Behavioural Theory (CBT) of ED that posits overvaluation of shape and weight is core to the psychopathology of EDs (Fairburn, 2008; Fairburn, Cooper, & Shafran, 2003). Shape and weight overvaluation occurs when an individual judges their self-worth predominantly on their shape and weight (Fairburn, 2008). However, shape and weight dissatisfaction and overvaluation do not appear to be central in all clinical samples. Interoceptive awareness, ineffectiveness (Olatunji, Levinson, & Calebs, 2018) and binge eating (Perko, Forbush, Siew, & Tregarthen, 2019) have also been identified as influential symptoms.

Fewer studies have been conducted to understand the structure of EDs in non-clinical samples. Rodgers, DuBois, Frumkin, and Robinaugh (2018) sought to explore EDs from a network persepctive in a sample of female undergraduate students. They found desire for thinness to be the most central symptom and in doing so, provided preliminary insight into how ED symptoms may relate in non-clinical female samples. However, further research is required to understand the network structure of EDs in community samples of adolescent males and females; this is an important avenue for inquiry given sub-clinical eating pathology is associated with significant reductions in quality of life (Wade, Wilksch, & Lee, 2012) and

is identified as a predictor of future clinical diagnosis (Neumark-Stzainer et al., 2006). Given the average age of onset for EDs occurs during adolescence (Deloitte Access Economics, 2012), focusing on early adolescence, when individuals may be beginning to experience sub-clinical eating pathology but have not meet full diagnostic criteria, is particularly important.

Studies conducted to explore the network structure of depression in community samples of adolescents have identified sadness and loneliness to be central symptoms (Gijzen et al., 2020; Mullarkey, Marchetti, & Beevers, 2019). The edge between sadness and loneliness appears to be among the strongest edges in these networks further reinforcing their importance in adolescent depression. Exploring the structure of depression in non-clinical samples is warranted given individuals who endorse symptoms of depression experience increased psychological distress (Rucci et al., 2003) and suicidal thoughts (Balazs et al., 2013) even when symptom severity and/or duration does not meet clinical diagnostic criteria.

Several studies assessing the relationship between depression and EDs from a network perspective in clinical samples (Elliott, Jones, & Schmidt, 2019; Levinson et al., 2017; Smith et al., 2018) have identified shape and weight dissatisfaction and overvaluation and desire to lose weight to be central symptoms. Items pertaining to self-worth, restlessness and fear of eating in public emerged as the most important symptoms bridging (i.e., connecting) depression and EDs (Elliott et al., 2019; Levinson et al., 2017; Smith et al., 2018). However, there are limited studies assessing this relationship in community samples. Sahlan et al. (2020) is a notable exception; this study explored the network structure of disordered eating and depression in a sample of Iranian adolescents and college students. Desire to lose weight was identified as the most central symptom for male and female adolescents aged between 12 and 19 (an individual depression network was not estimated). When the authors mapped ED

and depression symptoms together, they found feeling like a failure to be a key bridging symptom. This suggests low self-esteem and low self-worth may play a role in connecting depression and ED in non-clinical samples of adolescents.

Understanding how symptoms of depression and EDs may interact in community adolescent populations is warranted given the average age of onset for EDs and depression occurs during this developmental stage (Mission Australia, 2017). It is suggested that the period between 13 and 18 years poses the highest risk of ED onset (The Butterfly Foundation for Eating Disorders, 2012) and that sub-clinical symptoms are a predictor of a later clinical diagnosis; this is true for EDs and depression (Kotler, Cohen, Davies, Pine, & Walsh, 2001; Neumark-Stzainer et al., 2006). The period between 11 and 13 coincides with the transition from primary school to secondary school in Australia; a time marked by considerable social and environmental change that may leave young adolescents at risk of experiencing mental ill-health (Vaz et al., 2014). Currently, there is limited research using network analysis to explore the relationship between depression and ED in community samples during this crucial developmental stage. As such, the current study sought to explore the network structure of depression and ED (individually and combined) among Australian adolescents commencing their first year of secondary school. In doing so, this study extends the work of Sahlan et al. (2020) by assessing depression and ED network separately and by focussing specifically on early adolescence (i.e., the transition from primary school to secondary school).

Specifically, the present study sought to:

1. Explore the network structure of depression in early adolescence;
2. Explore the network structure of ED in early adolescence;

3. Explore the network structure of a combined network of depression and ED symptoms in early adolescence;
4. Identify bridge symptoms and bridge pathways connecting depression and ED networks.

In accordance with the CBT, it is hypothesised that items pertaining to shape and weight dissatisfaction and overvaluation will emerge as central ED symptoms. Given the importance of peer acceptance during adolescence, and the findings of prior studies (e.g., Elliott et al., 2019; Sahlan et al., 2020), it is hypothesised that items pertaining to self-confidence and self-comparison (e.g., 'avoidance of exposure', 'social eating') will emerge as important bridging symptoms between depression and EDs.

## Method

### Participant recruitment

This study used data collected as part of the Supporting Healthy Image, Nutrition and Exercise (SHINE) study. SHINE is a cluster randomised trial designed to test the effectiveness of a web-based body image and weight management program for secondary school students. SHINE enrolled 4 421 students (Male = 1 882, Female = 2 070, non-disclosed gender = 469) from 37 schools across metropolitan Melbourne and regional Victoria attending their first year of secondary school. Schools were recruited from 21, of a possible 79, different local government areas. Participants were aged between 10 and 15 years ($M$ = 12.59 years, $SD$ = 0.39). All students who provided complete data for the depression ($N$ = 3247) and ED measures ($N$ = 3011) at baseline were included in the analysis. Baseline data was collected between February and July 2019.

**Measures**

**Depression symptoms.** The Centre for Epidemiological Depression Scale – 10 item version (CES-D R 10) (Andresen, Malmgren, Carter, & Patrick, 1994) is a 10-item depression screening tool. The CES-D R 10 uses a 4-point response format ranging from 0 = *none of the time (less than 1 day)* to 3 = *most or all of the time (5-7 days)* to assess depression symptoms over the past week. The total score ranges from 0 to 30 with higher scores indicating higher levels of depression. The CES-D was found to have excellent internal consistency (Cronbach's alpha > 0.85) in a community samples of adolescents (Chabrol, Montovany, Chouicha, & Duconge, 2002) and has been validated for use with adolescent populations in the United States (Radloff, 1991). In this this study, internal consistency was acceptable (Cronbach's alpha > 0.70).

**Eating disorder symptoms.** The Eating Disorder Examination-Questionnaire - Adolescent version (EDE-Q)(Carter, Stewart, & Fairburn, 2001; Fairburn & Beglin, 2008) is a 36-item self-report version of the Eating Disorder Examination. The EDE-Q provides two types of information: (1) data on the number of days with ED behaviours (i.e., objective bulimic episodes, self-induced vomiting, laxative misuse, diuretic use and exercise) over the past two weeks; and (2) items assessing the frequency and intensity of thoughts and behaviours pertaining to weight, shape and eating patterns over the past 14 days. The response options for these items are rated on a 7-point scale from 0 = *no days* (i.e., characteristic was not present) to 6 = *everyday* (characteristic was present every day). An average score ranging from 0 to 6 can be calculated for each participant with higher scores indicating higher levels of ED. The EDE-Q was considered to have acceptable internal consistency (Cronbach's alpha > 0.70) when used with community samples of adolescents (Mantilla, Birgegård, & Clinton, 2017). In this study, the internal consistency was excellent (Cronbach's alpha > 0.80).

Further, the EDE-Q has been found to be effective in distinguishing between individuals with an ED and those without in both male (Schaefer et al., 2018) and female populations (Aardoom, Dingemans, Slof Op't Landt, & Van Furth, 2012)

**Procedure**

Trained research assistants (RA) visited participating schools to administer an online questionnaire containing a battery of assessment measures (including the CES-D and EDE-Q). Students were asked to complete the online questionnaire independently during one school period. Opt out consent was obtained from all parents and students prior to the commencement of the SHINE study.

## Data Analysis

**Node selection**

A combination of theoretical and empirical approaches guided item selection. Individual items of the CES-D and continuous items of the EDE-Q were assessed for suitability. Fried and Cramer (2017) caution against including nodes that are highly correlated as they may measure the same underlying construct. The Goldbricker function was applied, with a threshold of 0.25 and minimum zero-order correlation set to 0.5, to identify nodes that are likely to measure the same underlying construct.

The decision to combine the shape and weight items or to keep them separate was considered (i.e., '*Has your weight affected how you judge yourself as a person?*'/ '*Has your shape affected how you judge yourself as a person?*' and '*How unhappy have you felt about your weight?'*/*'How unhappy have you felt about your shape?'*)(Fairburn & Beglin, 2008). Shape and weight can be deemed conceptually different; however, it is plausible young adolescents

do not differentiate between weight and shape. Further, several studies (e.g., DuBois et al., 2017; Forrest, Sarfan, Ortiz, Brown, & Smith, 2019) have combined shape and weight items when estimating ED networks. Given this, and guided by the principle of parsimony, the shape and weight items were combined and then averaged. The positively worded CES-D items were reversed-scored, as per manual instructions, so that higher scores represent less happiness/hopefulness (e.g., 3 = rarely, none of the time). These items will be referred to as (un)happy and (un)hopeful.

**Network estimation**

Gaussian Markov random field estimation using graphical LASSO and extended Bayesian information criteria (EBIC) was used for all networks (Epskamp & Fried, 2018). In this model, nodes represent symptoms and edges represent regularised partial correlations between nodes. Spearman correlations were used to estimate networks given they produce more stable networks when compared to polychromic correlations (Epskamp & Fried, 2018). The EBIC hyperparameter was set to 0.5. R package 'bootnet' (version 1.4.3) (Epskamp, 2020a) and 'qgraph' (version 1.6.9) (Epskamp, 2020b) were used for analysis.

**Centrality**

One-step expected Influence (EI) was used to assess centrality. EI is the summed weight of all edges extending from a given node (Robinaugh, Millner, & McNally, 2016). EI is considered to be an accurate measure of centrality as takes into account both positive and negative edges. Strength centrality is similar to EI as it assesses the total sum of all edges connected to a particular node but it does not account for positive and negative edges (McNally, 2016). Strength centrality indices for all three networks are provided in the

Supplementary material (Supplementary Fig S1, Supplementary Fig S5, Supplementary Fig S9 and Supplementary Fig S10).

**Bridge centrality**

Bridge EI was used to identify the most important bridging symptoms (Jones, Ma, & McNally, 2019). Bridge EI assesses a node's total connectivity with symptoms of other disorders in the network. EI and bridge EI were assessed using the R package 'networktools' (version 1.2.3) (Jones, 2020).

**Stability**

Robustness of network estimated parameters was assessed using (1) non-parametric bootstrapping for edge-weight accuracy, and (2) case-dropping subset bootstrapping for centrality stability (i.e., EI and bridge EI). Case-dropping subset bootstrapping yields correlation stability coefficients (CS-coefficient). CS-coefficients above 0.25 are considered minimally acceptable but a value of above 0.5 is desired (Epskamp, Borsboom, & Fried, 2018). Non-parametric bootstrapping and case-drop bootstrapping were both performed with 1000 bootstrap samples using the R package 'bootnet' (version 1.4.3) (Epskamp, 2020a). Bootstrap 95% confidence intervals for the difference between estimates of two edge-weights or two centrality indices (i.e., EI) (Epskamp et al., 2018) were used to test the null hypothesis.

## Results

**Descriptive statistics**

The Goldbricker test did not identify any redundant pairs. Frequency data for each these items is available in the supplementary material (Supplementary Table S1 and Table S2).

**Model 1. Network structure of depression symptoms in early adolescence**

The network structure of depression symptoms is displayed in Figure 1. Green edges represent positive edge-weights (i.e., a positive relationship between symptoms) and red edges represent negative edge-weights (i.e., negative relationship between symptoms). The largest edge-weights in the network were between '(un)hopeful' and '(un)happy' (part r = 0.28), 'depressed' and 'lonely' (part r = 0.26) and 'effortful' and '(un)hopeful' (part r = -0.25). The bootstrap difference test for edge-weights found these edges to be significantly different to the majority of edges in the network (see online Supplementary Fig S2). Estimated edge-weights and their bootstrapped confidence intervals (CI) are presented in the online Supplementary Fig S3. Standardised EI values are presented in Figure 2. 'Depressed' (EI = 1.07), 'lonely' (EI = 0.91) and 'low energy' (EI = 0.88) had the highest EI. 'Depressed' had a significantly higher EI than all other nodes in the network. 'Lonely' had a significantly higher EI than all other nodes except '(un)happy' and 'low energy'. 'Low energy' had a significantly higher EI than all other nodes expect 'irritable', '(un)happy' and 'lonely' (see online Supplementary Fig S4 for the results of the node EI difference test). EI is considered to be stable (CS coefficient = 0.75).

**Model 2. Network structure of ED symptoms in early adolescence**

The network structure of ED symptoms is displayed in Figure 3. All edge-weights were positive indicating a positive relationship between symptoms. The largest edge-weights in the network were between 'shape and weight dissatisfaction' and 'shape and weight overvaluation'(part r = 0.37) and 'preoccupation with food, eating and calories' and 'preoccupation with shape or weight' (part r = 0.30). These edges-weights were significantly higher than the majority of other edges in the network (see online Supplementary Fig S6). Estimated edge-weights and their bootstrapped CI are presented in the online Supplementary

Fig S7. Standardised EI values are presented in Figure 4. 'Shape and weight dissatisfaction' (EI = 1.32), 'desire to lose weight' (EI = 1.18) and 'preoccupation with shape or weight' (EI = 1.11) had the highest EI. 'Shape and weight dissatisfaction' was significantly different to all other nodes in the network. 'Desire to lose weight' was significantly different to all other nodes except 'preoccupation with shape or weight'. 'Preoccupation with shape or weight' was significantly different from all other nodes except 'fear of weight gain', 'desire to lose weight', 'shape and weight overvaluation' and 'discomfort seeing body' (see online Supplementary Fig S8 for the results of the node EI difference test). EI is considered to be stable (CS coefficient = 0.75).

**Model 3: A combined network of depression and ED symptoms in early adolescence**

The network structure of the combined depression and ED symptoms is displayed in Figure 5. The largest edge-weights in the network were between 'shape and weight dissatisfaction' and 'shape and weight overvaluation' (part r = 0.37), 'preoccupation with shape or weight' and 'preoccupation with food, eating and calories' (part r = 0.31) and 'discomfort seeing body' and 'avoidance of exposure' (part r = 0.28). These edges were significantly different to the majority of other edges in the network (see online Supplementary Fig S11). Estimated edge-weights and their bootstrapped confidence intervals (CI) are presented in online Supplementary Fig S12. Standardised EI values are presented in Figure 6. Shape and weight dissatisfaction' dissatisfaction' was significantly different to all other nodes in the network. 'Desire to lose weight' was significantly different from all other nodes except 'depressed', 'fear of weight gain', 'feelings of fatness', 'shape and weight overvaluation' and 'discomfort seeing body'. The results of the EI difference test can be found in the supplementary material (see online Supplementary Figure S13).

Bridge EI (BEI) was calculated to identify important symptoms connecting (i.e., bridging) depression and ED. Standardised BEI values are presented in Figure 7. 'Irritable'(BEI = 0.23), 'social eating' (BEI = 0.20) and 'depressed' (BEI = 0.18) had the highest BEI. 'Irritable' had a significantly different BEI than 32% of nodes. 'Social eating' had a significantly different BEI than 77% of nodes. 'Depressed' had a significantly different BEI than 32% of nodes. The results of the EI difference test can be found in the supplementary material (see online Supplementary Figure S14). The CS-coefficient for EI and Bridge EI were 0.75 and 0.75 respectively. 'Irritable' was most strongly associated with the ED symptoms 'social eating' (part r = 0.05), 'shape and weight overvaluation'(part r = 0.05) and 'secret eating'(part r = 0.03). 'Social eating' was most strongly associated with the depression symptoms 'irritable'(part r = 0.05), '(un)happy' (part r = 0.03) and 'low energy' (part r = 0.03) and 'depressed' was most strongly associated with the ED symptoms 'empty stomach' (part r = 0.05), 'avoidance of eating' (part r = 0.03) and 'binges' (part r = 0.03).

## Discussion

This study sought to assess the network structure of depression and ED in a community sample of adolescents and, in doing so extend on the work of Sahlan et al. (2020). Influential symptoms of adolescent depression and ED and key symptoms bridging depression and ED symptoms were identified. 'Depressed', 'lonely' and 'low energy' were identified as core symptoms of adolescent depression and the connection between 'depressed' and 'lonely' was considered to be particularly important. This supports previous research that identified loneliness and sadness to be central symptoms, and the edge-weight between these symptoms to be the largest, in depression networks using community samples of adolescents (Gijzen et al., 2020; Mullarkey et al., 2019).

Adolescents are particularly vulnerable to feelings of loneliness (Goosby, Bellatorre, Walsemann, & Cheadle, 2013). This developmental period is marked by considerable social and emotional change (Kaniušonytė, Truskauskaitė-Kunevičienė, Žukauskienė, & Crocetti, 2019). Individuals transition from primary to secondary school and they don't often make this transition with the same peers. At the same time, the focus of social interactions shifts from the family to peer groups with increased need to feel socially connected and accepted. During this period, adolescents are often striving to define their personal identity. This balance between connectedness and independence can be a difficult one to navigate (Kaniušonytė et al., 2019).

'Shape and weight dissatisfaction', 'desire to lose weight' and 'preoccupation with shape or weight' were identified as core ED symptoms. This partially supports the findings of Sahlan et al. (2020) who also found 'desire to lose weight' to be a central symptom. However, they did not identify 'preoccupation with shape or weight' as a central symptom instead identifying 'discomfort seeing body' as a central symptom. Our findings, and those of Sahlan et al. (2020), provide further evidence to support the importance of body image dissatisfaction and cognitions pertaining to physical appearance in the structure of ED. In support of Sahlan et al. (2020), this study did not find shape and weight overvaluation to be a central symptom. This does not support research using clinical samples that identified shape and weight overvaluation as a central symptom (DuBois et al., 2017; Forbush et al., 2016; Forrest et al., 2018; Wang et al., 2018) suggesting shape and weight overvaluation may be more important when assessing the structure of ED in clinical samples than community samples.

When symptoms of depression and ED were mapped together, 'irritable', 'depressed' and 'social eating' were identified as important bridging symptoms. 'Social eating' was most strongly associated with 'irritable', '(un)happy' and 'low energy'. This finding did not support Sahlan et al. (2020) who found 'feeling like a failure' to be the most important bridging symptom. However, our findings do support earlier work that found fear of social eating to be an important bridging symptom between EDs and social anxiety (Levinson et al., 2018) and between EDs and trait anxiety (Forrest et al., 2019). Fear of eating in public may stem from a fear of negative social evaluation pertaining to body image and eating behaviours. Fear of negative social evaluation may be particularly problematic during adolescence due to the increased value that adolescents place on peer acceptance and belonging (Kaniušonytė et al., 2019). This finding provides preliminary evidence to suggest fear of negative social evaluation may play a role in the relationship between depression and ED in samples of non-clinical adolescents, but additional research is needed to explore this further.

'Irritable' was also identified as an important symptom bridging depression and ED symptoms. 'Irritable' was most strongly associated with the ED symptoms 'social eating', 'shape and weight overvaluation' and 'secret eating'. This supports research that has found irritability to be an important symptom bridging EDs and post-traumatic stress disorder symptoms (Vanzhula, Calebs, Fewell, & Levinson, 2019). Additionally, this finding supports research that has identified irritability as an important symptom of depression among ED populations. Giovanni et al. (2011) found depression in ED outpatients to be characterised by irritable mood and suggested characteristics of depression may differ between participants with and without an ED diagnosis. Less is understood about how irritability may influence the relationship between depression and ED among non-clinical samples of adolescents.

Given the findings from this study, future research should focus on the role of irritability in the interplay between depression and ED.

'Depressed' was also identified as an important symptom bridging ED and depression. 'Depressed' was most strongly associated with the ED symptoms 'empty stomach' and 'avoidance of eating'. This provides support for the Sociocultural theory of ED development (Ata, Schaefer, & Thompson, 2015). According to this theory, internalisation of thin body ideals (e.g., desire for a flat stomach) increases body image dissatisfaction and increases the onset of negative affect and disordered eating behaviours (e.g., avoidance of eating).

It is important to note, with the exception of 'depressed', symptoms that were considered influential symptoms when ED and depression were mapped separately were not identified as important bridging symptoms. This supports prior evidence that has found nodes with the highest centrality indices do not necessarily have the highest bridge centrality indices (e.g., Elliott et al., 2019; Forrest et al., 2018; Forrest et al., 2019; Sahlan et al., 2020). As mentioned by Forrest et al. (2018), this is consistent with transdiagnostic models of psychopathology that posit risk, protective and maintenance factors operate across diagnostic boundaries (Dalgleish, Black, Johnston, & Bevan, 2020). In this way, 'social eating' and 'irritability' may represent shared risk and/or maintenance factors for the relationship between depression and EDs while 'shape and weight dissatisfaction', 'desire to lose weight' and 'preoccupation with shape or weight' may play an important role in maintaining EDs.

This study provides an important symptom-level conceptualisation of the relationship between depression and ED in adolescents. Given much of the prior work in this area has focused on clinical samples consisting predominately of females (Elliott et al., 2019;

Levinson et al., 2017; Smith et al., 2018) the large community sample of male and female adolescents is considered a key strength of this study. Additionally, the use of bridge EI allows a quantitative identification of symptoms bridging depression and ED symptoms. Further, this study uses data collected at the beginning of secondary school; a period marked by considerable social and environmental change. Adolescents entering secondary school in Australia are approximately 11 years to 13 years. This is a crucial pre-clinical developmental stage as it often precedes the onset of clinically significant mental disorders but represents the beginning of sub-clinical eating pathology and increased psychological distress. Consequently, understanding how symptoms of depression and ED interact at this point is important for the development of targeted prevention and early intervention programs.

This study is not without limitations. Firstly, data are cross-sectional and consequently insight into the temporal relationship between depression and ED cannot be ascertained. Further, data were self-reported and may be susceptible to social desirability responding. The limitations of network analysis described in previous studies (e.g., Fried & Cramer, 2017; Gijzen et al., 2020; Levinson et al., 2017; Robinaugh, Hoekstra, Toner, & Borsboom, 2019) also apply here. For example, findings are limited by the items/symptoms used to define EDs and depression. Further, it is possible closely related nodes (e.g., 'preoccupation with food, eating and calories' and 'preoccupation with shape or weight') may measure the same underlying construct. However, application of the Goldbricker function suggests all included items are conceptually distinct.

## Conclusion

This study provides valuable insight into the network structure of depression and ED. Evidence is provided to demonstrate the importance of loneliness and depressed mood as key

symptoms of adolescent depression. Findings further support the importance of body image dissatisfaction and cognitions pertaining to physical appearance in the structure of ED but suggest shape and weight overvaluation may be more important in clinical samples than non-clinical samples. 'Irritability', 'depressed' and 'social eating' are identified as important nodes bridging symptoms of depression and ED. Identification of these symptoms offers an important avenue for future research.

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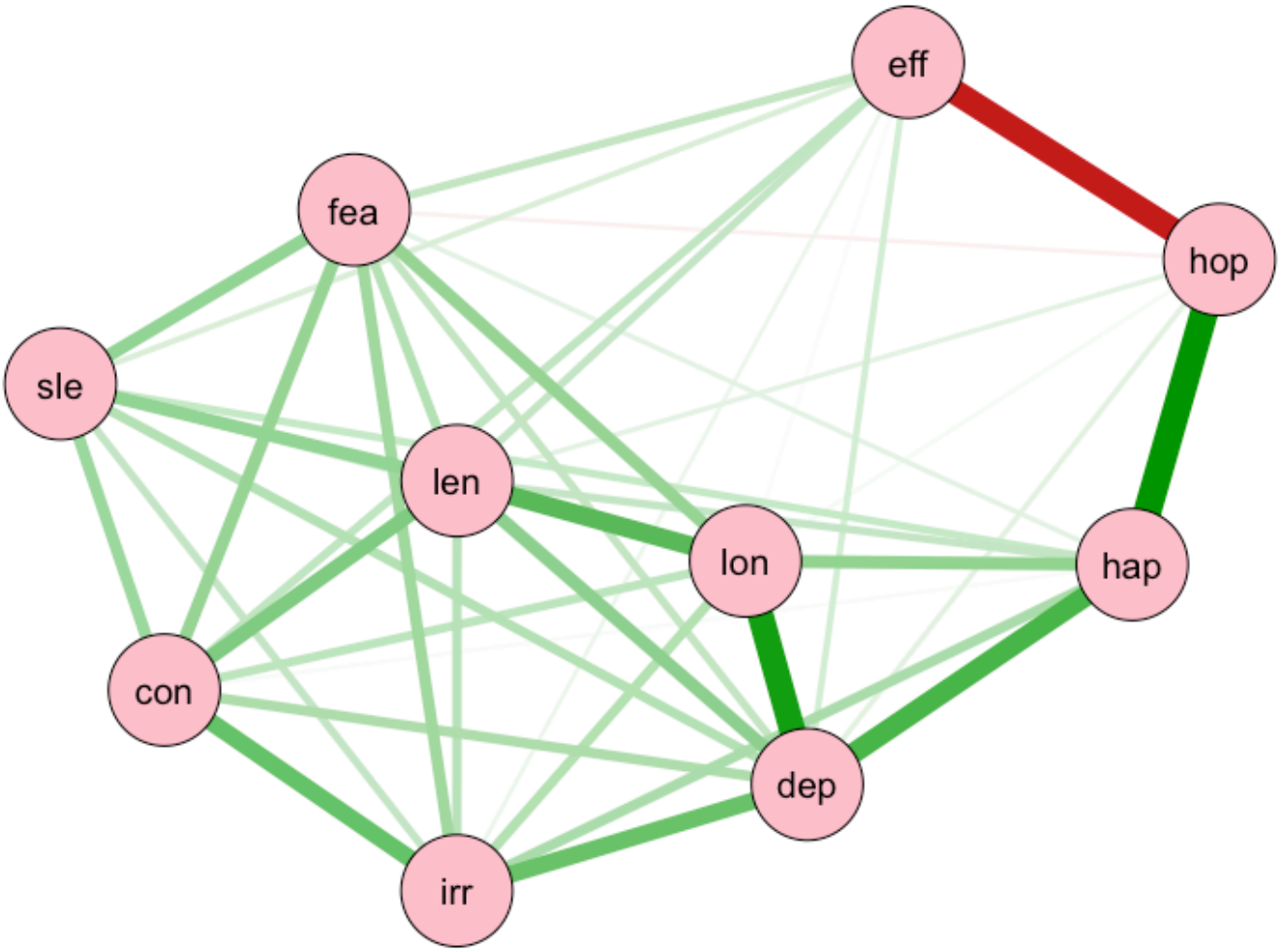


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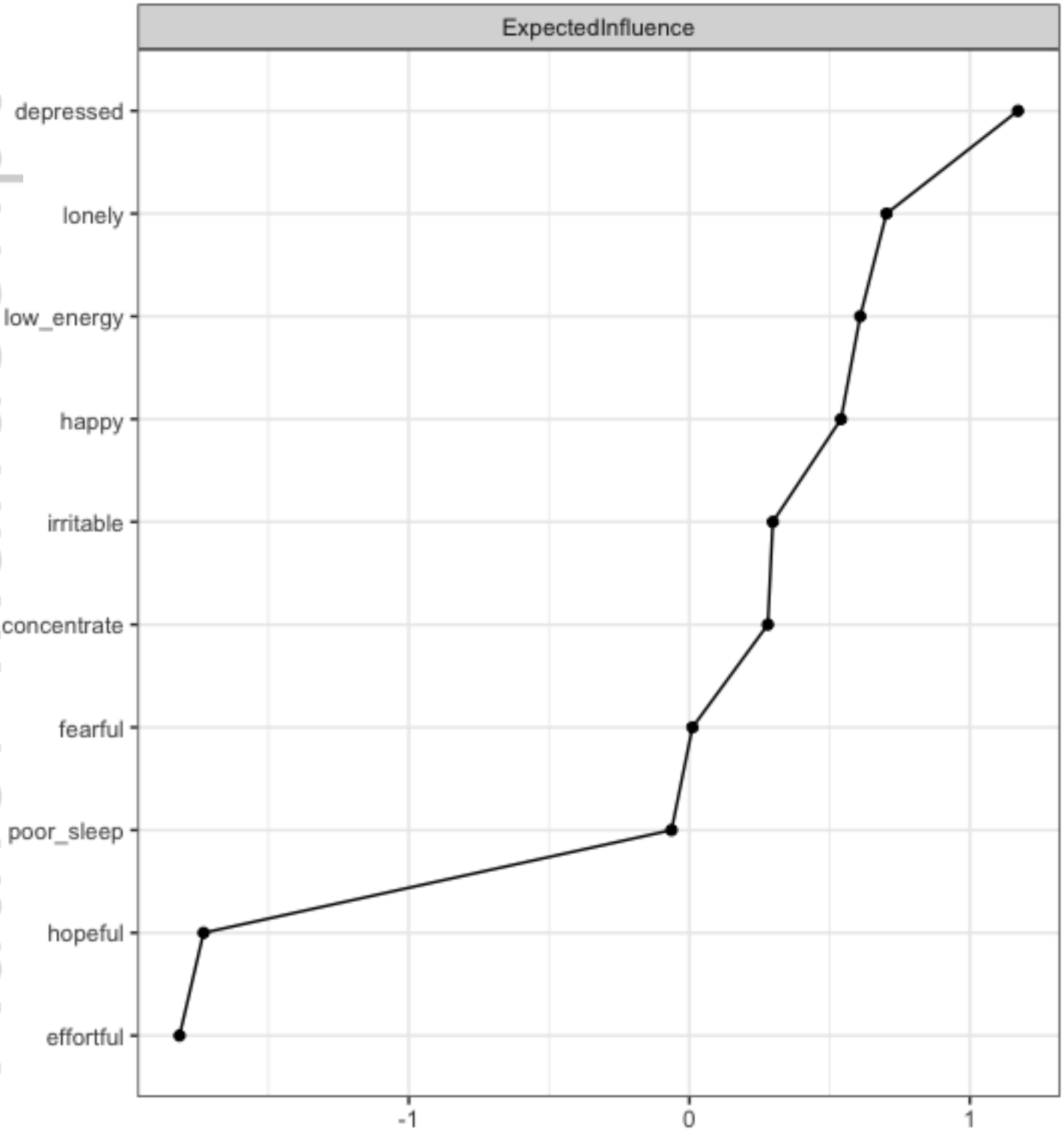


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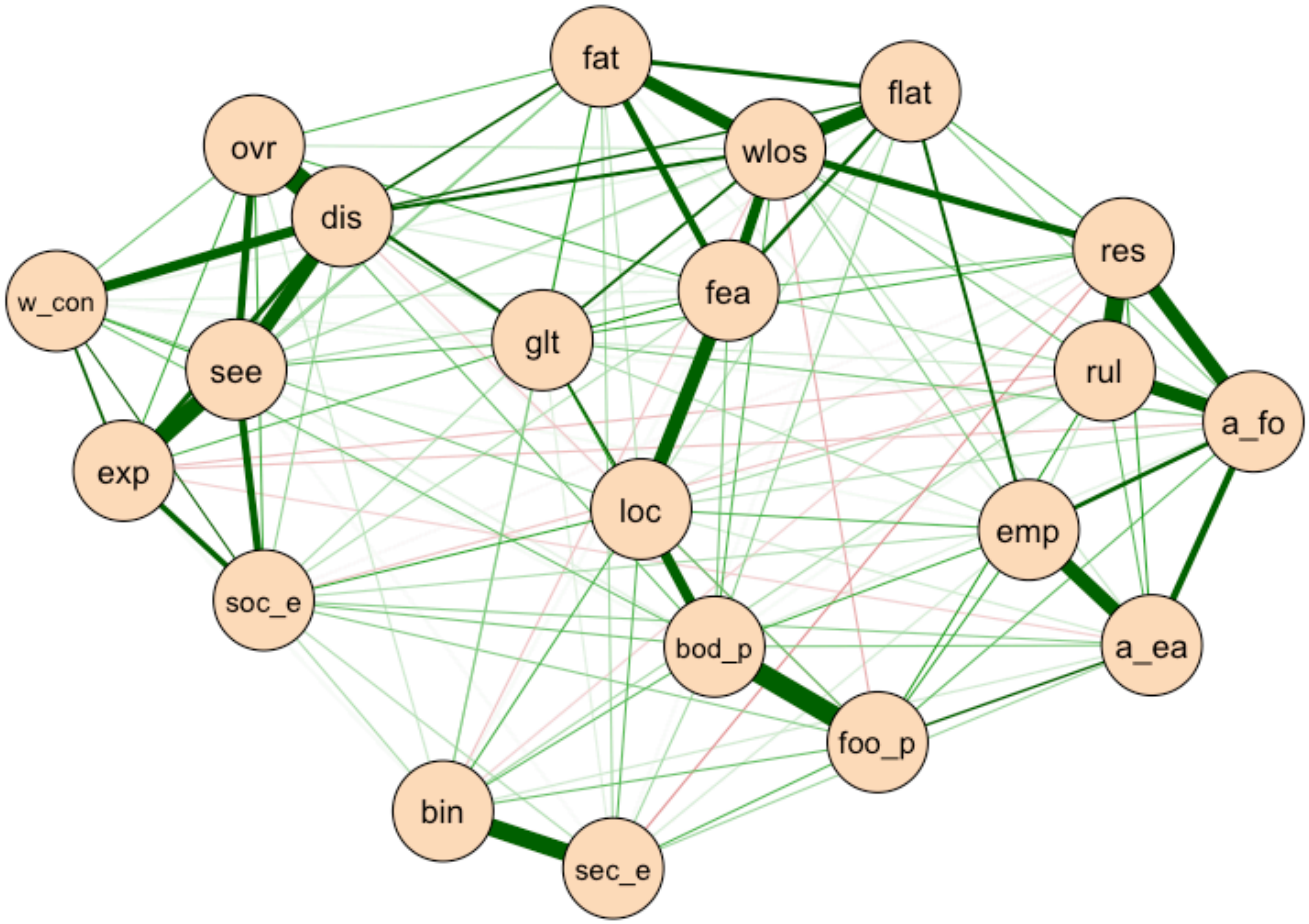


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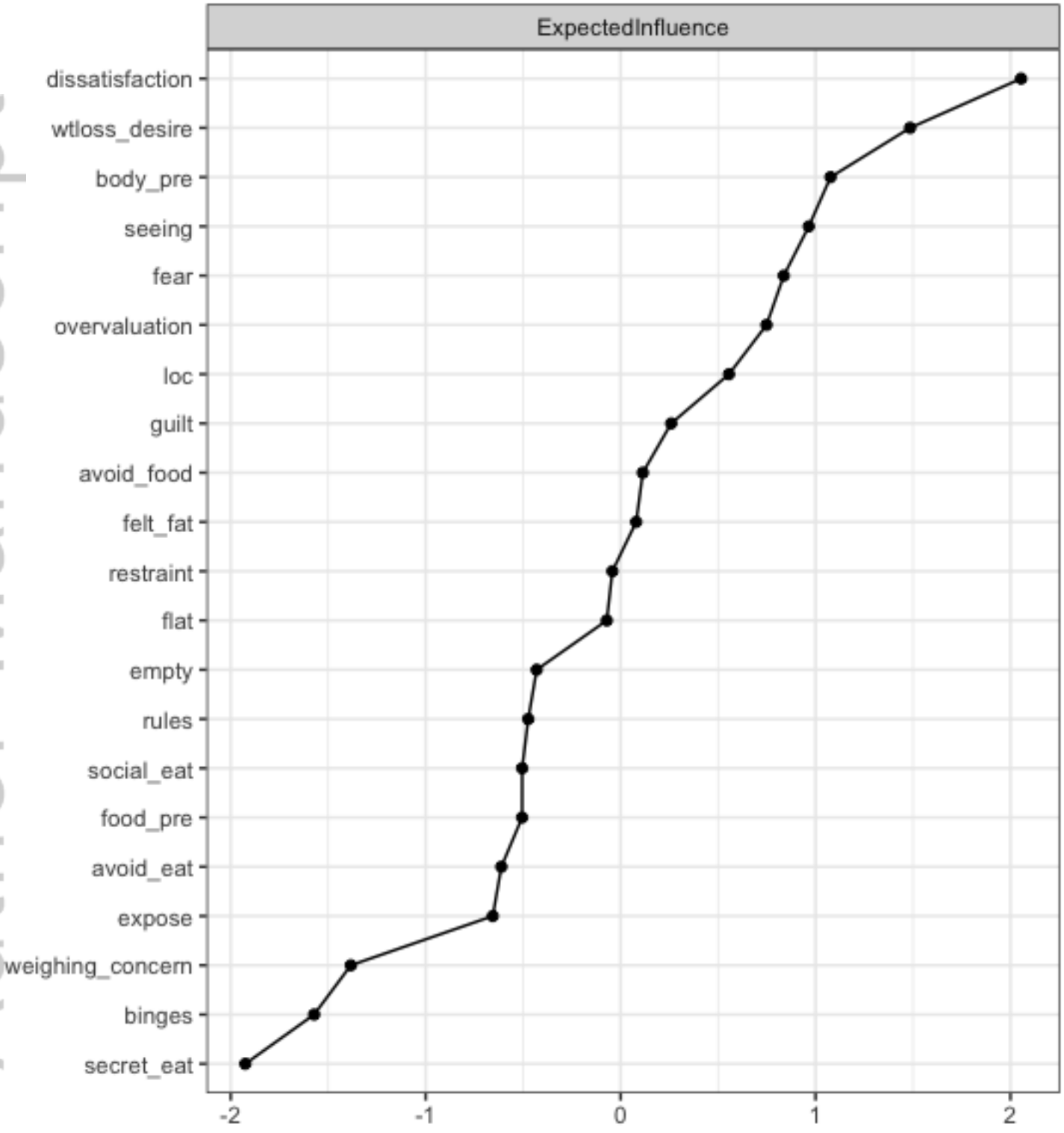


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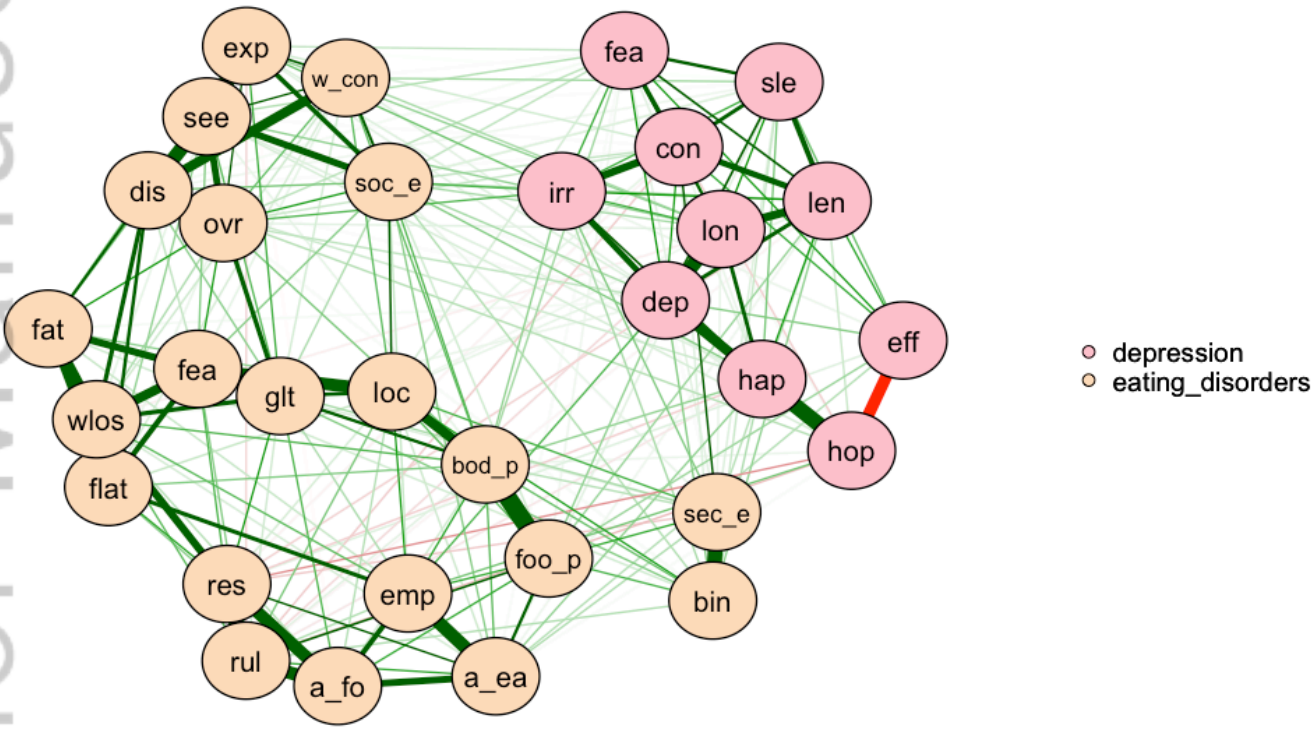


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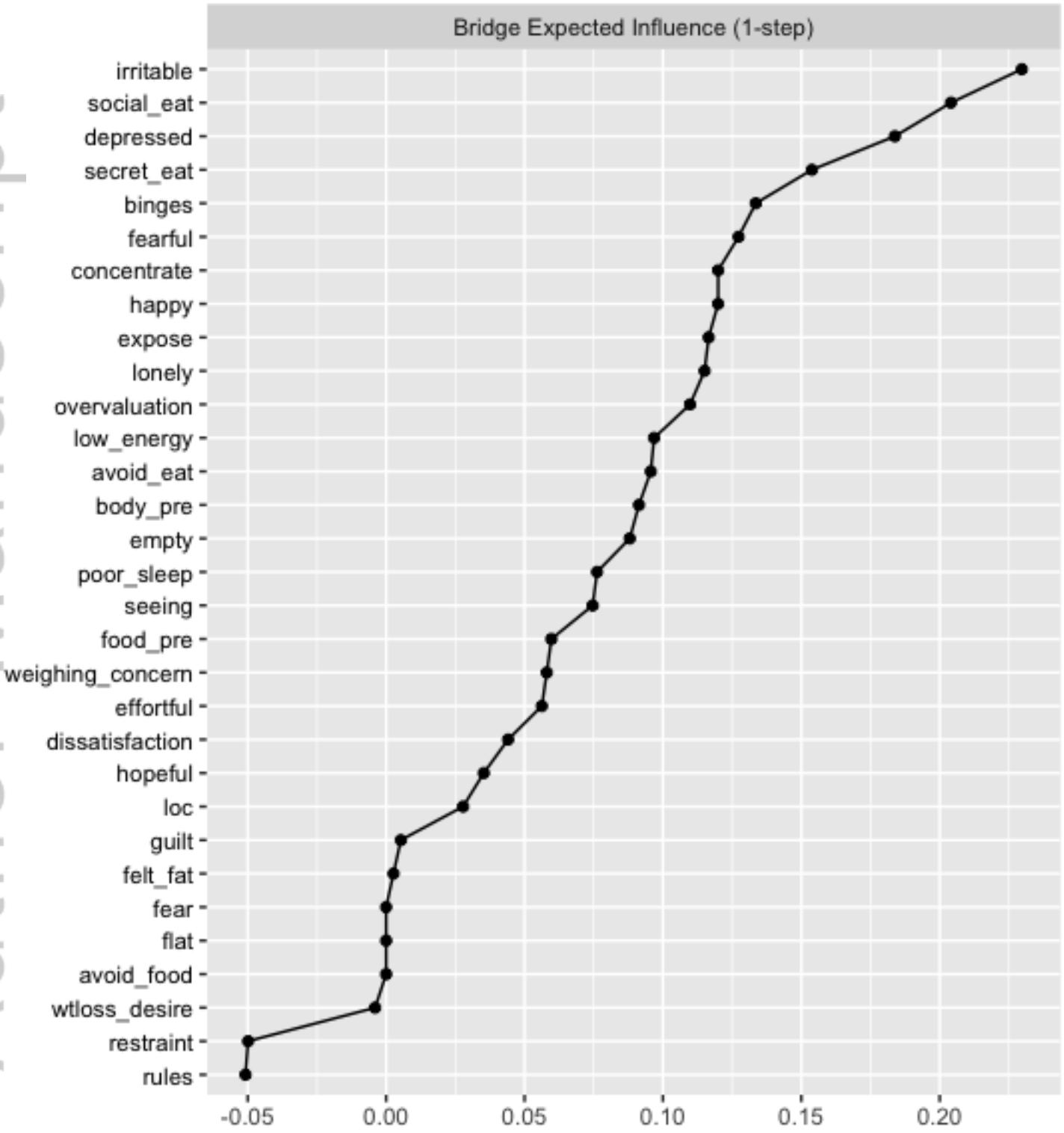


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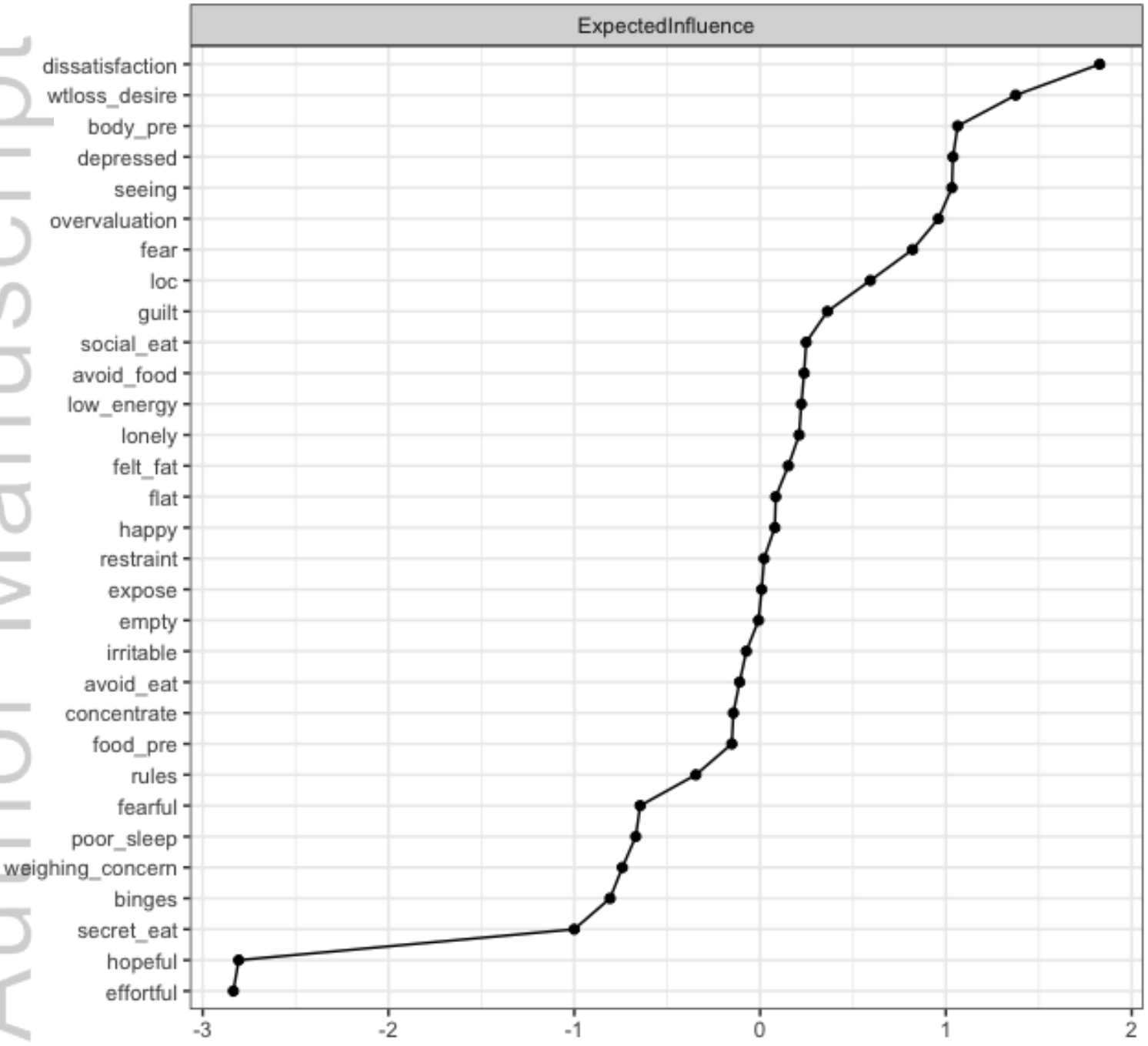


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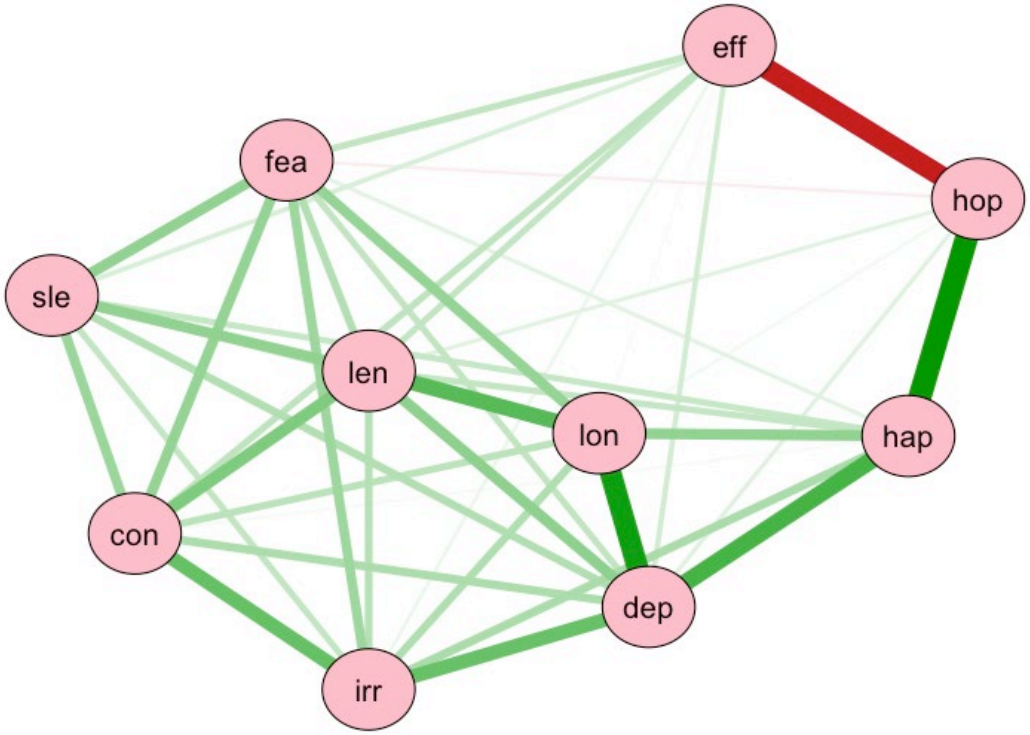
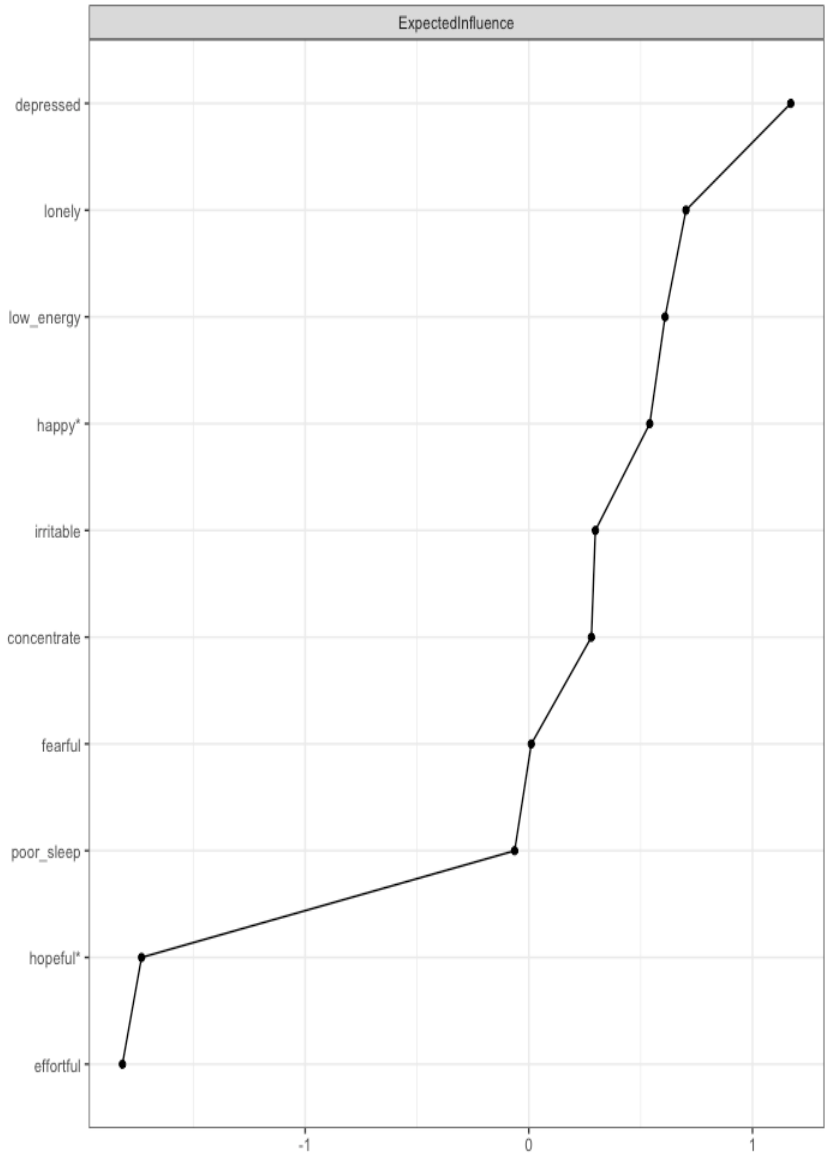
Figure 1. Depression network.



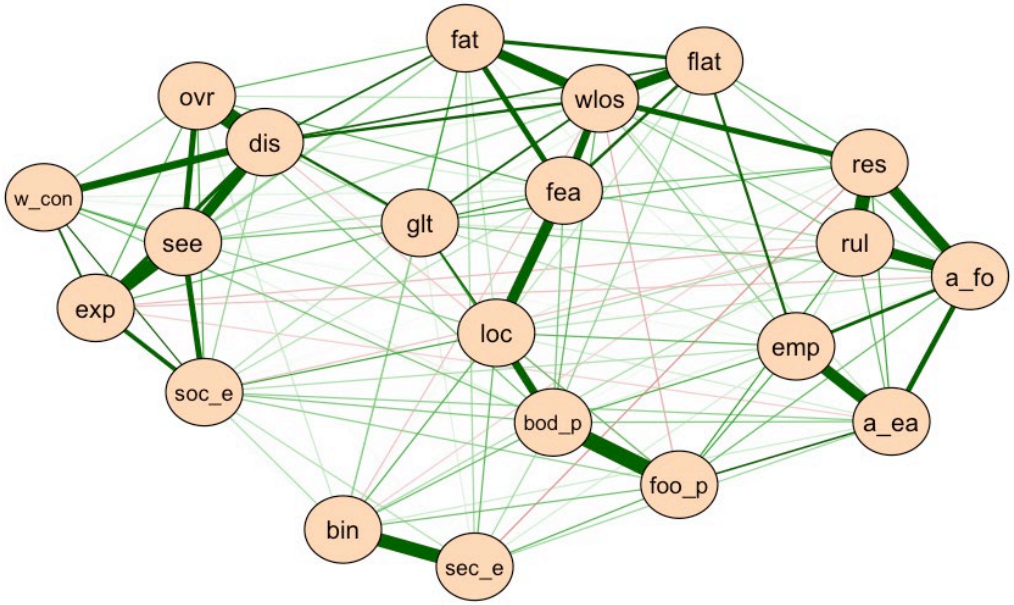

*Notes:* Nodes represent symptoms of depression and edges represent associations between nodes. Green edges represent positive associations and red edges represent negative associations. Thicker edges between nodes represent stronger associations. Depression label descriptions: irr = irritable, con = difficulty concentrating, dep = depressed, eff = effortful, hop= hopeful*, fea = fearful, sle= restless sleep, hap = happy*, lon = lonely, len= low energy.* = reverse-coded

Figure 2. Expected influence for the depression network.



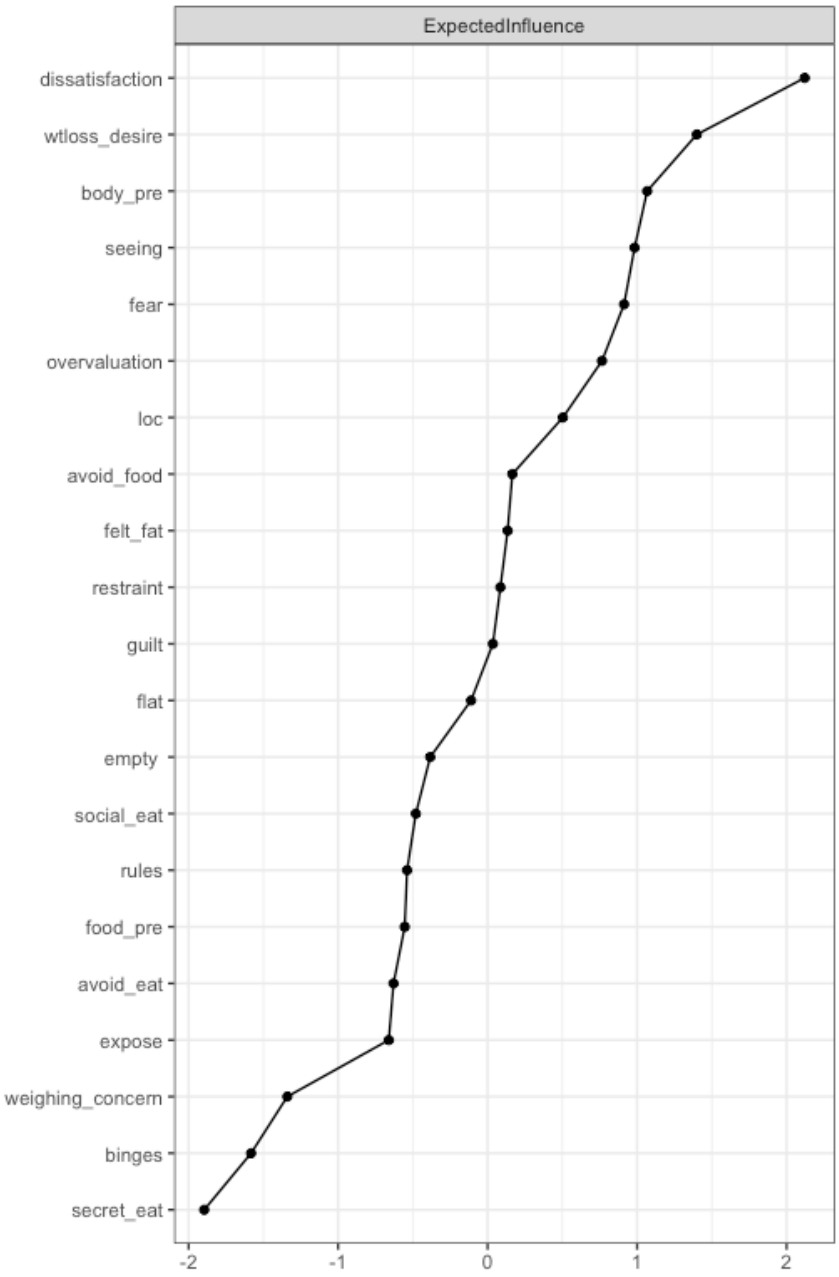

*Note:* Higher numbers indicate that the item is more central. Values shown on the horizontal-axis are z-scores. Items on the vertical-axis are ordered by EI value. Depression label descriptions: irritable = irritable, concentrate = difficulty concentrating, depressed = depressed, effortful = effortful, hopeful= hopeful*, fearful = fearful, poor_sleep = restless sleep, happy = happy*, lonely = lonely, low_energy = low energy.* = reverse-coded

Figure 3. Eating disorder network.




*Notes:* Nodes represent symptoms of ED and edges represent associations between nodes. Green edges represent positive associations and red edges represent negative associations. Thicker edges between nodes represent stronger associations. Eating disorder label descriptions: res = restraint over eating, a_ea = avoidance of eating, a_fo = food avoidance, rul = dietary rules, emp = empty stomach, foo_p = preoccupation with food, eating and calories, loc = fear of losing control over eating, bin = binges, sec_e = eating in secret, flat = flat stomach, bod_p = preoccupation with shape or weight, fea = fear of weight gain, fat = feelings of fatness, wlos = desire to lose weight, glt = guilt about eating, ovr = shape and weight overvaluation, w_con = reaction to prescribed weighing, dis = shape and weight dissatisfaction, soc_e = social eating, see = discomfort seeing body, exp= avoidance of exposure.

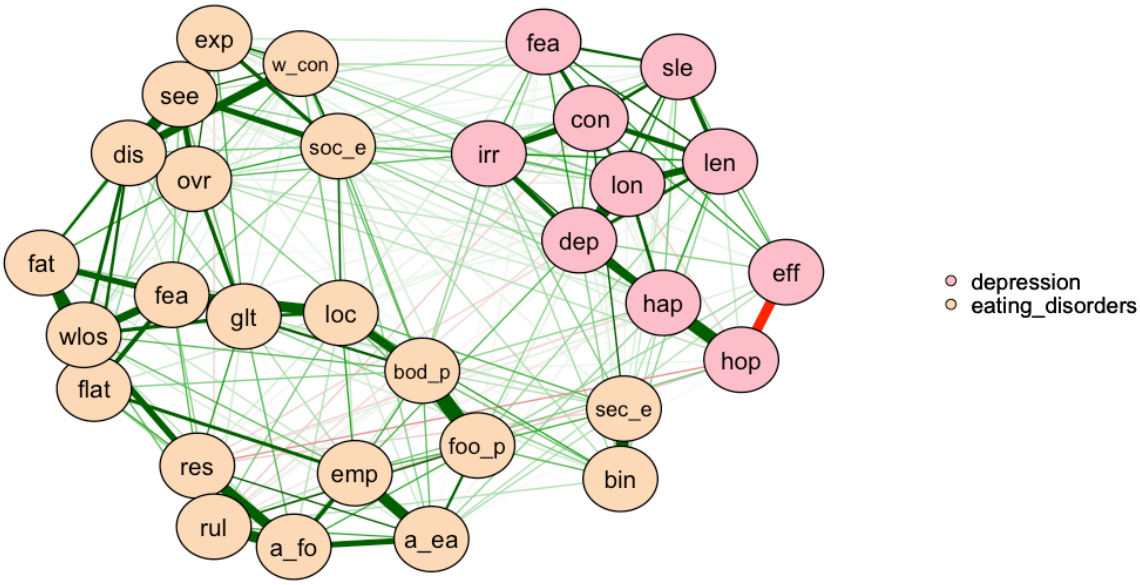
Figure 4. Expected influence for eating disorder network.




*Notes:* Higher numbers indicate that the item is more central. Values shown on the x-axis are z-scores. Values shown on the horizontal-axis are z-scores. Items on the vertical-axis are ordered by EI value. Eating disorder label descriptions: restraint = restraint over eating, avoid_eat = avoidance of eating, avoid_food = food avoidance, rules = dietary rules, empty= empty stomach, food_pre= preoccupation with food, eating and calories, loc = fear of losing control over eating, binges = binges, secret_eat = eating in secret, flat = flat stomach, body_pre = preoccupation with shape or weight, fear = fear of weight gain, felt_fat = feelings

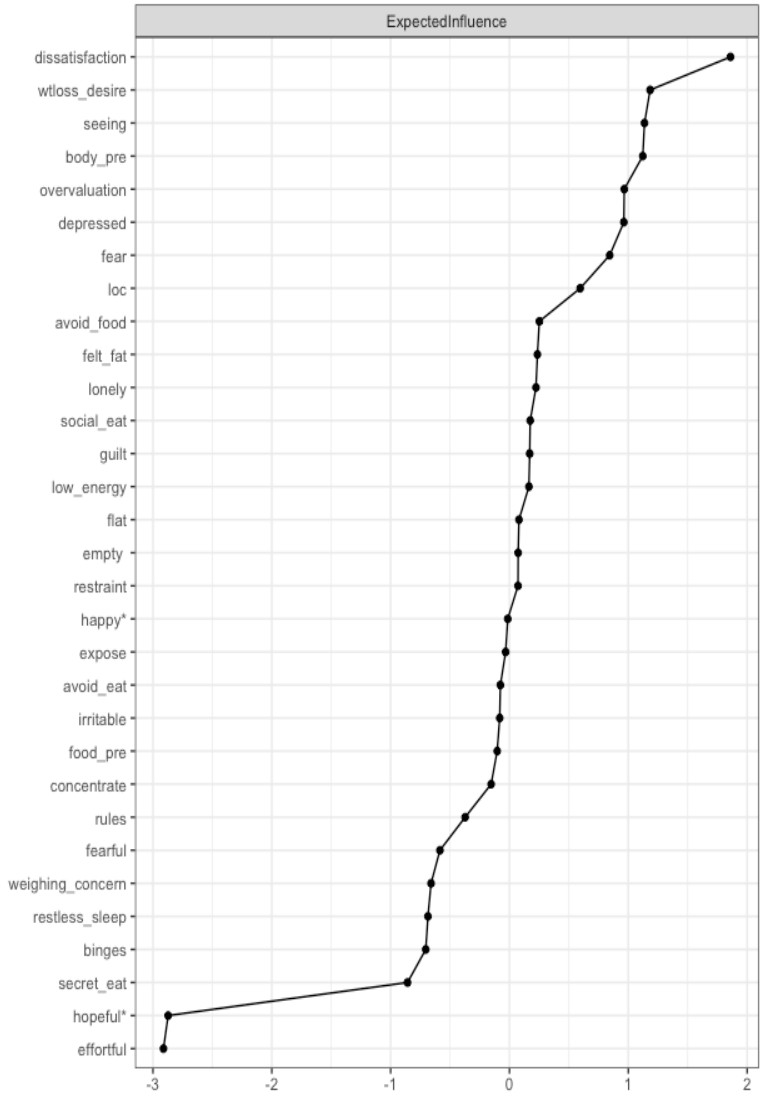
of fatness, wtloss_desire = desire to lose weight, guilt = guilt about eating, overvaluation = shape and weight overvaluation, weighing_concern = reaction to prescribed weighing, dissatisfaction= shape and weight dissatisfaction, social_eat = social eating, seeing = discomfort seeing body, expose = avoidance of exposure.

Figure 5. Network of depression and eating disorder symptoms combined




*Notes:* Nodes represent symptoms of depression and eating disorders and edges represent associations between nodes. Green edges represent positive associations and red edges represent negative associations. Thicker edges between nodes represent stronger associations. Absolute edge weights under 0.25 are not shown. Edges widths are scaled to 1. Depression label descriptions: irr = irritable, con = difficulty concentrating, dep = depressed, eff = effortful, hop= hopeful*, fea = fearful, sle= restless sleep, hap = happy*, lon = lonely, len= low energy.* = reverse-coded. Eating disorder label descriptions: res = restraint over eating, a_ea = avoidance of eating, a_fo = food avoidance, rul = dietary rules, emp = empty stomach, foo_p = preoccupation with food, eating and calories, loc = fear of losing control over eating, bin = binges, sec_e = eating in secret, flat = flat stomach, bod_p = preoccupation with shape or weight, fea = fear of weight gain, fat = feelings of fatness, wlos = desire to lose weight, glt = guilt about eating, ovr = shape and weight overvaluation, w_con = reaction to prescribed weighing, dis = shape and weight dissatisfaction, soc_e = social eating, see = discomfort seeing body, exp= avoidance of exposure.

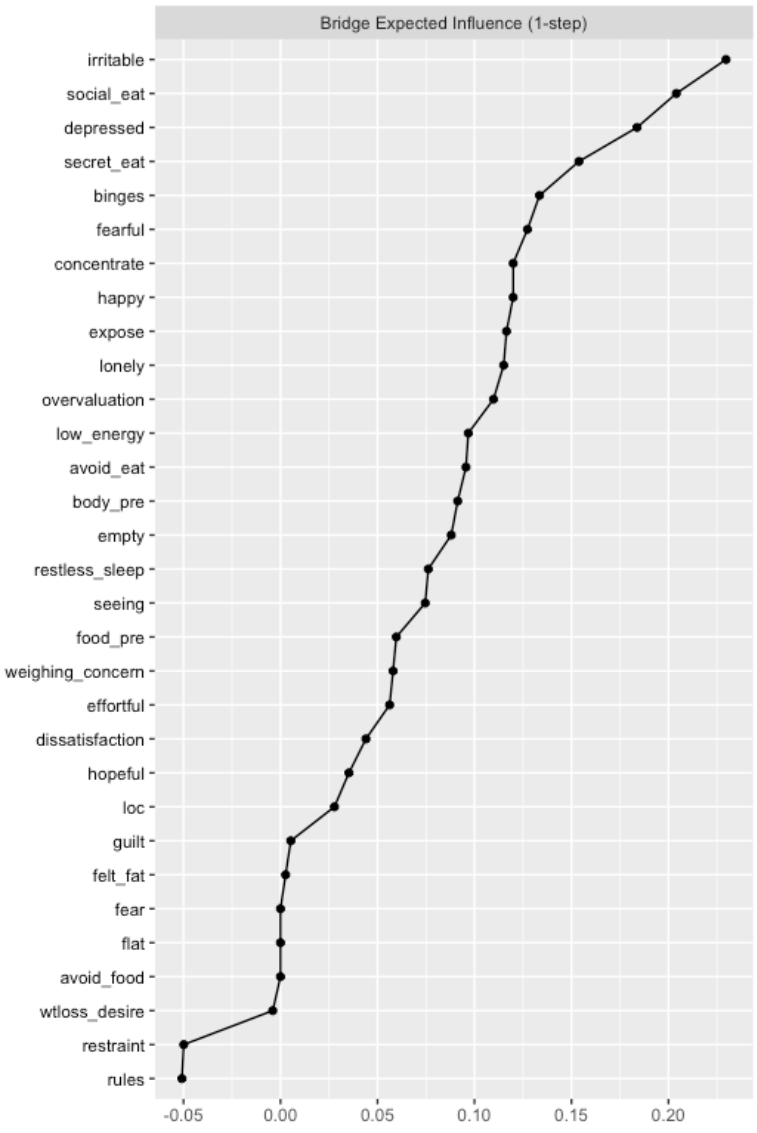
Figure 6. Expected influence for the combined depression and eating disorder network




*Notes:* Higher numbers indicate that the item is more central. Values shown on the horizontal-axis are z-scores. Items on the vertical axis are ordered by EI value. Depression label descriptions: irritable = irritable, concentrate = difficulty concentrating, depressed = depressed, effortful = effortful, hopeful= hopeful*, fearful = fearful, poor_sleep = restless sleep, happy = happy*, lonely = lonely, low_energy = low energy.* = reverse-coded. Eating disorder label descriptions: Eating disorder label descriptions: restraint = restraint over eating, avoid_eat = avoidance of eating, avoid_food = food avoidance, rules = dietary rules, empty= empty stomach, food_pre= preoccupation with food, eating and calories, loc = fear of losing control over eating, binges = binges, secret_eat = eating in secret, flat = flat stomach, body_pre = preoccupation with shape or weight, fear = fear of

weight gain, felt_fat = feelings of fatness, wtloss_desire = desire to lose weight, guilt = guilt about eating, overvaluation = shape and weight overvaluation, weighing_concern = reaction to prescribed weighing, dissatisfaction= shape and weight dissatisfaction, social_eat = social eating, seeing = discomfort seeing body, expose = avoidance of exposure.

Figure 7. Bridge expected influence for the combined network.




*Notes:* Higher numbers indicate that the item is more central. Values shown on the horizontal-axis are z-scores. Items on the vertical axis are ordered by EI value. Depression label descriptions: Depression label descriptions: irritable = irritable, concentrate = difficulty

concentrating, depressed = depressed, effortful = effortful, hopeful= hopeful*, fearful = fearful, poor_sleep = restless sleep, happy = happy*, lonely = lonely, low_energy = low energy.* = reverse-coded. Eating disorder label descriptions: restraint = restraint over eating, avoid_eat = avoidance of eating, avoid_food = food avoidance, rules = dietary rules, empty= empty stomach, food_pre= preoccupation with food, eating and calories, loc = fear of losing control over eating, binges = binges, secret_eat = eating in secret, flat = flat stomach, body_pre = preoccupation with shape or weight, fear = fear of weight gain, felt_fat = feelings of fatness, wtloss_desire = desire to lose weight, guilt = guilt about eating, overvaluation = shape and weight overvaluation, weighing_concern = reaction to prescribed weighing, dissatisfaction= shape and weight dissatisfaction, social_eat = social eating, seeing = discomfort seeing body, expose = avoidance of exposure.