Bridges over troubled waters:

Mapping the interplay between anxiety, depression and stress through network analysis of the DASS-21

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Abstract

Background. Symptoms of depression and anxiety often co-occur in the same individuals. In order to increase our understanding of concurrent depression and anxiety, it may be necessary to define and model psychopathology as a network of symptoms, that actively reinforce (or inhibit) one another. The current study set out to investigate how depression, anxiety and stress symptoms cluster together, and which symptoms act as bridges between these clusters.

Methods. Network analysis was used to investigate the symptom structure of the DASS-21 in a large international sample (N = 11647). After checking whether the original symptom structure was replicated, the network was further investigated at multiple levels: *individual symptoms* that are central in the network (1) or function as bridges between clusters (2); *symptom pairs* that show especially strong associations (3), and the *overall structure* that may or may not differ between gender groups (4).

Results. Items referring to panic, worry, worthlessness, hopelessness and meaninglessness of life emerged as potentially crucial symptoms in the interplay between depression and anxiety. When comparing female and male networks, the results suggest that the network structures are similar, but not identical.

Conclusions. Specific symptoms can function as bridges between depression, anxiety and stress, which is clinically relevant on top of being theoretically important.

Depressive and anxiety symptoms are highly prevalent across different countries (Lépine, 2001). For instance, about 8% of the individuals from a German community sample (~ 8000 individuals) show subclinical depressive symptoms (Busch et al., 2013), which is associated with lower income (Whooley et al., 2002), less academic success (Eisenberg et al., 2009), and worse health and quality of life (Herrman et al., 2002). Similarly, mild-to-moderate anxiety symptoms are frequently present in the general population as well (Fehm et al., 2008; Haller et al., 2014). Unfortunately, depressive and anxiety symptoms do not usually arise independently of each other, but often co-occur in the same individuals. In fact, about 42% of respondents in the World Mental Health Surveys (~74000 individuals, across 24 countries) that report a depressive episode in the past year, also report an anxiety disorder being present in the past year (Kessler et al., 2015). Similarly, data from 1783 respondents in a Dutch cohort study (Spinhoven et al., 2011) even suggests that the majority of people diagnosed with a depressive disorder are simultaneously diagnosed with an anxiety-related disorder, or vice-versa ("comorbidity problem", Meehl, 2001). Moreover, previous studies show that individuals who contemporarily report depressive and anxiety complaints show greater psychosocial disability (Hirschfeld, 2001), lower quality of life (Johansson et al., 2013), and are at higher risk of suicide attempts (Bronisch & Wittchen, 1994). Hence, it is of crucial importance to tackle the complexity of the dynamics between depressive and anxiety symptoms.

Several explanatory models have so far been proposed to shed light on this issue. For instance, the tripartite model (Clark & Watson, 1991; Watson et al., 1995) greatly informed our conceptualization of the relationship between depressive and anxiety symptoms. Specifically, the authors of this model suggest that three factors, each representing a cluster of symptoms, are required to properly delineate depression and anxiety, as well as to better

understand their interrelation. These factors are general distress, which is present in all emotional disorders, the absence of positive affect and the presence of hyper-arousal, which are differently related to depression and anxiety. According to this model, major depression is characterized by general distress and absence of positive affect, but not by hyper-arousal, while anxiety disorders usually show high levels of general distress and hyper-arousal, but no low levels of positive affect (Clark & Watson, 1991).

This theoretical framework has deeply influenced our understanding of the comorbidity problem and inspired the development of several self-report questionnaires, among which the Depression Anxiety Stress Scales (DASS) (Lovibond & Lovibond, 1995) and its shortened version (DASS-21) (Henry & Crawford, 2005). The DASS instruments include three factors, namely *depression*, *anxiety*, and *stress*, which partially mirror the tripartite model. The depression factor refers to low positive affect (i.e., “I couldn’t seem to experience any positive feelings at all” and “I was unable to become enthusiastic about anything”), while the anxiety factor mostly reflects physiological hyper-arousal (i.e., “I experienced breathing difficulty (e.g., excessively rapid breathing, breathlessness in the absence of physical exertion)” and “I was aware of the action of my heart in the absence of physical exertion (e.g., sense of heart rate increase, heart missing a beat)”). The nature of the DASS stress factor is more complex, in that it mostly refers to symptoms of tension (i.e., “I tended to over-react to situation” and “I found it difficult to relax”) (Lovibond & Lovibond, 1995), while the general distress in the tripartite model includes worrying, cognitive complaints (e.g., troubles concentrating, remembering, deciding, etc.) and various negative feelings (Watson et al., 1995).

Psychometric studies have repeatedly shown that the three subscales of the DASS show moderate-to-high correlations (Lovibond & Lovibond, 1995; Norton, 2007; Osman et

al., 2012). This finding is interesting, in that it can be interpreted in several, non-mutually exclusive manners. Traditionally, it has been proposed that depression, anxiety, and stress could share a common cause, such as neuroticism or common environmental stressors (Lovibond & Lovibond, 1995). Although plausible, this account is not unproblematic, in that, for instance, it cannot explain why depression and anxiety complaints show different temporal dynamics, with anxiety symptoms typically preceding depressive symptoms (Cole et al., 1998; Wetherell et al., 2001).

Recently, it has been proposed that in order to increase our understanding of concurrent depression, anxiety and stress, it may be necessary to move beyond categorical thinking. Rather than assuming that depression and anxiety are discrete, naturally occurring conditions with a common cause and a clearly defined set of symptoms, researchers have put forward an alternative view, namely the network approach to psychopathology (Borsboom & Cramer, 2013; Fried, 2015). In terms of the network framework, symptoms do not stem from latent causes, but they actively reinforce (or inhibit) one another, eventually leading to the emergence of full-blown mental disorders (Borsboom, 2017). For example, an individual that has gone through an embarrassing or humiliating event could start experiencing physical (e.g., sweating) and cognitive (e.g., catastrophizing) symptoms of anxiety in similar social situations. The individual may also feel more tense when anticipating social situations, potentially developing the tendency to avoid these situations. Hence, stress symptoms, behavioral avoidance, the physical experience of anxiety, and anxiety-related cognitive processes could sustain or even exacerbate one another, resulting in more serious complaints and gradually worse quality of life. It is clear from this example that rather than a latent disorder at the root of each of the symptoms, social anxiety emerges from the dynamics between symptoms themselves (Borsboom, 2017).

Another implication of this approach is that symptom dynamics do not necessarily stay within the borders of any given diagnostic category (Borsboom, 2017). In the network approach to psychopathology, the phenomenon of comorbidity can be understood as different clusters of strongly linked symptoms, some of which connect two (or more) clusters. When two symptoms that belong to two different clusters are connected, this forms a bridge, which represents a fundamental mechanism to understand comorbidity (Cramer et al., 2010). In fact, the presence of a bridge increases the chance that the activation of symptoms within a cluster will spread to and, eventually, activate another cluster of symptoms (Borsboom, 2017; Fried et al., 2017). For instance, for the individual described earlier, the anxiety cluster (with various physical symptoms, cognitive processes and behavioral avoidance as nodes) may not sufficiently capture the psychopathology of the individual, until a depression cluster is added to the network, consisting of feelings of sadness, worthlessness and loneliness, that are associated with one another. In this network, there may for example be a frequent co-occurrence of behavioral avoidance (anxiety) and feelings of loneliness (depression), effectively linking both symptom clusters together. Previous theoretical (Fried et al., 2017) and empirical work (Garabiles et al., 2019; Gilbar, 2020; Heeren et al., 2018; Jones et al., 2018; Smith et al., 2019) has shown that identifying network bridges in psychopathology is highly informative, as it can help to shed light on the symptoms that put patients at risk for comorbidity, and are therefore important to closely monitor or even directly target in clinical practice.

With the current study, we set out to investigate how depression, anxiety, and stress symptoms, as measured with the DASS-21 (Henry & Crawford, 2005), cluster together, and which symptoms act as bridges between these clusters. Importantly, we ran this study on a large sample (> 10.000 individuals), derived from all over the world. Additionally, we

investigated gender differences at the level of network *structure*, as well as gender differences in symptom *levels*.

Interestingly, earlier studies with the DASS in broad, mostly non-clinical samples have typically led to inconsistent findings, even when relying on the scale and total scores. For instance, in the seminal work by Crawford and Henry (2003) on the full version of the DASS, the female average was significantly higher for the depression, anxiety and total scores, but not for the stress score, with the same pattern of findings emerging with the DASS-21 (Henry & Crawford, 2005). By contrast, Norton (2007) only found a difference for the stress score (female average > male average). In other studies, there have been significantly higher scores for females on all or most scales (Pezirkianidis et al., 2018; Szabó, 2010), no differences at all (Bottesi et al., 2015), or even a difference in the opposite direction: a higher average on the depression score for males (Wang et al., 2015). In addition to differences related to the samples (e.g., age, cultural background, etc.), such inconsistencies may also be explained by the fact that the sum scores are concealing gender differences at a smaller scale, such as differences in the levels of individual symptoms, but also in the strength of the links between symptoms. As an example of the latter, Mullarkey and colleagues (2019) concluded that body-image and self-hatred were more strongly related in the female network than in male network.

In sum, with this study we primarily aimed to provide more fine-grained knowledge on how depression, anxiety, and stress are associated with one another and to shed light on key symptoms and symptom associations to consider when diagnosing, treating or even preventing comorbid psychopathology. As a secondary goal, we explored whether or not there are gender differences at the level of individual symptoms and symptom associations. We

relied on a careful investigation of the network structure of the DASS-21 as the means to answer our primary and secondary research questions.

Method

Participants

The original sample was derived from the *Open Source Psychometrics Project* and initially consisted of 39775 individuals[1]. To ensure high quality data, we excluded those individuals who were *non-native* English speakers (n = 25395) and/or failed a simple language test (i.e., not recognizing fake words) (n = 5192)[2]. The final sample consisted of 11647 individuals (25.7% males, 71.2% females, 3.1% other; age = 24.6 ± 11.5, range = 13 - 89). Different age groups were included, ranging from adolescents to elderly (13-17 = 27.6%; 18-24 = 41.4%; 25-40 = 19.8%; 41-64 = 10.3%; 65-90 = 0.9%). Different levels of education were present (40.1% high school; 28.8% university degree; 18.8% less than high school; 10.3% graduate degree; 2% no information provided). The sample was racially diverse (race/ethnicity: 53.7% White/Caucasian; 30% Asian; 3.2% Black; 1.1% Native American, 12% other). Of the final sample, about 50% of the sample was from the US, 25% from Malaysia, about 7% from the UK, 5% from Canada, 3.5% from Australia, and the remaining 12.5% from all over the world. Data are publicly available (https://openpsychometrics.org).

Measure

Depression Anxiety Stress Scales (DASS) (Lovibond & Lovibond, 1995). The DASS is a self-report questionnaire, specifically developed to cover the full range of core symptoms of depression, anxiety, and stress. The original version consisted of 42 items, measured on a

4-point Likert scale, ranging from 1 (“*did not apply to me at all*”) to 4 (“*applied to me very much, or most of the time*”). Several psychometric studies supported a three-factor solution in the general and clinical population (Brown et al., 1997; Lovibond & Lovibond, 1995), as well as in adolescent and elderly individuals (Szabo, 2010; Wood et al., 2010). Furthermore, the DASS has been validated in many languages, such as Spanish, Italian, Chinese, among other languages (Bados et al., 2005; Bottesi et al., 2015; Gong et al., 2010). More recently, a short version of the DASS was developed (Henry & Crawford, 2005). The DASS-21 consists of 21 items and has rapidly become the preferred version of this instrument, considering that it has solid psychometric properties and it is more time-efficient, as compared with the 42-item version (Norton, 2007). In this study, we analyzed the DASS-21 version (see below for the details) and the questionnaire was administered in English.

Statistical Analysis

Before starting the analytical process, we decided to focus on the DASS-21, instead of the DASS, given that the lengthier version contains several pair of symptoms that are almost identical (e.g., “*I felt I wasn’t worth much as a person*” and “*I felt I was pretty worthless*”). This decision was based on several considerations. The presence of items, which are only subtly different, can substantially alter the structure and the local properties of the network, such as inflating the strength of such items and obscuring the centrality of the other nodes. On the contrary, the DASS-21 does not list identical items, as they were removed during the shortening procedure (Henry & Crawford, 2005). Finally, the short version of the DASS is currently the most frequently used version (Norton, 2007) and a network analysis on the DASS-21 could be highly informative for a larger audience of researchers and practitioners.

We then proceeded as follows. First, we inspected the mean, standard deviation, and polychoric correlations of all the DASS-21 items. In line with previous studies (Marchetti, 2019; Mullarkey et al., 2019), we evaluated item mean level and item informativeness (i.e., standard deviation) to detect the presence of uninformative items. Moreover, we statistically evaluated whether overlapping pairs of items were present in the network. Two items were deemed to be overlapping if the polychoric correlations between the first node with the rest of the items and the second node and the rest of the items were statistically different in less than 25% of the cases (for details, see Jones, 2018).

Second, in line with current guidelines (Epskamp & Fried, 2018), we estimated an EBIC graphical LASSO network model with all the twenty-one items. By doing so, every association between two symptoms (i.e., *edge* between *nodes*) was controlled for all the symptoms, after applying a LASSO regularization. Blue edges indicate a positive relation, while red edges refer to negative ones.

Third, local network properties were operationalized as *strength*, *expected influence*, and *predictability*. Strength refers to the sum of the absolute weights of the edge connecting the node to all the other nodes (Valente, 2012), while expected influence is defined as the (non-absolute) sum of all edges extending from a given node, also known as one-step expected influence (Robinaugh, Millner, & McNally 2016). As compared to strength, expected influence explicitly considers the scenario where a given node is connected with other nodes in opposite directions (i.e., negative and positive) and this may cancel out its influence in the network. Then, predictability measures how well a certain node is predicted by all its neighboring nodes (Haslbeck & Waldorp, 2018). Hence, predictability ranges from 0 to 1 and quantifies the amount of variance of a certain node accounted for by all the related nodes.

Fourth, it is possible to detect nodes that share common properties and play a similar role within the network, namely communities (Fortunato, 2010). It has been argued that communities in networks mirror latent variables (Golino & Epskamp, 2017) and, under certain circumstances, network communities and latent models are mathematically equivalent (Chandrasekaran et al., 2010). Despite this equivalence, the interpretations derived from the two approaches are markedly different. Within the common cause model, all the symptoms are thought to stem from an underlying cause (i.e., depression), while the network approach contends that it is the way the different symptoms reinforce one another that allows the emergence of the disorder (Borsboom & Cramer, 2013). To investigate the internal network organization, we adopted the walktrap algorithm, which is the most frequent algorithm used for psychological networks (Golino & Epskamp, 2017) and provides a measure of similarities between nodes based on random walks (Yang et al., 2016). It is worth stressing that the walktrap algorithm is fully deterministic (i.e., no randomness involved) and it considers only the magnitude of the network edges, whether they are positive or negative. We then complemented this analysis with the spinglass algorithm, which clusters the nodes that are highly connected within the same community and poorly connected with nodes belonging to other communities (Yang, Algesheimer, & Tessone, 2016). The spinglass algorithm does take into account whether the edges are positive or negative and it is based on a probabilistic procedure. Given that this algorithm is non-deterministic (i.e., randomness involved), we replicated the spinglass clusterization 1000 times, in order to present trustworthy results. Moreover, we investigated the level of *bridge strength* and *bridge expected influence* of each symptom. Bridge strength is defined as the sum of the absolute value of all edges that exist between a node A and all nodes that are not in the same community as node A (Jones, 2018), while bridge expected influence is a similar index, but it considers the sum of the (non-absolute) value of all edges. In our study, we computed the bridge strength and bridge

expected influence of each symptom belonging to a given community with the symptoms belonging to other communities, separately (e.g., depression-anxiety, depression-stress, anxiety-stress).

Fifth, we tested the stability and accuracy of the network, by means of the bootstrap approach (Epskamp et al., 2018). Initially, we evaluated the stability of strength, bridge strength, and edges of the network. If the coefficient of stability (*CS-coefficient*) was above 0.5, the parameter was deemed as highly stable. Edge accuracy was also checked visually, by inspecting the 1000-bootstrap 95% non-parametric confidence of intervals (CIs), with narrower CIs suggesting a more precise estimation of the edge. Intra-network differences at level of both strength values and edges were also investigated. For instance, if the CI of the difference between two strength values did not contain zero, the two values were deemed as statistically different from each other.

Sixth, network differences between males and females were tested in three ways, namely at level of network global connectivity, network structure, and single edges (van Borkulo et al., 2016). Global connectivity refers to the absolute sum of all the edges of the network, while network structure difference indicates maximum (absolute) element-wise difference among all the possible edges. Conditional upon the network structure difference, we also tested for statistically significant differences at level of each single edge.

All the analyses were performed with the following R-packages: *igraph 1.2.*4, *qgraph 1.6.1*, *bootnet 1.2.2, mgm 1.2-2, networktools 1.2.1*, and *NetworkComparisonTest 2.0.1* (Csardi & Nepusz, 2006; Epskamp et al., 2018; Epskamp et al., 2012; Haslbeck & Waldorp, 2018; Jones, 2018; van Borkulo et al., 2016).

Results

Descriptive statistics and items check

Mean, standard deviation, and polychoric correlations of DASS-21 items are reported in Table 1. Before performing network analysis, we checked for item mean level, item informativeness (i.e., item standard deviation), and item redundancy. On average, the items reported a mean level of 2.4 on a range between 1 and 4. All items were above the informativeness threshold (i.e., 2.5 SD below mean level, $M_{SD} = 1.08 \pm 0.05$) and no item was considered as statistically redundant (i.e., > 25%). Hence, all items were included in the analysis.

Network estimation and local network properties

The network estimated on the DASS-21 items is shown in Figure 1. Several points are worth mentioning. First, different symptoms had different degrees of connectedness with the rest of the network. For instance, symptom #13 ("*I felt down-hearted and blue*") was highly connected, while symptom #2 ("*I was aware of dryness of my mouth*") was poorly connected.

Second, local properties analysis showed that symptom #15 ("*I felt I was close to panic*") was the most central node, followed by symptoms of meaninglessness, lack of enthusiasm, nervous energy expenditure, feelings of worthlessness, lack of positive feelings, and lack of positive expectations (third tertile) (Figure 2 and 3). Interestingly, the symptoms with the lowest centrality were experiencing a dry mouth, lacking initiative to do things, feeling touchy, and experiencing trembling (first tertile). Strength was particularly stable (CS-coefficient = 0.75), in that similar centrality values would be obtained, even if up to 75% of

the sample were dropped (Epskamp et al., 2018). Expected influence and strength value were highly correlated (r_s = .91 [.78; .96]) and almost identical results were obtained (Figure 2).

Third, the analysis of predictability revealed that on average about 50% of each node's variance could be explained by surrounding nodes ($M_{predictability} = 0.49 \pm 0.11$). While, symptom #21 ("*I felt that life was meaningless*") was substantially accounted for (predictability index = 0.64), symptom #2 ("*I was aware of dryness of my mouth*") was poorly explained (predictability index = 0.24). Although on average half of each symptom's variance could potentially be explained by the other nodes, this also implies that the remaining 50% of variance was not explained by only considering the interplay among symptoms.

Fourth, strength, expected influence and predictability were unrelated with item variability (r_s = .28 [-.16; .64], r_s = .29 [-.15; .64], and r_s = .39 [-.04; .70], respectively) or item mean (r_s = .08 [-.36; .49], r_s = .21 [-.23; .59], and r_s = .21 [-.24; .58], respectively).

Community analysis and bridge symptoms

Community analysis detected a pattern of clusterization (Figure 1), which was stable across the two different algorithms (i.e., walktrap and spinglass). The walktrap algorithm clustered the symptoms in a way that was almost identical with previous factor analysis studies (Henry & Crawford, 2005). The depression community consisted of seven symptoms, while anxiety and stress communities counted eight and six symptoms, respectively. Unlike previous factor studies (Henry & Crawford, 2005; Norton, 2007; Osman et al., 2012), symptom #8 ("*I felt that I was using a lot of nervous energy*") was included in the anxiety community, instead of the stress community.

Importantly, the spinglass algorithm detected the same pattern as the walktrap algorithm in the majority of the cases (i.e., 65% over 1000 repetitions). In about 33% of

repetitions, a similar pattern of communities was detected, with the exception of symptom #1 ("*I found it hard to wind down*") and #12 ("*I found it difficult to relax*"), which were clustered separately. Finally, in about 2% of the cases, five communities were detected, with different combinations involved. Given previous factor studies on DASS-21 (Anghel, 2020; Crawford & Henry, 2003), this variability is expected. In particular, the strong association between item #1 and #12 has previously been interpreted in factor studies as covariance of errors (Crawford & Henry, 2003; Johnson et al., 2016) and this could have affected the spinglass algorithm in a minority of the cases. Hence, in our study, we adopted the community solution most frequently detected by both the walktrap and spinglass algorithms.

Then, we analyzed bridge strength among communities, which produced highly stable results (CS-coefficient = 0.75). As for the interplay between the depression and anxiety community, the symptoms #17 ("*I felt I wasn't worth much as a person*", depression) and #9 ("*I was worried about situations in which I might panic and make a fool of myself*", anxiety) were the nodes with highest bridge strength (Figure S1). As for the interplay between the depression and stress communities, the symptoms #13 ("*I felt down-hearted and blue*", depression), #5 ("*I found it difficult to work up the initiative to do things*", depression), #12 ("*I found it difficult to relax*", stress), and #11("*I found myself getting agitated*", stress) were some of the nodes more strongly acting as bridge symptoms (Figure S2). Here, it is worth mentioning that in this particular set of bridge strength values, the differences between certain estimates are rather small, implying that the symptoms with higher values do not stand out as much as in the other cases. In specific terms, we are referring to the perhaps negligible differences between symptoms #11 and #12 on one hand, and two other stress symptoms on the other hand (i.e., "touchy" and "intolerant", cf. Figure S2). Finally, with respect to the interplay between the anxiety and stress communities, symptoms #8 ("*I felt that I was using a*

lot of nervous energy", anxiety), #6 ("*I tended to over-react to situations*", stress), and #12 ("*I found it difficult to relax*", stress) had the highest bridge strength values (Figure S3). When examining the bridge expected influence values, almost identical results were obtained (see Figure S1, S2, and S3) (range r_s = .64 [.29; 84] to .95 [.87; .98].

Accuracy and edge comparisons

The 210 edges were estimated in a precise way (Figure S4), as also confirmed by the CS-coefficient = 0.75. Hence, the network was deemed as highly accurate. Overall, the majority of edges were different from one another (Figure S5). In particular, five edges were statistically different from all the other edges in the network, namely symptoms #1-#12 ("*I found it hard to wind down*", "*I found it difficult to relax*"), symptoms #21-#17 ("*I felt that life was meaningless*", "*I felt I wasn't worth much as a person*"), symptoms #16-#3 ("*I was unable to become enthusiastic about anything*", "*I couldn't seem to experience any positive feeling at all*"), symptoms #10-#21 ("*I felt that I had nothing to look forward to*", "*I felt that life was meaningless*"), and symptoms #19-#4 ("*I was aware of the action of my heart in the absence of physical exertion*", "*I experienced breathing difficulty*").

Gender differences

Previous studies on adolescents showed that symptom networks could be partially different between males and females (Mullarkey et al., 2019). Hence, we directly tested whether global strength, structure, and single edges were different by gender. Overall, the two networks appeared similar (Figure S6), although there were some differences at the level of strength values (Figure S7). Global strength was not statistically different between males and females (males = 9.70, females = 9.66, $p < 0.26$), while the network structure was a function of gender (maximum difference = 0.09, $p < 0.005$). To follow up on this structure difference,

we tested for internetwork differences at the level of each edge. After applying Holm-Bonferroni correction, seventeen edges were different between males and females. Considering the large sample, we only reported edge difference ≥ 0.05. As compared to males, females had the stronger edges at level of symptoms #11-#13 ("*I found myself getting agitated*", "*I felt down-hearted and blue*"), and symptoms #21-#17 ("*I felt that life was meaningless*", "*I felt I wasn't worth much as a person*"). As compared to females, males had stronger edges at symptoms #20-#15 ("*I felt scared without any good reason*", "*I felt I was close to panic*"), symptoms #12-#20 ("*I found it difficult to relax*", "*I felt scared without any good reason*"), symptoms #18-#11 ("*I felt that I was rather touchy*", "*I found myself getting agitated*"), and symptoms #18-#7 ("*I felt that I was rather touchy*", "*I experienced trembling*").

Finally, we tested whether males and females reported statistically different symptom mean levels. There were 17 out of 21 symptoms with statistically significant (all adjusted *p*-values ≤ .012) differences (Table S1). For only one out of those 17 symptoms, the mean was higher in males than in females: symptoms #16 ("*I was unable to become enthusiastic about anything*"), which is part of the depression community. Moreover, each of the four remaining symptoms that do not show statistically significant mean-level differences between males and females (all adjusted *p*-values ≥ .42), are part of the depression community as well: symptoms #3 (*"I couldn't seem to experience any positive feeling at all"*), #5 ("*I found it difficult to work up the initiative to do things"*), #10 (*"I felt that I had nothing to look forward to"*), and # 21 (*"I felt that life was meaningless"*). However, the magnitude of the differences were negligible-to-small (Cohen's d ≤ 0.33). Symptom level differences in females and males should therefore be interpreted with caution.

Comparison between the selected and the original samples

For sake of completeness, we re-ran the analysis on the full original sample (n = 39775), without excluding any individual. Confirming our main findings, we obtained almost identical results, in terms of network edges ($r_s = 0.94$ [0.92; 0.95]), strength values, and community detection (Figure S8 and Figure S9).

Discussion

Symptoms of depression and anxiety are highly prevalent (Lépine, 2001) as well as frequently comorbid (Kessler et al., 2015), implying that the mechanisms behind their co-occurrence should be better understood. The current study thus set out to investigate the symptom structure of the 21-item version of the DASS, by using network analysis in a large, international sample. Through community analysis, we were able to replicate earlier research (Henry & Crawford, 2005), as depression, anxiety and stress symptoms are clustered identically, with the exception of one symptom (i.e., item 8: "*I felt that I was using a lot of nervous energy"*) that is part of the anxiety community rather than the stress community. This finding indicates that the different clusters in our sample are robust and comparable to earlier work. This allows a further examination of more specific aspects of the clustering between anxiety, depression, and stress, at the level of: (1) *individual symptoms* that are the most central in the network as a whole; (2) individual symptoms that bridge specific communities; (3) *symptom pairs* that show especially strong edges, and (4) the *overall network* strength and structure that may or may not differ between gender groups. The results are discussed below.

First, the strength and expected influence values of each symptom were evaluated. Feeling close to panic (symptom #15, anxiety community) has the highest centrality value,

with five out of seven symptoms from the depression community being not far behind: meaninglessness, lack of enthusiasm, feelings of worthlessness, lack of positive feelings, and lack of positive expectations. Panic as well as symptoms related to anhedonia are thus the most central nodes in the network. In other words, these nodes are overall most strongly connected with the other nodes in the network, which is largely in line with the existing literature. For instance, in a network analysis of the Clinician version of the Inventory of Depressive Symptomatology (Rush et al., 1996), loss of interest, loss of pleasure and panic were among the most central nodes as well (Fried et al., 2016). An important difference however, is the fact that sympathetic arousal was also a central symptom (Fried et al., 2016), whereas related symptoms from the DASS-21 (dry mouth, trembling and being aware of the action of my heart in the absence of physical exertion) are the least central nodes of the network in the current study. Crucially, our results are also consistent with findings at the level of disorders, as manualized by the Diagnostic and Statistical Manual of Mental Disorders (DSM). In a network analysis investigating 120 symptoms from twelve DSM-IV diagnoses, each diagnosis was connected with at least three other diagnoses, but both panic disorder and a major depressive episode had connections with ten other diagnoses, the highest amount that was observed (Boschloo et al., 2015).

It is worth reminding that the interpretation and implications of the centrality index is currently debated. On the one hand, several studies showed that the centrality of symptoms is predictive of subsequent diagnosis in both depression and PTSD (Boschloo, van Borkulo, Borsboom, & Schoevers, 2016; Haag, Robinaugh, Ehlers, & Kleim, 2017). Moreover, centrality indices are correlated with the magnitude of correlation between change in the symptom and change in the remainder of the network in social anxiety (Rodebaugh et al., 2018). Interestingly, recent evidence showed that central symptoms in anxiety are likely to be

more genetically heritable than peripheral symptoms (Olatunji, Christian, Strachan, & Levison, 2020). On the other hand, equating symptoms centrality to causality has been questioned at both theoretical (Bringmann et al., 2019) and empirical (Dablander & Hinne, 2019) level. Hence, while interpreting the results on centrality, we recommend great caution and suggest interpreting the most central items as the most connected ones. Future empirical and longitudinal studies will evaluate their causal status in the symptoms network.

Second, symptoms functioning as bridges between each pair of the aforementioned clusters were identified, by analyzing which symptoms of one community are most strongly connected with the symptoms of another community. When focusing on the connections between the depression and anxiety communities, one symptom of each community stands out in terms of bridge strength. Of all depression symptoms, item #17 ("*I felt I wasn't worth much as a person*") is most strongly connected with the anxiety community, while item #9 ("*I was worried about situations in which I might panic and make a fool of myself*") is the anxiety symptom that is most strongly connected with the depression community. These results suggest that individuals reporting feelings of worthlessness are likely to also report anxiety symptoms. In the same way, individuals that report depressive symptoms are likely to worry about situations in which they may panic and make a fool of themselves. Additionally, these worries, as well as feelings of worthlessness, tend to co-occur with other symptoms in their corresponding communities. As such, items #9 and #17 represent symptoms that are, according to our findings, key nodes in the spreading of activation across the depression and anxiety clusters within this network.

Given the importance of items #9 and #17 for the co-occurrence of symptoms of depression and anxiety, we will elaborate on each of these symptoms, starting with the former. Research in a non-clinical population suggests that worry (e.g., item #9) and

rumination (Nolen-Hoeksema, 2000), though they are often referred to as symptoms of anxiety and depression respectively, show more similarities than differences (Watkins et al., 2005). This finding supports the notion that both concepts refer to the same process, but with different content (Segerstrom et al., 2000). The temporal orientation of this content is one of the few differences, with worries being relatively more future-oriented, and ruminative thoughts more often relating to the past (Watkins et al., 2005). As such, people who tend to worry (e.g., about future situations in which they could panic) may also be more likely to ruminate (e.g., about past situations in which they felt embarrassed after panicking). Indeed, worry and rumination are considered to be specific examples of Repetitive Negative Thinking (RNT) (Ehring & Watkins, 2008), a more broadly defined construct that has been put forward as a transdiagnostic process in emotional disorders (Drost et al., 2014; Klemanski et al., 2017; McEvoy et al., 2013). The finding that worry (item #9) is the anxiety symptom that co-occurs most often with symptoms of the depression cluster, is thus in line with a transdiagnostic view on RNT. In addition, this finding is also consistent with other network analyses in the literature, that have identified strong bridging edges between worry and depressed mood or sadness, in youth (McElroy et al., 2018) and psychiatric patients (Beard et al., 2016). In a community sample of Kenyan adolescents, excessive and uncontrollable worry was the most central symptom in the anxiety network, whereas depressed mood and self-blame were most central in the depression network (Osborn et al., 2020). Unfortunately, the bridging edges of this particular network are unknown, as symptoms of depression and anxiety were investigated independently. Still, it is worth pointing out that the same (worry) or conceptually-related (self-blame versus worthlessness) symptoms seemed to play a key role.

Feeling worthless (item #17) is the other DASS-item that is key in terms of bridging the anxiety and depression communities, as it is the symptom in the depression cluster that co-occurs most often with symptoms of the anxiety cluster. Again, this result is in line with a

similar finding from an earlier network analysis (Langer et al., 2019). In that study, symptoms from major depressive disorder and social anxiety disorder were investigated in a sample of female patients. Despite a relatively modest sample size, the authors found support for a bridging role of worthlessness, as it is connected depressed mood with moodiness, which was in turn connected to social fear. Moreover, an important meta-analysis of longitudinal studies on self-esteem (Sowislo & Orth, 2013) is also of interest in this context, as the authors found that (low) self-esteem was not only prospectively and bidirectionally related to depressive symptoms, but to anxiety symptoms as well. Links between anxiety and low self-esteem should therefore not be overlooked, relative to the links between depression and low self-esteem, that have been investigated to a greater extent in the past (Sowislo & Orth, 2013). Although the current study lacks the longitudinal perspective of the studies in the abovementioned meta-analysis, it does indicate to what degree low self-esteem (i.e., feeling worthless) co-occurs with *specific* depression and anxiety symptoms, besides identifying it as a potentially important symptom in case of comorbidity.

With regards to the connections between the depression and *stress* communities, symptom #13 ("*I felt down-hearted and blue*") stands out. Symptoms #5 ("*I found it difficult to work up the initiative to do things"*), #11 ("*I found myself getting agitated*") and #12 ("*I found it difficult to relax*") also seem to hold potential as bridges, but to a somewhat lesser degree. Symptoms #12 and #13 in particular, together with the bridging potential of worry (cf. supra), is consistent with yet another network analysis (Price et al., 2019), in which two sets of strong edges (chronic worry – depressed mood and depressed mood – inability to relax) were put forward as a potential mechanism behind the co-occurrence of depression and (generalized) anxiety. One of our results regarding the connections between the *stress* and *anxiety* communities provides further support, as difficulties to relax (symptom #12) is also one of two stress symptoms that are most strongly connected with the anxiety cluster. The

other stress symptom that stands out in this regard, is a tendency to overreact (symptom #6). Symptom #8 ("*I felt that I was using a lot of nervous energy*") shows a high bridge strength as well, which is perhaps unsurprising: the symptom is part of the anxiety community, although it is normally a stress item. A potential explanation for this small deviation from the typical DASS-21 structure (Henry & Crawford, 2005; Norton, 2007) is that the understanding of this particular item was influenced by the different regions the respondents were from. Interestingly, about 25% of our sample is both a native English speaker and from Malaysia and a previous study showed that specifically symptom #8 cross-loaded on the anxiety factor in Asian samples (Oei et al., 2013).

Third, edges between symptom pairs were analyzed. With 21 nodes (symptoms) in the network, there are a total of 210 edges (associations) possible. The strengths of these edges can then be compared, which allows us to identify sets of two often co-occurring symptoms. The five edges that are statistically different from almost all other 215 edges in the network, are all between node pairs that are either within the stress community or within the depression community, suggesting frequent co-occurrence of those specific pairs of symptoms. This is compatible with the finding that an anxiety symptom (item #15: "*I felt I was close to panic*") is overall the most central node in the network, implying that this symptom shows the highest strength across all edges it has with every other node (symptom) in the network.

An interesting set of edges within the depression community is located around symptom #21 ("*I felt that life was meaningless*"), which shows strong connections with both symptom #10 ("*I felt that I had nothing to look forward to*") and symptom #17 ("*I felt I wasn't worth much as a person*"). These symptoms and their connections are of interest, because each item essentially relates to one aspect of the cognitive triad of depression (Beck, 1979): negative views about oneself (#17: worthlessness), the world/life (#21:

meaninglessness) and the future (#10: hopelessness). Crucially, recent data suggests that the cognitive triad is more than just a product of a depressed state: harboring such views may negatively influence the individual's communication style, potentially increasing the risk of interpersonal conflict and generating additional stress (Keser et al., 2017).

The importance of this triad is not limited to depression however, as the current study identifies feeling worthless as the depression symptom that shows the strongest connections with the anxiety community. Hopelessness, on the other hand, was previously found to be related to depression but not to anxiety (when controlling for anxiety and depression respectively), in both healthy and clinical samples (Marchetti et al., 2016). In addition, hopelessness explained a significant amount of variance in depressive symptoms, above and beyond RNT and dysfunctional attitudes, which only explained a negligible amount of unique variance (Marchetti et al., 2016). In light of these earlier findings, hopelessness seems to play a key role in depression in particular, though the current results also underline that symptom patterns often do not perfectly align with what is theoretically understood as either depression or anxiety. Hopelessness frequently co-occurs with meaninglessness and worthlessness, which tends to co-occur with symptoms in the anxiety cluster. Consequently, hopelessness may be present in a considerable subgroup of people reporting anxiety symptoms as well. In a clinical context, it is possible that severe and persistent anxiety symptoms can intensify or perhaps even trigger hopelessness. Crucial considerations in this case are whether or not the anxiety symptoms (e.g., panic attacks) block the individual's ability to attain highly valued goals, in the present as well as in the future, due to a perceived lack of control over said symptoms (Marchetti et al., 2019). On a related note, it is unfortunate that the DASS does not include an item measuring suicidal thoughts, as it would have been interesting to see whether such an item would show strong edges with symptoms #10 and #21 in particular.

Fourth, gender differences were explored. When looking at mean symptom *levels*, the female average was slightly but consistently higher than the male average for symptoms from both the stress cluster and the anxiety cluster. Such a pattern was absent in the depression cluster: depending on the symptom, the mean score can be slightly higher for females (#13: *"I felt down-hearted and blue"* and #17: *"I felt I wasn't worth much as a person"*), slightly higher for males (#16: *"I was unable to become enthusiastic about anything*"), or not different at all (symptoms #3, #5, #10 and, #21). These results are consistent with earlier findings from a Malaysian sample, in which the average scores on the anxiety and stress scales were significantly higher in females, whereas the average score on the depression scale did not significantly differ (Imam, 2008).

More importantly, the networks of male and female participants were checked for differences at the level of global strength and network *structure*. While the global strength of the network is not different between males and females, we found that the network structure is indeed a function of gender, which was further investigated by identifying the specific edges that are statistically different in males and females. Some edges are stronger in females, as is the case in the worthlessness/meaninglessness node pair mentioned earlier, for instance. On the other hand, symptom #20 ("*I felt scared without any good reason*") is more strongly connected with symptoms #12 and #15 ("*I found it difficult to relax*" and "*I felt I was close to panic*") in males than in females. Intriguingly, edges that were stronger in females included three symptoms from the depression cluster (symptoms #13, #17, and #21), versus one from the stress cluster (#11) and none from the anxiety cluster. The edges that were stronger in males, however, did not involve any symptom from the depression cluster, but consisted of symptoms from the anxiety (symptoms #7, #15, and #20) and stress clusters (symptoms #11, #12, and #18) instead. So, while the average scores tend to be slightly higher for all anxiety and stress symptoms in females, there are multiple edges within and between the anxiety and

stress clusters that suggest more *co-occurrence* of specific anxiety and stress symptoms in males. In the case of symptoms #13 (*"I felt down-hearted and blue"*) and #11 (*"I found myself getting agitated"*), both the average scores as well as the edge strength are higher in females, which suggests that these symptoms are not only reported to a slightly higher degree, but also more often at the same time in females.

Symptom #11 ("*I found myself getting agitated*) is also of special interest, as it demonstrates a contrast between the male and female network. In females, this symptom shows a stronger correlation with symptom #13 ("*I felt down-hearted and blue*"), whereas the correlation with symptom #18 ("*I felt that I was rather touchy*") is stronger in males. This pattern of results could be interpreted as males being on average more likely to respond to stress with hostility, as compared to females, who are more likely to show increased sadness (Verona et al., 2007). Such an interpretation is speculative at this point however, and rather than overemphasizing the differences between genders, it is important to stress that the overall structure of the networks of each gender group is rather similar, with individual symptoms showing negligible-to-small mean level differences at best.

Overall, caution is warranted when interpreting these findings, as the data is correlational and does not allow to infer specific causal mechanisms between symptoms, especially given the fact that on average half of the variance in the symptoms is *not* explained by the other symptoms in the network (see the results regarding node predictability). In other words, the network is likely missing relevant symptoms that could be highly correlated with symptoms that are already in the network. With the inclusion of such crucial symptoms, new strong edges would emerge, while some of the original edges may turn out to be less important in the process (Haslbeck & Fried, 2017). The variables that could be added to a network are not limited to symptoms either, and could include biological predisposition and

external stressors (Haslbeck & Fried, 2017). In addition, it should be stressed that our findings are based on group-level analyses, that do not necessarily generalize to the individual level (cf. Fisher et al. (2018), but see Adolf and Fried (2019)). Specific patterns of symptom association that may actually occur in only some individuals, are likely clouded by our nomothetic approach. In other words, it is entirely within the realm of possibilities that symptoms that do not seem to take a central place in the current network, which aggregates information across (sub)samples, could in fact be crucial at the individual level.

Still, the results from the current study are largely in line with the literature, and often plausible from a clinical perspective. For instance, feeling worthless (symptom #17) as part of a pre-existing depression may trigger anxiety, if the individual *expects* to embarrass him/herself *because of his/her assumed worthlessness*, becoming overly self-aware and behaving in avoidant or even self-defeating ways (e.g., not properly trying “as it is pointless anyway”). An inverse direction is also possible: a pattern of anxiety including panic and repeated embarrassment may have negative implications for one’s self-esteem, potentially setting the stage for feelings of worthlessness and depression.

In addition to the cross-sectional nature of the data, the method of measurement is also considered a limitation. Self-report questionnaires such as the DASS-21 may be less suited for evaluating physiological symptoms than for evaluating mood and cognitions, which could explain why these symptoms are poorly connected (but see Fried et al., 2016). Lastly, it is important to point out that one nationality (i.e., Malaysian) is particularly overrepresented in the sample, and may explain why one symptom (#8) is allocated to the anxiety cluster, instead of the stress cluster. Nevertheless, the network analyses are based on a very large and international sample, which contributed to the highly reliable results. Great care was put into the quality of the data: participants with limited knowledge of the English language were

removed from the sample before running the analyses, though the analyses were rerun on the entire sample, to check the robustness of the findings. The fact that very similar results were obtained in the original sample (~40000) adds to their trustworthiness.

Conclusion

In sum, network analysis allowed us to investigate the relationship between symptoms of anxiety, depression, and stress as measured by the DASS-21. The results highlight that specific symptoms can function as bridges between anxiety, depression and stress clusters, which helps to better understand their comorbidity and reciprocal influences. The cross-sectional data of the current study hamper strong conclusions about directionality, but paves the way for prospective studies to better understand the nature of the interrelatedness of anxiety and depression. Ideally, future research should expand on the current methodology, by including an idiographic approach (e.g., individualized networks), though such an endeavor hinges on dedicated, large scale and intensive data gathering (e.g., experience sampling).

Declaration of Conflicting Interests

The authors declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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Footnotes

1. The study was conducted on the data set made available on February 21st 2019, which was accessed on May 25th 2019.
2. Similar results were obtained when the full data set was analyzed (see the section "Comparison between the selected and the original samples")

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Figures & Tables

Figure 1. DASS-21 network with community analysis

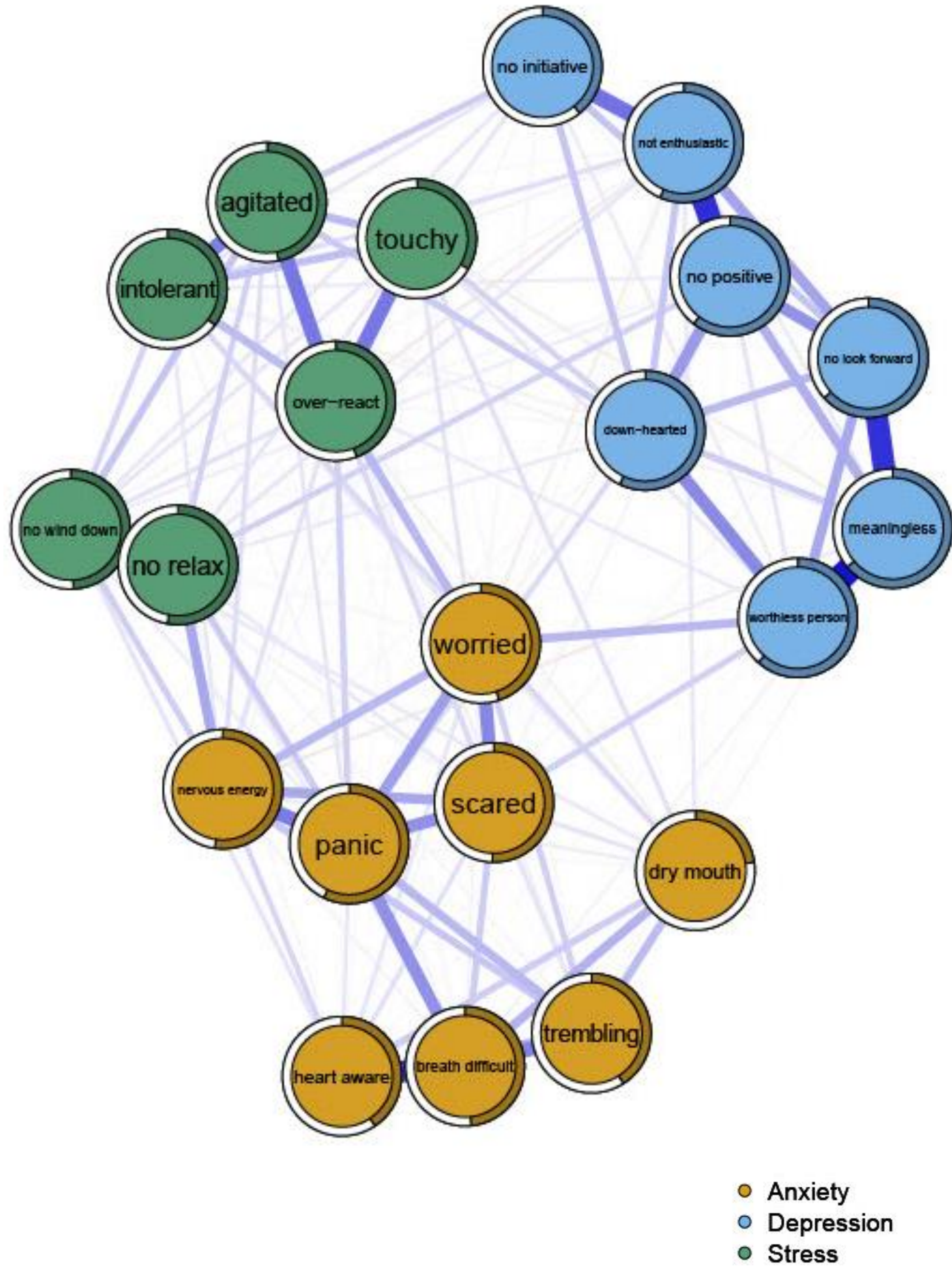


Figure 2. Strength and expected influence scores, shown as standardized *z* scores.

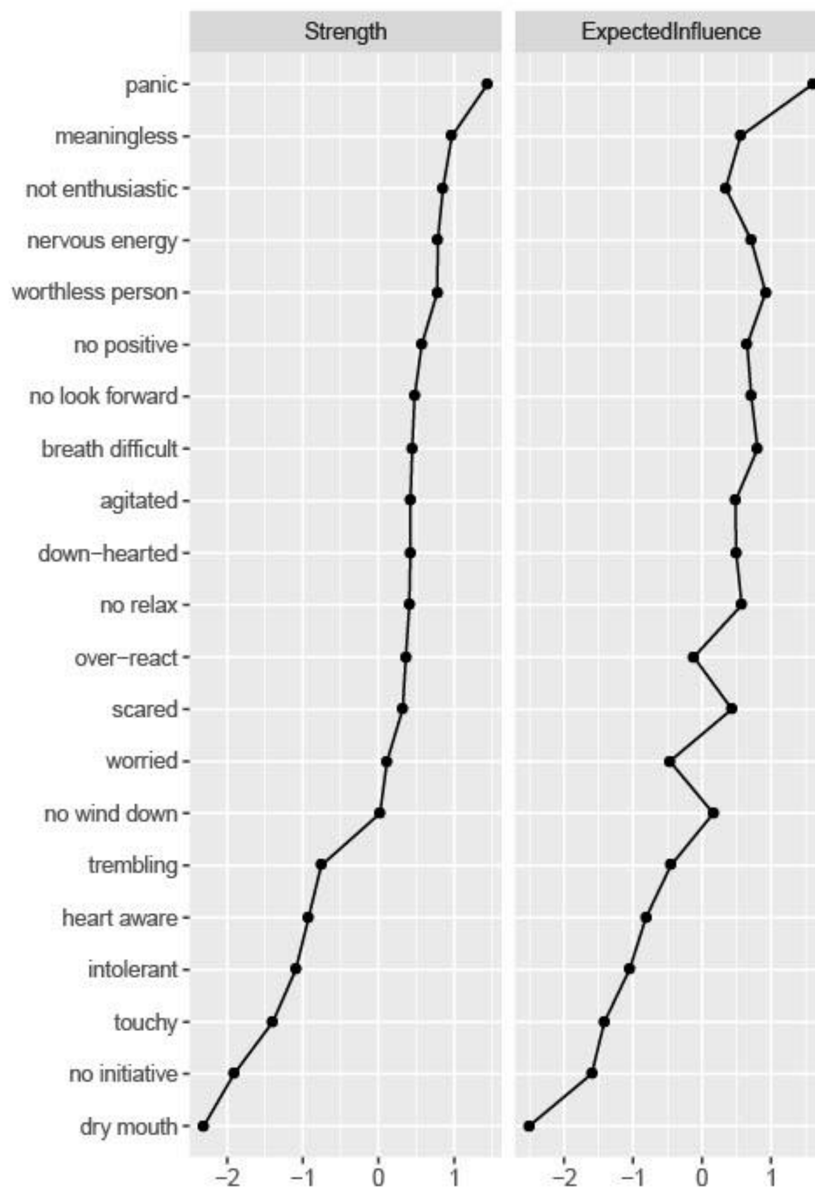


Figure 3. Nonparametric bootstrapped difference test for strength. Gray boxes indicate no significant difference, whereas black boxes indicate statistically significant difference ($p < 0.05$). Diagonal values represent the strength score of each node.

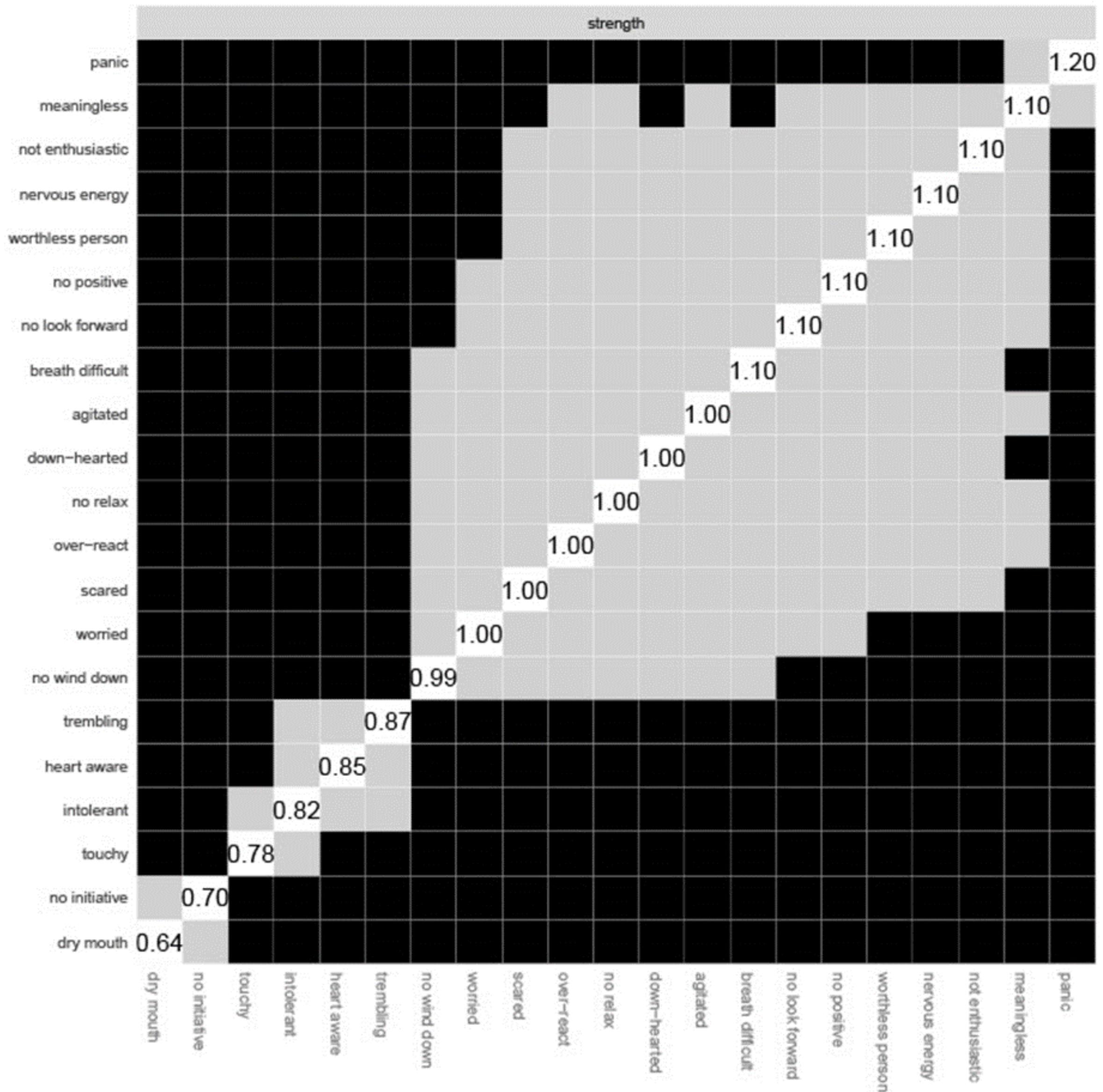


Table 1. *Means, standard deviations, and polychoric correlations of the DASS21 items*

Variable (item #)	*M*	*SD*	#2	#3	#4	#6	#12	#10	#8	#17	#18	#20	#1	#19	#13	#15	#16	#14	#21	#11	#9	#7
dry mouth (2)	2.07	1.09	1																			
no positive (3)	2.27	1.06	.32	1																		
breath difficult (4)	1.97	1.05	.46	.42	1																	
over-react (6)	2.58	1.06	.3	.44	.45	1																
no relax (12)	2.60	1.06	.36	.54	.5	.5	1															
no look forward (10)	2.48	1.15	.29	.74	.41	.41	.48	1														
nervous energy (8)	2.46	1.08	.39	.45	.56	.53	.61	.43	1													
worthless (17)	2.65	1.17	.33	.68	.44	.47	.49	.74	.47	1												
touchy (18)	2.42	1.07	.31	.4	.38	.54	.44	.39	.44	.43	1											
scared (20)	2.26	1.11	.4	.48	.58	.53	.55	.48	.64	.54	.44	1										
no wind down (1)	2.45	1.06	.35	.49	.47	.5	.72	.45	.57	.45	.44	.51	1									
heart aware (19)	2.20	1.08	.41	.36	.65	.38	.46	.34	.52	.37	.35	.52	.44	1								
down-hearted (13)	2.72	1.07	.33	.71	.44	.47	.53	.71	.49	.72	.45	.51	.5	.39	1							
panic (15)	2.28	1.10	.39	.48	.65	.55	.6	.47	.69	.51	.44	.68	.55	.55	.53	1						
not enthusiastic (16)	2.42	1.06	.32	.75	.39	.39	.51	.7	.43	.62	.39	.44	.47	.36	.66	.44	1					
intolerant (14)	2.30	1.01	.33	.44	.4	.5	.45	.42	.46	.42	.45	.43	.47	.35	.42	.45	.43	1				
meaningless (21)	2.42	1.19	.3	.71	.42	.42	.47	.8	.42	.8	.37	.49	.43	.35	.7	.47	.65	.42	1			
agitated (11)	2.61	1.01	.31	.48	.45	.6	.55	.47	.53	.48	.51	.47	.55	.39	.53	.54	.47	.56	.46	1		
worried (9)	2.59	1.13	.37	.41	.53	.53	.47	.42	.59	.52	.4	.63	.44	.48	.46	.64	.38	.42	.45	.47	1	
trembling (7)	1.98	1.06	.43	.4	.62	.42	.48	.38	.56	.43	.37	.54	.45	.55	.42	.6	.38	.38	.4	.44	.52	1
no initiative (5)	2.81	1.03	.28	.57	.36	.38	.47	.58	.42	.54	.35	.41	.44	.33	.57	.42	.62	.4	.54	.47	.39	.35

Note: the order in which the items are presented, is consistent with the order of occurrence in the DASS-42. The number between brackets refers to the DASS-21 numbering.

Supplemental Material

Figure S1. Bridge strength and bridge expected influence values between the depression and the anxiety communities.

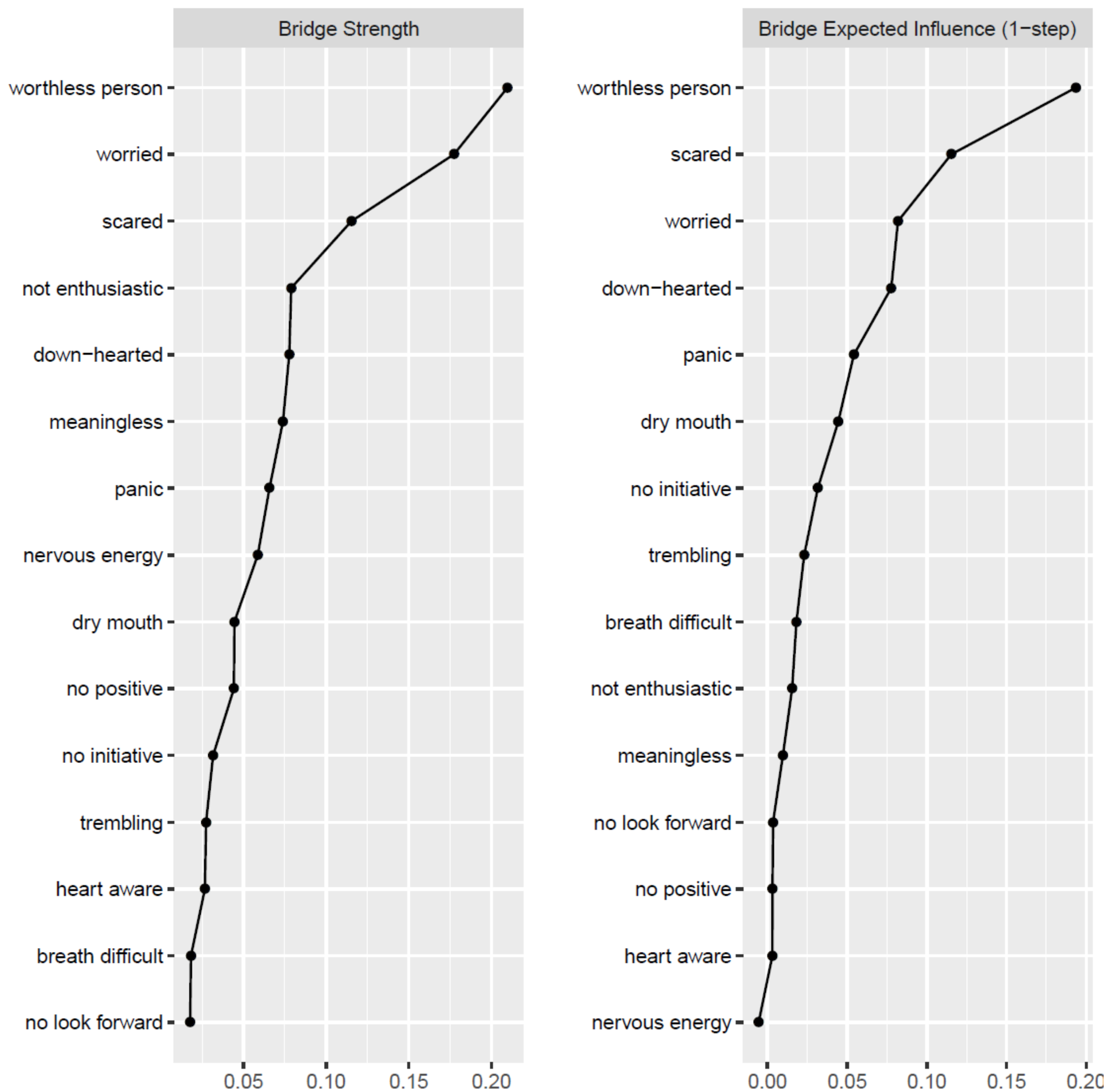


Figure S2. Bridge strength and bridge expected influence between the depression and the stress communities.

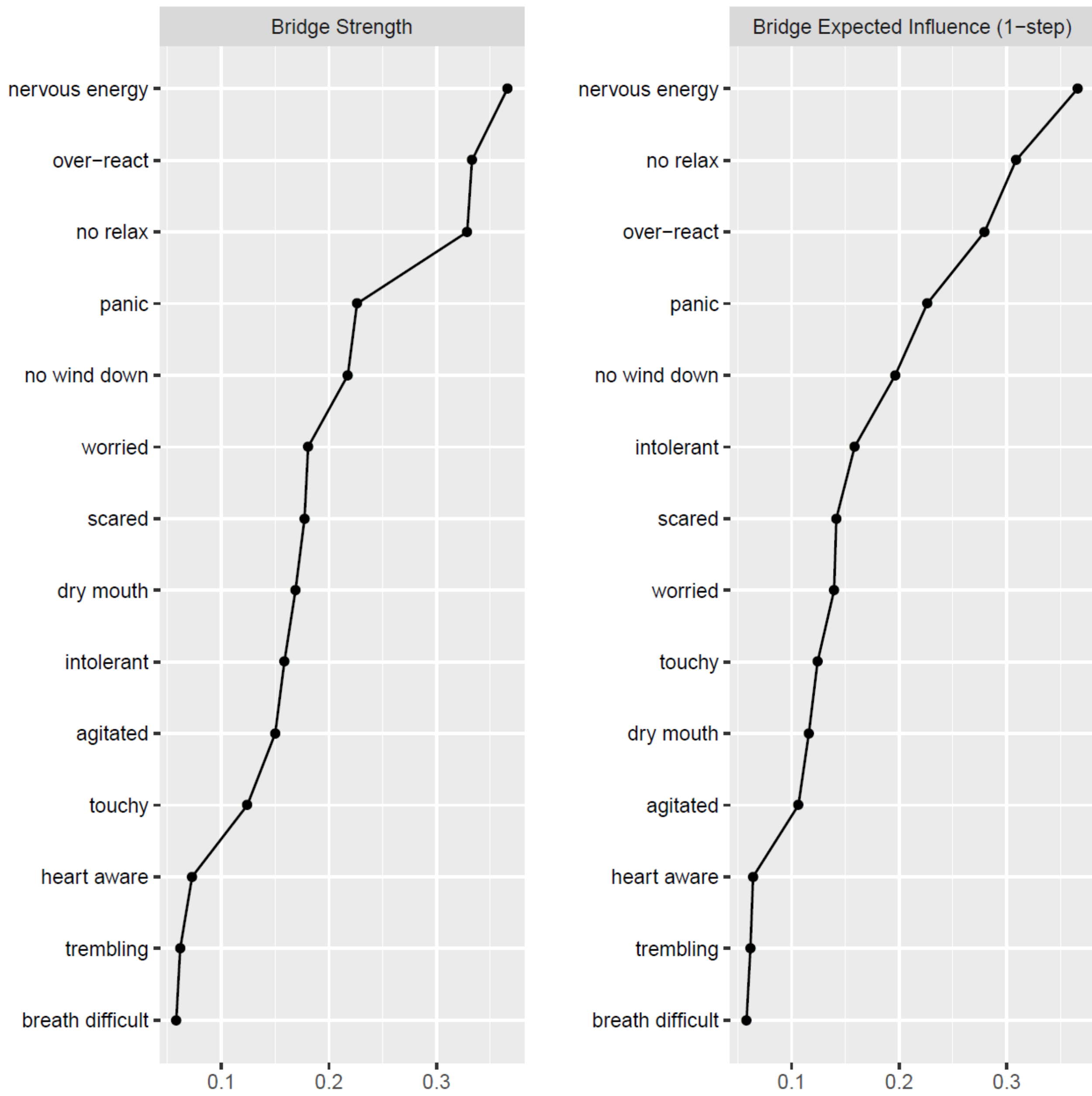


Figure S3. Bridge strength values between the anxiety and the stress communities.

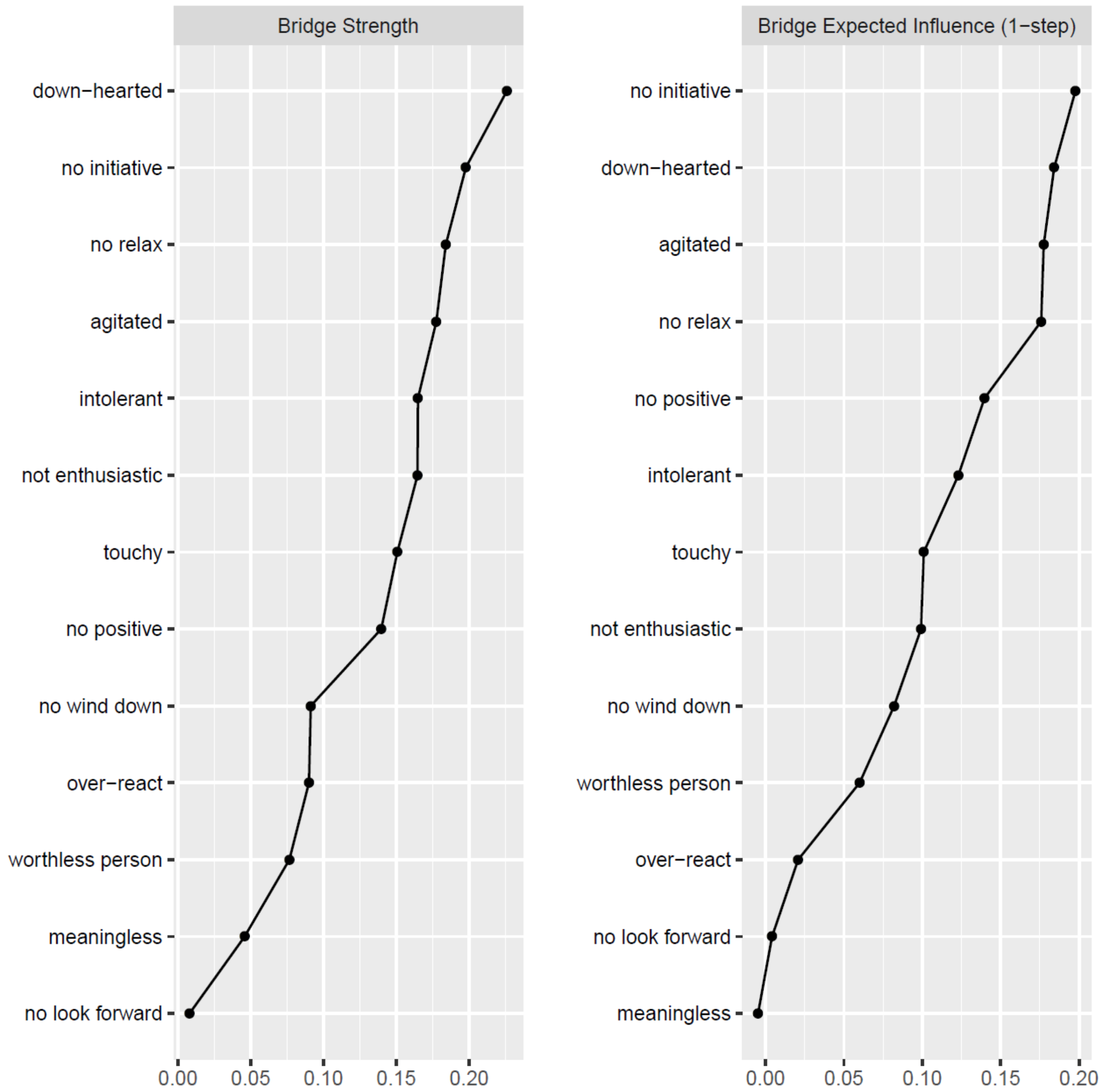


Figure S4. Nonparametric bootstrapped confidence intervals of estimated edges. The red line represents the estimated edge, while the dark area indicates the 95% bootstrap confidence interval.

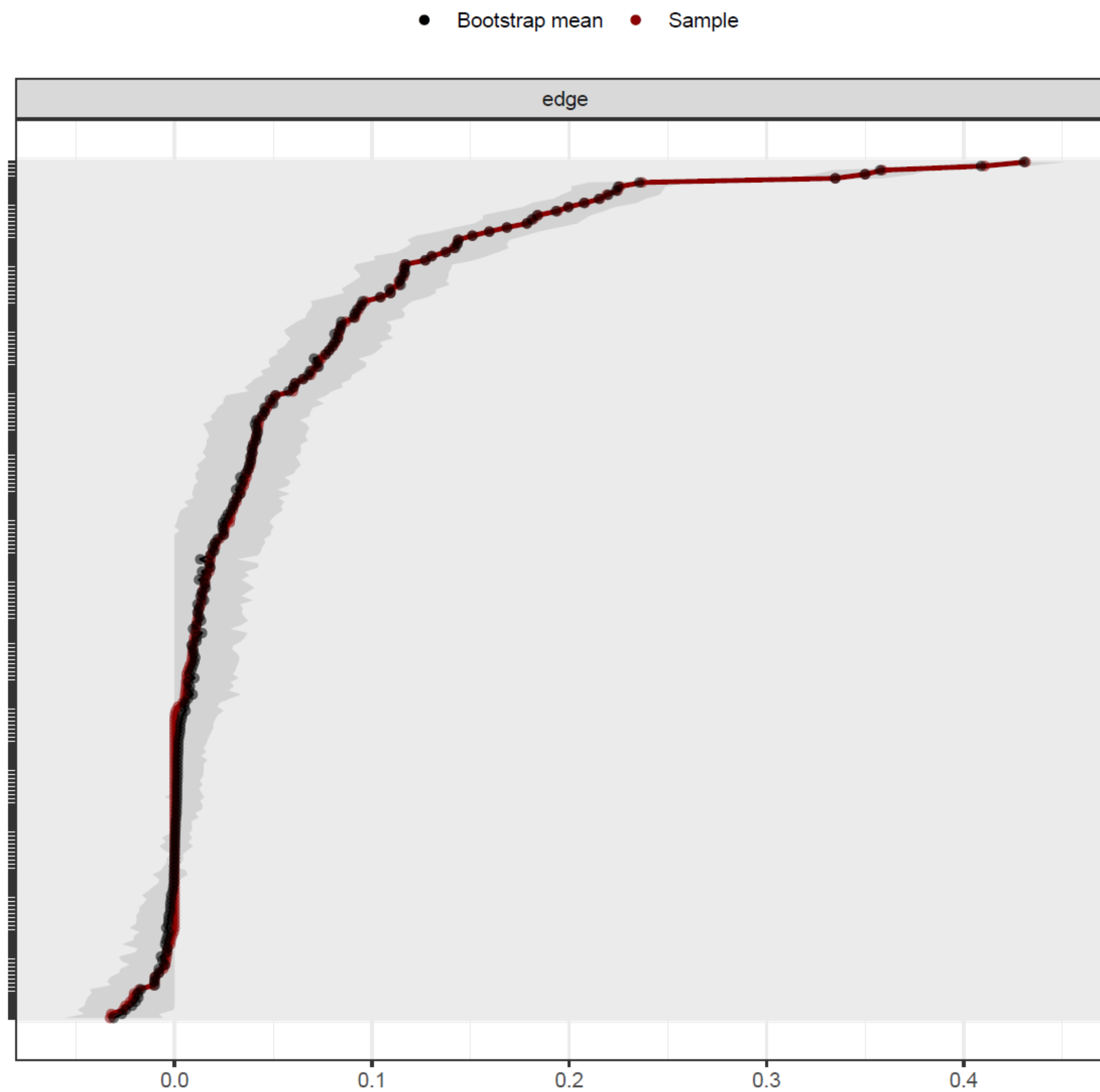


Figure S5. Nonparametric bootstrapped difference test for edges. Gray boxes indicate no significant difference, whereas black boxes indicate statistically significant difference ($p < 0.05$). Diagonal color and saturation represent the magnitude and direction of each estimated edge.

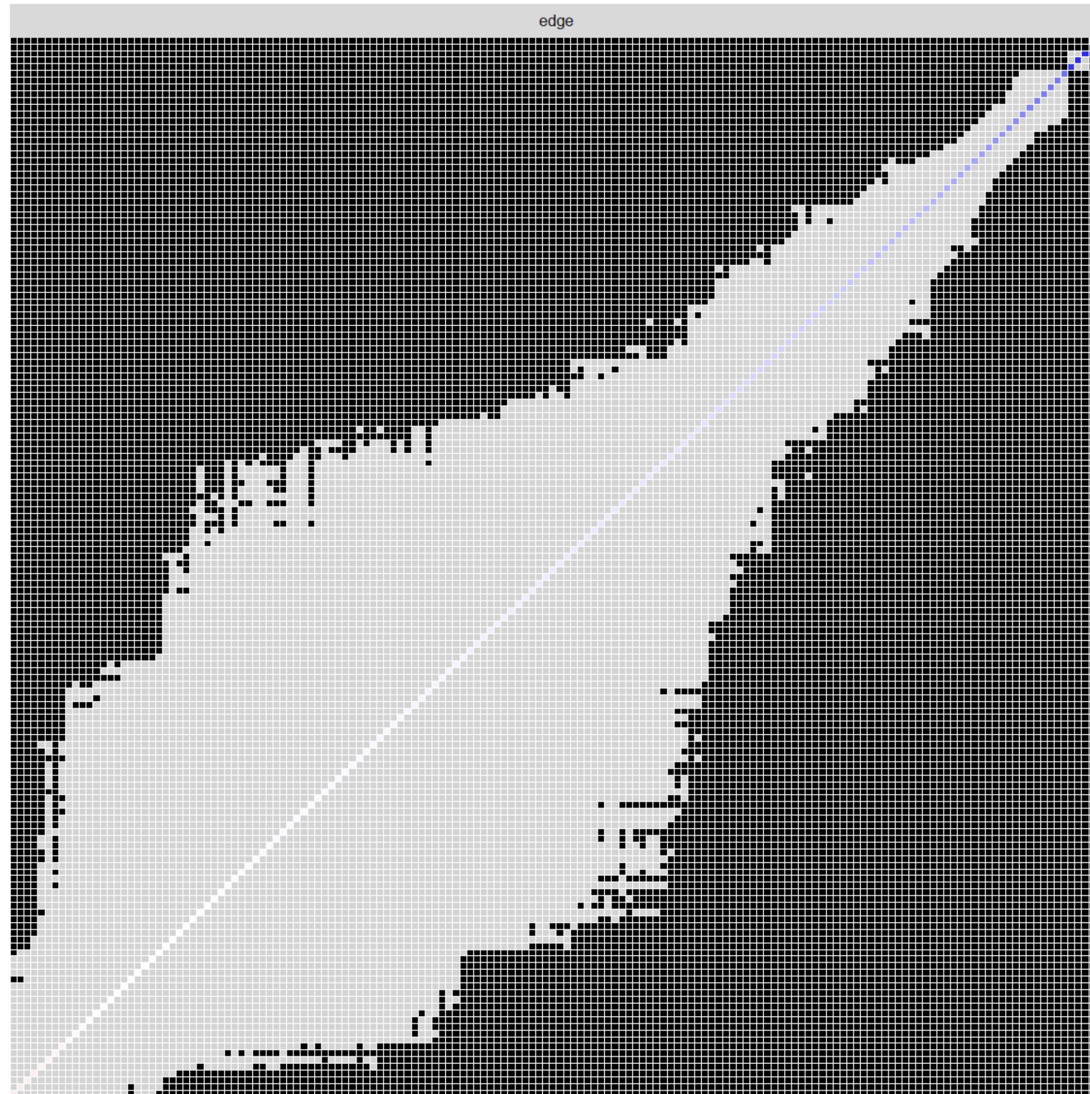
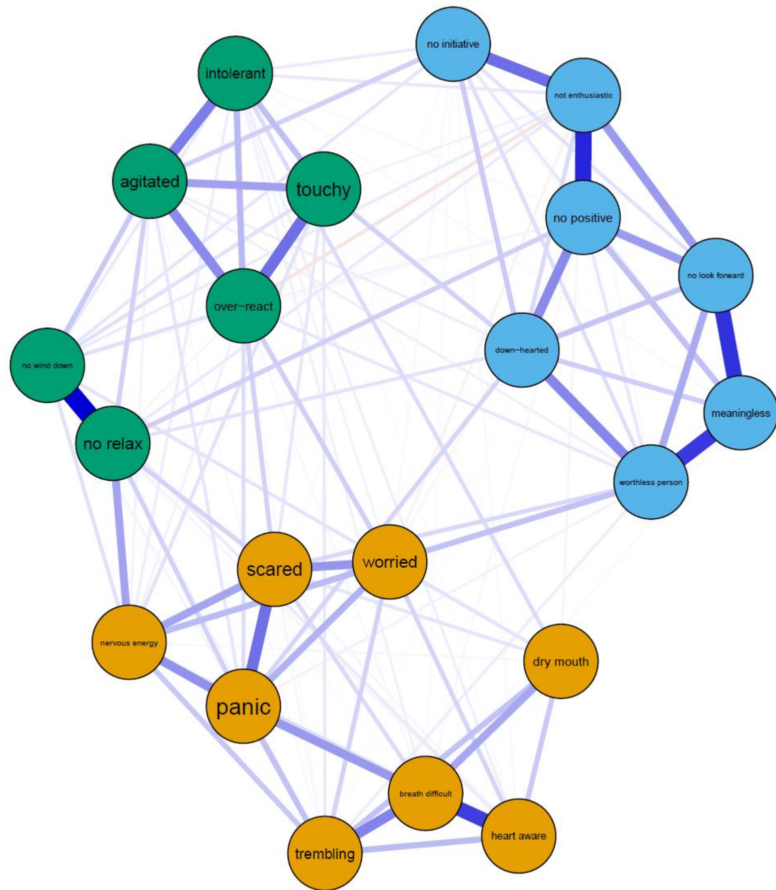


Figure S6. DASS-21 network across genders.



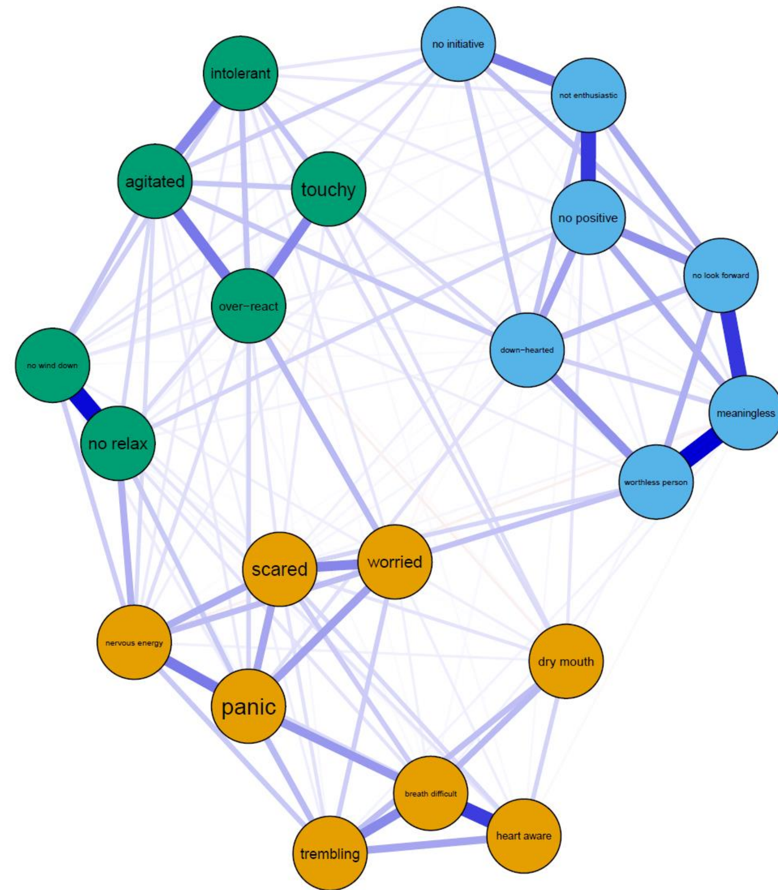


Figure S7. Strength scores (centrality), shown as standardized z scores, across genders.

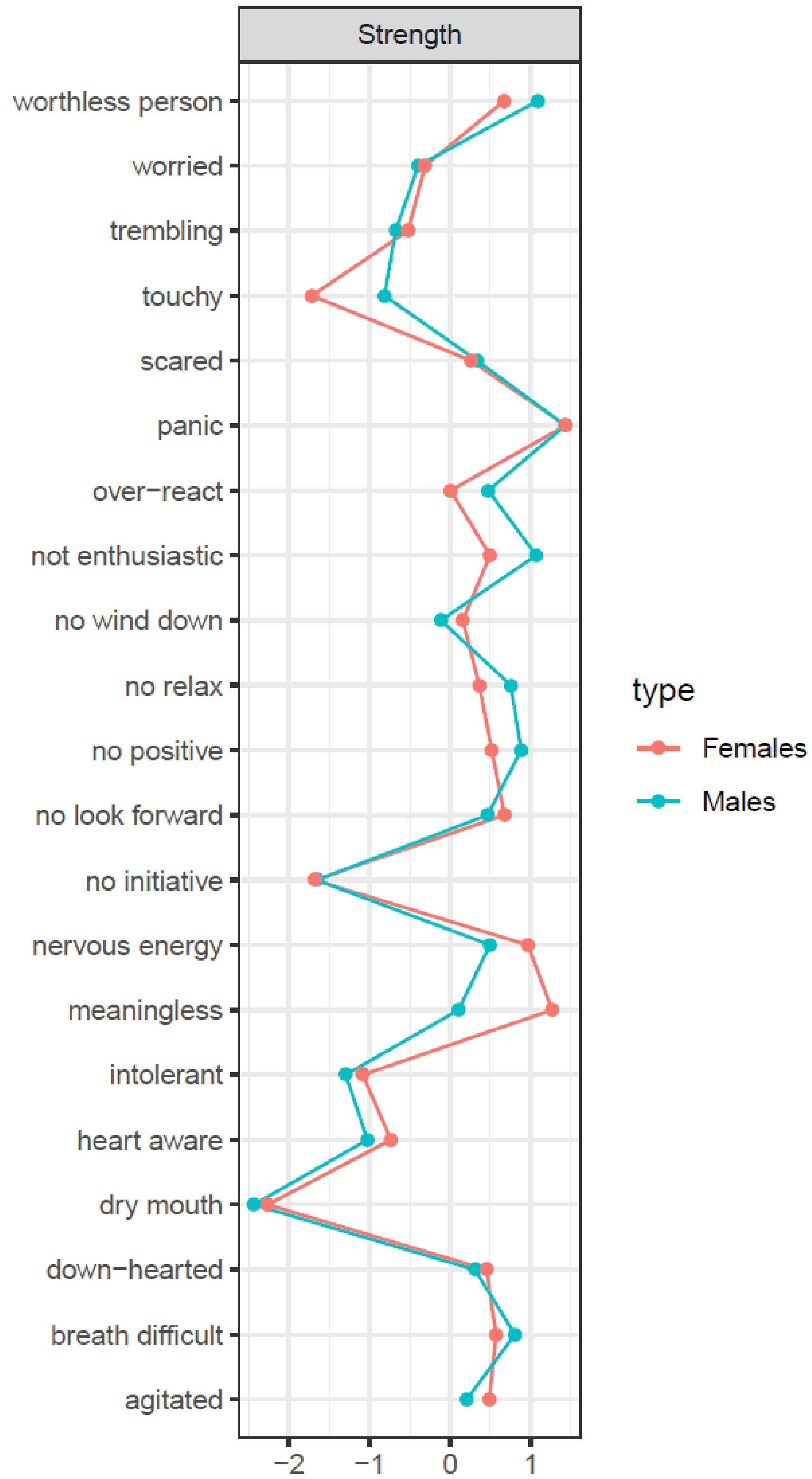
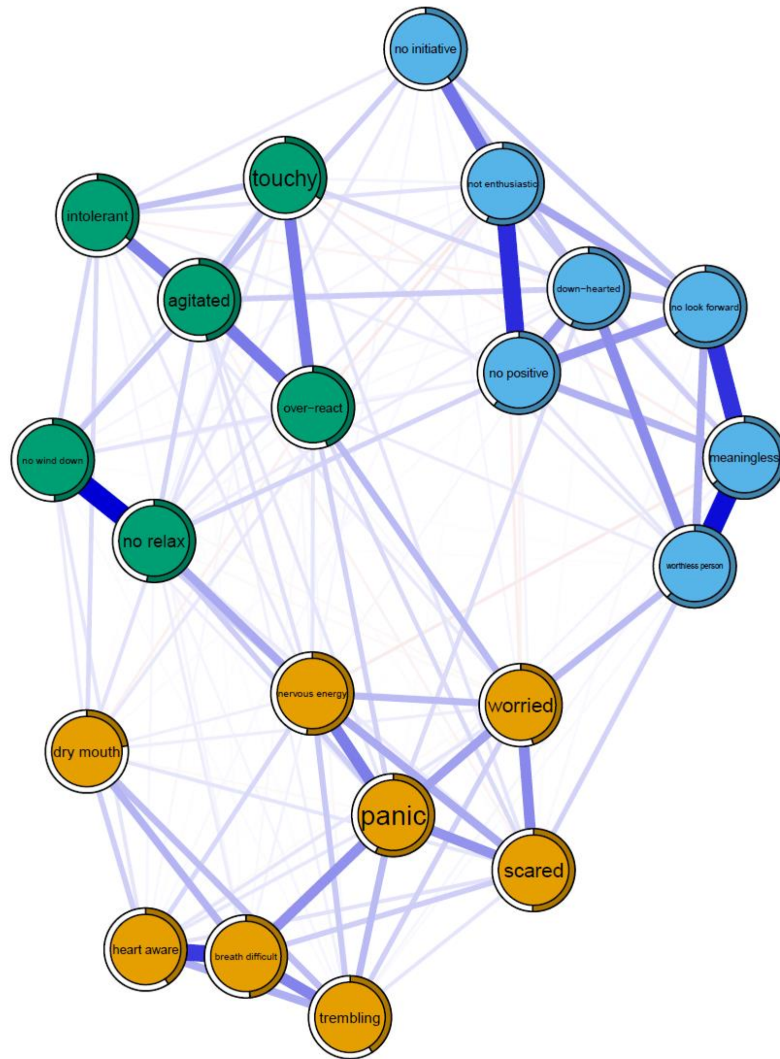


Figure S8. DASS-21 network in the original (n = 11647) and the original (n = 39775) samples.

n = 11647



n = 39775

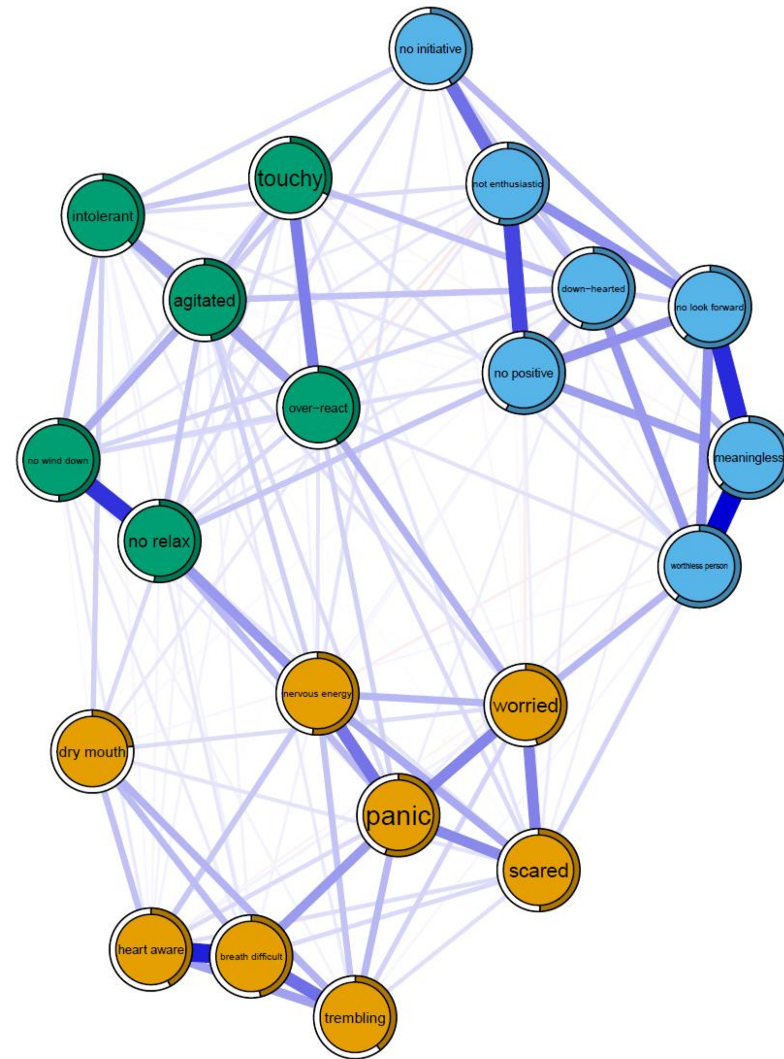


Figure S9. Strength scores (centrality), shown as standardized z scores, in the final and the original samples.

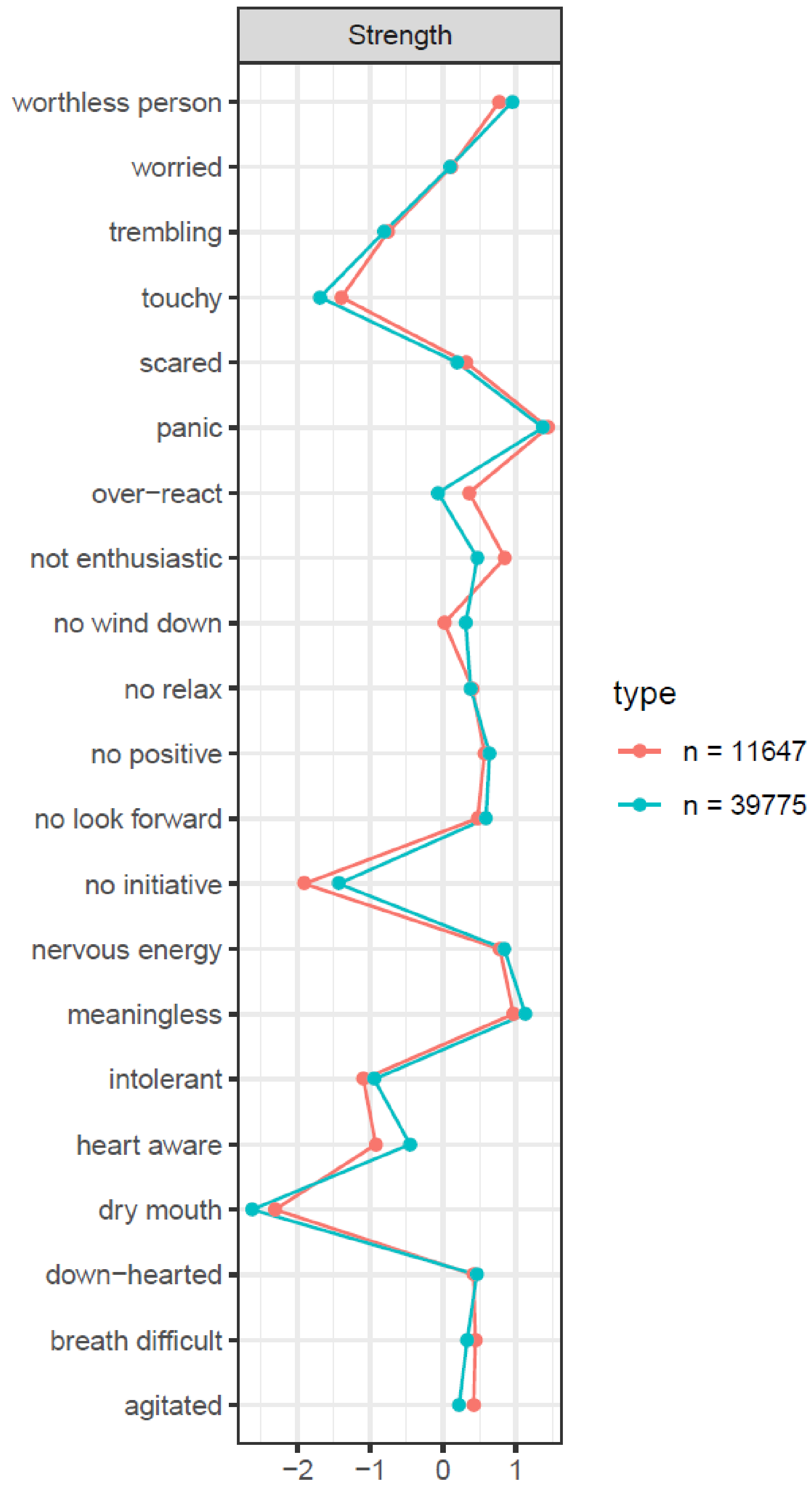


Table S1. *Means, standard deviations, t test, Bonferroni-adjusted p value, and Cohen's d, in males (n = 2996) and females (n = 8292)*

Variable (item #)	$M_{(male)}$	$SD_{(male)}$	$M_{(female)}$	$SD_{(female)}$	*t-test*	*adjusted p*	*Cohen's d*
dry mouth (2)	1.98	1.07	2.10	1.09	5.28	<0.001	0.11
no positive (3)	2.27	1.08	2.26	1.05	0.05	1	0.001
breath difficult (4)	1.71	0.97	2.05	1.07	16.12	<0.001	0.33
over-react (6)	2.32	1.06	2.67	1.05	15.71	<0.001	0.33
no relax (12)	2.51	1.08	2.63	1.05	5.37	<0.001	0.11
no look forward (10)	2.49	1.16	2.46	1.14	1.1	1	0.02
nervous energy (8)	2.27	1.09	2.51	1.06	10.43	<0.001	0.22
worthless person (17)	2.57	1.19	2.66	1.16	3.44	0.012	0.07
touchy (18)	2.20	1.05	2.49	1.07	12.92	<0.001	0.27
scared (20)	2.01	1.09	2.34	1.11	14.27	<0.001	0.30
no wind down (1)	2.36	1.08	2.47	1.05	5.11	<0.001	0.11
heart aware (19)	2.04	1.06	2.24	1.08	9.03	<0.001	0.19
down-hearted (13)	2.64	1.09	2.74	1.06	4.15	<0.001	0.08
panic (15)	2.01	1.07	2.36	1.10	15.35	<0.001	0.32
not enthusiastic (16)	2.47	1.09	2.39	1.05	3.72	0.004	0.08
intolerant (14)	2.21	1.02	2.32	1.01	5.11	<0.001	0.11
meaningless (21)	2.44	1.20	2.39	1.19	2.22	0.55	0.05
agitated (11)	2.48	1.00	2.64	1.02	7.41	<0.001	0.15
worried (9)	2.35	1.14	2.67	1.12	13.34	<0.001	0.28
trembling (7)	1.82	1.03	2.02	1.07	8.66	<0.001	0.18
no initiative (5)	2.84	1.05	2.79	1.02	2.32	0.42	0.05

Note: the order in which the items are presented, is consistent with the order of occurrence in the DASS-42. The number between brackets refers to the DASS-21 numbering.