



Emotion Networks in Individuals with High and Low Social Anxiety Symptoms

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Abstract

Background Social Anxiety Disorder (SAD) is a highly prevalent mental health disorder. Theoretical models of SAD emphasize the role of cognitive and behavioral factors in the development and maintenance of the disorder, although emotional experiences are equally relevant. Most studies focus on the relationship between SAD and affect broadly (positive and negative affect), or address specific emotions separately, rather than examining multiple positive and negative emotions in one integrated model. Network analysis can provide important insights into the emotional system underlying SAD and how it is organized differently between individuals with high and low social anxiety. Therefore, we aimed to identify the central emotions and compare several macro-network properties (e.g., connectivity) between high and low socially anxious individuals.

Methods Two networks were estimated using a Mixed Graphical Model (MGM). The Positive and Negative Affect Schedule (PANAS) was used to assess emotional states, and social anxiety symptoms were measured with the Liebowitz Social Anxiety Scale—self-report version (LSAS-SR), previously adapted and validated. Participants recruited from the community were divided into two groups based on the LSAS-SR cut-off score: with high ($N=306$, $M_{age}=28.50$; $SD_{age}=10.59$) and low social anxiety symptoms ($N=306$, $M_{age}=34.30$; $SD_{age}=13$).

Results Network connectivity distinguished the two groups. Participants with higher social anxiety symptoms showed a more interconnected emotion network. Feeling scared, disturbed, and guilty were central emotions and were identified as valuable treatment targets.

Conclusions The results contribute to the understanding of emotional experience in the context of SAD from a network perspective, and to the growing literature on network theory, by clarifying which network properties are promising markers of an emotional system resistant to change.

Keywords Social anxiety disorder · Emotions · Affect · Network analysis · Network properties

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Social Anxiety Disorder (SAD) is one of the most prevalent mental health disorders worldwide (Bandelow & Michaelis, 2015) and, if left untreated, tends to be chronic and unremitting, causing impairments in various life domains. Decreased functionality increases when a comorbid condition, such as Major Depressive Disorder (MDD), is present (Jefferies & Ungar, 2020).

Individuals with SAD experience intense and recurrent fear in social and/or performance situations related to being embarrassed, humiliated, or rejected. This leads to avoidance or exposure with high anxiety, remaining hyper-vigilant to social threat cues and focusing on impression management, safety behaviors, and post-event rumination (American Psychiatric Association, 2013). Theoretical models of SAD emphasize the importance of cognitions and behaviors in the development and maintenance of the disorder (Hofmann, 2007; Rapee & Heimberg, 1997), although emotions play an equally important role (Cândeia & Szentagotai-Tăta, 2018; Oren-Yagoda et al., 2021).

Growing evidence suggests that difficulties in perceiving, expressing, understanding, differentiating, and regulating emotions are common across various forms of psychopathology (Beauchaine & Cicchetti, 2019), including SAD (Lacombe et al., 2023; Rozen & Aderka, 2023). Individuals with SAD tend to experience more negative emotions and fewer positive emotions when compared to those without symptoms (Kashdan et al., 2013). Indeed, studies suggest that high negative affect (NA) and low positive affect (PA) are core features of SAD, and that both may predict the disorder (Babaei et al., 2014). Recent studies also show that individuals with SAD experience significantly more NA (e.g., Mishra, 2020) and less PA when compared to low-anxious individuals (e.g., Cohen & Huppert, 2018). This affective profile of SAD, characterized by both high NA and low PA, is more similar to depression than to other anxiety disorders (Bowers et al., 2023).

Regarding specific emotions, there is more research addressing negative emotions in the context of SAD. Fear, as a core symptom, is one of them (American Psychiatric Association, 2013), with feelings of nervousness, irritability, and distress being strongly associated (Mishra, 2020). Shame (Cândeia & Szentagotai-Tăta, 2018; Lazarus & Shahr, 2018; Swee et al., 2021), embarrassment (Bas-Hoogendam et al., 2018; Gee et al., 2012), anger (Conrad et al., 2021; Kashdan & Collins, 2010; Mishra, 2020; Moscovitch et al., 2008), and envy (Oren-Yagoda et al., 2021) have also been identified as prominent emotions. However, research on guilt and its relationship with SAD has yielded mixed findings (Cândeia & Szentagotai-Tăta, 2018; Schuster et al., 2021). Because SAD used to be perceived as a condition whose emotional core is negative, positive emotions have received less attention. Cohen and Huppert (2018) found

that pride, contentment, joy, love, awe, and amusement were significantly and negatively linked to SAD. Pride was a predictor of SAD when using a clinical sample. More recently, Chin et al. (2023) showed that individuals with SAD experienced less awe, inspiration, interest, joy, as well as amusement, love, hope, pride, and contentment than individuals with MDD and comorbid conditions.

In summary, both positive and negative emotions are experienced concurrently in SAD, with individuals often struggling to perceive, understand, express, differentiate, and regulate their emotions (Rozen & Aderka, 2023). This suggests that, like other mental disorders (Pe et al., 2015), people experiencing SAD may have an emotional system resistant to change. Thus, recent studies have called for more research to integrate positive and negative emotions into the conceptualization of SAD (Cohen & Huppert, 2018), the role of such emotions in the development and maintenance of the disorder, and the temporal or causal relations between them to improve treatment outcomes (Rozen & Aderka, 2023; Schuster et al., 2021). However, many studies still use affect in a broad, unidimensional manner (PA and NA) or address specific emotions separately, not incorporating them into an integrated model. Network analysis, derived from the network approach to psychopathology (Borsboom, 2017, 2022), offers a promising way for investigating the emotional system underlying SAD as a whole. Network analysis has been used to explore emotions in other mental disorders, such as depression (Pe et al., 2015), bipolar and eating disorders (Curtiss et al., 2019; Wong et al., 2021).

The network approach to psychopathology proposes that mental disorders arise from dynamic interactions among symptoms, rather than being the underlying cause of them (Borsboom, 2017; Borsboom & Cramer, 2013; Borsboom et al., 2019). As the interaction between symptoms can be understood as a network, the symptoms are represented as nodes, and the relationships between them as edges. Nodes with strong associations to others are highly central symptoms and valuable treatment targets (Borsboom, 2017; Hofmann et al., 2016). It is suggested that highly connected networks (networks with stronger connections) are more likely to be pathogenic, and the activation of one symptom (especially if it is a highly central one) can trigger others, maintaining or leading to an episode of disorder (Borsboom, 2017, 2022). This is confirmed by several studies. Castro et al. (2024) and Heeren and McNally (2018) found that the network for those with SAD had higher connectivity than that of participants without SAD. Micro and macro-level network properties, namely centrality or connectivity, could then function as markers of psychopathology and its treatment.

Many individuals experience social anxiety (SA) symptoms without meeting the full diagnostic criteria for SAD.

These subclinical manifestations can still significantly impair daily functioning and well-being. Research shows that people with subthreshold social anxiety (SSA) often experience emotional distress and social challenges comparable to those with a clinical diagnosis of SAD (Kim et al., 2023). Such findings support a dimensional perspective of SA, in which symptoms exist along a spectrum ranging from low to high levels of SA rather than a binary diagnosis. From this perspective, SSA also deserves attention in research, as it may impact individuals in meaningful ways outside the boundaries of SAD.

Considering this, using network analysis to explore emotions in the context of SA symptoms can clarify the relationship between multiple emotions, identify core emotions in the maintenance of the disorder (Borsboom & Cramer, 2013), and point to key emotions for treatment (Borsboom, 2017; Hofmann et al., 2016). This would contribute to emotionally focused interventions or pave the way for improving current first-line treatments for SA, such as CBT-based treatments (Bowers et al., 2023; Rozen & Aderka, 2023). Treatments are relatively effective, but individuals with SA symptoms continue to be less likely to experience complete symptom remission than individuals with MDD or other anxiety disorders (Bowers et al., 2023). Furthermore, understanding how the network connectivity comprising emotions differs between individuals with higher and lower levels of social anxiety symptoms may promote important insights, which may ultimately inform the network theory at this level (Borsboom, 2017). Finally, since recent studies have suggested that network connectivity results may not be sufficient to characterize mental disorders, further exploration of different network properties (e.g., average path length) may be useful to help understand which ones may serve as potential markers of psychopathology states (Castro et al., 2024). To our knowledge, no previous study has explored a wide range of emotions in the context of SA symptoms using network analysis, comparing different properties of emotion networks between individuals with high and low levels of these symptoms, including whether those with higher symptoms have a more interconnected emotion network.

In this study, we estimated two networks of positive and negative emotions for participants with high and low levels of SA symptoms recruited from the community. The aim was to identify central emotions (i.e., the most interconnected) and compare a set of network properties at the macro-level, including overall connectivity, between these two groups.

Methods

Participants and Procedure

A community-based sample was used to estimate emotion networks in individuals with high and low levels of SA symptoms (high SA group vs. low SA group). Eligibility criteria were: (1) being over 18 years of age, and (2) proficiency in Portuguese. The sample consisted of 847 adults, mostly women (77.57%), aged 18 to 78 ($M_{\text{age}}=31.93$; $SD_{\text{age}}=12.07$). Among them, 306 (36.13%) scored above the cut-off score of 60 on the LSAS-SR total score (Caballo et al., 2019), indicating high symptoms of SA ($M_{\text{age}}=28.50$; $SD_{\text{age}}=10.59$). The remaining participants ($n=541$) scored below the cut-off, and a random subsample of 306 was selected to form the low SA group ($M_{\text{age}}=34.30$; $SD_{\text{age}}=13$), matching the sample size of the high SA group. Positive and negative emotional states were measured using PANAS (Watson et al., 1988). Depression symptoms (measured by PHQ-9; Kroenke et al., 2001) were also assessed. Sociodemographic characteristics and descriptive statistics for both groups are provided in Table 1 (also see Table 6 in Supplement 2.1 of the Supplementary Materials). Note that the groups differ significantly in age [$t(586.09)=-6.06$, $p<0.001$].

This study was carried out in Portugal, with data collected through a cross-sectional survey between October 2022 and January 2023 using social media platforms (e.g., Facebook, Instagram, LinkedIn), institutional mailing lists (e.g., university students' emails), and personal networks (through snowball sampling). Participation was voluntary and anonymous, with no incentives provided. To ensure data quality, incomplete or invalid data entries were removed prior to analysis. Only complete and valid responses were retained for data analysis. Participants provided informed consent, and the study received approval from the Ethics and Deontology Board of the University of Maia (No. 84/2022).

As no exclusive Portuguese version of the LSAS-SR existed prior to this study, the scale was first adapted and validated. After obtaining the original author's permission, translation and back-translation were performed by experienced researchers and bilingual experts. Two researchers conducted the forward translation (English–Portuguese), and one bilingual expert conducted the back-translation (Portuguese–English). The original author reviewed and approved the final version. To ensure quality, a small group of participants outside this study initially completed the Portuguese version of the scale, reporting no issues with item clarity or bias. Details on the LSAS-SR adaptation and validation, including results, are available in the Supplementary Materials (see Supplements 1.1 to 1.3).

Table 1 Sample characteristics for participants with high and low social anxiety symptoms

Sample	High SA (N=306)	Low SA (N=306)
Age, Mean (SD)	28.50 (10.59)	34.30 (13)
Female, <i>n</i> (%)	256 (83.7)	224 (73.2)
Education level (in years), Mean (SD)	14.99 (3.04)	15.84 (3.19)
Marital status		
Single, <i>n</i> (%)	234 (76.5)	176 (57.5)
Married, <i>n</i> (%)	58 (18.9)	108 (35.3)
Divorced, <i>n</i> (%)	11 (3.6)	22 (7.2)
Widowed, <i>n</i> (%)	3 (1)	–
Job status		
Employee, <i>n</i> (%)	97 (31.7)	156 (51)
Student, <i>n</i> (%)	125 (40.9)	85 (27.8)
Worker/Student, <i>n</i> (%)	60 (19.6)	50 (16.3)
Unemployed, <i>n</i> (%)	23 (7.5)	11 (3.6)
Retired, <i>n</i> (%)	1 (0.3)	4 (1.3)
Current psychological treatment ^a , <i>n</i> (%)	180 (58.8)	149 (48.7)
Current psychiatric treatment ^a , <i>n</i> (%)	95 (31)	72 (23%)
LSAS-SR (total)		
Mean (SD)	83.94 (18.24)	28.82 (16.10)
Minimum–Maximum	0–144	0–144
PHQ-9 (total)		
Mean (SD)	14.43 (6.22)	7.29 (5.50)
Minimum–Maximum	0–27	0–27

Number of participants (*N*), sociodemographic characteristics, and descriptive statistics— including the mean (*M*), standard deviation (*SD*), minimum and maximum for the total-scores on the Liebowitz Social Anxiety Scale— self-report version (LSAS-SR) and the Patient Health Questionnaire-9 (PHQ-9), presented separately for participants with high and low levels of social anxiety symptoms

^aConcerns the number and percentage of participants answering "yes" to this question

Measures

Liebowitz Social Anxiety Scale–Self-Report Version (LSAS-SR)

The Liebowitz Social Anxiety Scale— self-report version (LSAS-SR) (Liebowitz, 1987) is a 24-item self-report questionnaire assessing anxiety and avoidance in social (11 items; e.g., “Talking to people in authority”) and performance situations (13 items; e.g., “Acting, presenting or giving a speech in front of an audience”). Items are rated on a 4-point Likert scale from 0 (no fear/anxiety; never avoid) to 3 (severe fear/anxiety; usually avoid), with a global score ranging from 0 to 144. Caballo et al. (2019) used a cut-off score of 60 as indicative of SA symptoms in a large Spanish and Portuguese-speaking community sample. The scale demonstrated good internal consistency ($\alpha=0.88$ – 0.93) (Caballo et al., 2019).

Positive and Negative Affect Schedule (PANAS)

The Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988; Portuguese version from Galinha & Pais-Ribeiro, 2005) is a 20-item measure of positive and negative affective states. Positive affect refers to a global pleasantness feeling or emotion, while negative affect is the tendency to experience unpleasant emotions (American Psychological Association, 2018). In the Portuguese version, negative affect subscale includes emotions such as distressed, disturbed, afraid, scared, nervous, shaky, regretful, guilty, irritable, and disgusted; while positive affect subscale includes emotions such as interested, enthusiastic, excited, inspired, determined, proud, active, delighted, warmed, and surprised. Note that the Portuguese version of PANAS used in this study differs in some items from the original version of the PANAS, which is mentioned in more detail in the limitations section. Items are scored on a 5-point Likert scale from 1 (not at all) to 5 (very much). Internal consistency was good for both positive ($\alpha=0.86$) and negative affect ($\alpha=0.89$).

Patient Health Questionnaire-9 (PHQ-9)

The Patient Health Questionnaire-9 (PHQ-9) (Kroenke et al., 2001); Portuguese version from Ferreira et al., 2018) is a 9-item self-report scale assessing depression symptoms. Items are scored on a 4-point Likert scale from 0 (never) to 3 (almost every day), with a total score ranging from 0 to 27. The cut-off score is 9. The original scale showed strong reliability ($\alpha=0.89$) (Kroenke et al., 2001), as did the Portuguese version ($\alpha=0.86$) (Ferreira et al., 2018).

Statistical Analyses

Data analyses were performed in R version 4.2.3 (R Core Team, 2025).

Networks Estimation

The first step to estimating emotion networks in individuals with high and low levels of SA was to divide participants based on the LSAS-SR cut-off score. The low SA group included more participants ($n=541$) than the high SA group ($n=306$). As network estimation and metrics such as connectivity can be influenced by sample size (Isvoranu & Epskamp, 2023), it was important to minimize group size differences to reduce potential bias and ensure comparability between groups. Therefore, a random subsample of 306 participants from the low SA group was selected to match the size of the high SA group.

Emotion networks were then estimated using a Mixed Graphical Model (MGM) with the *mgm* default (Haslbeck & Waldorp, 2020) implemented via the *bootnet* package (Epskamp et al., 2018). MGM combines the Ising model and GGM to assess the relationship between nodes, allowing continuous, categorical, and count variables (Borsboom et al., 2021). It employs a nodewise regression method to calculate intercepts (node's threshold) and beta coefficients (strength of connections between nodes). Regularization minimizes false-positive connections, producing a sparser and interpretable network structure, where insignificant edges are reduced to zero (Haslbeck & Waldorp, 2020). The regularization parameter was selected using tenfold cross-validation. Networks were graphically represented with the *qgraph* package (Epskamp et al., 2012). Potential confounding effects of sociodemographic variables (gender, age, marital status, job status) were tested, as in previous studies (van Borkulo et al., 2015) (see Supplement 2.3 of the Supplementary Materials).

Central nodes were identified by calculating the expected influence (EI; Robinaugh et al., 2016), using the *centrality-Plot* function in the *qgraph* package (Epskamp et al., 2012). EI is the sum of the weights of a node's edges (positive and negative) shared with the other nodes in the network (Robinaugh et al., 2016).

A set of network properties was also estimated for each network, primarily using *igraph* (Csardi & Nepusz, 2006): average degree, average path length, assortativity, clustering, density, and connectivity. Average degree is the mean number of edges per node (Opsahl et al., 2010); average path length is the average distance between all possible pairs of nodes (Chen et al., 2008); assortativity measures nodes' tendency to connect with other nodes with similar properties (Noldus & Van Mieghem, 2015); clustering is the number of closed triplets (i.e., subgraphs with three edges and three nodes) over the total number of connected triplets of vertices (Barrat et al., 2004); and density is the ratio of the number of edges compared to the maximum number of potential edges (Faust, 2006). While many of these properties have not been formalized theoretically in the context of network theory, exploring them might unveil important insights into the processes of psychopathological networks (Castro et al., 2024). Connectivity, described below, was estimated using the Network Comparison Test (NCT) package (van Borkulo et al., 2022).

Network Comparison

Differences between the networks of participants with high and low levels of SA symptoms were explored using the NCT (van Borkulo et al., 2022). NCT is a permutation-based test that randomly splits the dataset and refits the

network models repeatedly (1,000 permutations) to generate a reference distribution under the null hypothesis that no differences exist between the two networks. Four aspects were formally tested: (1) global strength, indicating differences in overall network connectivity, calculated as the sum of absolute edge weights; (2) network structure, defined as the largest difference in edge weights between the two networks, reflecting differences in the overall configuration of associations; (3) edge weights, referring to which specific associations between nodes differ significantly between networks; and (4) centrality, indicating differences in the expected influence values of each node across the two networks (van Borkulo et al., 2022).

Network Stability

Network stability was assessed using the *bootnet* package (Epskamp et al., 2018). Measures to quantify the stability of centrality indices using subset bootstraps were computed: (1) edge stability correlation coefficient (ES-coefficient) and (2) expected-influence stability correlation coefficient (EI-coefficient). Coefficients should not be below 0.25, and preferably above 0.50 (Epskamp et al., 2018).

Results

Emotion Networks in Participants with High and Low Social Anxiety Symptoms

Figure 1 presents the estimated emotion networks for participants with high and low levels of SA symptoms. The network for the high SA group comprised 92 connections, compared to 68 in the group with low SA. The strongest connections weights (all positive edges) were observed between feeling distressed and disturbed (high SA group=0.44; low SA group=0.36); regretful and guilty (high SA group=0.38; low SA group=0.50); and scared and afraid (high SA group=0.35; low SA group=0.51). Network properties for both groups are shown in Table 2.

Central Nodes

In the network of participants with high SA, feeling scared (7), disturbed (4), and guilty (6) were the most central negative emotions; while feeling enthusiastic (10), determined (17) and inspired (15) were the most central positive ones, as indicated by the centrality index EI. In the network of participants with low SA, the strongest EI values were feeling scared (7), afraid (20), and nervous (16) among negative emotions; and feeling enthusiastic (10), determined

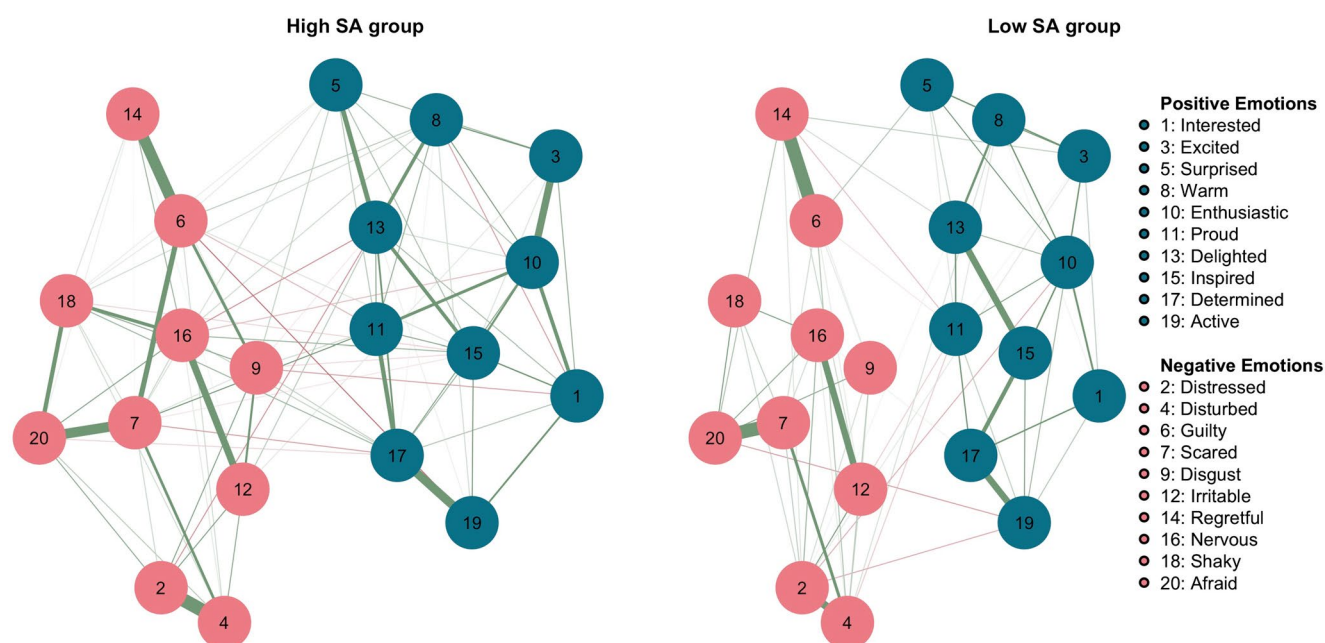


Fig. 1 Graphical representation of the emotion networks of participants with high and low social anxiety symptoms *Note.* The left panel represents the network of participants with high social anxiety symptoms (high SA group); the right panel represents the network of participants with low social anxiety symptoms (low SA group). Nodes represent

emotions (PANAS items); edges represent partial correlations between emotions. Blue nodes correspond to positive emotions, and pink nodes correspond to negative emotions. Green lines indicate positive associations; red lines indicate negative associations

Table 2 Network properties for participants with high and low social anxiety symptoms

Network	Average degree	Average path length	Assortativity	Clustering	Density	Connectivity
High SA	4.6	1.526	− 0.006	0.553	0.484	10.033
Low SA	3.4	1.742	− 0.011	0.455	0.357	8.406

Network properties for the high and low social anxiety (SA) groups

(17), and delighted (15) among positive emotions. Figure 2 shows the centrality plots based on EI for both networks.

Network Comparison

The two networks differed significantly in global strength (S), with the high SA group showing higher overall connectivity compared to the low SA group (10.033 vs. 8.406, $S=1.627$, $p=0.039$). However, there was no significant difference in network structure ($M=0.185$, $p=0.775$), suggesting that the emotional states were organized similarly in the two groups despite differences in global connectivity. Figure 3 presents the plot of network connectivity differences. Significant differences in edge weights were found between the two groups. Specifically, eleven pairs of nodes showed significant differences ($p<0.05$), such as scared–determined, distressed–determined, and enthusiastic–nervous.

Network Stability

Both networks showed adequate stability. In the network of the high SA group, the ES-coefficient was 0.673, and the EI-coefficient was 0.438. For the low SA network, the ES-coefficient was also 0.673, and the EI-coefficient was 0.595. Stability plots can be found in Supplement 2.2 of the Supplementary Materials.

Discussion

This study is the first to characterize and compare the network of positive and negative emotions among individuals with high and low levels of social anxiety (SA). Different network properties were considered to compare the two groups, such as centrality, average degree, average path length, assortativity, clustering, density, and connectivity.

One of the key findings of this study was the significantly higher network connectivity observed in participants with high SA compared to those with low symptoms.

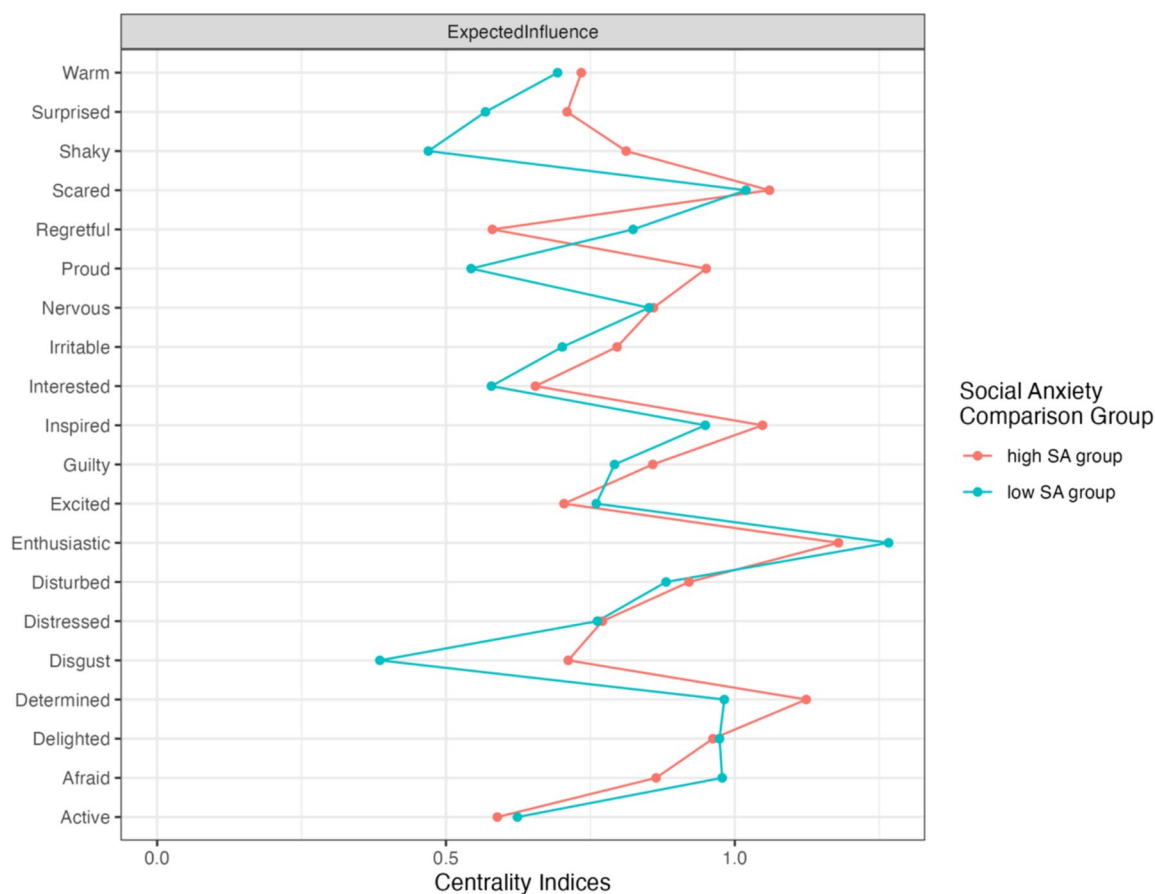
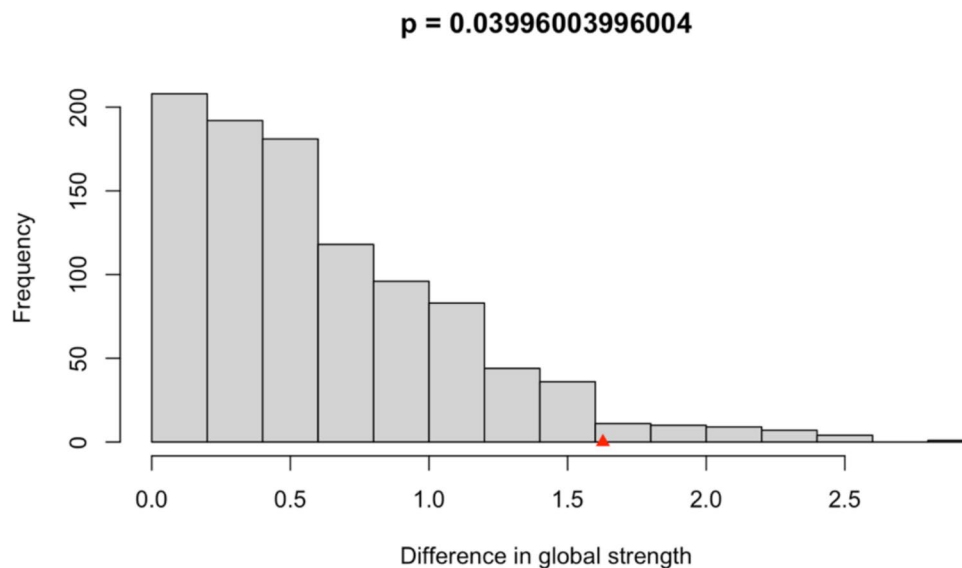


Fig. 2 Centrality plot of each emotion for participants with high and low social anxiety symptoms *Note.* Centrality plot for the expected influence of each node (PANAS items) in both networks

Fig. 3 Significant differences in global strength *Note.* The plot displays the observed significant difference in global strength (S) between the networks of participants with high and low social anxiety. The red triangle on the x-axis marks the observed difference (S = 1.627)



Concurrently, this network also exhibited greater density, reflecting a more interconnected and denser emotional system. These results align with the network theory (Borsboom, 2017), which posits that highly interconnected symptom

networks are more pathogenic and resistant to change than those with fewer and weaker connections. In such networks, the activation of one symptom easily spreads to others, leading to a cascade of symptom activation (Borsboom, 2017;

Borsboom & Cramer, 2013). Thus, our findings suggest that higher connectivity is an important marker of an emotional system that is more rigid, maladaptive, and resistant to change in individuals with elevated SA symptoms. Similar results have been found in prior network studies of other clinical populations. For example, Pe et al. (2015) found denser emotion networks in individuals with MDD when compared to healthy controls, indicating that the emotional system of the diagnosed group was more resistant to internal (e.g., emotion-regulation efforts) and external (e.g., environmental) demands. Curtiss et al. (2019) reported that, for individuals in the bipolar disorder group, the activation of one affective state increases the likelihood of activation of another, regardless of its positive or negative valence.

Our findings for other network macro-properties, such as average degree, average path length, assortativity, or clustering, further support these conclusions. To illustrate, the network of the high SA group showed a higher average degree, indicating more edges between emotions, and a shorter average path length, suggesting that emotions are closer and reinforce each other more rapidly. The higher clustering coefficient in the network of the high SA group also reveals more interconnected emotional clusters, that is, aligning with the network theory's description of tightly bound emotion networks in disordered states (Borsboom, 2017). Overall, our findings emphasize previous research suggesting that individuals with various forms of psychopathology, including SA, often exhibit reduced emotion differentiation or granularity (Erbas et al., 2022; O'Toole et al., 2014)—that is, less nuanced emotional experiences (Hoe-mann et al., 2023)—which is further linked to less effective emotion regulation strategies (Rozen & Aderka, 2023).

Despite these macro-level differences between groups (e.g., connectivity, average degree), central nodes showed no striking differences. Similar findings were reported by Heeren and McNally (2018) for symptom networks of individuals with and without SAD. Nonetheless, as these nodes represent the most interconnected emotional states and potential treatment targets, discussing them is important.

Feeling scared, disturbed, and guilty were identified as most central in the network of participants with high SA symptoms, suggesting their influence on other emotional states. The centrality of “scared” is unsurprising, aligning with key characteristics of SAD. Anticipation or exposure to social situations often triggers intense fear of embarrassment, rejection, humiliation, or disapproval (American Psychiatric Association, 2013). Furthermore, this finding suggests that fear acts as a key node, potentially activating other negative emotions and intensifying social avoidance, hypervigilance, and hyperresponsiveness to social threats. A previous network study identified fear in situations involving unfamiliar people as a core symptom of

SAD, reinforcing the threat value attributed to social evaluative stimuli as a process that triggers other symptoms and propagates through the network (Heeren & McNally, 2018). “Disturbed” also showed high centrality in the network of the high SA group, which may reflect the ongoing emotional turbulence experienced by individuals with high SA in social or performance situations. Although individuals with elevated SA symptoms are not typically described as highly anxious outside these contexts, they may experience greater discomfort, internal agitation, and personal distress when anticipating social evaluation (Duffy et al., 2020; Israelashvili et al., 2024; Stork et al., 2023). The centrality of guilt may reflect self-blame following perceived social failures. Although findings on guilt in the context of SAD are mixed (Rozen & Aderka, 2023), our result is consistent with research suggesting that individuals with SAD often engage in post-event rumination marked by detailed revision of their social performance and associated negative thoughts (Edgar et al., 2024). They tend to perceive others as holding high standards for social interactions, to which they compare themselves (Goodman et al., 2021). A greater discrepancy between self-image and these perceived standards increases the likelihood of predicting unfavorable outcomes and considering failure to meet self-imposed standards following feared social situations. This contributes to anxiety-related behaviors and symptoms (Goodman et al., 2021; Rapee & Heimberg, 1997), where feelings of guilt may be included. Additionally, the high comorbidity between SAD and MDD (Jefferies & Ungar, 2020), along with the fact that guilt is a key symptom of depression (American Psychiatric Association, 2013), makes its prominent role in the high SA network less surprising. This group showed moderate depressive symptoms (measured by PHQ-9), while the low SA group exhibited mild symptoms (see Table 1). In sum, guilt contributes to the activation of the global network, which is characterized by emotions resistant to change and a tendency to sustain the psychopathological state.

In turn, feeling enthusiastic, determined, and inspired were the most central positive emotions in the high SA network. The prominence of enthusiasm or inspiration may result in part from their limited presence, as people with SA often suppress positive affect and have diminished experiences of these emotions (Bowers et al., 2023). This suppression could make such emotions central to their perceived absence, especially in social interactions. A recent study highlighted the prominence of positive emotions, including inspiration, interest, and contentment, among individuals meeting diagnostic criteria for SAD and/or MDD, emphasizing their deficits compared to controls (Chin et al., 2023). The centrality of “feeling determined” is not surprising and may reflect the focus of socially anxious individuals on avoiding mistakes in feared situations (e.g., avoiding

stuttering) as part of their drive to meet high social standards (Goodman et al., 2021; Rapee & Heimberg, 1997). This may represent an anxious determination to perform well socially and be accepted. Notably, “feeling determined” has also been identified as a central node in other populations with psychopathology, such as individuals with eating disorders (Wong et al., 2021).

In the low SA network, central nodes also included negative fear-related emotional states (scared, afraid, nervous), in addition to positive ones (enthusiastic, determined, delighted). These results suggest that differences between the two networks may not relate to the centrality of emotions but rather to how emotions are experienced and interconnected. The significantly lower overall connectivity, among other network properties (e.g., lower density, lower average degree, greater average path length) observed in the low SA network, suggests a less rigid and more adaptive emotional system. This is in line with studies on other forms of psychopathology (Pe et al., 2015) and further supports evidence linking emotional experience with better mental health. Studies indicate that high emotional granularity— that is, a better degree of recognition, specification and verbal differentiation of emotions, often correlated with a larger emotional vocabulary (Ikeda, 2023)— is positively associated with frequent emotion regulation, improved coping regarding stressful experiences (Tan et al., 2022), and a broad range of well-being outcomes (Erbas et al., 2022).

Taking all the above considerations into account, our findings have important clinical implications. Network connectivity (along with other network properties, such as density) may be a viable marker for predicting a more rigid and maladaptive emotion system and, consequently, the prognosis of a mental health disorder such as SAD— as proposed by network theory (Borsboom, 2017). Thus, turning off a highly connected emotion may lead to a beneficial cascade of downstream benefits, rapidly influencing other emotions, potentially reducing network connectivity. “Feeling scared” and “feeling disturbed” have been identified as emotions highly interconnected with other emotions among individuals with high SA symptoms and may serve as key targets for treatment. Interventions such as exposure therapy may be an option to target such emotional states (Heeren & McNally, 2018). This may increase tolerance of such emotions and disrupt the reinforcing cycle of negative emotional dynamics in SAD and reduce avoidance of feared situations. Addressing “guilt” through modules targeting depressive symptoms, particularly among individuals with comorbid symptoms, could also be beneficial. In turn, the centrality of “feeling determined” emphasizes the importance of therapeutic strategies that can help break the dysfunctional focus patterns related to social threats. Attention training within Cognitive Therapy (Clark et al., 2006) is an example.

Although in this study we did not estimate the associations between positive (and negative) emotions and specific symptoms of SA (which is a limitation), promoting positive emotions, such as “enthusiasm”, may further aid recovery. The network connectivity results mentioned above also highlight the need to address strategies to improve emotional differentiation and regulation skills to enhance treatment efficacy for SA (Rozen & Aderka, 2023).

Limitations

Our findings should be interpreted with limitations in mind. The stratification applied in this study— dividing participants using the LSAS-SR cutoff and randomly selecting low-symptom participants to match the sample size of the high-symptom group— may have restricted item variance in the low SA group. The possibility of self-selection bias also should be considered. Given the core features of SAD, such as fear of evaluation and discomfort discussing emotions, individuals with more severe symptoms may have been less likely to participate, potentially leading to an underrepresentation of high-severity cases and attenuated group differences. These limitations, along with unmodeled biases such as response bias and social desirability in questionnaire responses (Caputo, 2017), may have affected group comparisons and related results. Although splitting samples based on instrument scores is suitable for network comparisons (Haslbeck et al., 2020), previous research suggests that these biases may contribute to network connectivity differences between samples (Bos et al., 2018; Fried et al., 2016). Concurrently, the fact that we relied only on the LSAS-SR cut-off for stratification, without controlling comorbid symptoms such as depressive symptoms, may have affected results regarding central emotions (e.g., guilt). As reported, the high SA group exhibited moderate depression. Our findings may thus be less generalizable to SA samples with lower levels of depressive comorbidity. Symptoms of other comorbid mental disorders were not assessed, and the fact that a considerable number of participants may have been receiving psychological treatment, and some of them psychiatric treatment, may affect emotional processing, and consequently, our findings. Furthermore, we estimated cross-sectional networks, and the sample was predominantly female, which further limits generalization. The literature makes it clear that the prevalence and severity of social anxiety symptoms differ by age (e.g., higher among young people) (Jefferies & Ungar, 2020), but the fact that both groups showed a significant age difference (with the high SA group being younger than the low SA group), should still be taken into account. Replication studies with alternative stratification, longitudinal networks to capture dynamic changes in emotion networks (Curtiss et al., 2019),

and more gender-diverse samples across different settings (e.g., clinical sample rather than community-recruited sample) are needed. Understanding whether emotion networks differ by gender in the context of SAD (as done by Pe et al., 2015 for MDD) would be relevant. There is still a lot of uncertainty regarding the minimum sample size for network calculation and comparison, so studies with larger samples are also needed. Some edges may have been thicker with a larger sample, improving understanding of associations between negative and positive emotions, especially if the networks were estimated using other methods rather than MGM (Haslbeck & Waldorp, 2020). We explored micro (e.g., central nodes) and macro (e.g., average degree, connectivity) properties, but network analysis can provide several others like meso-properties (e.g., motifs) (Castro et al., 2024) that may contribute to distinguishing networks of participants with high and low levels of psychopathological symptoms. These network properties also need future attention. The Portuguese PANAS used in this study differs in some items from the original version of the PANAS (Watson et al., 1988), excluding emotions that we currently consider closer to the Portuguese culture, and which recent studies have shown to be relevant in the context of SA. Feeling ashamed, sad, angry, proud, or attentive are examples. Pride has recently been identified as a specific positive emotion that is likely to be central to SA (Chin et al., 2023); feeling attentive may also be a relevant emotion in SA, as individuals display biased attention to social stimuli/negative signs in the audience (Rapee & Heimberg, 1997); shame is also shown by extensive research to be prominent in SA (Swee et al., 2021). The presence or absence of these emotions in our networks would likely alter network metrics under study (e.g., centrality). Therefore, future network analysis studies should include them. Future studies should use measures that assess a broader emotional range, including neutral valence states (Kutsuzawa et al., 2022), and not just positive or negative valence states (as the PANAS), to improve robustness and generalizability.

Conclusion

In summary, our study represents a first step towards understanding the emotional experience associated with high and low levels of SA from a network perspective. Specifically, our findings contribute to elucidating which emotional states may play a key role in the maintenance of elevated SA symptoms and to the growing body of literature on network theory by exploring different network properties between emotion networks of participants with high *versus* low SA. Although we did not formally assess diagnostic status, our findings offer potentially relevant insights to understanding

mechanisms underlying SAD and highlight emotion network features— such as connectivity and centrality— that may inform clinical practice.

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Data availability The R code used for data analysis can be found at <https://osf.io/2fvsu/>.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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