A three-wave network analysis of COVID-19's impact on schizotypal traits, paranoia and mental health through loneliness

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Abstract (248/250)

Background The 2019 coronavirus (COVID-19) pandemic has impacted people's mental wellbeing. Studies to date have examined the prevalence of mental health symptoms (anxiety, depression, loneliness), yet fewer longitudinal studies have compared across background factors and other psychological variables to identify vulnerable sub-groups. This study tests to what extent higher levels of psychotic-like experiences – indexed by schizotypal traits and paranoia – are associated with various mental health variables 6- and 12-months since April 2020.

Methods Over 2,300 adult volunteers (18-89 years, female=74.9%) with access to the study link online were recruited from the UK, USA, Greece, and Italy. Self-reported levels of schizotypy, paranoia, anxiety, depression, aggression, loneliness, and stress from three timepoints (17 April to 13 July 2020, N_1 =1,599; 17 October to 31 January 2021, N_2 =774; and 17 April to 31 July 2021, N_3 =586) were mapped using network analysis and compared across time and background variables (sex, age, income, country).

Results Schizotypal traits and paranoia were positively associated with poorer mental health through loneliness, with no effect of age, sex, income levels, countries, and timepoints. Loneliness was the most influential variable across all networks, despite overall reductions in levels of loneliness, schizotypy, paranoia, and aggression during the easing of lockdown. Individuals with higher levels of schizotypal traits/paranoia reported poorer mental health outcomes than individuals in the low-trait groups.

Conclusion Schizotypal traits and paranoia are associated with poor mental health outcomes through self-perceived loneliness, suggesting that increasing social/community cohesion may improve individuals' mental wellbeing in the long run.

Keywords: Network Analysis; Schizotypy; Anxiety; Depression; Stress; Loneliness; Sleep; COVID-19; Longitudinal; Mental Health.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has caused sustained global disruptions to our livelihoods, yet the international scientific community has come together to collect time-sensitive data to shape rapid government responses, policies, and vaccine development programs. Between January 2020 and July 2021, one database[1] documented a total of 501,212 publications on coronavirus have been published, with mental health research being a key area of research interest. Some large birth cohort study findings reporting pre- and post-pandemic comparisons have been valuable in assessing change. Many more findings from newly developed cross-sectional country-/population-specific studies have reported on mental health prevalence during the early days of the pandemic. This latter set of studies has primarily defined mental health as 'internalizing' problems such as anxiety, depression, and loneliness (often excluding externalizing problems like aggression), focused on specific populations (e.g., medical frontline workers, teachers, parents with young children, children with special education needs) and often lacked a control group. While prevalence rates provide a good 'snapshot' of people's experiences during the pandemic, studies assessing the stability and change of these symptoms in the same individuals throughout the pandemic are limited due to COVID restrictions, with the exception of some timeseries studies.[2] All in all, studies have aimed to examine possible environmental factors, including the impact of national lockdown restrictions (e.g., physical distancing and social isolation) on mental health (Carollo et al., 2021) in order to identify groups of individuals who may be more vulnerable and in need of support.

Arguably a less researched yet important area is the impact of COVID-19 on psychotic-like experiences – as indexed by schizotypal personality disorder and paranoia. It is conceivable that COVID-19 an airborne 'invisible killer' that has infected over 184 million people – many of whom are asymptomatic – and caused 3.9 million deaths and counting globally,[3] has instilled doubt and distrust in all aspects of society. We know from existing research on paranoia, the unfounded fixed belief that others cause intentional harm (Freeman & Garety, 2000), that

[1] Dimensions COVID-19 database. https://reports.dimensions.ai/covid-19/

[2] UCL COVID Social Study. https://www.covidsocialstudy.org/

[3] Data comes from Wikipedia, government health ministries, The New York Times, and other authoritative sources, as attributed.

paranoia is a key symptom of schizophrenia-spectrum disorders like schizotypal personality disorder - both of which exist in varying intensities in the general population (Bebbington et al., 2013; Wong, & Raine, 2018). For example, as of November 2020, 57% of UK respondents aged 16-75 years (N = 2,244) expressed distrust in the government's control over the spread of coronavirus, an increase from 28% at the start of the pandemic in April 2020 (Ipsos MORI, 2020). Framing of public health messages which focus on the origin of coronavirus has caused xenophobia towards people of Asian descent (Dhanani & Franz, 2021). Fear of others not social distancing, fear of catching COVID, lack of control over the restrictions, financial uncertainty, are all well-documented stressors that may lead to heightened levels of suspicion towards others and reclusive habits (Wong, 2020). It is conceivable then that lockdown will have a bigger effect for individuals with higher levels of schizotypal traits and paranoia compared to their peers.

Compliance with government physical distancing and lockdown restrictions thought necessary may perpetuate other health issues. For example, lockdown duration can likely increase feelings of loneliness over the course of forced stay-at-home mandates (Carollo et al., 2021) and fuel anxiety and psychotic-like experiences (Lim et al., 2018). Increased fear of one's and others' safety, stress about COVID, and the lack of social contacts with others may fuel maladaptive thoughts that if sustained may become paranoia known to be associated with poor psychological wellbeing (Freeman et al., 2014); including, feelings of anxiety, worries (Freeman et al., 2012), depression (Drake et al., 2014), insomnia (Freeman, Pugh, Vorontsova, & Southgate, 2009; Freeman et al., 2017), loneliness (Lamster et al., 2007) and to a lesser degree aggression (Tone & Davis, 2012; Wong, Freeman, & Hughes, 2014). Psychotic-like experiences as highlighted in a large representative sample of UK adults in April 2020, demonstrated that mistrust and belief in conspiracy theories were associated with lower compliance in government restrictions, antibody testing and vaccine adoption (Freeman et al., 2020). Thus, more than ever, research on psychotic-like experiences and its correlates are of utmost importance in informing public health and policy.

To the author's knowledge, four studies have investigated paranoia and schizotypal personality traits in relation to mental health during the pandemic – although findings have been mixed. In one study of UK and Germany adults between 27 April and 31 May 2020, 3.5% Germany) and 4.4% (UK) respondents reported experiencing schizotypal traits for the first time and a similar group reported increases in schizotypal traits after the pandemic (Germany = 4.1%,

UK = 4.8%) (Knoelle, Ronan, & Murray, 2021). By October 2020, researchers recruited an additional sample and found an increase in schizotypal traits was associated with higher levels of loneliness, use of drugs, and financial burden (Daimer et al., 2021). These changes were thought to be due to national lockdown restrictions and physical distancing measures. In another cross-sectional survey of Tunisian university students between 1 June and 15 July 2020, students in the high schizotypal traits group (top-10% on the 74-item Schizotypal Personality Questionnaire) reported significantly more maladaptive coping strategies and fear of COVID-19 compared to those in the low-schizotypy group (bottom-10%) (Fekih-Romdhane, Dissem, & Cheour, 2021). Contrastingly, in an online survey of French adults between 13 April to 11 May 2020 (N = 728), paranoia and hallucination were found to be relatively low and associated with cognitive-affective experiences (loneliness, jumping-to-conclusions, anxiety, experiential avoidance), but not associated with COVID19-related variables (e.g., length of isolation, hospitalisation, COVID symptoms) (Bortolon et al., 2021). While these studies shed light on the mental health correlates with schizotypal traits and paranoia during the pandemic, they are limited in the scope of mental health variables and the short-term cross-sectional designs, which preclude the understanding of specific target variable(s) for intervention as well as how relative associations change over time.

One way to fill these gaps is to use network analysis (NA). Mental health variables such as anxiety, depression, aggression, and schizotypal traits are often correlated with each other, yet traditional bivariate correlations only focus on the association between two variables each time and preclude comparison across interactions or identification of the most influential variable in the network across multiple time points. NA addresses this by estimating a network structure, which consists of *'nodes'* representing the variables and *'edges'* representing the partial correlations between each pair of variables (Borsboom & Cramer, 2013; McNally, 2021; Wang et al., 2020). Other common statistical comparisons include the '*centrality index*' of nodes, which reflect the influence of a node in the network and the '*strength*' of the centrality indices, which is the summed weight of all edges connected to a node in the network. By mapping the nodes and estimating the edges, we can investigate the independent relationships between pairs of variables whilst controlling for the effects of all the other variables and associations in the network to obtain a more holistic view of the interactions between all the variables of interest as a network and identify influential variables for intervention.

This prospective study tests to what extent higher levels of psychotic-like experiences – indexed by schizotypal traits and paranoia – relate with various mental health variables at 6- and 12-months since April 2020. Three 30-minute online surveys were conducted at three time-points: 17 April to 13 July 2020 (N_1 = 1,599), 17 October to 31 January 2021 (N_2 = 774) and 17 April to 31 July 2021 (N_3 = 586) which coincide with the UK national lockdown 1, lockdowns 2 and 3, and easing of restrictions respectively. It remains unclear how mental health variables beyond internalizing problems, like externalizing problems (aggression), sleep quality, and COVID-related stressors relate with schizotypal traits and paranoia over time during the pandemic. Understanding how schizotypal traits and levels of paranoia have changed in relation to both internalizing and externalizing problems for different groups of individuals (by sex, age, income, country) during the pandemic can help inform government rapid response and COVID-19 recovery plans importantly, current public health interventions. Using a network analysis, this study tests three hypotheses that:

1. Schizotypal traits and paranoia will be positively associated with both internalizing and externalizing problems.
2. The social networks may be the same or different for participants across different sex, age (<35 vs 35+ years), countries (UK vs Others), income level (low, medium, high), and timepoints (wave 1, 2, 3).
3. The network structure will be different for high vs low paranoid and schizotypal individuals, with associations being stronger for those in the high symptom groups.

2. Methods

2.1. Participants

Over 2300 volunteers took part in the survey and were recruited via online advertising of the study, university lists, charity lists, Linkedln, Twitter, Instagram and word-of-mouth. All adults aged 18 years and above with access to the study website www.GlobalCOVIDStudy.com could take part. The 30-minute survey hosted online on Qualtrics was available in English and 7 other languages (Greek, Italian, Spanish, Chinese Traditional, Chinese Simplified, French, German). Forward translations were first conducted by Google translate and cross-checked and corrected by at least one native speaker. This study was pre-registered (https://osf.io/4nj3g/ on 17 April 2021) and ethical approval was obtained from the University College London Institute of

Education Ethics and Review Committee in April 2020 (REC 1331; Wong & Raine, 2020). Informed consent was sought from participants at the start of the 30-minute online Qualtrics survey and at subsequent follow-ups, with opt-out options available throughout. Participant demographic and missing data on all study variables across the two waves of data collection are presented in **Table 1**. The analytic sample for this study consisted of data from participants at 3 time-points: wave 1 (N_1=1599; 17 April to 14 July 2020), wave 2 (N_2=774; 17 October 2020 to 31 January 2021), and wave 3 (N_3=586; 17 April to 31 July 2021).

2.2. Measures

2.2.1. Psychotic-like experiences (PLEs)

Schizotypal traits were assessed by the *Schizotypal Personality Questionnaire – Brief* (SPQ-B; Raine & Benishay, 1995), a 22-item yes/no questionnaire that when summed creates a total score ranging from 0 to 44 with a higher score reflecting more schizotypal traits. Three additional subscales were also created by summing the respective items to form the factors: Cognitive-Perceptual (F1), Interpersonal (F2), and Disorganized (F3) features of schizotypy. The internal reliability for the subscales and total score was good (α = .87).

Paranoia was assessed using the *Social Mistrust Scale* (SMS; Wong, Freeman, & Hughes, 2014), a 12-item 3-point scale (No [0], Sometimes [1], Yes [2]). Summing all items created a total mistrust score ranging from 0 to 24, whereby a higher score reflected higher levels of paranoia and suspiciousness. Past studies have denoted a score of 7 and above to be 'mistrustful'. The internal reliability for the total score was good (α = .79).

2.2.2. Externalizing problems

Self-reported levels of aggression were assessed by the *Reactive-Proactive Questionnaire* (RPQ; Raine et al., 2006), a 23-item self-report questionnaire with a never (0), sometimes (1), often (2) scale. Summing all items produces a total aggression score ranging from 0 to 46 with a higher score reflecting more aggressive behaviours with good internal reliability (α = .85).

2.2.3. Internalizing problems

Depression was assessed using the *Patient Health Questionnaire-9* (PHQ-9: Kroenke et al., 2001) 9-item 4-point scale (not at all [0], several days [1], more than half the days [2], nearly

every day [3]) which when summed produce a total score ranging from 0 to 27. A higher score reflected higher levels of depressive symptoms and a score above 15 was the clinical cut-off. The internal reliability for this study was excellent (α = .90).

Anxiety was assessed using the *General Anxiety Disorder-7* (GAD-7; Spitzer et al., 2006) 7-item 4-point scale (not at all [0], several days [1], more than half the days [2], nearly every day [3]) where a higher summed score across the 7-items ranging from 0 to 21 reflects higher levels of anxiety, with a score above 15 being the clinical cut-off. The internal reliability for this study was excellent (α = .92).

The *Loneliness Questionnaire* (LQ; Russell, 1996) is a 20-item (10 reverse-coded items) 4-point scale (never [1], rarely [2], sometimes [2], often [3]) that when summed creates a total score ranging from 20 to 77. A higher score denotes higher levels of loneliness. The internal reliability for this study was excellent (α = .94).

2.2.4. COVID-19-related stressors

Participants selected from a list of 27 potential stressors related to the COVID-19 pandemic that they thought caused them stress in the past 14 days. Participants were shown a follow-up question with the selected stressors and asked to what extent the following stressors have caused them stress on a 5-point scale: No stress (0), A little bit of stress (1), Moderate Stress (2), Quite a lot of stress (3), Extremely Stressful (4). Scores were summed and ranged from 0 to 92.

2.2.5. Sleep quality

Self-reported sleep quality was indexed by summing 4-items from *The Consensus Sleep Diary* (Carney et al., 2012) ('During the past month: - How would you rate your overall sleep quality?', 'How would you rate the quality of your sleep overall?' and 'How rested or refreshed do you feel when you wake up?') and the *Karolinska Sleepiness Scale* (Åkerstedt & Gillberg, 1990), 'How sleepy have you felt during the last 5 minutes?'. Scores were summed and range from 4 to 23 with moderate internal reliability (α = .66).

2.2.6. Demographic variables

Participants were asked to report on their date of birth (<35 or 35+), gender (female = %), and country at the time of completing the survey (UK vs Other), which were dichotomized and included in our between-group analyses (see **Table 1**).

2.2.7. Covariates

Participants reported on their annual pre-tax income in $/£10,000 bands (under £30,000 [0], £30,000-£59,999 [1], £60,000+ [2]), which was categorized and included in our analyses as covariates.

2.3 Data analysis

The descriptive statistics of all study variables are reported in Table 1&2 and bivariate relationships are reported in Table 3.

Group comparison. Independent sample t tests were performed to examine the differences between age groups (older vs. younger), gender groups or sites (UK vs. other counties). Paired sample t-tests were also performed to examine the changes of all psychological variables between two waves. SPSS 19.0 was used for descriptive analysis and t tests mentioned above, and a significant threshold was set as $p < 0.05$.

Network Estimation. Firstly, psychological networks were estimated in whole sample collected at first wave to examine direct links between psychological variables including anxiety (GAD), depression (PHQ), sleep, COVID-related levels of stress, loneliness, aggressions (RPQ), social mistrust (SMS) and the three factors of the schizotypy subscales (SPQ-B). Nodes and edges are core components of a network. In this study, nodes were defined as participants' scores on psychological scales and edges were calculated using partial correlations between each pair of nodes after controlling for all the other variables in the network. Graphical Least Absolute Shrinkage and Selection Operator (LASSO) (Tibshirani, 1996) in combination with Extended Bayesian Information Criteria (EBIC) model selection (Foygel & Drton, 2010) were used to estimate Gaussian graphical model and construct networks. In addition, the importance of each node in the network was further investigated by examining the strength of each node by summing up all connections of the node. Out of all the centrality indices, we mainly report the index of "*strength*" as all connections are positive, and nodes are total or subscale scores of psychological questionnaires. The standardized z scores of centrality indices were calculated and

reported. The "*bootnet*" package (https://CRAN.R-project.org/package=bootnet) implemented in R statistical software (version 4.0.2, https://www.r-project.org/) were used for network construction and "*qgraph*" package (https://CRAN.Rproject.org/package=qgraph) was used for centrality calculation and visualization. Force-directed Fruchterman–Reingold algorithm (Fruchterman & Reingold, 1991) was used to determine the placement of nodes in the network and how they are estimated in the sample.

Network Comparison Test (NCT). The "Network Comparison Test" package (https://CRAN.R-project.org/package=NetworkComparisonTest) was used to examine invariance of two networks. The tests of network invariance usually include invariance of network structure, global strength, and edge weights of the network. In order to compare the networks between age groups, gender groups, countries as well as income levels, we estimated networks for each subset of data and then performed the NCT respectively using two-tailed permutation tests (10,000 times) (van Borkulo et al., 2017). In addition, to address multiple comparisons of invariance tests of edge-weights and nodal strength, false discovery rate (FDR) correction was used. The significance threshold was set at p or adjusted $p< 0.05$.

Network stability and accuracy. The stability and accuracy of each network we estimated in this study were examined according to a tutorial paper (Epskamp et al., 2018) (see *Supplementary Figures S1-S8*).

3. Results

3.1. Descriptive statistics.

Descriptive statistics of study variables (Table 1 and 2) and bivariate correlations of all study variables are presented below (Table 3). All correlation coefficients were statistically significant and positively correlated with each other at $p < 0.001$ level.

Table 1. Demographic statistics of all study variables.

	Wave 1 17 April to 14 July 2020 (N_1=1599)		**Wave 2** 17 October 2020 to 31 January 2021 (N_2=774)		**Wave 3** 17 April to 31 July 2021 (N_3=586)	
	n	**%**	**n**	**%**	**n**	**%**
Age						

< 35 years	952	59.5	446	57.6	339	57.8
>=35 years	642	40.2	323	41.7	244	41.6
Missing	5	0.3	5	0.6	3	0.5
Gender						
Male	404	25.3	174	22.5	134	22.9
Female	1172	73.3	589	76.1	444	75.8
Else	23	1.4	11	1.4	8	1.4
Countries						
UK	649	40.6	360	46.5	281	48
Others	576	36	234	30.2	162	27.6
Missing	374	23.4	180	23.3	143	24.4
Income						
Low (< 30k)	639	40	281	36.3	179	30.5
Medium (30-60k)	348	21.8	165	21.3	155	26.5
High (> 60k)	519	32.5	292	37.7	232	39.6
Missing	93	5.8	36	4.7	20	3.4

Table 2. Descriptive statistics of all variables in network**.**

Wave 1	*n*	range	min.	max.	*M*	*SD*	skewness	kurtosis
SPQ-B Total	1599	22	0	22	6.15	4.71	0.73	-0.09
SPQ-B F1	1599	8	0	8	1.73	1.82	1.07	0.55
SPQ-B F2	1599	8	0	8	2.99	2.36	0.44	-0.86
SPQ-B F3	1599	6	0	6	1.43	1.69	1.08	0.14
SMS Total	1599	24	0	24	2.38	2.95	1.90	5.04
RPQ Total	1599	34	0	34	6.74	4.56	1.04	2.02
PHQ-9	1599	27	0	27	7.29	5.60	0.94	0.44
GAD-7	1599	21	0	21	5.60	4.96	1.04	0.40
Stress Total	1599	72	0	72	15.24	11.26	1.26	2.12
LQ Total	1599	57	20	77	42.49	11.22	0.43	-0.44
Sleep Total	1599	19	4	23	12.42	3.69	0.08	-0.57
Wave 2	*n*	range	min.	max.	*M*	*SD*	skewness	kurtosis
SPQ-B total	774	21	0	21	5.67	4.82	0.79	-0.16
SPQ-B F1	774	8	0	8	1.50	1.78	1.25	1.04
SPQ-B F2	774	8	0	8	2.88	2.47	0.52	-0.87
SPQ-B F3	774	6	0	6	1.29	1.64	1.20	0.43
SMS Total	774	24	0	24	2.10	2.91	2.29	7.92
RPQ Total	774	24	0	24	4.05	3.97	1.34	2.28
PHQ-9	774	27	0	27	7.14	5.80	1.03	0.58
GAD-7	774	21	0	21	5.56	5.00	1.08	0.55
Stress Total	774	92	0	92	15.46	11.41	1.22	2.82
LQ Total	774	57	20	77	42.77	11.72	0.41	-0.51
Sleep Total	774	18	4	22	13.03	3.67	-0.07	-0.59
Wave 3	*n*	range	min.	max.	*M*	*SD*	skewness	kurtosis
SPQ-B Total	586	22	0	22	5.35	4.64	0.95	0.39
SPQ-B F1	586	8	0	8	1.32	1.68	1.40	1.49
SPQ-B F2	586	8	0	8	2.83	2.45	0.57	-0.76
SPQ-B F3	586	6	0	6	1.20	1.61	1.34	0.85
SMS Total	586	24	0	24	1.90	2.88	2.58	9.59
RPQ Total	586	30	0	30	3.60	3.92	2.02	6.56
PHQ-9	586	27	0	27	6.86	5.94	1.33	1.38
GAD-7	586	21	0	21	5.47	5.06	1.22	0.94
Stress Total	586	59	0	59	12.95	10.57	1.54	2.54
LQ Total	586	55	20	75	41.38	11.81	0.52	-0.26
Sleep Total	586	19	4	23	12.81	3.57	0.14	-0.26

Note. SPQ-B: Schizotypal Personality Questionnaire – Brief; SPQ-B F1: Cognitive-Perceptual; SPQ-B F2: Interpersonal, SPQ-B F3: Disorganized; SMS: Social Mistrust Scale; RPQ: Reactive-Proactive Questionnaire; PHQ-9: Patient Health Questionnaire-9; GAD-7: General Anxiety Disorder-7; LQ: Loneliness Questionnaire.

Table 3. Bivariate Pearson's correlation coefficients between study variables in the network at wave 2.

	1	2	3	4	5	6	7	8	9	10	11
1. SPQ-B Total	-										
2. SPQ-B F1	.765	-									
3. SPQ-B F2	.839	.413	-								
4. SPQ-B F3	.792	.479	.494	-							
5. SMS Total	.453	.403	.336	.358	-						
6. RPQ Total	.335	.360	.193	.276	.311	-					
7. PHQ-9	.426	.347	.350	.324	.392	.278	-				
8. GAD-7	.420	.396	.319	.298	.354	.336	.752	-			
9. Stress Total	.270	.272	.203	.177	.283	.256	.565	.595	-		
10. LQ Total	.610	.365	.619	.442	.502	.243	.539	.453	.320	-	
11. Sleep Total	.240	.187	.204	.182	.238	.137	.558	.454	.352	.338	-

Notes. SPQ-B: Schizotypal Personality Questionnaire – Brief; SPQ-B F1: Cognitive-Perceptual; SPQ-B F2: Interpersonal, SPQ-B F3: Disorganized; SMS: Social Mistrust Scale; RPQ: Reactive-Proactive Questionnaire; PHQ: Patient Health Questionnaire-9; GAD: General Anxiety Disorder-7; LQ: Loneliness Questionnaire.

3.2 Comparisons of all study variables across age, gender, countries and income groups at wave 1

Independent samples t-tests were performed to compare groups differences between younger and older groups, males and females, as well as Countries (UK vs. Others). In addition, MANOVA was conducted to compare groups with different levels of income. Adjusted p (0.05/11 = 0.0045) was considered as a significance threshold to correct multiple comparisons. The results in detail were shown in Table 4.

In summary, the younger group reported higher levels of schizotypal traits, aggression, depression stress, and anxiety, as well as more sleep problems compared to older participants; females reported more severe depression stress, and anxiety than male participants. Compared to the other countries, participants from the UK had higher levels of schizotypal traits, depression, anxiety, loneliness and sleep problems, and lower aggression. High income group showed a

better situation in terms of schizotypal trait, negative affect, and loneliness compared to the other two groups with medium- or low-income levels.

Table 4. Comparisons across age, gender, countries and income groups

	Age		**Gender**		**Countries**		**Levels of Income**		
Wave 1	Younger vs. Older		Male vs. Female		UK vs. others		(Low vs. Medium vs. High)		
	t	p	t	p	t	p	F	p	Post hoc
SPQ-B Total	**4.47**	<0.001	2.00	0.045	**2.94**	0.003	**30.52**	<0.001	L>M>H
SPQ-B F1	**3.16**	0.002	-0.62	0.537	0.78	0.437	**21.14**	<0.001	L>M>H
SPQ-B F2	**3.09**	0.002	1.06	0.289	**3.50**	<0.001	**18.87**	<0.001	L=M>H
SPQ-B F3	**4.84**	<0.001	**4.53**	<0.001	2.41	0.016	**21.27**	<0.001	L>M>H
SMS Total	-1.28	0.201	1.51	0.131	0.40	0.691	**29.15**	<0.001	L>M>H
RPQ Total	**3.22**	0.001	-0.69	0.493	-2.84	0.005	**21.96**	<0.001	L>M=H
PHQ-9	**6.31**	<0.001	**-4.65**	<0.001	**6.13**	<0.001	**18.00**	<0.001	L=M>H
GAD-7	**5.79**	<0.001	**-6.98**	<0.001	**4.18**	<0.001	**9.09**	<0.001	L=M>H
Stress Total	**5.71**	<0.001	**-5.00**	<0.001	**3.00**	0.003	**16.20**	<0.001	L>M>H
LQ Total	0.87	0.383	1.08	0.279	**3.80**	<0.001	**16.23**	<0.001	L=M>H
Sleep Total	**2.91**	0.004	-2.41	0.016	**4.84**	<0.001	0.50	0.606	-

Note. SPQ-B: Schizotypal Personality Questionnaire – Brief; SPQ-B F1: Cognitive-Perceptual; SPQ-B F2: Interpersonal, SPQ-B F3: Disorganized; SMS: Social Mistrust Scale; RPQ: Reactive-Proactive Questionnaire; PHQ: Patient Health Questionnaire-9; GAD: General Anxiety Disorder-7; LQ: Loneliness Questionnaire. $p < 0.0045$ (0.05/11) was set as threshold to adjust for multiple comparisons.

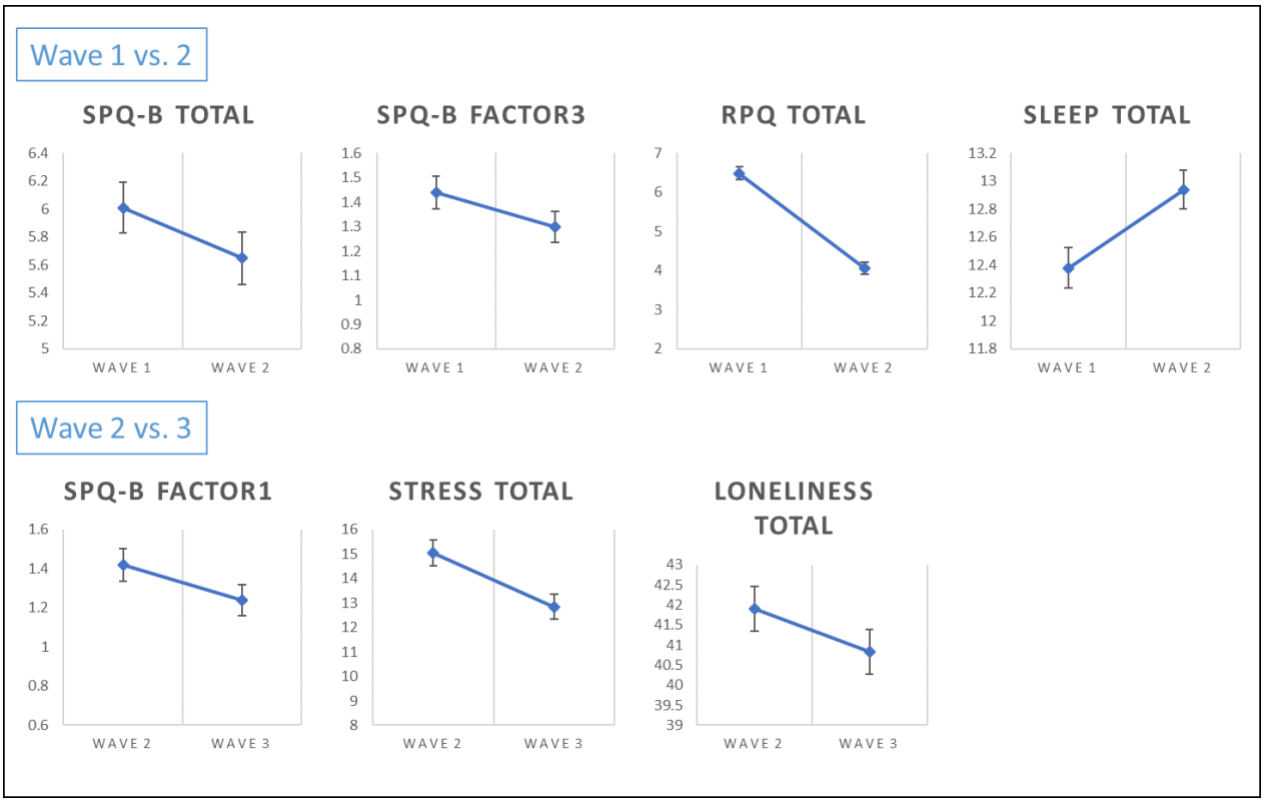
3.3 Comparisons of all study variables across time

To examine the changes across time, we conducted paired samples t tests on all study variables between Wave 1 and 2, as well as between Wave 2 and 3, respectively. The results suggested that participants reported lower levels of aggression and more sleep problems at wave 2 compared to wave 1. At the last wave, participants had lower levels of schizotypal trait and stress caused by COVID. These changes are significant after multiple comparison corrections with adjusted $p < 0.0045$.

Table 5. ***Comparisons of all study variables across time using paired samples t tests***

	T1 vs. T2					T2 vs. T3				
	mean diff.	***SD***	***t***	***df***	***p***	**mean diff.**	***SD***	***t***	***df***	***p***
SPQ-B Total	0.36	3.00	**3.09**	672	0.002	0.23	2.40	2.00	435	0.046
SPQ-B F1	0.05	1.26	1.10	672	0.272	0.18	1.14	**3.32**	435	0.001
SPQ-B F2	0.16	1.58	2.59	672	0.010	-0.03	1.46	-0.49	435	0.622
SPQ-B F3	0.15	1.29	**2.94**	672	0.003	0.08	1.05	1.64	435	0.101
SMS Total	0.10	2.38	1.08	672	0.279	0.25	2.26	2.27	435	0.024
RPQ Total	2.42	3.89	**16.17**	672	<0.001	0.37	3.20	2.38	435	0.018
PHQ-9	0.15	4.33	0.87	672	0.383	0.16	4.30	0.77	435	0.443
GAD-7	-0.02	4.10	-0.12	672	0.903	-0.07	4.22	-0.35	435	0.725
Stress Total	0.24	8.85	0.69	672	0.492	2.19	8.39	**5.46**	435	<0.001
LQ Total	-0.31	7.27	-1.10	672	0.273	1.07	7.29	**3.08**	435	0.002
Sleep Total	-0.56	3.53	**-4.13**	672	<0.001	0.20	3.16	1.29	435	0.199

Note. SPQ-B: Schizotypal Personality Questionnaire – Brief; SPQ-B F1: Cognitive-Perceptual; SPQ-B F2: Interpersonal, SPQ-B F3: Disorganized; SMS: Social Mistrust Scale; RPQ: Reactive-Proactive Questionnaire; PHQ: Patient Health Questionnaire-9; GAD: General Anxiety Disorder-7; LQ: Loneliness Questionnaire. $p < 0.0045$ (0.05/11) was set as threshold to adjust for multiple comparisons.



3.4 Network analysis: network estimation and inference in the whole sample of wave 1

In the whole sample of wave 1, we estimated a network using all study variables including three factors of the SPQ-B, shown in **Figure 1**. The line between a pair of variables indicates the partial correlations after controlling all the other variables in the network, thicker lines represent stronger connections. There are strong connections of schizotypal traits and social mistrust with mental health. For example, SPQ-B factor 1 was linked to anxiety and aggression, social mistrust was correlated with loneliness, aggression and depression. We also observed strong connections between the negative dimension of schizotypy, interpersonal deficits (SPQ-B F2) and loneliness.

The strength of all variables was shown in Figure 1, depression, anxiety and loneliness were the most influential nodes in the network as they had relatively high nodal strength. According to the network, anxiety, depression and stress from COVID were closely correlated with each other, while sleep problems were only linked to depression. More interestingly, we found that loneliness was connected with multiple nodes in the network, including schizotypal traits (SPQ-B F2 and F3), social mistrust and depression. This finding suggested that loneliness may serve as a bridge connecting both schizotypal traits/paranoia and mental health.

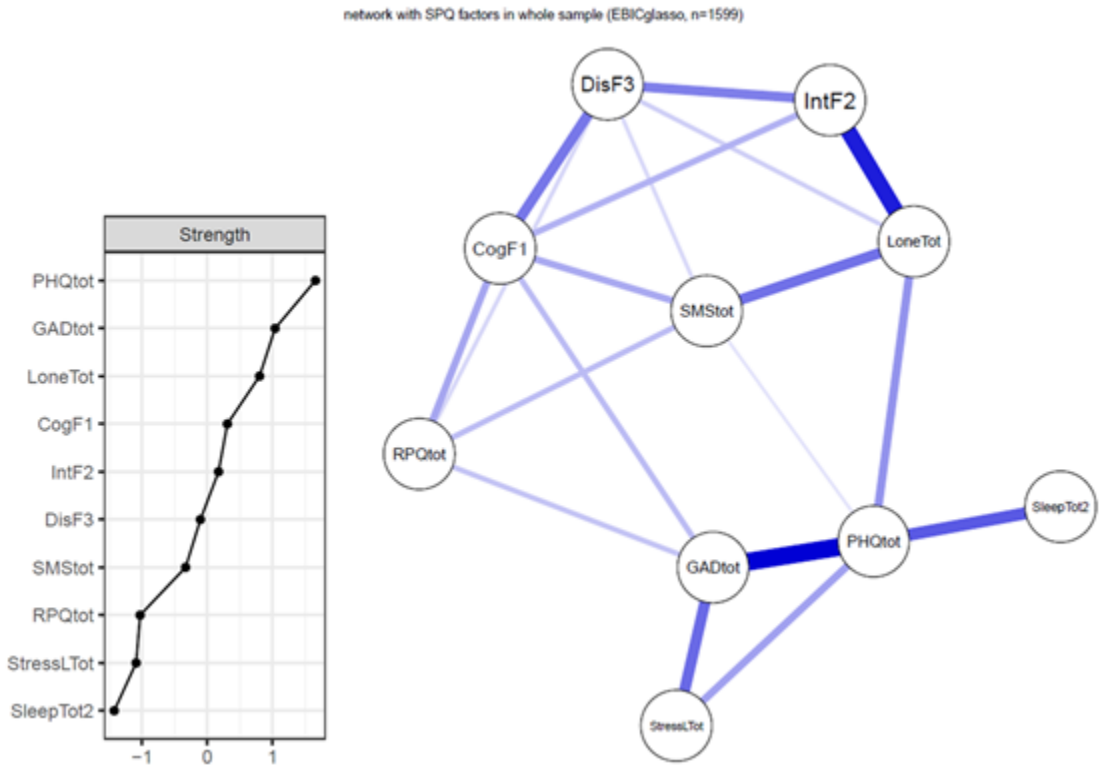


Figure 1. Estimated network structure using SPQ factor scores (right) and nodal strength (left). All lines in the network showed positive partial correlations, thicker lines represent stronger correlations. SPQ-B: Schizotypal Personality Questionnaire – Brief, SMStot: Social Mistrust Scale, RPQtot: Reactive-Proactive Questionnaire, PHQtot: Patient Health Questionnaire-9, GADtot: General Anxiety Disorder-7, LoneTot: Loneliness Questionnaire, StressTot: COVID-19-related stressors, SleepTot: self-reported sleep quality, CogF1: Cognitive-Perceptual factor of SPQ-B, IntF2: Interpersonal factor of SPQ-B, DisF3: Disorganized factor of SPQ-B.

3.5 Network comparisons across groups

At the first wave, network comparisons were conducted across groups by age, gender, countries and levels of income.

The results of NCT did not show significant differences in terms of the invariance of network structures or global strength between **age groups** (younger vs. older groups, network structure invariance test: $M = 0.12$, $p = 0.243$; global strength invariance: 3.86 for younger group

and 4.04 for older group, $S = 0.18$, $p = 0.106$, global strength for network of younger group is 3.86 and 4.04 for the network of older group). As sample sizes of two groups were different, we repeated NCT for 100 times using random subsamples of younger participants, only 1% and 16% of the invariance tests for network and global strength were found significant.

Similarly, we did not find any significant differences between male and female participants (network structure: $M = 0.12$, $p = 0.448$; global strength: $S = 0.16$, $p = 0.196$, global strength for the network of males is 3.86 and 4.02 for females). Repeated subsampling and NCT showed that only 13% and 3% in invariance tests of the network structure and global strength were significant respectively.

In addition, we compared the networks of participants from UK and other countries, no significant differences were found no matter on network structure ($M = 0.15$, $p = 0.170$) or global strength ($S = 0.07$, $p = 0.610$, global strength for the network of UK participants is 3.98 and 3.91 for others).

Among groups with low, medium and high levels of income, we performed a series of NCT to compare the networks with each other and no significant differences were observed (Low vs. Medium income group: network structure: $M = 0.14$, $p = 0.300$; global strength: $S = 0.07$, $p = 0.647$; Low vs. High income group: network structure: $M = 0.13$, $p = 0.335$; global strength: $S = 0.06$, $p = 0.570$; Medium vs. High income group: network structure: $M = 0.23$, $p < 0.05$; global strength: $S = 0.003$, $p = 0.984$).

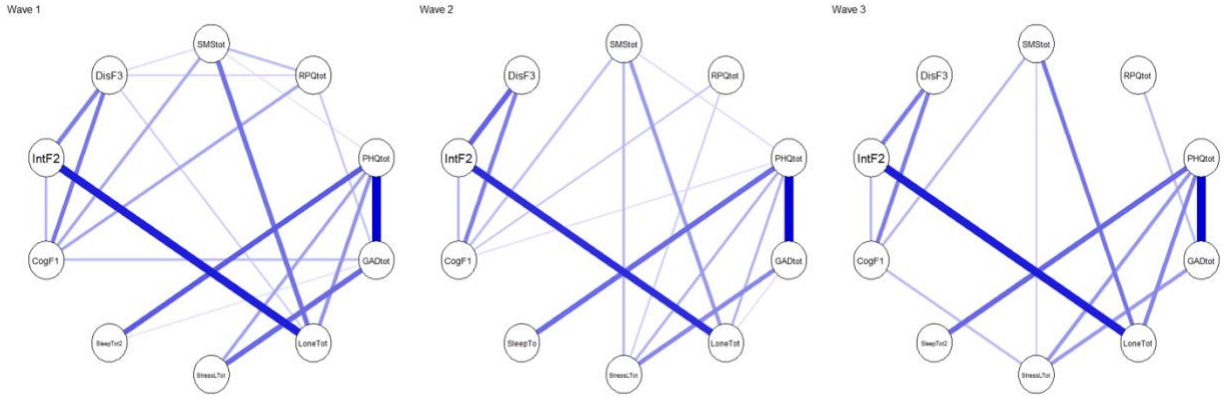
These findings indicated that networks were comparable across different groups including age groups, gender groups, countries as well as groups with different levels of income.

3.6 Network comparisons across three waves

We also performed the network comparisons to test the invariance of network structure and global strength across three waves with each other (Figure 2). Compared to the Wave 1 network, Wave 2 network had comparable network structure ($M = 0.11$, $p = 0.153$) and global strength ($S = 0.02$, $p = 0.879$, 3.99 for wave 1 and 4.02 for wave 2), suggesting that no significant differences on the networks were found across two waves. Similarly, the networks of Wave 2, and Wave 3 are similar as no significant differences were found ($M = 0.08$, $p = 0.983$; $S = 0.07$, $p = 0.519$, global strength is 4.02 for wave 2 and 3.95 for wave 3). These findings

indicate that network structure and partial correlations among variables were similar across three waves.

Figure 2. Invariance test of network structures across three time-points.

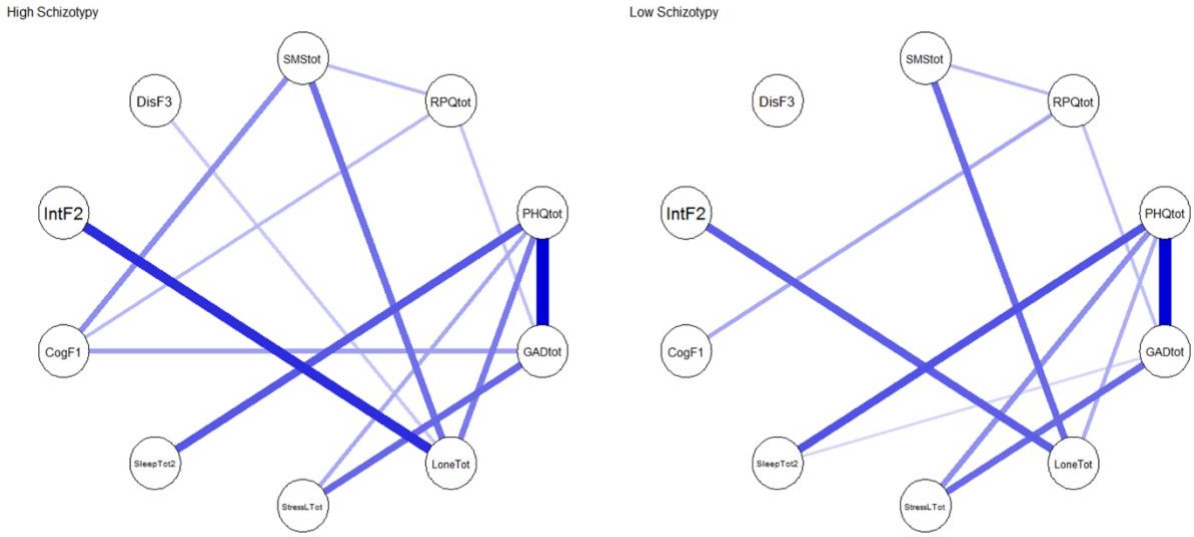


3.7. Network comparisons between high vs. low schizotypy/paranoia

The network structures between groups with high and low SPQ-B scores were different (M = 0.21, p < 0.001). The individuals with high SPQ-B showed significantly stronger correlations between social mistrust and SPQ-B factor1(adjusted p = 0.005), between anxiety and SPQ-B factor1 (adjusted p = 0.027), as well as between loneliness and SPQ-B factor2 (adjusted p < 0.001). The global strength of the high schizotypy group is higher than the low schizotypy group (S = 1.10, p < 0.001, 2.66 for low SPQ group and 3.76 for high SPQ group).

In terms of the social mistrust, the high SMS group also showed a different network structure from the low social mistrust group (M = 0.183, p = 0.004). The connections of social mistrust with SPQ-B factor 1 (adjusted p < 0.05) and loneliness (adjusted p < 0.001) were stronger in the network of the high SMS group than the low SMS group. The global strength for the high SMS group is 3.82, significantly higher than the global strength of the low SMS group which is 3.30 (S = 0.53, p < 0.05). Networks were shown in Figure 3.

Figure 3. Networks of all study variables by high-/low-schizotypy groups (top) and high-/low-social mistrust groups (bottom).



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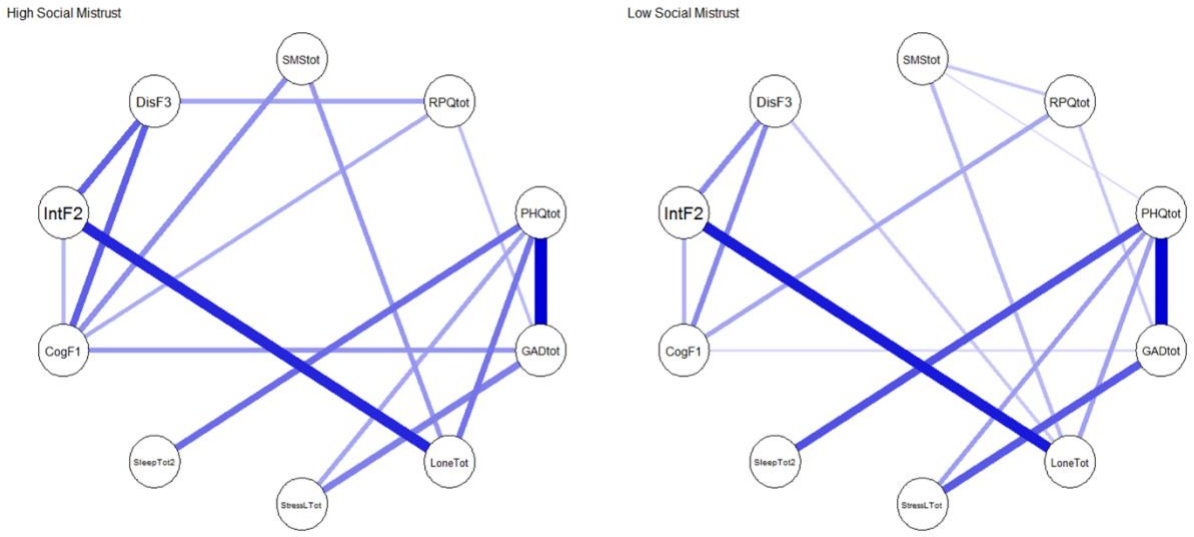

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447 **4. Discussion**

448 **4.1. Main Findings**

449 In this three-time point network analysis study of the associations between psychotic-like
450 experiences (paranoia/schizotypal traits) and mental health (anxiety, depression, loneliness,
451 aggression, COVID-related stress, poor sleep), we found that both schizotypal traits and paranoia
452 were positively associated with depression, anxiety, stress, and poor sleep primarily through self-
453 perceived loneliness. Specifically, interpersonal and disorganized features were associated with

loneliness and depression – a key feature in individuals in the high-schizotypy and high-paranoia group but not the low-trait groups - while cognitive-perceptual features of schizotypy were specifically associated with anxiety. Both paranoia/schizotypal traits were uniquely associated with aggression. Interestingly, there were no network structure differences across sex, age groups, countries, and income level, suggesting that no single vulnerable group can be identified. Between time 1 and 2, there was a reduction in schizotypal traits, aggression, but an increase in poor sleep for the same participants. Between time 2 and 3, there was an overall reduction in levels of COVID-related stress, schizotypal traits, aggression, paranoia, and loneliness – likely reflecting the easing of COVID restrictions across countries especially the UK. On balance, these findings suggest that intervening on self-perceived loneliness - an influential variable across all participant groups which may have improved during the easing of lockdown - may break the negative associations between paranoia/schizotypy and negative mental health symptoms, but externalizing symptoms may still remain.

Although the empirical evidence for why schizotypal traits is associated with loneliness remains sparse, it is conceivable that individuals with schizotypy often have no close friends, anhedonia, and this in turn may distance other people and result in perceived level of loneliness. Indeed, a large-scale meta-analytic study has documented a moderate effect between loneliness and schizotypal traits (N = 15,647; k =13, r = .32, *95%CI* [.20 - .44]) (Michalska da Rocha, Rhodes, Vasilopoulou, & Hutton, 2018) that is replicated for both positive and negative symptoms of schizotypy (Badcock *et al.*, 2016). This is also consistent with studies of first-episode schizophrenia patients who report having more days during the week in which they feel lonely, perhaps associated with the poorer social network and support, and associated symptoms of depression and anxiety (Sündermann *et al.*, 2014). Another explanation for this relationship could be that the fear of others causing harm (paranoia), coupled with an individual's odd behaviors, and social anxiety resulting in avoidance from social situations, can in turn lead to reduced interactions with others, and self-perceived detachment from others (loneliness). Whether this is purely due to the COVID easing of restrictions taking place during time 3 (April to July 2021) or existing poor social support/earlier childhood experiences may be disputed, as we do not have pre-pandemic baseline measures of paranoia. Yet we know from developmental research that compared with trusting children, highly mistrustful 9-16-year-olds were more likely

to report feelings of loneliness, more negative peer relationships like being victims of bullying and a hostile attributional style of thinking about others (Wong, 2015).

Over a 12-month period (time 1 and time 3), schizotypal traits and paranoid ideations have reduced over time, and we only see reductions in levels of loneliness between time 2 and 3 (p<.002) and not between time 1 and time 2 (p=.273) (see Table 5). Two explanations may account for this: the first is that levels of loneliness were generally felt and sustained for the large majority of people in the sample given that the UK was in full national lockdowns coinciding with time 1 and time 2 and worldwide travel restrictions were in place. By time 3, reductions in self-perceived levels of loneliness were reported coinciding with the initial easing of restrictions, albeit still limited (e.g., reopening of shops and social distancing still in place until the end of time 3 data collection 19 July 2021). Unfortunately, without a fourth time point, it is not possible to see whether levels of loneliness continue to reduce as would be expected to pre-pandemic times. Perhaps unsurprisingly, initial easing with certain restrictions still in place (e.g., limited numbers for gathering, work from home, shops not fully open, vaccine roll-out at 90%) is helping reduce feelings of loneliness for the majority of respondents. This is consistent with a small experimental study of community samples (N = 60) whereby using a false-feedback paradigm to manipulate feelings of loneliness have been shown to lead to decreases in paranoid beliefs (Lamster, Nittel, Rief, Mehl, & Lincoln, 2017). This suggests that government and community efforts to reduce feelings of loneliness may be beneficial for the majority of the general public.

A second explanation for the evolution of self-perceived levels of loneliness observed in our study is based on individual differences. Participants respond to the survey at different times of the lockdown period, and our assessment at 6/12 months maybe too long to capture smaller in-person fluctuations. Yet we know from our wave 1 findings that the levels of loneliness follow an inverted U-shape to predict the length of lockdown whereby individuals at the beginning and end of the lockdown period reported significantly higher levels of loneliness compared to those in the middle weeks of the lockdown period (Carollo et al., 2021). This may suggest that there are individual differences in the length of lockdown on self-perceived levels of loneliness, above and beyond other mental health variables, perhaps relating to an individual's ability to cope and access financial and emotional support during the lockdown period (Fekih-Romdhane, Dissem, & Cheour, 2021). This was not measures in our study. Thus, future studies using latent class

analysis to identify high vs low levels of loneliness groups in relation to differences in mental health and schizotypal traits may help clarify the role of loneliness in this network.

By using network analysis to map out symptoms of paranoia and schizotypy in relation to mental health variables in different groups of individuals (by sex, age, income, country), this study sought to understand which variable(s) may be a key target of intervention for the specific populations – something that prior studies have not investigated. Controlling for other variables in the network, we did not find network structure differences across groups, suggesting that for all groups, loneliness is a key variable *through* which paranoid ideations and schizotypal traits are associated with heightened levels of mental health issues (e.g., depression, anxiety, poor sleep, covid-related stress). This finding is well-documented in the literature, whereby reductions in loneliness can improve psychological wellbeing for older adults (Chen & Feeley, 2014) and promising short-term effects of a weekly positive psychology intervention for patients with psychosis (Lim, Penn, Thomas, & Gleeson, 2019), and community interventions to reduce loneliness as also increased neighbourhood's identification and social belonging (Fong, Cruwys, Robinson, & Haslam, 2021), and investing in services that prevent social isolation can reduce loneliness as well (Windle, Francis, & Coomber, 2011).

Since most published findings focus primarily on internalizing problems and not externalizing problems - a key gap addressed in this study - the finding that paranoia/schizotypy are uniquely related to aggression highlights the importance of assessing comorbid psychopathology (Wong, Francesconi, & Flouri, 2021). The schizotypy-aggression relationship observed in this study is consistent with prior pre-pandemic literature (Liu et al., 2019; Wong & Raine, 2019), indicating that above and beyond the included mental health variables in the network, schizotypal traits are associated with more aggressive behaviors, specifically reactive retaliatory aggression and not proactive, instrumental aggression. This suggests that individuals with high schizotypal traits are unlikely to be individuals who are aggressive toward others, report retaliatory aggression as a result of social interactions with others, and thus more likely to perhaps avoid social situations, engage in reclusive behaviors and report higher feelings of loneliness, despite easing of lockdown that help reduce feelings of loneliness for the majority.

4.2. Strengths and Limitations

This study begins to answer how schizotypal traits and paranoid ideations are associated with various mental health variables for different groups of individuals during the pandemic year. To our knowledge, this is also the first study to explore both internalizing and externalizing problems using a network analytic approach that could likely identify the variable(s) of influence in the network for intervention and demonstrate a holistic mapping of bivariate associations whilst controlling for other network variables. Our study was able to examine macro and micro associations to test for significance across groups and also time points that coincided with national lockdown/easing periods. This analytic technique though not commonly used in behavioural sciences may be valuable when applied to big data in providing a holistic understanding of the web of comorbid relationships that are often observed in mental health research.

This study is not without limitations. First, our participants were recruited online via convenience sampling and may not be generalizable to the population of each country where sample size remained relatively small - although this time-sensitive data may still be helpful where future collaborations with international groups with the same measures are possible. Second, those who chose to take part were particularly willing and had access to technology to complete the survey online, thus potentially they are of a more affluent and motivated group. However, the median income reported by our sample shows that 50% are under £30,000 that is similar to the UK National average for 2021, £31,460 (Clark, 2021). Third and finally, our survey relies on self-reporting, which would suggest that the associations between variables are inflated, although arguably self-reporting is the most valid and appropriate method of design given the COVID pandemic restrictions. Nonetheless, these study findings spanning the 12-month pandemic period following the same participants do replicate pre-pandemic findings in the literature, specifically highlighting loneliness as a key variable for intervention for governments and local communities in the COVID recovery plans to improve people's psychological and relational health.

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Table S1. Correlation coefficients between each pair of variables in network of Wave 2

	0	1	2	3	4	5	6	7	8	9	10
0. SPQ-B total	1										
1. SPQ-B Factor1	.762**	1									
2. SPQ-B Factor2	.865**	.437**	1								
3. SPQ-B Factor3	.811**	.496**	.563**	1							
4. SMS	.424**	.380**	.323**	.348**	1						
5. RPQ total	.160**	.218**	0.059	.144**	.201**	1					
6. PHQ total	.467**	.401**	.382**	.362**	.467**	.172**	1				
7. GAD total	.420**	.374**	.338**	.321**	.432**	.215**	.789**	1			
8. Stress total	.378**	.343**	.301**	.285**	.446**	.233**	.623**	.632**	1		
9. Loneliness total	.610**	.358**	.635**	.450**	.487**	.150**	.569**	.514**	.453**	1	
10. Sleep total	.274**	.215**	.235**	.218**	.256**	.082*	.559**	.452**	.387**	.356**	1

Note. SPQ-B: Schizotypal Personality Questionnaire – Brief, SMS: Social Mistrust Scale, RPQ: Reactive-Proactive Questionnaire, PHQ: Patient Health Questionnaire-9, GAD: General Anxiety Disorder-7. **: $p<0.01$, *: $p<0.05$.

Table S2. Correlation coefficients between each pair of variables in network of Wave 3

	0	1	2	3	4	5	6	7	8	9	10
0. SPQ-B total	1										
1. SPQ-B Factor1	.759**	1									
2. SPQ-B Factor2	.862**	.444**	1								
3. SPQ-B Factor3	.780**	.470**	.499**	1							
4. SMS	.480**	.421**	.387**	.355**	1						
5. RPQ total	.281**	.272**	.225**	.186**	.310**	1					
6. PHQ total	.478**	.399**	.405**	.347**	.462**	.315**	1				
7. GAD total	.447**	.357**	.392**	.320**	.429**	.351**	.772**	1			
8. Stress total	.408**	.397**	.323**	.270**	.428**	.319**	.633**	.610**	1		
9. Loneliness total	.636**	.408**	.653**	.414**	.556**	.289**	.609**	.517**	.480**	1	
10. Sleep total	.202**	.145**	.185**	.149**	.181**	.137**	.516**	.416**	.357**	.296**	1

Note. SPQ-B: Schizotypal Personality Questionnaire – Brief, SMS: Social Mistrust Scale, RPQ: Reactive-Proactive Questionnaire, PHQ: Patient Health Questionnaire-9, GAD: General Anxiety Disorder-7. **: $p<0.01$.

Network stability and accuracy

Bootstrapping with 2500 permutations was performed to estimate the accuracy of edge-weights. Bootstrapped CIs are plotted in **Figure S1**. The relatively narrow bootstrapped CIs suggested that the order of the edges in the network was stable.

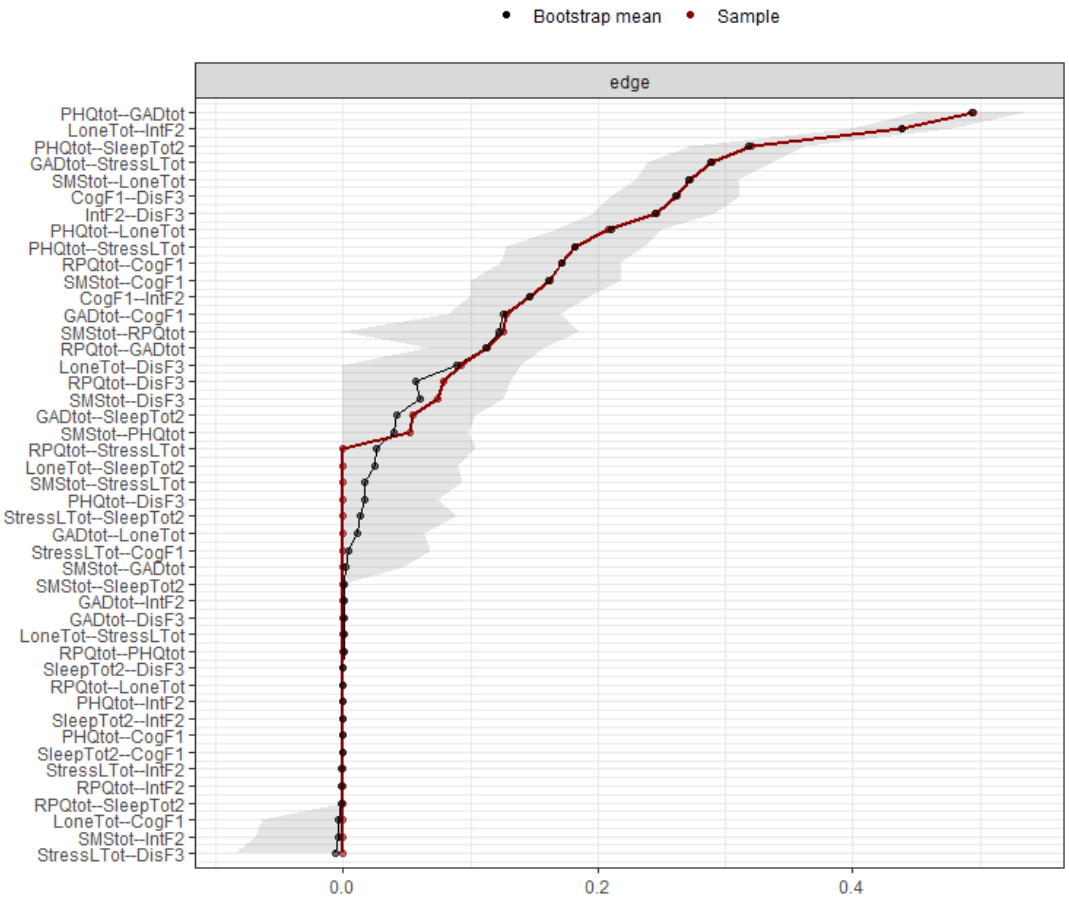


Figure S1. Bootstrapped CIs of estimated edge-weights for the estimated network. The red line indicates the sample values and the grey area indicates the bootstrapped CIs. Each horizontal line represents one edge of the network ordered by edge-weights.

S1.2 Centrality stability

The stability of the order of centrality indices was investigated based on observation of subsets of the data (2500 permutations). **Figure S2** below shows the good stability of strength. Stability of centrality indices could be quantified using the **CS-coefficient**, which calculated the maximum drop in proportions to retain a correlation of 0.7 in at least 95% of the sample. We

found that the CS-coefficient for strength (CS (cor=0.7) = 0.75) is higher than 0.5 suggesting the centrality indices were stable.

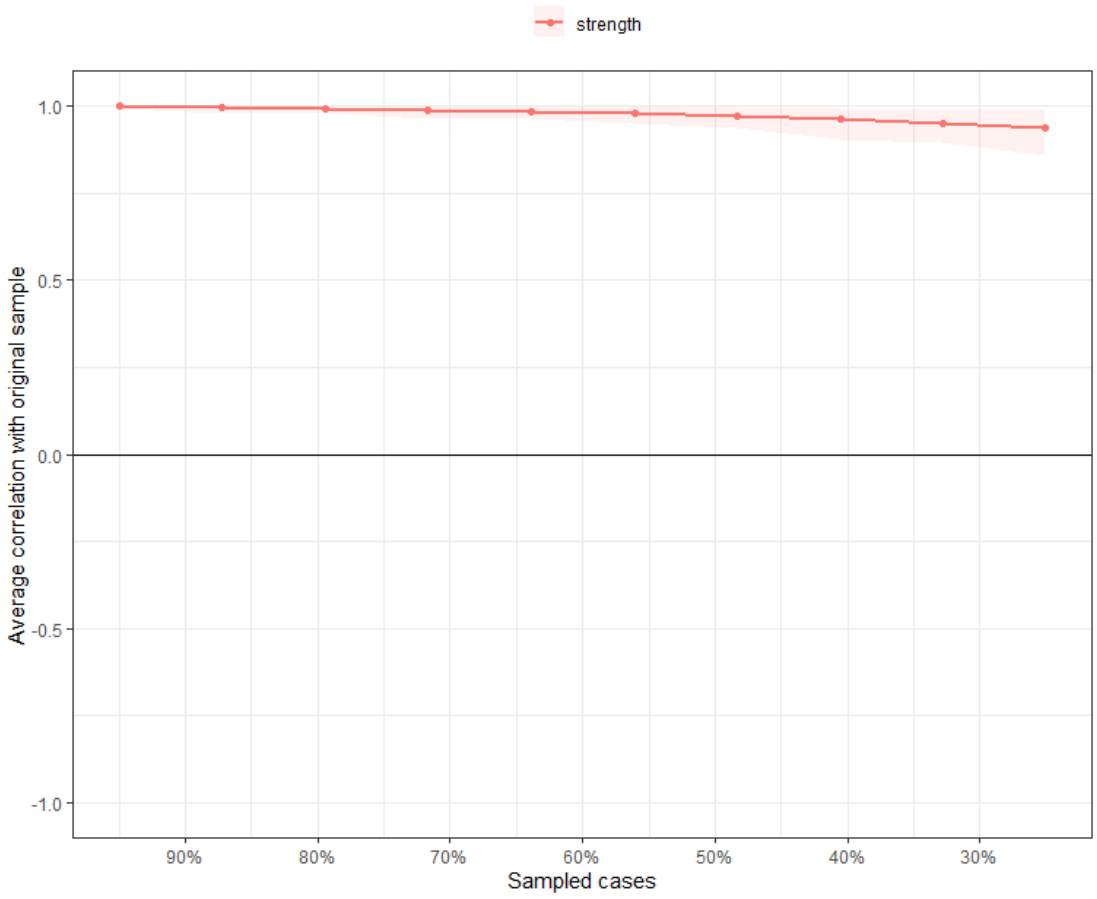
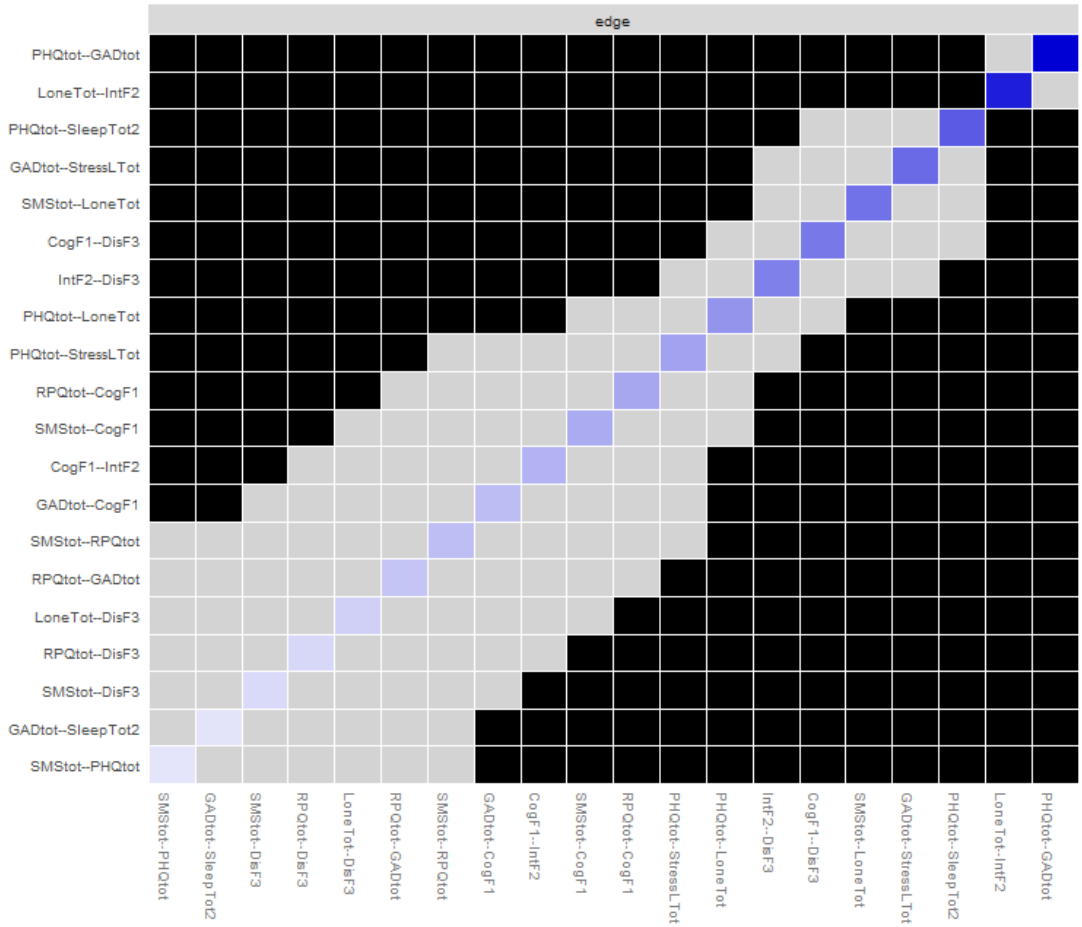


Figure S2. Average correlations between strengths of networks estimated with sampled participants and original sample. Lines indicate the means and areas indicate the range from the 2.5th to the 97.5th percentile.

S1.3 Testing for significant differences of edge-weights and centrality

We then performed bootstrapped difference tests (with 2500 permutations) of edge-weights and centrality indices to test whether they differed significantly from each other. The results are shown in **Figure S3 and S4** respectively.


edge
PHQtot--GADtot
LoneTot--IntF2
PHQtot--SleepTot2
GADtot--StressLTot
SMStot--LoneTot
CogF1--DisF3
IntF2--DisF3
PHQtot--LoneTot
PHQtot--StressLTot
RPQtot--CogF1
SMStot--CogF1
CogF1--IntF2
GADtot--CogF1
SMStot--RPQtot
RPQtot--GADtot
LoneTot--DisF3
RPQtot--DisF3
SMStot--DisF3
GADtot--SleepTot2
SMStot--PHQtot
SMStot--PHQtot
GADtot--SleepTot2
SMStot--DisF3
RPQtot--DisF3
LoneTot--DisF3
RPQtot--GADtot
SMStot--RPQtot
GADtot--CogF1
CogF1--IntF2
SMStot--CogF1
RPQtot--CogF1
PHQtot--StressLTot
PHQtot--LoneTot
IntF2--DisF3
CogF1--DisF3
SMStot--LoneTot
GADtot--StressLTot
PHQtot--SleepTot2
LoneTot--IntF2
PHQtot--GADtot

765

Figure S3. *Bootstrapped difference tests on the non-zero edge-weights of the estimated network. Black boxes indicate edges that differ significantly from other corresponding edges in the matrix. Coloured boxes in the edge-weight plot correspond to the colour of edges in the estimated network.*

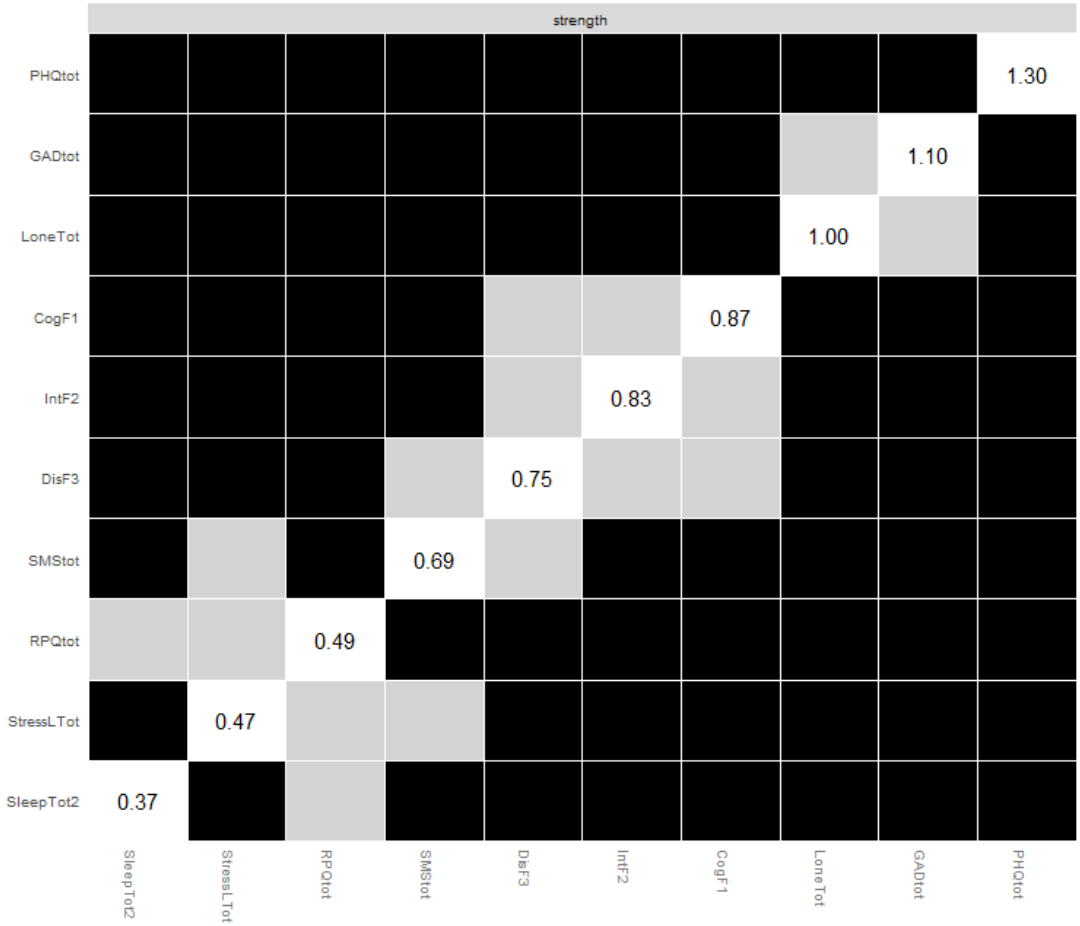


Figure S4. *Bootstrapped difference tests on the nodal strength of all the variables in the network. Black boxes indicate nodes that differed significantly from another corresponding node in the matrix. Numbers in white boxes in the centrality plot show the strength of the corresponding node.*

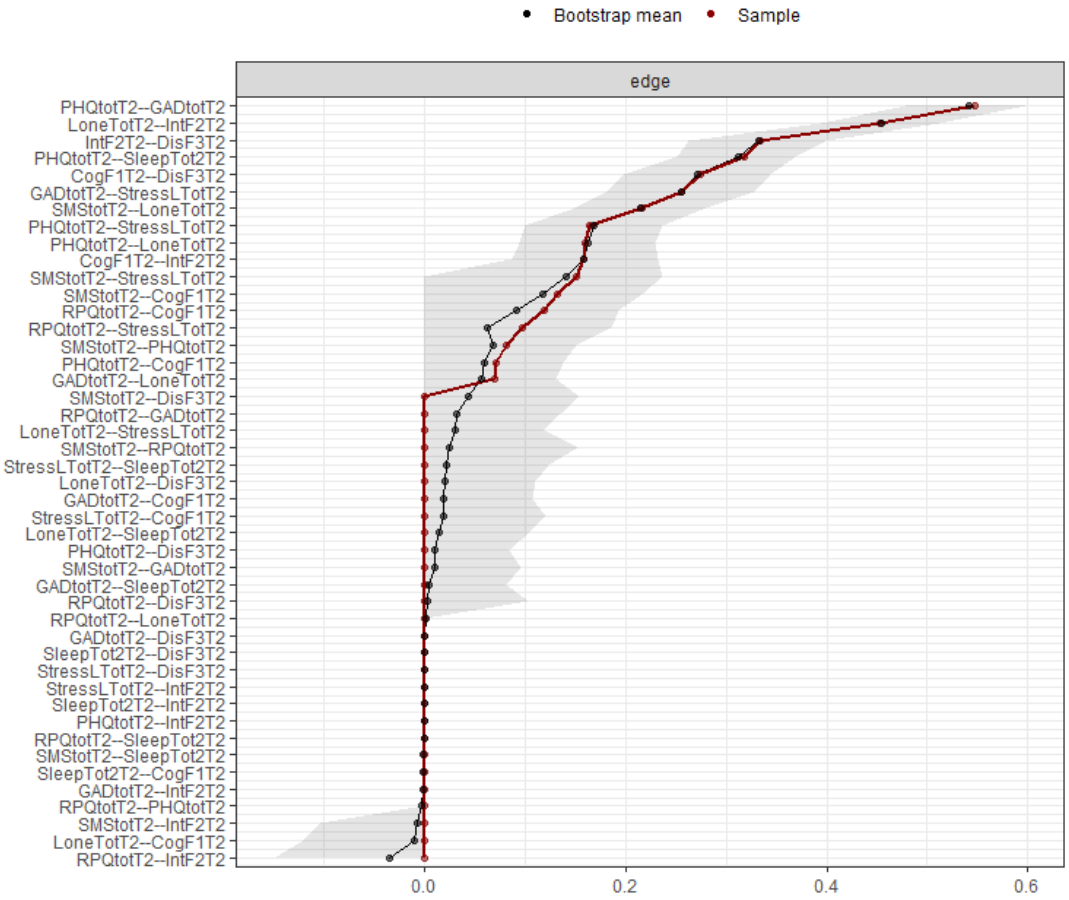


Figure S5. Bootstrapped CIs of estimated edge-weights for the estimated network at Wave 2. The red line indicates the sample values and the grey area indicates the bootstrapped CIs. Each horizontal line represents one edge of the network ordered by edge-weights.

2.2 Centrality stability

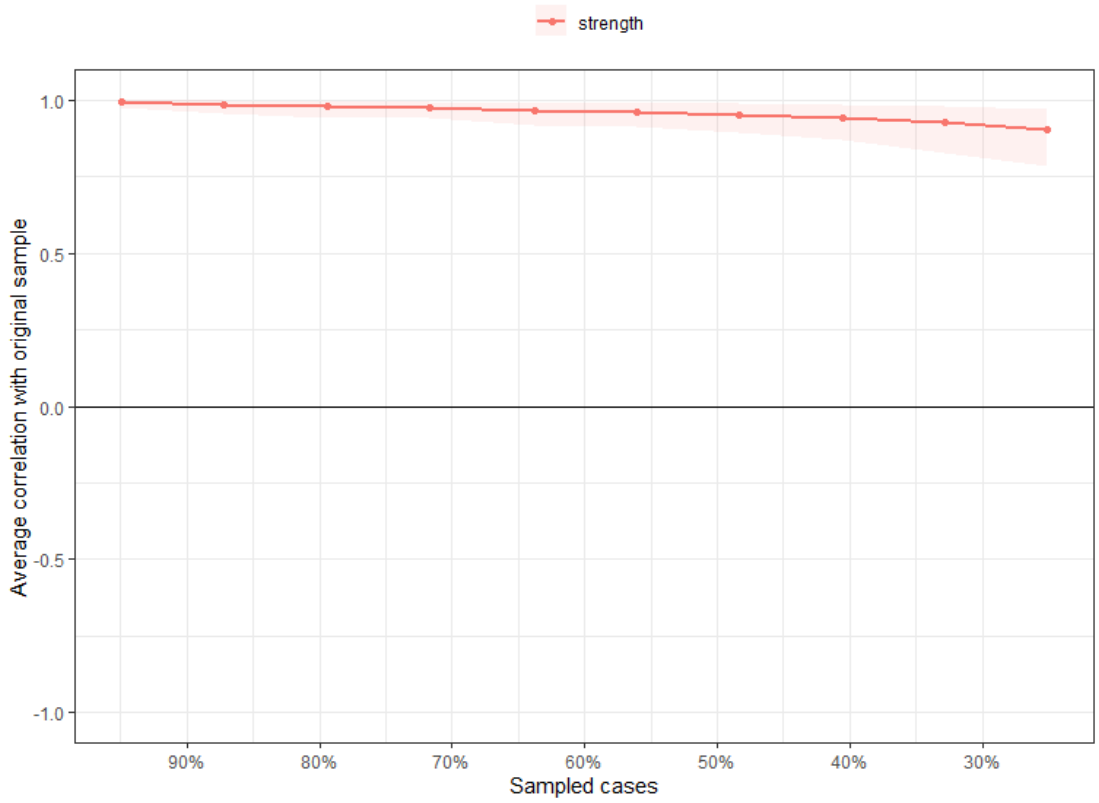
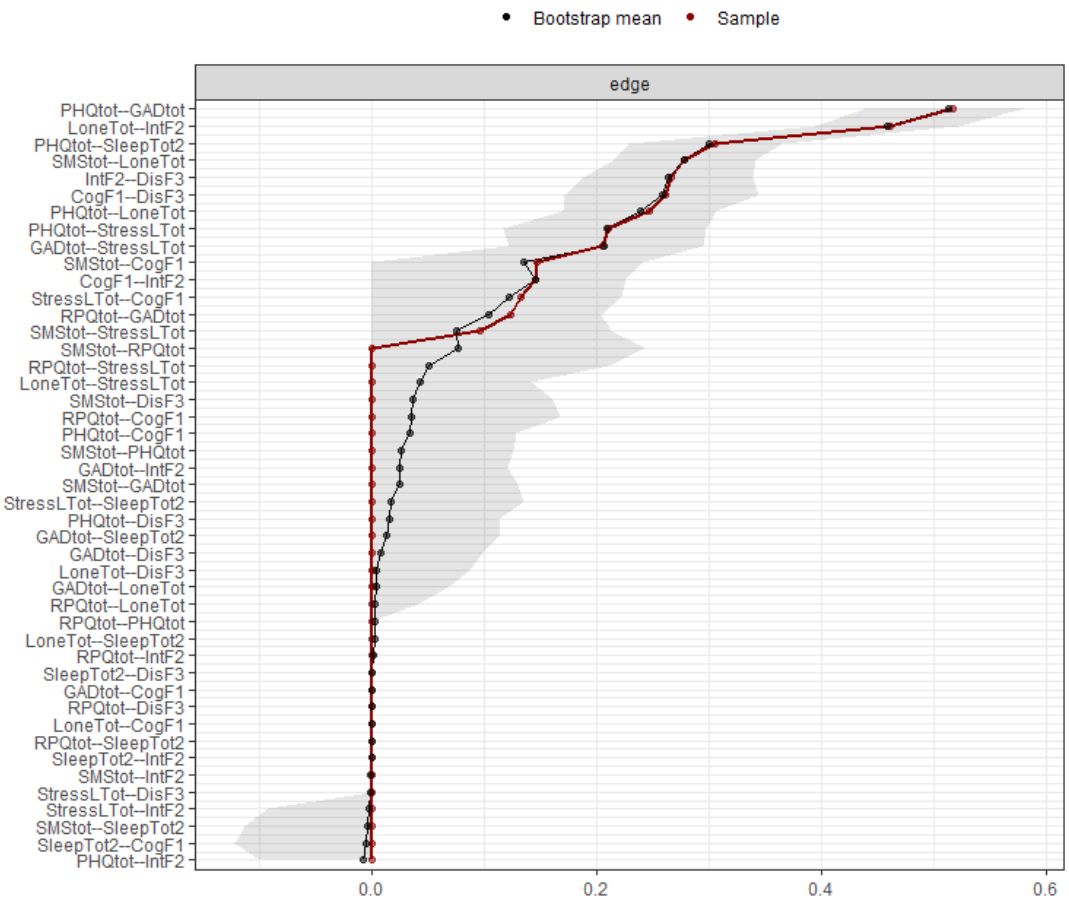


Figure S6. Average correlations between strengths of networks estimated for Wave 2 with sampled participants and original sample. Lines indicate the means and areas indicate the range from the 2.5th to the 97.5th percentile. The CS-coefficient for strength (CS (cor=0.7) = 0.749) is higher than 0.5 suggesting the centrality indices were stable.



787
788 **Figure S7. Bootstrapped CIs of estimated edge-weights for the estimated network at Wave**
789 **3.** The red line indicates the sample values and the grey area indicates the bootstrapped CIs. Each
790 horizontal line represents one edge of the network ordered by edge-weights.

5.2 Centrality stability

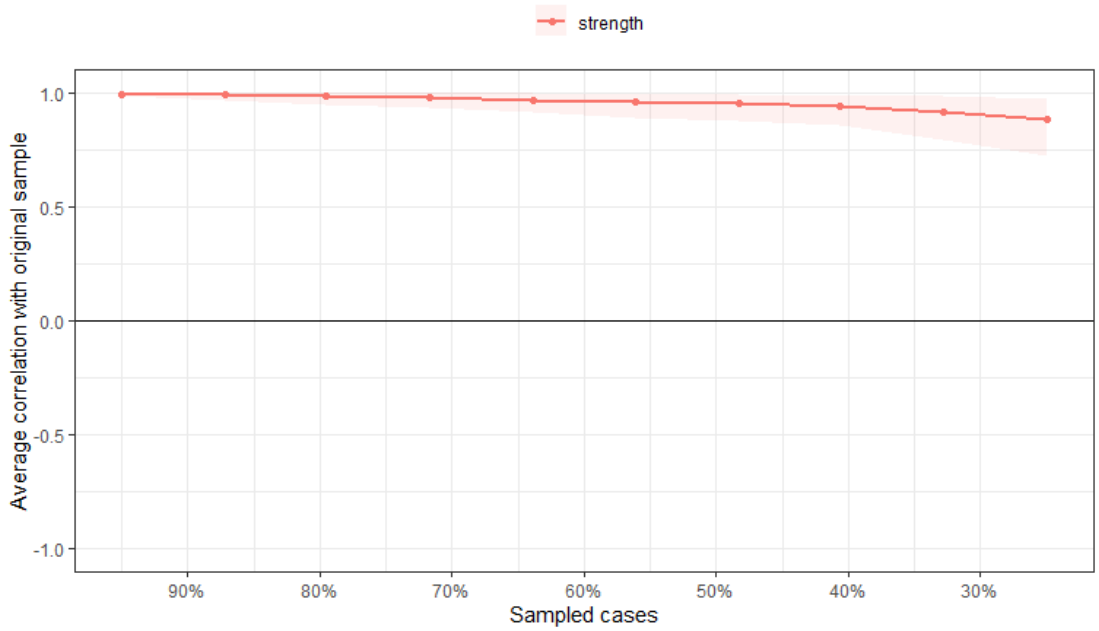


Figure S8. Average correlations between strengths of networks estimated for Wave 3 with sampled participants and original sample. Lines indicate the means and areas indicate the range from the 2.5th to the 97.5th percentile. The CS-coefficient for strength (CS (cor=0.7) = 0.751) is higher than 0.25 suggesting the centrality indices were relatively stable.