The interaction between mentalizing, empathy and symptoms in people with Eating Disorders: a network analysis integrating experimentally induced and self-report measures.

Abstract

Background. The role of mentalizing and empathy in the socio-emotional processing deficits of Eating Disorder (ED) patients has been under investigated. We aimed to assess these psychological processes and their interplay with ED symptoms by means of the network analysis approach.

Methods. Seventy-seven women with EDs completed self-report questionnaires assessing ED, anxious and depressive symptoms, and underwent two computerized tasks; the *Movie for the Assessment of Social Cognition* (MASC), assessing emotional and non-emotional mental state inferences, and the *Empathic Accuracy Task-Revised* (EAT-R), measuring accuracy in identifying others' emotions and the extent to which those emotions are shared. A partial correlation network and bridge function analyses were computed.

Results. In the partial correlation network inference of cognitive mental states and shape concern were the nodes with the highest strength centrality. Inference of emotional mental states was the node with the highest bridge strength in the cluster of social cognition functions. Empathic and mentalizing abilities were directly connected with each other and with ED symptoms.

Conclusions. This is the first network analysis study which integrates self-reported symptoms and objective socio-cognitive performance in people with EDs. Results highlight the importance of mentalizing abilities in that they contribute to maintenance of ED psychopathology and to empathic ability.

Keywords

Network analysis; eating disorders; mentalization; empathy; social cognition; experimental psychopathology.

Introduction

Among the numerous factors which contribute to Eating Disorder (ED) development and maintenance, social difficulties seem to play a crucial role. For example, it has been demonstrated that despite some differences between people with Anorexia Nervosa (AN) and those with Bulimia Nervosa (BN), interpersonal sensitivity represents an important maintaining factor for ED psychopathology (Arcelus, Haslam, Farrow & Meyer, 2013). A meta-analysis by Caglar-Nazali et al. (2014) confirmed that people with EDs exhibit a number of social problems, which may stem from alexithymia (an inability to identify and describe one's own emotions), negative self-evaluations, impaired inference of others' mental states, impaired facial communication and perceived inferiority. More recently, a systematic review and meta-analysis demonstrated that EDs are associated with atypical processing of stimuli suggestive of negative social evaluation (Monteleone, Treasure, Kan, & Cardi, 2018). The importance of impaired socio-emotional processing in EDs has been further supported by evidence that self-reported avoidance of emotions and submissiveness behaviors predict therapeutic outcome in adults with AN (Oldershaw, Lavender & Schmidt, 2018).

Given the importance of social functioning in EDs, assessing the psychological mechanisms which contribute to social competence (and which may therefore impact on ED symptomatology) is a research priority. Mentalizing (also known as theory of mind) and empathy are two higher-order psychological constructs that play a crucial role in social functioning (Happé, Cook & Bird, 2017; Happé & Frith, 2014). The former is the ability to represent, and to accurately infer, the mental states that underlie social interaction (Conway, Catmur & Bird, 2019). Previously, it has been demonstrated that individuals, and clinical groups, may show differential ability to infer accurately mental states depending on whether emotion understanding is required (Oakley, Brewer, Bird & Catmur, 2016; Shah, Catmur & Bird, 2017). Only a few studies have investigated mentalizing in EDs, and fewer still using ecologically-valid tasks. These studies suggest that individuals with EDs are more impaired at inferring accurately those mental states requiring an understanding of

emotions than those which do not (Leppanen, Sedgewick, Treasure & Tchanturia, 2018; Russell, Schmidt, Doherty, Young & Tchanturia, 2009). The use of objective task overcomes the problems associated with the use of self-assessment instruments which may require an intact mentalizing ability to be completely accurate (Fonagy et al., 2016; Nosek, Hawkins & Frazier, 2011).

Empathy is a complex psychological construct which is defined in multiple different ways (Cuff, Brown, Taylor & Howat, 2016). Even though multiple definitions exist, it is largely accepted that empathy involves at least two separate processes (Bird & Viding, 2014; Coll et al., 2017): identifying the emotional state of the other (also known as *emotion recognition or identification*), and affect sharing (or *emotion contagion*), in which the emotional state of the other causes a matching emotional state in the self (De Vignemont & Singer, 2006). A recent meta-analysis (Kerr-Gaffney, Harrison & Tchanturia, 2019) revealed that individuals with AN exhibit lower levels of emotion recognition in comparison to healthy subjects (the same analysis was not conducted for individuals with BN due to a lack of studies), although this meta-analysis only included studies which used self-report measures of empathy.

To date, no study has investigated the relationships between impairments in mentalizing and empathy, assessed as multifaceted constructs, and core symptoms of EDs. In order to clarify the complex dynamics among these variables, a network analysis approach is used here (Borsboom, 2017). Network analysis reveals how many nodes in a network remain statistically associated while controlling for all other nodes (Borsboom & Cramer, 2013). This approach does not identify predictors and outcome a priori: this may be important when assessing the connections between social cognition and ED symptoms, given that social cognition impairment is thought to constitute a vicious circle with ED symptoms contributing to the maintenance of EDs (Treasure, Corfield, & Cardi, 2012; Treasure & Schmidt, 2013). Thus, we have not a priori hypothesis of specific pathways of influence on one or more dependent variables. These features may advise the employment of network analysis approach instead of other traditional statistical approaches (i.e. regression analyses). Borsboom (2017) described the *external field* of a network in which are placed

variables which are not part of the psychopathological network itself, but can interact with symptoms included in the network. Thus, network analysis makes it possible to integrate different levels of symptom explanations (Borsboom, 2017; Borsboom, Cramer & Kalis, 2019). In accordance with this approach, Levinson, Vanzhula, Brosio and Forbush (2018) recommended to build network models including different levels of analysis in order to improve knowledge of ED psychopathology. So far, no study has been conducted on EDs which include multiple units of analysis in a network. To the best of our knowledge, the only study to adopt this approach thus far has been conducted in social anxiety disorder (Heeren & McNally, 2016). Therefore, we aimed to identify the complex interactions between the sub-components of mentalizing and empathy and ED and affective symptomatology in people with EDs through a network analysis approach. Given the paucity of studies assessing these psychological variables in this clinical population, we had no a-priori hypotheses.

Methods

Procedure

Women aged between 16 and 65 years with a current diagnosis of ED (i.e. AN or BN) were recruited through social media (i.e. Twitter, Facebook, King's College London website and newsletter), advertisements in public places in south-east London and from the ED inpatient and outpatient units at South London and Maudsley NHS Hospital. Inclusion criteria included: (1) fluency in English language, (2) no visual or audio impairment not corrected through aids, (3) no lifetime diagnosis of psychosis, (4) consent to provide details from general practitioner. EC screened participants over the phone for eligibility employing the SCID screening module and the SCID-5 for Feeding and Eating Disorders. The screening also included questions regarding participant's current weight and height, medical diagnosis of an ED and lifetime medical diagnosis of a comorbid psychiatric disorder. Suicidal risk was assessed with the Mini International

Neuropsychiatric Interview (MINI) (Pettersson, Modin, Wahlström, Af Winklerfelt Hammarberg & Krakau, 2018).

This study received approval from the Research Ethics Committee of Fulham (REC approval number: 18/LO/0482). Participants provided written informed consent prior to completing the study and received monetary reimbursement for their participation (£10 voucher).

Psychological assessment

Participants completed self-report questionnaires and computerized tasks in one session, on the online platform Gorilla (<https://gorilla.sc/admin/home>).

Information about age, level of education, ethnicity, relationship status and household composition and employment status were collected through a socio-demographic questionnaire.

The Eating Disorders Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994) includes 36 items and evaluates ED psychopathology over the previous 28 days. Ratings are summarized into a total score and four sub-scales (i.e. restraint eating, eating concern, weight concern and shape concern). The Cronbach's alpha for the total score in this study was 0.91.

The Depression, Anxiety and Stress Scales (DASS) (Lovibond & Lovibond, 1995) was employed to assess symptoms of depression, anxiety and stress over the previous 7 days. This scale consists of 21 items with 3 subscales (depression, anxiety and stress). The Cronbach's alpha in this study for the total score was 0.964.

Computerized Tasks

The Movie for the Assessment of Social Cognition (MASC). The MASC (Dziobek et al., 2006; Brockmeyer, Pellegrino, Münch, Herzog, Dziobek & Friederich, 2016) includes a 15-min film clip describing a real-life scenario of social interactions between two men and two women. The actors engage in different types of social interaction, and experience different emotions, during the film. Participants answer 45 multiple choice questions at set points in the film clip testing their

understanding of the characters' mental states. Questions are designed to assess mental states which either do not (cognitive) or do (emotional) depend upon emotion understanding. Inaccurate answers ('errors') are used to calculate over-mentalising (over-interpretative mental states) and under-mentalising (insufficient reasoning about others' mental states). The MASC has been shown to be a highly sensitive measure for mindreading abilities, even in typical adults (Dziobek et al., 2006).

Empathic Accuracy Task- Revised (EAT-R). Empathy was assessed using the EAT-R (Coll et al., 2017) a revised version of the Empathy Accuracy Task (Ickes, Stinson, Bissonnette & Garcia, 1990). In this task participants ('Empathizers') watch video-recorded interviews in which individuals ('Targets') describe a time in which they experienced a strong emotion (i.e. an experience eliciting fear, anger, sadness, disgust, happiness or fun). As they recount their experience, Targets record their emotional state. Empathizers watch the video-recorded interviews (total duration of approximately 30 minutes) and provide two ratings; how they think the Target feels and how they feel in response. The correspondence between each Target's report of their emotion and Empathizers' judgement of the Targets' emotion provides a measure of emotion identification - how good Empathizers are at determining Targets' emotional state. The correspondence between the emotion attributed to the Target by the Empathizer and the emotion the Empathizer felt in response provides a measure of affect sharing – the degree to which Empathizers' judgement of Targets' emotion causing them to share that emotion.

Statistical Analyses

One-way ANOVA followed by post-hoc Tukey's tests were used to compare clinical, socio-demographical and behavioral measures between each ED subgroup (AN-restricting group; AN-purging group and BN group). The prevalence of categorical variables in each ED subgroup was compared using Chi-square tests. Statistical analyses were conducted using the Statistical Package for Social Science, Version 25 (IBM-SPSS Statistics 25).

Network Analyses

In accordance with Epskamp, Cramer, Waldorp, Schmittmann and Borsboom (2012), network analysis was performed using R, version 3.4.4, using *qgraph* package. First, we estimated a *partial-correlation* network. The partial-correlation network shows correlations between pairs of nodes after adjusting for the influence of all other variables in the network (Epskamp & Fried, 2018). A network is composed of *nodes*, which represent variables, connected by *edges*. To address the issue of spurious connections and retain only meaningful associations, we applied a ‘least absolute shrinkage and selection operator’ (LASSO) regularization (Friedman, Hastie & Tibshirani, 2014), that shrinks small partial correlations, setting them to zero, so only the most robust partial correlations remain visible (McNally, 2016). The Extended Bayesian Information Criterion (EBIC) (Chen & Chen, 2008), a parameter that sets the degree of regularization/penalty applied to sparse correlations, was set to 0.5 in this analysis.

The *centralityPlot* function in *qgraph* was used to calculate indices of centrality (strength, closeness and betweenness). In addition, we tested whether the centrality of nodes significantly differed from one-another through the bootstrapped centrality difference test.

In order to assess the internal reliability of the network, following the Epskamp, Borsboom and Fried recommendations (2018), first we calculated the Correlation Stability (CS) coefficient, which is the maximum proportion of the population that can be dropped so that the correlation between the re-calculated indices of the obtained networks and those of the original network is at least 0.7. It has been recommended that the minimum cut-off to consider the network as stable is 0.25 (Epskamp et al., 2018). Then we estimated the accuracy of edge-weights by drawing bootstrapped confidence intervals calculated using nonparametric bootstrapping ($n_{\text{boots}} = 2500$). Network stability analyses were performed using the *bootnet* package (Epskamp, Maris, Waldorp & Borsboom, 2016).

Finally, given that correlations between MASC nodes may artificially inflate centrality, we applied the bridge function of the *networktools* package (Jones, 2017) in order to identify bridge

symptoms between a cluster including all socio-cognitive metrics and a cluster including ED and affective symptoms. Given this study aim, we defined *a-priori* symptoms clusters. By calculating the bridge strength, we identified which symptom was most strongly connected to all social cognition functions, and viceversa. Bridge strength is the sum of the absolute value of all edges that exist between a node and all nodes that are not in the same cluster (Jones, Ma & McNally, 2019).

Results

Patient Characteristics

Seventy-seven female patients were included into the study. 42 (54.5%) of them met the diagnostic criteria for acute AN-restricting subtype, 18 (23.4%) met the criteria for acute AN-purging subtype and 17 met the criteria for BN (22.1%).

Clinical characteristics of the study participants distinguished by their ED diagnosis are reported in Table 1.

The three groups (AN-restricting subtype, AN-purging subtype, BN) showed no differences in the mean scores of both self-report and behavioral (MASC and EAT sub-scores) measures included in our network analyses (Table 1), with the exception of the EDE-Q eating concern score which was higher in the group with BN than in AN-restricting subtype ($F = 3.98$; $p = 0.03$). However, this group difference was no longer significant after Bonferroni correction for multiple comparisons was applied. No differences were detected among groups regarding mean age, age at ED onset, illness duration, years of education and months of unemployment. As expected, BMI was significantly lower in the AN-restricting and AN-purging groups in comparison to the BN group ($F = 12.69$; $p < 0.01$).

The three study groups did not show differences in the prevalence of current anxious, depressive or obsessive-compulsive disorders (Table 1). There were also no significant differences in the proportion of participants taking psychotropic medication at the time of assessment among

the three study groups. However, although this finding was confirmed in relation to anti-depressant drugs (Chi-square = 3.3; $p = 0.19$), the use of antipsychotic medication was more frequent in people with AN-purging type in comparison to the other two groups (Chi-square = 8.01; $p = 0.02$).

Overall, the three study groups did not differ significantly in almost all clinical and demographical characteristics, and were therefore considered a unitary ED sample in our network analyses.

Partial Correlation network

The network structure is reported in Figure 1. Blue lines indicate positive correlations while negative correlations are represented in orange.

The centrality stability coefficient of the network was < 0.25 for betweenness, < 0.25 for closeness, and 0.325 for strength. Thus, strength was the centrality index with the highest stability, and this parameter exceeded the criteria (>0.25) suggesting adequate accuracy and reproducibility of the network (Epskamp et al., 2018). The plot of strength centrality index of the variables included in the network is represented in Figure 2. The accuracy of the strength centrality index is shown in Supplementary Figure 1.

The node strength was highest for MASC under-mentalizing ($M = 1.63$), MASC over-mentalizing ($M = 1.47$), MASC cognitive mental state inference ($M = 1.34$) and EDE-Q shape concern ($M = 1.21$). Thus, these variables were most strongly (directly) connected to other nodes in the network. However, the strength centrality difference test showed that MASC cognitive mental state inference and EDE-Q shape concern were the nodes that most significantly differed from the other nodes included in the network.

The strongest correlations among MASC and psychopathological symptoms were the negative correlation between MASC emotion and EDE-Q shape concern (indicating that more accuracy on mental state inference requiring emotional understanding was associated with lower ED symptoms with respect to shape concern) and the positive correlation between MASC over-

mentalization and DASS anxiety (indicating that greater anxiety was associated with more over-mentalizing errors). The most robust association between EAT-R components and clinical symptoms was the negative relationship between EAT-R emotion identification and EDE-Q eating concern (indicating that individuals with more severe eating concern ED symptoms had worse emotion identification). Finally, the strongest connections between the MASC and the EAT-R nodes were the positive correlation between MASC cognition and EAT-R affect sharing, (indicating that better comprehension of others mental states based on cognitive understanding is associated with greater ability to share affect) and the negative correlation between MASC under-mentalization and EAT-R emotion identification (indicating that individuals who are more likely to under-mentalize are less accurate at identifying another's emotion). The bootstrapped confidence intervals (CI) of estimated edge-weights are reported in Supplementary Figure 2. The edge-weight bootstrapped CIs display the accuracy of edge-weight estimates and allow to compare edges to one-another (Epskamp et al., 2018). Thus, Supplementary Figure 2 reveals that many edge-weights, including those of the above-mentioned connections, are not including the zero although they likely do not significantly differ from one-another.

Bridge function

In the community of eating related and affective symptoms the node with the highest bridge strength was EDE-Q Restraint ($M = 0.31$), while in the community of social cognition functions MASC Emotion ($M = 0.29$) was the node with the highest bridge strength. It means that EDE-Q Restraint was the symptom most connected to nodes of social cognition and, viceversa, MASC Emotion was the social cognition node most connected to symptoms.

Discussion

The main objective of this study was to evaluate the complex interactions between objective measures of mentalizing and empathy and ED symptomatology through a network analysis

approach. In the present study we included, for the first time, data from multiple levels of analysis (i.e. objective measures of socio-emotional ability and clinical traits) and the resulting network was sufficiently stable and reproducible for analysis. The results show that cognitive mental state inference and shape concern were the nodes with the highest centrality in the network. The network structure also revealed direct connections between symptoms and both empathy and mentalizing with specific connections between the sub-components of these two psychological constructs. In addition, we computed bridge function analysis and found that emotional state inference and restraint eating were the nodes with the highest bridge strength.

This is the first study employing the MASC and EAT tasks in people with AN and BN. ED diagnostic groups showed no differences in the mean scores of both behavioral measures. Although larger samples are recommended to confirm our findings, they point to experimentally assessed social cognition as a transdiagnostic function in people with EDs.

So far, only one study has employed the MASC task in adults with AN (Brockmeyer et al., 2016) and found that, compared to a healthy control group, individuals with AN have difficulties in inferring the emotional mental states of the others. A previous meta-analysis showing that people with EDs have more difficulties than typical individuals in recognizing the mental states of the others (Caglar-Nazali et al., 2014) primarily reported data using the *Reading the Mind in the Eyes* task (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001), which has been shown to be a test of emotion recognition rather than mentalizing (Oakley et al., 2016). Regardless of the relative performance on individuals with EDs relative to controls, the current results point to the high importance of both types of mentalizing abilities (emotion- and cognitive-mental state inference). Indeed, according to the results of the centrality difference test, the ability to infer cognitive states of the others was the node with the highest strength in our network together with shape concern. High centrality indicates that these are the nodes most directly connected to the other nodes in the network (Epskamp et al., 2018). However, it is not possible to rule out that these findings are at least partially biased by the connections existing among the MASC nodes. Thus, we also conducted

bridge function analysis and found that the inference of mental states depending on emotion understanding, among the different components of social cognitive functioning, is the node most connected to the symptoms. This finding supports previous meta-analytic evidence of difficulties in emotional theory of mind in people with EDs relative to healthy individuals (Leppanen et al., 2018). Taken together, network and bridge analyses allow us to confirm that the ability to infer others' mental state may represent a useful target for clinical intervention, in accordance with network theory (Borsboom, 2017). This is also in line with the treatment predictive value of mentalizing impairments recently seen in both people with AN and those with BN (Kuipers, Hollander, den van der Ark & Bekker, 2017; Kuipers, van Loenhout, van der Ark & Bekker, 2018).

The network analysis also highlighted the connectivity between mentalizing and empathy. In particular, the inability to consider complex models of the other's mind (*under-mentalization*) seems to be connected with the ability to identify emotional states. On the other hand, the production of mental representations without appropriate evidence to support them (*over-mentalization*) is connected with a reduced ability to share another's emotion. In addition, the network also demonstrates direct connections of the mentalizing and empathy nodes with psychopathological symptoms. The connection between mentalizing ability, ED core symptoms (shape concern) and anxious symptoms is novel in the literature; previous studies did not identify significant association between mentalizing impairment, assessed by means of self-report questionnaires, and ED symptoms (Jewell et al., 2016; Kuipers, van Loenhout, van der Ark & Bekker, 2016). It is interesting to note that Kuipers et al. (2016) suggested the lack of evaluation of different facets of mentalizing may have significantly contributed to the observed lack of association between the global capacity to mentalize and ED symptoms. Thus, the use of the MASC in our study may have allowed us to overcome limitations of previous studies, allowing the connection between impaired social cognition and ED and anxious symptoms to be revealed. Similarly, the connection between empathy and ED symptoms is novel; in fact, two previous studies did not find significant relationships between ED symptoms and (self-reported rather than

objectively measured) empathy (Baron-Cohen, Jaffa, Davies, Auyeung, Allison & Wheelwright, 2013; Calderoni et al., 2013). Furthermore, we observed that the social cognition nodes are directly connected to ED core symptoms as well as to anxious and depression symptoms. Although anxious and depression symptoms have been revealed to play a crucial role in the ED psychopathology in previous network studies (Elliott, Jones & Schmidt, 2018; Monteleone et al., 2019; Solmi, Collantoni, Meneguzzo, Degortes, Tenconi & Favaro, 2018), present findings seem to rule out that internalizing symptoms are included in the connection between psycho-social functioning and ED core symptoms. Moreover, in the symptoms cluster, restraint eating was the node with the highest bridge strength, thus indicating that ED core symptoms, more than affective symptoms, are associated with empathy and mentalizing abilities. Regarding the direction of the effects between social cognition and symptoms nodes, the cross-sectional nature of our data does not clarify the possible bidirectional influence between social cognition and symptoms hypothesized in EDs (Treasure et al., 2012; Treasure & Schimdt, 2013). In line with literature, both mentalizing measures and eating symptoms (shape concern) are included among the most central nodes in our network.

These findings should be considered in the light of some significant limitations. First, the cross-sectional design does not allow any conclusions regarding the direction of causality between symptoms and social cognition impairments. Second, the size of our sample, although similar to that of another study including multilevel data in a network analysis (Heeren & McNally, 2016), does not allow analyses to be performed in each separate ED subgroup (i.e AN-restricting type, AN-purging type and BN groups), and is relatively under-powered for network analyses. This may affect the reproducibility of the network; in fact, although they are not essential parameters for clinical networks (McNally, 2016), closeness and betweenness indices were not enough stable. Third, the lack of a control group prevents the possibility to infer if observed relationships are specific to ED patients. In contrast, the main strength is that this study is the first to employ the network analysis approach including data from multiple levels of analysis in EDs. In addition, the

use of behavioral tasks to assess mentalizing and empathy provides a more reliable evaluation of these social processes than that obtained through self-report instruments (Roefs et al., 2011). Finally, the tasks employed are characterized by high ecological validity and allow multiple constituent components of mentalizing and empathy to be assessed.

To conclude, results provide evidence of the complex interactions between mentalizing, empathy and psychopathological symptoms in people with EDs. Results also suggest that mentalizing processes play a central role in the ED psychopathology and are connected with specific aspects of empathy and with ED symptoms. According to network theory, future studies should allow to clarify if manipulation of central nodes promotes a cascade of downstream benefits (Borsboom, 2017). If this the case, the present findings may support previous studies (Kuipers et al., 2017) suggesting mentalizing as an important therapeutic target in EDs, as well as treatments targeting social cognition difficulties (Tchanturia, Doris, & Fleming, 2014; Cardi et al., 2015).

References

- Arcelus, J., Haslam, M., Farrow, C., & Meyer, C. (2013). The role of interpersonal functioning in the maintenance of eating psychopathology: A systematic review and testable model. *Clinical Psychology Review*, 33(1), 156–167. <https://doi.org/10.1016/J.CPR.2012.10.009>
- Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The “Reading the Mind in the Eyes” Test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 42(2), 241–251. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/11280420>
- Baron-Cohen, S., Jaffa, T., Davies, S., Auyeung, B., Allison, C., & Wheelwright, S. (2013). Do girls with anorexia nervosa have elevated autistic traits? *Molecular Autism* 2013 4:1, 4(1), 24. <https://doi.org/10.1186/2040-2392-4-24>
- Bird, G., & Viding, E. (2014). The self to other model of empathy: Providing a new framework for understanding empathy impairments in psychopathy, autism, and alexithymia. *Neuroscience & Biobehavioral Reviews*, 47, 520–532. <https://doi.org/10.1016/J.NEUBIOREV.2014.09.021>
- Borsboom, D. (2017). A network theory of mental disorders. *World Psychiatry*, 16(1), 5–13. <https://doi.org/10.1002/wps.20375>
- Borsboom, D., Cramer, A. O. J., & Kalis, A. (2019). Brain disorders? Not really: Why network structures block reductionism in psychopathology research. *Behavioral and Brain Sciences*, 42, e2. <https://doi.org/10.1017/S0140525X17002266>

- Borsboom, D., & Cramer, A. O. J. (2013). Network Analysis: An Integrative Approach to the Structure of Psychopathology. *Annual Review of Clinical Psychology*, 9(1), 91–121. <https://doi.org/10.1146/annurev-clinpsy-050212-185608>
- Brockmeyer, T., Pellegrino, J., Münch, H., Herzog, W., Dziobek, I., & Friederich, H.-C. (2016). Social cognition in anorexia nervosa: Specific difficulties in decoding emotional but not nonemotional mental states. *International Journal of Eating Disorders*, 49(9), 883–890. <https://doi.org/10.1002/eat.22574>
- Caglar-Nazali, H. P., Corfield, F., Cardi, V., Ambwani, S., Leppanen, J., Olabintan, O., ... Treasure, J. (2014). A systematic review and meta-analysis of ‘Systems for Social Processes’ in eating disorders. *Neuroscience & Biobehavioral Reviews*, 42, 55–92. <https://doi.org/10.1016/J.NEUBIOREV.2013.12.002>
- Calderoni, S., Fantozzi, P., Maestro, S., Brunori, E., Narzisi, A., Balboni, G., & Muratori, F. (2013). Selective cognitive empathy deficit in adolescents with restrictive anorexia nervosa. *Neuropsychiatric Disease and Treatment*, 9, 1583–1589. <https://doi.org/10.2147/NDT.S50214>
- Cardi, V., Esposito, M., Bird, G., Rhind, C., Yiend, J., Schifano, S., ... Treasure, J. (2015). A preliminary investigation of a novel training to target cognitive biases towards negative social stimuli in Anorexia Nervosa. *Journal of Affective Disorders*, 188, 188–193. <https://doi.org/10.1016/j.jad.2015.08.019>
- Chen, J., & Chen, Z. (2008). Extended Bayesian information criteria for model selection with large model spaces. *Biometrika*, 95(3), 759–771. <https://doi.org/10.1093/biomet/asn034>
- Coll, M.-P., Viding, E., Rütgen, M., Silani, G., Lamm, C., Catmur, C., & Bird, G. (2017). Are we really measuring empathy? Proposal for a new measurement framework. *Neuroscience & Biobehavioral Reviews*, 83, 132–139. <https://doi.org/10.1016/j.neubiorev.2017.10.009>

- Conway, J. R., Catmur, C., & Bird, G. (2019). Understanding individual differences in theory of mind via representation of minds, not mental states. *Psychonomic Bulletin and Review*, 26(3), 798–812. <https://doi.org/10.3758/s13423-018-1559-x>
- Cuff, B. M. P., Brown, S. J., Taylor, L., & Howat, D. J. (2016). Empathy: A Review of the Concept. *Emotion Review*, 8(2), 144–153. <https://doi.org/10.1177/1754073914558466>
- De Vignemont, F., & Singer, T. (2006). The empathic brain: how, when and why?. *Trends in cognitive sciences*, 10(10), 435-441. <https://doi.org/10.1016/j.tics.2006.08.008>
- Dziobek, I., Fleck, S., Kalbe, E., Rogers, K., Hassenstab, J., Brand, M., ... Convit, A. (2006). Introducing MASC: A Movie for the Assessment of Social Cognition. *Journal of Autism and Developmental Disorders*, 36(5), 623–636. <https://doi.org/10.1007/s10803-006-0107-0>
- Elliott, H., Jones, P. J., & Schmidt, U. (2018). Central Symptoms Predict Post-Treatment Outcomes and Clinical Impairment in Anorexia Nervosa: A Network Analysis in a Randomized-Controlled Trial. PsyArXiv Preprint. <https://dx.doi.org/10.31234/OSF.IO/HW2DZ>
- Epskamp, S., Borsboom, D., & Fried, E. I. (2018). Estimating psychological networks and their accuracy: A tutorial paper. *Behavior Research Methods*, 50(1), 195–212. <https://doi.org/10.3758/s13428-017-0862-1>
- Epskamp, S., Cramer, A. O. J., Waldorp, L. J., Schmittmann, V. D., & Borsboom, D. (2012). *qgraph: Network Visualizations of Relationships in Psychometric Data*. *JSS Journal of Statistical Software* (Vol. 48). Retrieved from <http://www.jstatsoft.org/>
- Epskamp, S., & Fried, E. I. (2018). A tutorial on regularized partial correlation networks. *Psychological Methods*, 23(4), 617–634. <https://doi.org/10.1037/met0000167>

- Epskamp, S., Maris, G., Waldorp, L., & Borsboom, D. (2016). Network psychometrics. In Irwing, P., Hughes, D., and Booth, T., (Eds), *Handbook of Psychometrics*. New York, NY: Wiley.
- Fairburn, C. G., & Beglin, S. J. (1994). Assessment of eating disorders: Interview or self-report questionnaire? *International Journal of Eating Disorders*, 16(4), 363–370.
[https://doi.org/10.1002/1098-108X\(199412\)16:4<363::AID-EAT2260160405>3.0.CO;2-#](https://doi.org/10.1002/1098-108X(199412)16:4<363::AID-EAT2260160405>3.0.CO;2-#)
- Friedman, J., Hastie T., Tibshirani, R. (2014). Glasso: Graphical lasso estimation of Gaussian graphical models, R package version 1.8 [Computer Software]. <https://cran.r-project.org/web/packages/glasso/index>
- Fonagy, P., Luyten, P., Moulton-Perkins, A., Lee, Y.-W., Warren, F., Howard, S., ... Lowyck, B. (2016). Development and Validation of a Self-Report Measure of Mentalizing: The Reflective Functioning Questionnaire. *PLOS ONE*, 11(7), e0158678.
<https://doi.org/10.1371/journal.pone.0158678>
- Happé, F., Cook, J. L., & Bird, G. (2017). The Structure of Social Cognition: In(ter)dependence of Sociocognitive Processes. *Annual Review of Psychology*, 68(1), 243–267.
<https://doi.org/10.1146/annurev-psych-010416-044046>
- Happé, F., & Frith, U. (2014). Annual Research Review: Towards a developmental neuroscience of atypical social cognition. *Journal of Child Psychology and Psychiatry*, 55(6), 553–577.
<https://doi.org/10.1111/jcpp.12162>
- Heeren, A., & McNally, R. J. (2016). An integrative network approach to social anxiety disorder: The complex dynamic interplay among attentional bias for threat, attentional control, and symptoms. *Journal of Anxiety Disorders*, 42, 95–104.
<https://doi.org/10.1016/j.janxdis.2016.06.009>

- Ickes, W., Stinson, L., Bissonnette, V., & Garcia, S. (1990). *Naturalistic Social Cognition: Empathic Accuracy in Mixed-Sex Dyads*. *Journal of Personality and Social Psychology* (Vol. 59).
- Jewell, T., Collyer, H., Gardner, T., Tchanturia, K., Simic, M., Fonagy, P., & Eisler, I. (2016). Attachment and mentalization and their association with child and adolescent eating pathology: A systematic review. *International Journal of Eating Disorders*, 49(4), 354–373. <https://doi.org/10.1002/eat.22473>
- Jones, P. J. (2017). Networktools: Assorted Tools for Identifying Important Nodes in Networks. R package version 1.1.0. [Computer Software] Retrieved from <https://CRAN.R-project.org/package=networktools>
- Jones, P. J., Ma, R., & McNally, R. J. (2019). Bridge centrality: A network approach to understanding comorbidity. *Multivariate behavioral research*, 1-15. <https://doi.org/10.1080/00273171.2019.1614898>
- Kerr-Gaffney, J., Harrison, A., & Tchanturia, K. (2019). Cognitive and Affective Empathy in Eating Disorders: A Systematic Review and Meta-Analysis. *Frontiers in Psychiatry*, 10, 102. <https://doi.org/10.3389/fpsy.2019.00102>
- Kuipers, G. S., Hollander, S. den, van der Ark, L. A., & Bekker, M. H. J. (2017). Recovery from eating disorder 1 year after start of treatment is related to better mentalization and strong reduction of sensitivity to others. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, 22(3), 535–547. <https://doi.org/10.1007/s40519-017-0405-x>
- Kuipers, G. S., van Loenhout, Z., van der Ark, L. A., & Bekker, M. H. J. (2018). Is reduction of symptoms in eating disorder patients after 1 year of treatment related to attachment security

and mentalization? *Eating Disorders*, 26(3), 263–269.
<https://doi.org/10.1080/10640266.2017.1384916>

Kuipers, G. S., van Loenhout, Z., van der Ark, L. A., & Bekker, M. H. J. (2016). Attachment insecurity, mentalization and their relation to symptoms in eating disorder patients. *Attachment & Human Development*, 18(3), 250–272. <https://doi.org/10.1080/14616734.2015.1136660>

Leppanen, J., Sedgewick, F., Treasure, J., & Tchanturia, K. (2018). Differences in the Theory of Mind profiles of patients with anorexia nervosa and individuals on the autism spectrum: A meta-analytic review. *Neuroscience & Biobehavioral Reviews*, 90, 146–163.
<https://doi.org/10.1016/j.neubiorev.2018.04.009>

Levinson, C. A., Vanzhula, I. A., Brosos, L. C., & Forbush, K. (2018). Network Analysis as an Alternative Approach to Conceptualizing Eating Disorders: Implications for Research and Treatment. *Current Psychiatry Reports*, 20(9), 67. <https://doi.org/10.1007/s11920-018-0930-y>

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour Research and Therapy*, 33(3), 335–343. [https://doi.org/10.1016/0005-7967\(94\)00075-U](https://doi.org/10.1016/0005-7967(94)00075-U)

McNally, R. J. (2016). Can network analysis transform psychopathology? *Behaviour Research and Therapy*, 86, 95–104. <https://doi.org/10.1016/J.BRAT.2016.06.006>

Monteleone, A. M., Treasure, J., Kan, C., & Cardi, V. (2018). Reactivity to interpersonal stress in patients with eating disorders: A systematic review and meta-analysis of studies using an experimental paradigm. *Neuroscience & Biobehavioral Reviews*, 87, 133–150.
<https://doi.org/10.1016/j.neubiorev.2018.02.002>

- Monteleone, A. M., Mereu, A., Cascino, G., Criscuolo, M., Castiglioni, M. C., Pellegrino, F., Patriciello, G., Ruzzi, V., Monteleone, P., Vicari, S., Zanna, V. (2019). Re-conceptualization of anorexia nervosa psychopathology: A network analysis study in adolescents with short duration of the illness. *The International Journal of Eating Disorders*, 52(11), 1263–1273. <https://doi.org/10.1002/eat.23137>
- Nosek, B. A., Hawkins, C. B., & Frazier, R. S. (2011). Implicit social cognition: from measures to mechanisms. *Trends in Cognitive Sciences*, 15(4), 152–159. <https://doi.org/10.1016/j.tics.2011.01.005>
- Oakley, B. F. M., Brewer, R., Bird, G., & Catmur, C. (2016). Theory of mind is not theory of emotion: A cautionary note on the reading the mind in the eyes test. *Journal of Abnormal Psychology*, 125(6), 818–823. <https://doi.org/10.1037/abn0000182>
- Oldershaw, A., Lavender, T., & Schmidt, U. (2018). Are socio-emotional and neurocognitive functioning predictors of therapeutic outcomes for adults with anorexia nervosa? *European Eating Disorders Review*, 26(4), 346–359. <https://doi.org/10.1002/erv.2602>
- Pettersson, A., Modin, S., Wahlström, R., Af Winklerfelt Hammarberg, S., & Krakau, I. (2018). The Mini-International Neuropsychiatric Interview is useful and well accepted as part of the clinical assessment for depression and anxiety in primary care: A mixed-methods study. *BMC Family Practice*, 19(1). <https://doi.org/10.1186/s12875-017-0674-5>
- Roefs, A., Huijding, J., Smulders, F. T. Y., MacLeod, C. M., de Jong, P. J., Wiers, R. W., & Jansen, A. T. M. (2011). Implicit measures of association in psychopathology research. *Psychological Bulletin*, 137(1), 149–193. <https://doi.org/10.1037/a0021729>

- Russell, T. A., Schmidt, U., Doherty, L., Young, V., & Tchanturia, K. (2009). Aspects of social cognition in anorexia nervosa: Affective and cognitive theory of mind. *Psychiatry Research*, 168(3), 181–185. <https://doi.org/10.1016/j.psychres.2008.10.028>
- Shah, P., Catmur, C., & Bird, G. (2017). From heart to mind: Linking interoception, emotion, and theory of mind. *Cortex. Cortex; a journal devoted to the study of the nervous system and behavior*, 93, 220. <https://doi.org/10.1016/j.cortex.2017.02.010>
- Solmi, M., Collantoni, E., Meneguzzo, P., Degortes, D., Tenconi, E., & Favaro, A. (2018). Network analysis of specific psychopathology and psychiatric symptoms in patients with eating disorders. *International Journal of Eating Disorders*, 51(7), 680–692. <https://doi.org/10.1002/eat.22884>
- Tchanturia, K., Doris, E., & Fleming, C. (2014). Effectiveness of Cognitive Remediation and Emotion Skills Training (CREST) for Anorexia Nervosa in Group Format: A Naturalistic Pilot Study. *European Eating Disorders Review*, 22(3), 200–205. <https://doi.org/10.1002/erv.2287>
- Treasure, J., Corfield, F., & Cardi, V. (2012). A Three-phase Model of the Social Emotional Functioning in Eating Disorders. *European Eating Disorders Review*, 20(6), 431–438. <https://doi.org/10.1002/erv.2181>
- Treasure, J., & Schmidt, U. (2013). The cognitive-interpersonal maintenance model of anorexia nervosa revisited: a summary of the evidence for cognitive, socio-emotional and interpersonal predisposing and perpetuating factors. *Journal of Eating Disorders*, 1(1), 13. <https://doi.org/10.1186/2050-2974-1-13>

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Table 1. Demographic and clinical characteristics of the diagnostic groups. MASC, Movie for the Assessment of Social Cognition; EAT-R, Empathic Accuracy Task- Revised; DASS, Depression, Anxiety and Stress Scales; EDEQ, Eating Disorders Examination Questionnaire; OCD, obsessive-compulsive disorder.

		AN – R (N=42)	AN – BP (N=18)	BN (N=17)	F
Age, yrs		28.38±7.89	26.76±7.25	27.06±11.73	0.29
Months before diagnosis		112.46±115.37	77.06±64.37	70.13±123.73	1.41
Illness duration, yrs		11.39±8.27	10.71±7.15	9.93±9.51	0.09
Body Mass Index, kg/m ²		18.09±3.6	18.04±2.84	23.21±4.54	12.69 ^a
Months unemployed		5.85±22.34	9.06±29.21	6.56±13.66	0.05
Education, yrs		16.05±2.89	16.06±2.53	15.56±3.38	0.39
MASC - Emotion		12.51±2.13	12.88±2.02	11.44±3.52	1.41
MASC - Cognition		20.03±3.95	20.71±2.84	17.81±4.4	2.69
MASC - Overmentalization		5.56±2.89	5.71±2.54	5.94±2.56	0.13
MASC - Undermentalization		4.59±2.54	3.94±2.61	5.31±2.96	0.58
EAT-R Emotion identification		0.41±0.23	0.41±0.14	0.32±0.21	1.09
EAT-R Affect sharing		0.30±0.19	0.26±0.11	0.18±0.23	1.67
DASS - Depression		15.38±12.39	24.59±20.08	22.38±11.29	2.54
DASS - Anxiety		12.56±9.65	13.18±11.85	17.13±10.91	0.87
DASS - Stress		21.44±10.92	23.53±12.73	25.38±9.05	0.96
EDEQ - Restraint		2.49±1.56	3.57±2.01	3.25±1.69	2.95
EDEQ - Eating concern		2.44±1.55	3.31±1.65	3.56±1.33	3.98 ^b
EDEQ - Shape concern		3.65±1.81	4.75±2.37	4.23±1.36	1.75
EDEQ - Weight concern		3.01±1.91	4.09±2.06	3.77±1.67	2.01
Drugs (yes, %)	Antidepressants	35.9	41.2	13.3	3.3§
	Antipsychotics	7.7	29.4	0.0	8.0§*
Comorbidity (yes, %)	Depression	28.6	16.7	17.6	1.3§
	Anxiety	26.2	22.2	29.4	0.2§
	OCD	7.1	5.6	5.9	0.1§

Post hoc Tukey's test ^aBN>AN-R, AN-BP p<0.05; ^bBN>AN-R p<0.05;

§ Chi square test, * p<0.05

Figure Captions

Figure 1. Partial correlation network (for the color version, see online).

Figure 2. Plot of strength centrality index of nodes included in the partial correlation network.

Abbreviations: R, Eating Disorders Examination Questionnaire Restraint Eating; EAT, Eating Disorders Examination Questionnaire Eating Concern; SH, Eating Disorders Examination Questionnaire Shape Concern; W, Eating Disorders Examination Questionnaire Weight Concern; DEP, Depression; ANX, Anxiety; STR, Stress; EMO, Movie for the Assessment of Social Cognition Emotion; COG, Movie for the Assessment of Social Cognition Cognition; OVE, Movie for the Assessment of Social Cognition Over-mentalization; UND, Movie for the Assessment of Social Cognition Under-mentalization; EI, Empathic Accuracy Task-Revised Emotion Identification; AS, Empathic Accuracy Task-Revised Affect Sharing.

Supplementary Figure 1. Average correlation between the strength centrality index of the partial correlation networks sampled with persons dropped and the original sample. Lines indicate the means and areas indicate the range from the 2.5th quantile to the 97.5th quantile.

Supplementary Figure 2. Bootstrapped confidence intervals of estimated edge-weights of the partial correlation network.