Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Research paper

The network of stress-related states and depression and anxiety symptoms during the COVID-19 lockdown

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ABSTRACT

Background: The coronavirus (COVID-19) pandemic and the social distancing protocols used to impede the spread of the virus may have severe mental health consequences. The purpose of this study was to investigate the network of components of pandemic-related negative psychological states (i.e., fear of infection, financial worries, loneliness) and symptoms of major depressive disorder (MDD) and generalized anxiety disorder (GAD).
Methods: Data from 10,061 Norwegian adults recruited through an online survey during a period of strict social distancing protocols were analyzed by cross-sectional network methods.
Results: Of the infection fears, fear of being infected, fear of dying from the coronavirus and fear of significant others dying from it had notable connections to the GAD symptoms anxiety and/or fear of awful events. The financial worry component worry about personal economy was connected to the MDD symptom sleep problems and to the GAD symptom generalized worry. Each of the loneliness components was connected to a specific MDD symptom. Depressed mood, low energy and worthlessness had the highest strength centrality among the MDD symptoms; generalized worry, uncontrollability of worry, and trouble relaxing among the GAD symptoms; fear of dying from the virus among the fear of infection components; and feeling isolated among the loneliness components.
Limitations: Full random sampling was not conducted, although the sample turned out to be relatively representative of the Norwegian population.
Conclusions: Some components of the pandemic-related distressing states of fear of infection, financial worry and loneliness seem to be associated with specific symptoms of MDD and GAD.

1. Introduction

The coronavirus (COVID-19) pandemic and the social distancing protocols used to impede the spread of the virus may have severe mental health consequences (Holmes et al., 2020). In particular, depression and anxiety are likely to increase, as documented during previous pandemics (Brooks et al., 2020) and the present pandemic (Ebrahimi et al., 2020; Salari et al., 2020). In the present study, a network approach was adopted to enhance understanding of the interrelations among psychological states elicited by COVID-19-related stressors and symptoms of depression and anxiety. In the traditional psychiatric disease model of mental disorders, stressful life events are assumed to activate a latent underlying pathological process, which, in turn, causes observable symptoms (Kendler et al., 2011; McNally et al., 2015). The focus is on the underlying process, which is measured by tallying symptoms into an overall sum-score. Thus, the possibility that symptoms may cause each other is ignored and causal relationships and potential intervention targets are studied on the level of latent constructs. According to the network perspective of psychopathology, by contrast, mental disorders arise from the direct causal interactions of symptoms and external events (Borsboom, 2017). Thus, stressful life events may activate one or two symptoms, which, in turn, elicit more symptoms. Symptoms are thought to have different causal roles and centrality indices are used to estimate their overall importance in the network of events and symptoms (Opsahl et al., 2010). For instance, strength centrality is the sum of a symptom's connections to other symptoms in the network. By spreading their potential influence to many other symptoms, central symptoms may be particularly suitable targets for intervention (Cramer et al., 2010). Moreover, symptom-level targets are more specific and precise than the disorder-level targets identified in the psychiatric

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disease model.

Three kinds of stressors related to the pandemic and society's handling of it are likely to affect individuals and potentially elicit certain distressing psychological states in them. First, the threat of infection posed by the virus may elicit a fear that significant others may become infected and die, fear of infecting others, fear of oneself being infected, and fear of dying from the virus. Thus, a fear that something awful might happen may be implied, a clinical feature of generalized anxiety disorder (GAD; Spitzer et al., 2006). In addition, the infection fears are likely to elicit nervousness and anxiety, also a feature of GAD (American Psychiatric Association, 2013). Second, the work-related and economic consequences of the social distancing measures, such as shutdown of enterprises and laying off and dismissal of employees, may increase individuals' worry about their personal economy and job. This state implies worry about future adversities, a hallmark symptom of GAD (American Psychiatric Association, 2013). Moreover, individuals tend to blame themselves for work- and financial problems (Shamir, 1986), leading to rumination and low self-esteem, which in severe degrees are clinical features of major depressive disorder (MDD; American Psychiatric Association, 2013). Third, the social distancing measures involve social isolation and loss of availability of direct social contacts. These circumstances promote the experience of loneliness, with its many components, such as missing companionship, feeling left out and feeling isolated. Due to increased frictions and conflicts within households, people may also feel a lack of companionship with others that are still around. Loneliness have proved to be associated with increased risk of depression and anxiety (Yuanguas et al., 2011). On the level of observable variables, loneliness has been found to be related to depressed mood through sadness (Fried et al., 2015). Thus, pandemic-related stressors may elicit distressing states, which, in turn, may precipitate MDD and GAD symptoms in some people and aggravate symptomatology in those already suffering from these symptoms. In a network approach, the relationships among the specific components of these states and specific symptoms can be estimated concurrently in one analysis, allowing identification of state components that may serve as bridge variables connecting states with disorders. Activation of a bridge component may increase the risk of a disorder through the resulting symptom's activation of other symptoms. Targeted interventions for bridge components may prevent the development of clinical disorders in the context of stressor-related psychological states.

MDD and GAD often occur together. The literature has highlighted GAD as the disorder with the highest rate of co-occurrence with MDD (Kessler et al., 2005), suggesting that these disorders may include symptoms that may easily activate and influence each other. By moving the level of causality to that of observable symptoms rather than unobservable latent entities, the network perspective easily accommodates this possibility by pointing to overlapping clinical features and symptoms (e.g., concentration difficulties, sleep problems, low energy; Cramer et al., 2010) as well as bridge symptoms connecting the two disorders. Studies have found the strongest bridges between anhedonia and generalized worry (Cramer et al., 2010), psychomotor problems and restlessness (Beard et al., 2016; Kaiser et al., 2021), and depressed mood and anxiety (Garabiles et al., 2019).

Among previous network studies of MDD, Cramer et al. (2010) identified anhedonia and depressed mood and Hakulinen et al., (2020) anhedonia and worthlessness as those with highest strength centrality in Western adult community samples. In a community sample of Kenyan youths, depressed mood and worthlessness were most central (Osborn et al., 2020). In Western clinical samples, anhedonia and depressed mood (Beard et al., 2016), anhedonia and low energy (Fried et al., 2016) and depressed mood (Kaiser et al., 2021) have been found to be most central. In specific populations, depressed mood (Briganti et al.; 2020; Belgian students), anhedonia and worthlessness (Makhubela, 2020; South African students), and low energy (Garabiles et al., 2019; migrant Filipino domestic workers) have been identified as most central. Thus, anhedonia, depressed mood, low energy, and worthlessness are often identified as central. Whether the differences between studies reflect systematic differences between type of sample or sampling differences is difficult to decide, as few studies of each sample type have been conducted so far. However, the influence of type of stressor is indicated by finding low energy to be most central among migrant Filipino workers, which may be due to the exhausting nature of their work (Garabiles et al., 2019). Among GAD symptoms, Beard et al. (2016), Osborn et al. (2020), and Kaiser et al. (2020) all found generalized worry and/or uncontrollability of worry as the symptoms with the highest strength centrality.

Related to COVID-19 pandemic, Wang et al. (2020) investigated the MDD and GAD networks among Chinese adults during the COVID-19 outbreak. The MDD symptoms depressed mood, low energy, psychomotor problems and suicidality and the GAD symptoms generalized worry, trouble relaxing and restlessness showed high strength centrality. The psychomotor symptoms (psychomotor agitation/retardation, restlessness, trouble relaxing) also had strong connections across disorders. Consistent with Wang et al. (2020), Heeren et al. (2021) found generalized worry and trouble relaxing to be the most central GAD symptoms in a community sample during the first Belgian COVID-19 lockdown. Thus, these studies suggest that psychomotor symptoms (and perhaps suicidality) are more prominent during the pandemic. However, little is known about the relationships between the components of pandemic stress-related states and MDD and GAD symptoms, except that Fried et al. (2021) estimated dynamic networks from EMA data provided by students at the COVID-19 outbreak in the Netherlands. In their temporal network, representing the lagged within-person relationships between variables from one three-hour period to the next, loneliness (missing companionship or not being close to others) predicted worry about the coronavirus and health, which, in turn, predicted anhedonia.

In a previous paper, we have reported the prevalence of clinically significant levels of symptoms of MDD and GAD in sample of adult Norwegians during the implementation of strict social distancing protocols (Ebrahimi et al., 2021). This investigation revealed that 30.8% exceeded the cut-off of for clinically significant levels of MDD symptoms, and 27.6% the cut-off of for clinically significant GAD symptoms, respectively, during the pandemic, estimates which have since been replicated in international meta-analyses (e.g., Salari et al., 2020). In another study from the same data set, the total score on a measure of loneliness was found to be related to worry about job and personal economy, health anxiety (fear of infection items were included in the measure) and MDD and GAD total symptom scores (Hoffart et al., 2020). The purpose of the present exploratory study was to investigate the network of components of pandemic-related negative psychological states and symptoms of MDD and GAD in the same sample, analyzing the items of the measures used in the previous studies. More specifically, the relationships of these components to particular symptoms and to each other, in addition to the centrality of these components and symptoms, were examined. Of note, this cross-sectional study only reveal partial correlations and does not indicate causal directions.

2. Methods

2.1. Study design, participants and representativity

A cross-sectional design was implemented in an epidemiological survey of the general adult Norwegian population during the COVID-19 pandemic. Eligible participants were all individuals of 18 years and above, were living in Norway and experiencing identical social distancing protocols, who provided informed consent to participate in the study. The implemented protocols included not leaving home unless essential, home isolation if infected, quarantine after exposure to possible infection, closure of kindergartens, schools, universities, workplaces and other public spaces, restrictions on traveling, and prohibitions of social gatherings and public events. These protocols were implemented in Norway on March 12th 2020. The period of data

collection lasted seven days between March 31st 2020 and April 7th 2020. Consequently, at the time of measurement, the duration that the respondents had experienced the implementation of the protocols ranged from 19 to 26 days. The implemented social distancing protocols were held constant for approximately three weeks prior to data collection and during the data collection period. Additionally, no information was given by the government during this period with regard to changes of the protocols, keeping expectation effects constant.

The number of participants was 10,061. In terms of representation of the Norwegian population, a larger proportion of females (7,851, 78%) than males (2,184, 21%) responded. The sample was also not representative of the Norwegian population in terms of educational level as 5,644 (56%) had completed a university degree, compared to about 34% in the population (Statistics Norway, 2019). The sample was relatively representative on the other demographic variables. The age of the participants ranged between 18 and 86 with a mean age of 36.0 years (S. D. = 13.5), 4,751 (47%) were married or in a civil union, 8,140 (81%) were currently employed, 574 (6 %) were non-natives, 4,253 (42%) had children. The proportion having a psychiatric diagnosis was 1,721 (17%) of 10,061, reflecting the lower end of the known rate of psychiatric disorders in the adult population of Norway which is between 17 to 25% (Norwegian Institute of Mental Health, 2016).

Ethical approval of the study was granted by the Regional Committee for Medical and Health Research Ethics (reference: 125510) and the Norwegian Centre for Research Data (reference numbers: 802810), where the study protocol and analysis plan was approved prior to data collection. The study is part of the Norwegian COVID-19 Mental Health and Adherence Project (Ebrahimi et al., 2021).

2.2. Procedure

Due to the sudden onset of the pandemic and the time-sensitive research aim of measuring mental health during a period with strict and stable social distancing measures, we could not disseminate the survey through conventional methods such as access to registry data. To approach the desired standard of giving the adult Norwegian population an equal opportunity to participate, the survey was disseminated through a Facebook Business algorithm, through broadcasting on the national television channel of Norway, and through national, regional and local radio stations and newspapers, as well as local and regional media and social media sources. The dissemination procedure is described in more detail elsewhere (Ebrahimi et al., 2021).

2.3. Measures

The participants were asked to report demographic variables. In addition, stressor-related questions about suspicions of being infected, the time staying home and reasons for this, and whether one had been laid off from or lost one's job due to COVID-19 were included.

For the measures of network nodes, the participants were asked to consider the last two weeks. The Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001) consists of nine items (e.g., "Little interest or pleasure in doing things") covering the DSM-IV criteria for major depression (American Psychiatric Association, 1994) scored on a 4-point 0 (*not at all*), 1 (*several days*), 2 (*more than half the days*) and 3 (*almost every day*) scale.

The Generalized Anxiety Disorder-7 (GAD-7; Spitzer et al., 2006) consists of seven items (e.g., "Feeling nervous, anxious, or on edge") covering the DSM-IV criteria for GAD (American Psychiatric Association, 1994) scored on the same 4-point scale as for PHQ-9.

Due to the lack of available instruments for measuring fear of infection of the specific virus and financial worries as a result of the pandemic at the time, we developed specific questions for this purpose. Thus, fear of infection was measured by the following four items: "I fear that a significant other may die from the coronavirus", "I fear that I may infect others", "I fear that I am infected with the coronavirus", and "I fear that I will die from the coronavirus". Financial worry was measured by two items: "I worry that I will lose my job" and "I worry about my personal economy". The fear of infection and financial worry items were scored on the same 4-point scale as described above.

The UCLA Loneliness Scale-8 (ULS-8; Hays and DiMatteo, 1987) measures the frequency of components of loneliness, using a 1 (*never*), 2 (*rarely*), 3 (*sometimes*) and 4 (*often*) scale. One of the eight items refers to a personality style ("I am an outgoing person") and was excluded. Some of the remaining seven items have pairwise overlapping content. Of these, the ones with the highest scores in the original psychometric study were selected (Hays and DiMatteo, 1987). Thus, the following four items were utilized: "I lack companionship", "I feel left out", "I feel isolated from others" and "People are around me but not with me".

2.4. Statistical analysis

All statistical analyses were conducted in R (version 4.0.2; R Core Team, 2019). The scale of the ULS-8 items were transformed from a 1 to 4 to a 0 to 3 scale to be comparable in mean scores to the other items analyzed. The items are measured on an ordinal scale and many of the distributions were skewed. Consequently, Spearman correlations were used to estimate the network. Given the large number of participants in the present study, an unregularized method referred to as the Graphical Gaussian Model ModSelect Algorithm (i.e., ggmModSelect) in the R-package *qgraph* (Epskamp et al., 2012) was used in line with recent recommendations (Fried et al., 2020; Williams et al., 2019). In this procedure (see online supplementary material for R code), the graphical least absolute shrinkage and selection operator (gLASSO) is used to estimate the structure of 100 regularized network models ranging from sparse to dense. The algorithm continues to fit an unregularized network for each of these models using gLASSO without regularization, but with zeroes constrained according to the network structure. Within this model selection technique, parameters are obtained through maximum likelihood estimation, yielding unbiased estimates of parameters. Consequently, gLASSO is used to obtain the structure of the network, while maximum likelihood estimation is used to obtain the parameters. The Bayes Information Criterion (BIC) for each newly estimated model is computed iteratively, and the model with the lowest BIC is selected. In other words, all possible models in which one edge changed (i.e., was absent or present) is tested. The final model is attained when no edge can be removed or added to optimize the BIC.

The Fruchterman-Reingold algorithm was used to visualize the network, which pulls nodes with the highest centrality towards the center of the network, while nodes that are less central are placed toward the periphery (Fruchterman and Reingold, 1991). Of note, the aim of this algorithm is to minimize the number of crossing edges and to position nodes so that edges have approximately equal length. The spatial arrangement does not reflect the relationships between the variables.

Three common node centrality indices (Opsahl et al., 2010) were estimated using the centrality plot function of the *qgraph* package. Node strength is the direct connection of a node to the network, calculated as the sum of the edge weights that connect that node to the other nodes in the network. Closeness is the indirect connection of a node to the network, calculated as the sum of the inverse of all shortest path lengths between one node and all others. Betweenness is the indirect connection of a node to the network, calculated as the number of times a node lies on the shortest path connecting two other nodes in the network. Strength centrality was emphasized, as it is proportional to the extent to which a given node uniquely explains variance in nodes to which it is connected. The centrality indices were standardized to *z*-scores.

The accuracy of edge weights was assessed by nonparametric bootstrapping (1000 iterations) 95% confidence intervals (CIs) using the R-package *bootnet* (Epskamp et al., 2018). The stability of node strength was assessed using case-dropping subset *bootstrap* (1000 iterations). In this procedure, the correlation between the original centrality indices

and the centrality indices as obtained from smaller subsets, with up to 75% of participants dropped, is assessed. To quantify the stability of the indices, correlation stability coefficients (CS-coefficients) were calculated. A CS-coefficient indicates the maximum proportion of cases that can be dropped to retain, with 95% certainty, a correlation with the original centrality indices of 0.70 or higher. The CS-coefficient should preferably be 0.50 or higher (Epskamp et al., 2018). Finally, to investigate the community structure of the overall network, the spinglass algorithm (Reichardt and Bornholdt, 2006) from the *igraph* package (Csardi and Nepusz, 2006) was used. This algorithm allows items to solely be part of one community. There were no data missing in our set because the online survey system comprised of mandatory fields of response.

3. Results

3.1. Stressor-related characteristics of participants

Relevant to the stressors studied here, 3,583 (35.6%) of the 10,061 participants reported suspecting being infected by COVID-19 during the two-week period. The majority (n = 7,952, 79.0%) of the sample had adhered to the social distancing protocols and stayed home most of the days (at least 10) of the last two weeks, 1,429 (14.2%) had been in home isolation or quarantine because of potential or proved infection, 693 (6.9%) has stayed home because of closure of own enterprise and 854 (8.5%) had been assigned to home office by their employer. The number partly or fully laid off from work because of COVID-19 was 1,289 (12.8%) and 132 (1.3%) had lost their job due to the COVID-19.

3.2. Descriptive statistics for the network variables

The descriptive statistics of the PHQ-9, GAD-7 and state items are reported in Table 1, showing that the PHQ items 8 and 9 about psychomotor problems (retardation or agitation) and suicidal ideation, the GAD item 5 about restlessness, and the fear of dying from the corona virus had low levels. Suicidal ideation and the fear of dying items had the numerically lowest standard deviations and their distributions were skewed.

3.3. Estimated network

The partial correlation network, based on Spearman rank order correlations, is visualized in Fig. 1. As mentioned above, the spatial relations cannot be meaningfully interpreted because a force-directed algorithm was used. There were 137 significant ($p < 0.05$) connections. This large number is related to the large power of the study and here only those that have an edge weight greater than 0.05 will be noted. The fear of infection components had notable connections solely to the GAD symptoms. Fear of dying from the coronavirus and fear of significant others dying from the virus had marked connections to fear of awful events (0.22 and 0.19, respectively). Fear of being infected and fear of dying were connected to anxiety (0.07 and 0.06, respectively). Of the financial worries, worry about personal economy had connections to sleep problems (0.06) and to generalized worry (0.07). Each of the loneliness components was connected to a specific MDD symptom: missing companionship to anhedonia (0.08), feeling left out was connected to worthlessness (0.09), feeling isolated to depressed mood (0.07), and experiencing that people are around but not with one to suicidal ideation (0.06).

Across disorders, the MDD symptom psychomotor problems was strongly connected to the GAD symptom restlessness (0.28) and the MDD symptom concentration problems was connected to the GAD symptom trouble relaxing (0.19). There were no notable (> 0.05) connections across the distressing states.

Within constructs, the strongest connections appeared between the MDD symptoms anhedonia and depressed mood (0.27), low energy and sleep problems (0.25), and low energy and anhedonia (0.24). Among the GAD symptoms, the strongest connections appeared between uncontrollable worry and generalized worry (0.31), uncontrollable worry and anxiety (0.23), trouble relaxing and restlessness (0.22), and anxiety and fear of awful events (0.19). Among the fear of infection components, the strongest connection was between fear of infecting others and fear of being infected (0.38). There was a strong connection between the two financial worries components (0.52). Among the loneliness components, the strongest connection was between missing companionship and feeling isolated (0.47).

Table 1
Descriptive statistics for the network variables.

Construct/nodes	Label	*M*	S.D.	Skewness	Kurtosis	Cluster
MDD						
Anhedonia	D1	1.01	0.88	0.76	0.03	3
Depressed mood	D2	0.90	0.86	0.88	0.28	3
Disturbed sleep	D3	1.08	1.02	0.63	-0.72	3
Low energy	D4	1.32	0.89	0.49	-0.48	3
Appetite problems	D5	0.98	1.00	0.71	-0.60	3
Worthlessness	D6	0.86	0.95	0.93	-0.07	3
Trouble concentrating	D7	0.87	0.96	0.88	-0.21	5
Psychomotor problems	D8	0.41	0.73	1.86	3.00	5
Suicidal ideation	D9	0.19	0.55	3.36	11.93	3
GAD						
Anxiety	A1	0.91	0.89	0.86	0.08	1
Uncontrollable worry	A2	0.65	0.87	1.28	0.85	1
Generalized worry	A3	0.99	0.91	0.77	-0.11	1
Trouble relaxing	A4	0.92	0.92	0.84	-0.07	5
Restlessness	A5	0.55	0.77	1.42	1.64	5
Irritability	A6	1.05	0.86	0.68	-0.04	3
Fear of awful events	A7	0.66	0.81	1.23	1.08	4
Fear of infection						
Fear of significant others dying	F1	1.33	1.00	0.40	-0.90	4
Fear of infecting others	F2	1.09	0.91	0.66	-0.27	4
Fear of being infected	F3	0.72	0.79	1.14	1.17	4
Fear of dying	F4	0.36	0.66	2.11	4.67	4
Financial worry						
Worry about losing job	W1	0.53	0.87	1.64	1.72	1
Worry about personal economy	W2	0.98	1.04	0.79	-0.59	1
Loneliness						
Missing companionship	L1	1.79	0.96	-0.30	-0.89	2
Feeling left out	L2	1.15	0.88	0.33	-0.67	2
Feeling isolated	L3	1.42	1.02	0.05	-1.13	2
People around but not with	L4	1.16	0.94	0.36	-0.81	2

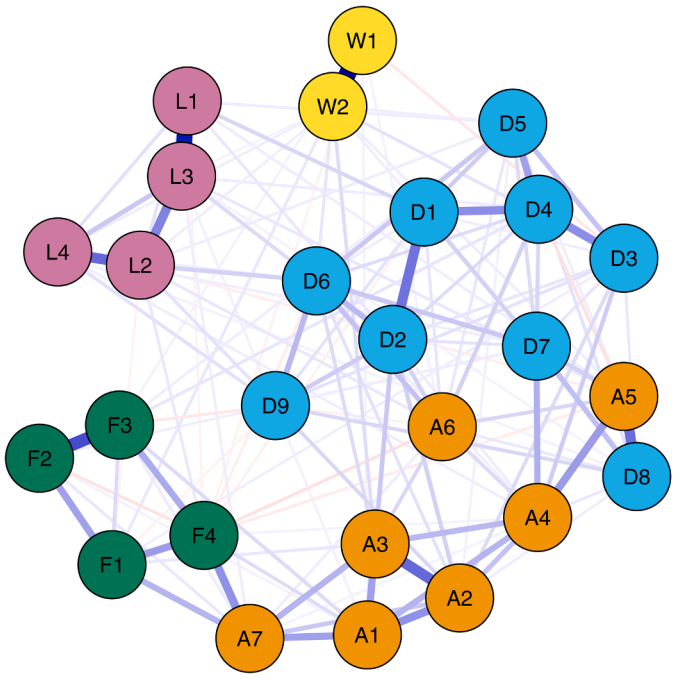
MDD = major depressive disorder, GAD = generalized anxiety disorder.

3.4. Centrality

The strength, closeness, and betweenness centrality *z*-scores are presented in Fig. 2. Of the MDD symptoms, depressed mood, low energy and worthlessness had high strength ($z >= 1$). Of the GAD symptoms, generalized worry, uncontrollability of worry, and trouble relaxing had high strength. Of the fear of infection components, fear of dying from the virus had the highest strength. Of the loneliness components, feeling isolated had high strength. These nodes followed a similar patterns on the closeness and betweenness dimensions, except that uncontrollability of worry had low betweenness and feeling isolated had low closeness.

3.5. Accuracy

The bootstrapped CIs for the edge-weights are shown in Fig. 3. They were small, indicating that they were reasonably accurate and that many



Anxiety
- A1: Anxiety
- A2: Uncontrollable worry
- A3: Generalized worry
- A4: Trouble relaxing
- A5: Restlessness
- A6: Irritability
- A7: Fear of awful events

Depression
- D1: Anhedonia
- D2: Depressed mood
- D3: Sleep problems
- D4: Low energy
- D5: Appetite problems
- D6: Worthlessness
- D7: Trouble concentrating
- D8: Psychomotor problems
- D9: Suicidal ideation

Fear of infection
- F1: Fear of significant others dying
- F2: Fear of infecting others
- F3: Fear of being infected
- F4: Fear of oneself dying

Financial worry
- W1: Worry about losing job
- W2: Worry about personal economy

Loneliness
- L1: Missing companionship
- L2: Feeling left out
- L3: Feeling isolated
- L4: People around but not with

Fig. 1. Estimated partial correlation network of symptoms of major depressive disorder as measured by the Patient Health Questionnaire-9 (D1-D9), of symptoms of generalized anxiety disorder as measured by the Generalized Anxiety Disorder-7 (A1-A7), of components of fear of infection (F1-F4), of components of financial worry (W1-W2) and of components of loneliness as measured by the UCLA Loneliness Scale-8 (L1-L4). Blue lines represent positive associations, red lines represent negative associations and the thickness of an edge indicates the association strength. Absence of edges between nodes denotes statistical independence (color online). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

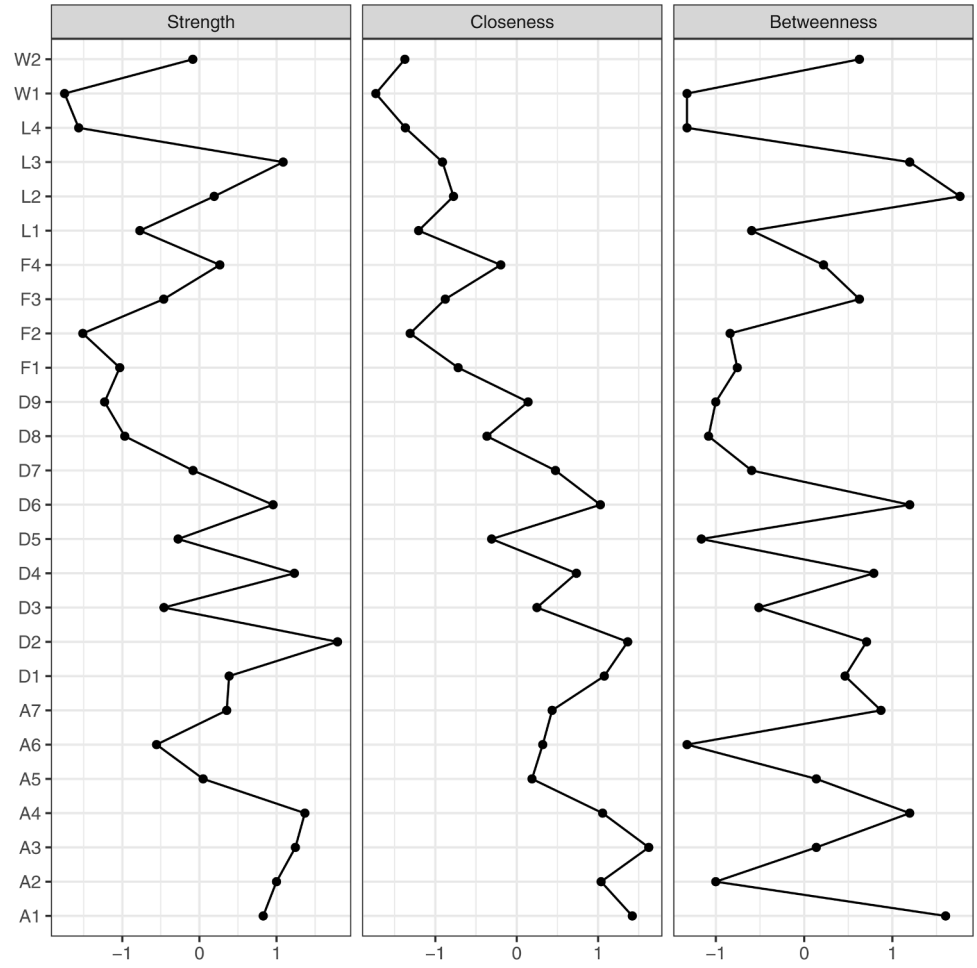


Fig. 2. Centrality indices of node strength, closeness and betweenness of the estimated network. Indices are shown as standardized *z*-scores. See Fig. 1 or Table 1 for description of the labels.

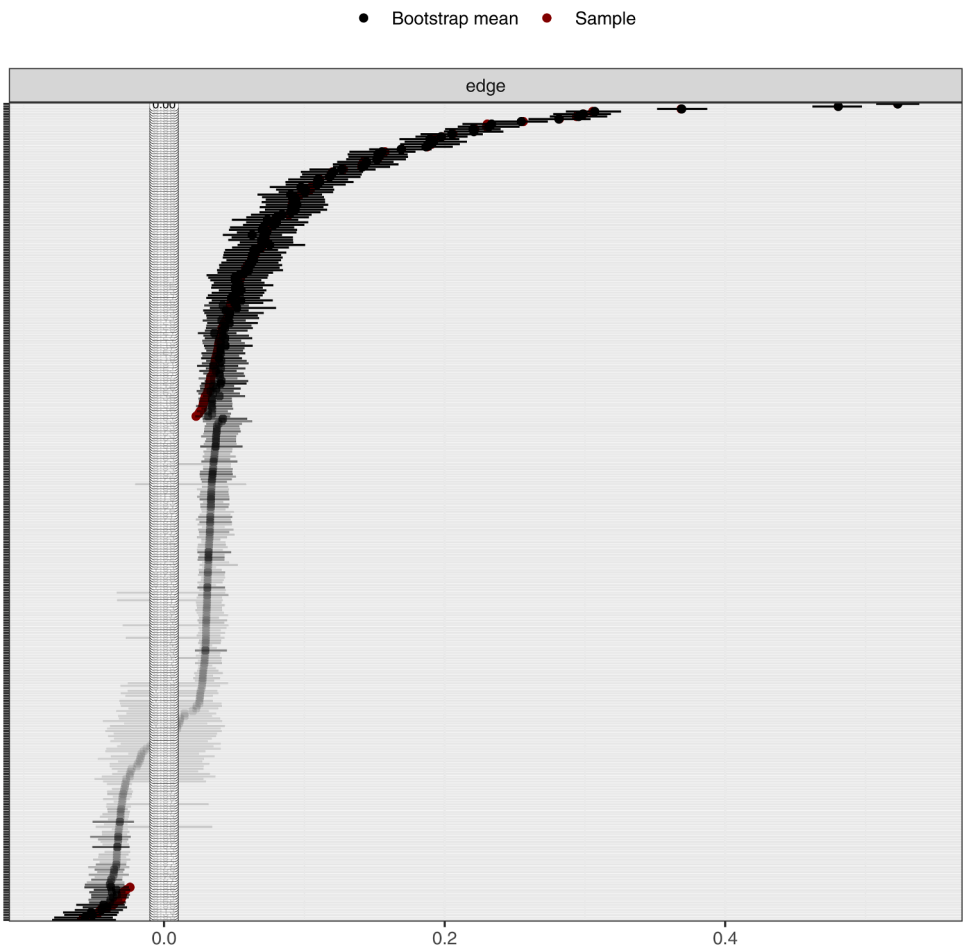


Fig. 3. Non-parametric bootstrapped confidence intervals of estimated edge weights. The red line represents the edge, as estimated in the sample. The gray area indicates that 95% bootstrapped confidence interval. The x-axis represents the edges, while every line on the y-axis represents a specific edge. See Fig. 1 or Table 1 for description of the labels. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

of them differed significantly from each other.

3.6. Stability, edge weight and strength centrality differences

Figure S1 in supplemental material indicates a high stability of the centrality estimates. It shows that up to 75% of the sample could be dropped while retaining a correlation with the centrality estimates for the whole sample of 0.70 with 95% certainty. Figure S2 and S3 in supplemental material show the results of bootstrapped difference tests between edge-weights and between node strengths, respectively.

3.7. Community analysis

The spin glass community analysis identified 5 clusters (communities) reported in Table 1. The first consisted of the three worry symptoms, the anxiety symptom of GAD and the two financial worry items. The second cluster consisted of the four loneliness items. The third cluster consisted of most MMD symptoms (anhedonia, depressed mood, disturbed sleep, low energy, appetite problems, worthlessness and suicidal ideation) and one GAD symptom (irritability). The fourth cluster consisted of the four infection fears and the GAD symptom fear of awful events. The fifth cluster consisted of symptoms from MDD and GAD reflecting cognitive and bodily symptoms.

4. Discussion

The present study investigated the network of the components of three salient pandemic-related distressing states (i.e., fear of infection, financial worries, loneliness) in addition to MDD and GAD symptoms in the general population during a period of strict social distancing protocols to impede the spread of the COVID-19 virus. The primary question was whether components of these psychological states were related to common psychiatric symptoms and – because they had likely been elicited or strengthened by the pandemic and the protocols - could be interpreted to influence the symptoms. Also small edge weights (> 0.05) are considered theoretically important as they are well controlled. The ggmModSelect estimates the correlation between two variables after conditioning on and thus controlling for all other variables in the data set.

Of the infection fears, fear of dying from the coronavirus and fear of significant others dying from it had marked connections to the GAD symptom fear of awful events. These connections are reasonable, as dying from the virus or losing significant others are both examples of awful events. Fear of infection and fear of dying were connected to the GAD symptom anxiety. Thus, these infections fears and GAD symptoms may function as bridge components between the fear of infection and GAD constructs, explaining how the pandemic-related fear of infection may have the impact of activating a network of GAD-symptoms.

Of the financial worry components, worry about personal economy was connected to the MDD symptom sleep problems and to the GAD symptom generalized worry. Thus, worry about personal economy may activate both the MDD and the GAD network.

Each of the four loneliness components was connected to a particular MDD symptom - missing companionship to anhedonia, feeling left out to

worthlessness, feeling isolated to depressed mood, and people around but not with to suicidality. Interestingly, while our study focus between-person relationships at one time-point, Fried et al. (2021) - in their temporal network study of within-person relationships - also found that missing companionship (or not being close to others) was related to anhedonia, but through worry about health and the coronavirus. Thus, the loneliness that has been elevated by the presence of the social distancing measures may spread to depression symptoms through several paths and eventually activate an inter-connected network of depression symptoms. The particular paths seem meaningful, for instance feeling left out implies that self is being negatively evaluated by others and thus may lead to the experience of worthlessness. However, it should be noted that only associations have been found and the causal directions between state components and symptoms may be otherwise, for instance worthlessness may lead to feeling left out through interpretation of others' behavior as rejective.

The community analysis yielded five clusters: a depression cluster of six MDD symptoms and the GAD symptom irritability; a GAD worry cluster including worry uncontrollability, generalized worry, anxiety, worry about job, and worry about personal economy; a fear of infection cluster including the fear of infection components and the GAD symptom fear of awful events; a pure cluster of the loneliness components and, finally, an across disorder cluster of cognitive and bodily symptoms. These findings support that MDD and GAD are separate disorders as both had a distinct community. The findings also suggest that MDD and GAD are often co-occurring because the cognitive and bodily symptoms community cut across them and because one DSM-defined GAD symptom – irritability - may rather be more closely connected to depression symptoms. The presence of COVID-19 and the associated stress states possibly affect the comorbidity structure of MDD and GAD. It seems that the stronger bridges are between psychomotor symptoms (MDD psychomotor problems and GAD trouble relaxing and restlessness) during pandemics (Wang et al., 2020; the present findings), whereas additional strong bridges between more pure psychological symptoms (anhedonia and generalized worry, depressed mood and anxiety) are present in non-pandemic times (Cramer et al., 2010; Garabiles et al., 2019).

Centrality values depend on such coincidental features as number of items measuring a construct and the density of a construct's network, making it less informative to compare centrality values across constructs. We analyzed centrality of all nodes as part of one coherent structure, but because within-construct edges tended to be much stronger than between-construct edges, within-construct centrality is supposed to be fairly accurately reflected. Among the MDD symptoms, depressed mood, low energy, and worthlessness had the highest strength, meaning that they uniquely explained much variance in the neighboring nodes. Each of these findings are consistent with at least some of the non-pandemic studies (see Introduction), except that anhedonia was less central in our study as it was in Wang et al. (2020). Thus, the pandemic-related social distancing measures seriously restrict activity, but loss of interest or pleasure in doing things is not a central symptom. Also Wang et al. found low energy to be central during the outbreak of the pandemic in China. The centrality of low energy possibly reflects the exhausting nature of the COVID-19 situation with its associated stress states. Wang et al. also found psychomotor problems and suicidality to be central symptoms. Thus, suicidality appeared to have more influence on other symptoms in China than in Norway and one may speculate that this relates to the more forceful implementation of the distancing measures in China.

Among the GAD symptoms, generalized worry, uncontrollability of worry, and trouble relaxing were those with highest strength centrality. Compared to non-pandemic studies (see introduction), the centrality of trouble relaxing was different. Consistent with our finding, Wang et al. (2020) and Heeren et al. (2021) found trouble relaxing and Wang et al. restlessness to be central in their pandemic studies. The importance of the psychomotor symptoms may be due to the restrictions on movement associated with the outbreak (Wang et al., 2020).

Fear of dying had the highest strength among the fear of infection items, probably reflecting that the most serious consequence of infection influences the other fears. Worry about personal economy had the highest strength among the financial worry items, likely because the other component – worry about losing job – largely concerns personal economy. Feeling isolated had the highest strength among the loneliness items, which is reasonable given that isolation is the most direct consequence of society's distancing measures. If these findings are replicated in longitudinal within-person studies, the central symptoms and components may possibly turn out to be promising targets for intervention.

4.1. Limitations and strengths

A limitation of this study is that full random sampling was not conducted. However, the sample of respondents turned out to be relatively representative of the adult Norwegian population in terms of the proportion of sub-groups. Notable exceptions were large proportions of females and of people with higher education. A second limitation is that the variables were assessed by self-report. Third, the centrality measures used have limitations (Bringmann et al., 2019). We have focused strength centrality, which gives information on the strength of the direct connections (partial correlations) between a node and its neighboring nodes. However, this measure does not capture indirect associations between nodes. A fourth limitation is the cross-sectional design, which impairs the ability to draw conclusions about temporal precedence and greater insight into causal direction of the relationships obtained. Finally, the sample was drawn from a general population. Thus, even though there were high levels of anxiety and depression, this was not a clinical sample. Hence other associations and network structure may be present in a clinical sample.

A strength of this study is that it captured the effects of the social distancing protocols momentarily as they happened and were held constant during the measurement period. Thus, this study provides the grounds for evaluation and modification of these protocols in real time, as they are still in practice worldwide. Moreover, the large sample size contributed to accuracy, stability, and robustness of the network estimates.

6. Conclusion

In sum, the findings support that the components of states elicited by the pandemic and the social distancing protocols are associated with depression and anxiety symptoms. Some of the fear of infection components were related to some GAD symptoms, the financial worry component worry about personal economy was related to a MDD symptom and a GAD symptom, and each of the loneliness components were related to a specific MDD symptom. These bridge components may turn out to be suitable targets of intervention to avert the development of MDD and GAD symptoms and disorders. Other potential targets of interventions suggested by the findings for the complex of pandemic-related states and disorders are the symptoms depressed mood, low energy and worthlessness when focusing on MDD, the symptoms generalized worry, uncontrollability of worry, and trouble relaxing within a GAD cluster, the component fear of dying with regard to infection fears, and the component feeling isolated concerning loneliness. However, the assumption that components and symptoms causally interact with each other implies that they do so within the individual and over time (Spiller et al., 2020). Future studies should therefore follow Fried et al. (2021) in using a longitudinal design to estimate within-person networks and thereby more forcefully investigate whether the presented central variables may represent effective targets for intervention in pandemic settings.

Authors' contribution

AH analyzed the data, wrote the first draft of the paper, and revised it based on SUJ's and OVE's comments. OVE administered the collection of the data, conducted data curation, and contributed to the analysis of the data. All authors contributed to the conceptualization and methodology of the study.

Declaration of Competing Interest

The authors declare that they have no competing interests that could influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jad.2021.07.019.

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