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

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Response Letter

We would first like to thank the reviewers for their time and patience in reviewing our manuscript titled, "**A three-wave network analysis of COVID-19's impact on schizotypal traits, paranoia and mental health through loneliness**". Below please find our response to each of the comments. Changes below are highlighted where appropriate and additional in-text changes for clarity are visible in track changes.

Reviewer #1

This is a very timely investigation on the relationship between schizotypy, paranoia, loneliness and mood disturbances during the COVID-19 pandemic. The three-wave design and large multi-site sample are unique and precious. I hope the manuscript would do justice to the amount of work that has already been put in by clarifying the following issues:

1. The conceptuliastion of some words, such as 'mental health', 'wellbeing', and 'symptoms' seems to be blurred throughout the manuscript. For example, it is debatable whether loneliness is considered a symptom (see Abstract) just like anxiety and depression. While anxiety and depression have established cutoffs and are typically considered as sympotms within numerous clearly defined psychiatric disorders, the construct of loneliness may or may not be clinical/ symptomatic. In this paper, loneliness has been phrased as 'symptom' in Abstract, but 'problem' on p. 3, and 'feelings' on p. 4. Another example is p. 4 (last paragraph): 'four studies have investigated paranoia and schizotypal personality traits in relation to mental health during the pandemic' - it is not clear what 'mental health' is referred to here. From the abstract, my guess is that 'mental health' means anxiety, depression, and loneliness, but it wasn't made clear. Moreover, it wasn't clear why then paranoia wouldn't also be part of mental health?

   Response: Thanks for your comments. Self-perceived levels of loneliness were measured in our study, and we consider them as feelings. Mental health refers to anxiety and depression. In terms of paranoia, this is considered as part of schizotypal traits and a symptom of mental health. We have now revised these concepts throughout the paper to clarify this issue.

2. On a related note, while the authors set out to consider 'psychotic-like experiences' as indexed by schizotypal personal disorder and paranoia (see p. 3), the studies cited focused on mistrust and suspicion only, i.e. concepts of paranoia rather the PLE (which is broader). Freeman et al (2020) was cited (p. 4, paragraph 2) as follows: 'Psychotic-like experiences as highlighted in a large representative sample of UK adults in April 2020...'. However, while Freeman et al (2020) used a paranoia measure (R-GPTS) and a trust barometer, they did not include a PLE measure. It would be easier for readers to follow if the constructs of concern are discussed with more clarity.

   Response: Thanks for raising this point. We have removed the expressions of 'psychotic-like experiences' in our study for accuracy as we only focused on schizotypal traits and paranoia specifically.

3. On p. 4 (paragraph 2), a range of variables have been suggested to be consequences of lockdown restrictions (e.g. loneliness, anxiety and PLE), but it wasn't clear how the authors think that these variables may contribute to each other. Even though network analysis is a data-driven approach, a bit more theoretical discussion of the expected directions of associations would still be helpful for interpretation of results.

   Response: In light of your comments, we have added a few sentences to paragraph 2 of p.4 to state the expected directions of the associations.

4. On p. 6 (paragraph 1), the authors specified the lockdown periods in the UK. However, this was a multi-site sample and it wasn't clear whether the same periods would be relevant to lockdown measures in other sites. If not, then it needs to be specified in the Introduction and Discussion sections so as to facilitate interpretation of results.

   Response: Thanks for raising this point. We have now clarified our position in the introduction (p.6) and discussion (p. 22) sections.

5. Hypotheses: what are 'social networks' in the context of hypothesis 2? [check also the expression of 'psychological networks' on p. 9 last paragraph]. Hypotheses are supposed to be tested for or against, but the way hypothesis 2 is phrased isn't testifiable. In addition, why is the 3-wave design not mentioned in the hypotheses?

   Response: Thanks for spotting this. Psychological network would be the correct expression according to the paper by Borsboom & Cramer (2013). We have changed the social networks to psychological networks and revised the hypotheses.

6. Since the 3-wave design is a major design element, which certainly reflects the amount of work involved in this study, it would seem fitting for more discussion on the 3-wave design and use of network analysis to be included in the Introduction section. In particular, as network analyses can be done in multiple ways, it would be helpful if the authors link the specific type of network analysis with the research question in the Introduction section. e.g. Why were the 3 time points needed? Should readers expect to see 3 separate networks? Were the strengths of edges (within each network) of interest, or the changes in edges across networks?

   Response: Thanks for this suggestion. We have now inserted the following sentence on Page 6 ("Using a network comparison technique, we are able to test invariance of the network structure and strength between variables across networks (age, sex, income, country, timepoints, and high vs. low schizotypal trait groups). Furthermore, this study crucially includes a 12-month follow-up at time 3 which allows us to perform the cross-lagged panel network analysis and examine the longitudinal relationships of how variables in the previous timepoint predicts a future timepoint of nodes across two timepoints. ").

7. This manuscript will benefit from thorough proof-reading and grammar check.

Response: Thank you. We have done now completed a thorough proof of the manuscript.

Reviewer #2

This study investigated the relation between schizotypal traits and various mental health variables during the COVID19 pandemic. The method of network analysis highlighted the important role of loneliness in linking schizotypal traits and poor mental health outcomes. The longitudinal design further demonstrated stable network structures over time despite reductions in overall symptom levels.

Overall, this was a well-written manuscript, and the method and results sections are clear and easy to follow. However, given the rich longitudinal data collected and the network approach used, there are several additional questions that could be addressed to make this paper stand out from among the others in this area.

Below are more specific comments and suggestions for revision:

Significance of this study: One of my major concern is how this study could contribute uniquely to the impact of COVID19 on paranoia and schizotypal traits. The focus of the analysis was the relation between schizotypal traits/paranoia and other mental health outcomes over time, but little is known concerning COVID19-related variables. For example, whether and how would paranoia be associated with social distancing and length of lockdown? If the data were collected without the impact of COVID19 (in pre-pandemic periods), would we have similar findings?

Response: Thanks for your astute comment. Our definition of paranoia from Freeman and Garety (2000) states that paranoia constitutes unchangeable ideas that 'other people are intentional causing harm and are threatening to the individual'. As stated in our introduction, there are not that many studies conducted during the pandemic on schizotypy and paranoia and how these relate to mental health outcomes except for two specific studies, see p.4 (second one added since first draft):

1) Freeman et al., (2021) documented higher levels of paranoia being associated with poorer compliance with COVID19 restrictions (e.g., social distancing), vaccination adoption and antibody testing.

2) Suthaharan et al., (2021) also found that paranoia was associated with more endorsements of conspiracy theories around mask-wearing, potential vaccines, and QAnon conspiracy theories.

Although outside of the scope of this study as we do not have pre-pandemic data on our participants, there are pre-pandemic studies of paranoia/schizotypy which show these individuals have poorer mental health (anxiety, self-esteem, depression, aggression) more generally and poorer physical health (as they tend to be fearful of the outdoors and choose to stay indoors more). Thus, the implication of our study is clearly of public health importance: individuals with high levels of paranoia/schizotypal traits have the potential to not get vaccinated and experience

heightened feels of threat and mental health issues that need to be addressed in light of the ongoing pandemic.

Framing of primary measures: Throughout the manuscript, the authors regarded "schizotypal traits" and "paranoia" as two different concepts/variables to index psychotic-like experiences. I am not sure about this, because paranoia/suspiciousness is a sub-dimension of schizotypal traits (as measured by SPQ). Even in the short version of the SPQ-B, there are 4 items specifically assessing paranoia, which were included in both the cognitive-perceptual and the interpersonal factor of the SPQ-B.

Response: Thanks for your comment. We appreciate that this was not clear and have now gone through the manuscript and removed all instances of 'psychotic-like experiences' to include only schizotypal traits and paranoia. Yes, as you correctly mention, paranoia constitutes a subscale of the SPQ with 4-items cross-loading on F1 & F2. For our study, we feel it is important to have a more thorough dimensional scale of paranoia, 12-items, to facilitate the investigation of unique contributions of schizotypal subscales vs. paranoia separately.

Additional analyses should be considered: Given the longitudinal data, the authors could consider using **cross-lagged panel network modelling** to explore longitudinal associations between different variables. This method can provide further insight into which node was most strongly predicted by other variables, and also which node shows the strongest power to predict other symptoms. Such analysis could help us to better understand the causal relationship between schizotypal traits and mental health outcomes.

See relevant studies using cross-lagged panel network modelling:

Bringmann, L. F., Lemmens, L. H. J. M., Huibers, M. J. H., Borsboom, D., & Tuerlinckx, F. (2015). Revealing the dynamic network structure of the Beck Depression Inventory-II. Psychological Medicine, 45(4), 747–757. https://doi.org/10.1017/S0033291714001809

Savelieva, K., Komulainen, K., Elovainio, M., & Jokela, M. (2021). Longitudinal associations between specific symptoms of depression: Network analysis in a prospective cohort study. Journal of Affective Disorders, 278, 99–106. https://doi.org/10.1016/j.jad.2020.09.024

Groen, R. N., Snippe, E., Bringmann, L. F., Simons, C. J. P., Hartmann, J. A., Bos, E. H., & Wichers, M. (2019). Capturing the risk of persisting depressive symptoms: A dynamic network investigation of patients' daily symptom experiences. Psychiatry Research, 271, 640–648. https://doi.org/10.1016/j.psychres.2018.12.054

Response: Thank you for the suggestions and helpful references. We agree with the reviewer that cross-lagged network analysis would be provide more information about the associations between variables, even for direct connections between nodes. By reviewing the publications using cross-lagged network modelling, it is common to have a large set of timepoints for model estimation. For example, Bringmann et al., (2015) examined dynamics of depression in

depressed individuals with an average of 14 weekly assessments; Groen et al., (2019) performed an Experience Sampling Method with an average of 14-15 daily diary assessments completed and 11 lagged observation, Multilevel vector autoregressive (VAR) modelling was used in this study. Considering that there are only three timepoints in our sample, we performed the cross-lagged panel network analysis (reference to Funkhouser et al., 2021) and reported the result in the manuscript.

Ref: Funkhouser, C. J., Chacko, A. A., Correa, K. A., Kaiser, A. J. E., & Shankman, S. A. (2021). Unique longitudinal relationships between symptoms of psychopathology in youth: A cross-lagged panel network analysis in the ABCD study. Journal of Child Psychology and Psychiatry, 62(2), 184–194. https://doi.org/10.1111/jcpp.13256

Further, the authors did not introduce the method of network comparison across three waves in the Method section. Please add this part. Note that we should account for the dependence of measurements within the same individual when comparing networks at different time points, so this analysis is a bit different from network comparison across groups.

Response: Thanks for spotting this. We have now clarified this point by including the network comparison in our introduction (p.6-7) and hypotheses.

Results:

1. The authors should give more details about the samples of the three waves. As a considerable proportion of participants dropped out at Wave 2 and Wave 3, it is better to clarify whether there are any differences in demographic characteristics and mental health outcomes between those dropping out and those who completed 3 waves of surveys.

Response: Thanks for your suggestion. The analytic sample in our paper includes all those with complete data on all study variables (they may not necessarily have 'dropped out'). The basic information was shown in Table 1 and distributions of age, sex and income level are similar between time 3 and time 1 ($p > 0.1$, Z-test was performed on the webpage: https://www.medcalc.org/calc/comparison_of_proportions.php) and a line was included on p. 11 "Comparison of proportions using https://www.medcalc.org/calc/comparison_of_proportions.php found no significant differences in participants in time 1 and 3 on age, sex, and income ($p > 0.1$).".

2. The authors only showed the results of centrality indices (strength) for Wave 1 data. How about the other 2 waves? Does the node of "loneliness" stably show high centrality in the network and serve as a bridge connecting schizotypal traits and mental health?

Response: Thank you. We do have those results but didn't want to over-burden the paper. The nodal strength of three timepoints were shown below, and it shows that strength of node "loneliness" (LoneTot) is stably high across three time-points.

Strength	Time 1	Time 2	Time 3
PHQtot	1.658	1.918	1.784
GADtot	1.040	0.467	0.495
LoneTot	**0.802**	**0.554**	**0.914**
CogF1	0.308	0.112	0.019
IntF2	0.173	0.692	0.579
DisF3	-0.104	-0.351	-0.450
SMStot	-0.332	-0.429	-0.471
RPQtot	-1.029	-1.557	-1.653
StressLTot	-1.090	-0.163	-0.106
SleepTot2	-1.426	-1.244	-1.111

3. As shown in Figure 2, the network seems to become less densely connected over time (reduced global strength from Wave 1 to Wave 3). Therefore, it is a bit strange that the global strength of Wave1 network (3.99) is smaller than that of the Wave 2 network (4.02). Please check if the result was correctly presented. Also, have the authors compared the network structures between Wave 1 and Wave 3? Is it possible that the network differences become significant over a longer time period (i.e., 1 year)?

Response: Thanks for your suggestion. The global strength of Wave1 network (3.99) and Wave 2 network (4.02) are correctly presented. We have checked and rerun the calculations – there are no significant differences in network global strength between wave 1 to wave 2, wave 2 to wave 3, and wave 1 to wave 3 (p=0.139).

Discussion:

Based on the main findings summarized in the first paragraph of the Discussion, I feel confused and not very convinced how the authors could come to the conclusions 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."

In the second paragraph, the authors tried to explain why schizotypal traits were correlated with loneliness. The results that "both paranoia and the interpersonal dimension of schizotypy were strongly associated with loneliness in the network" could support the two interpretations proposed by the authors.

The authors used two entire paragraphs to explain the changes in self-reported loneliness during the pandemic. I agree this is an interesting finding, but I cannot see why and how this result contributes to the main purposes of the current study. Maybe **more emphasis should be put on the bridge function of loneliness linking schizotypal traits and mental health outcomes.** (Moreover, I feel it hard to understand why individual differences could explain the evolution of self-perceived loneliness.)

Although loneliness may serve as a bridge symptom in the network, loneliness was not the node with the highest strength. Both depression and anxiety had high centrality in the network. Targeting the node with the strongest influence can lead to significant changes of the network structure and the levels of other symptoms. Therefore, should we also consider the interventions targeting depressive and anxiety symptoms?

The authors did not discuss the results of the more densely connected network for individuals with high schizotypal traits compared with individuals with low levels of schizotypy/social mistrust. This is an interesting finding worth more detailed discussion.

Response: Thanks for the points your raised and suggestions to clarify the discussion, see page 21 and 24.

Minor issues:

Introduction:

Page 4 line 1, "both of which……" It is unclear what constructs the authors were referring to. Are they "paranoia and schizotypal traits"?

Response: Thanks for spotting this. Yes, we have now clarified this by inserting the line "paranoia and schizotypy".

Page 4 line 9 ("It is conceivable……") The second paragraph in the Introduction provided evidence to show the COVID19 pandemic caused heightened levels of social distrust. However, it seems a bit far-fetched to come to the hypothesis that "lockdown will have a bigger effect for individuals with higher levels of schizotypal traits and paranoia compared to their peers".

Response: Thanks for your suggestion but we disagree that this is a farfetched hypothesis. In addition to the cited studies (Freeman et al., 2021; Suthaharan et al., 2021), individuals with high levels of schizotypal traits and paranoia even pre-pandemic time are often found to have high incidences of mental health issues (anxiety, low self-esteem, depression, aggression). Particularly with the covid pandemic – where the coronavirus is an invisible virus that has infected many individuals, there is a real genuine sense of fear of threat. Forced lockdown is unnatural and

unprecedented for many individuals in this lifetime. So the forced 'stay-at-home' mandates, testing, and fear of catching covid and dying from it can induce anxiety/paranoia for many individuals, especially those who may already be in the high-risk groups to begin with. The idea is that these paranoid thoughts are even more strengthened as there is genuine reason for paranoia that is not unfounded.

Page 4 the last two lines: "a similar group reported increases in schizotypal……" This sentence is ambiguous and I am not sure what "a similar group" meant. Does the author mean "a similar proportion of individuals reported increases in schizotypal traits (compared with the proportion of individuals reporting the experience of schizotypal traits for the first time)"? In addition, the work from Knoelle and colleagues (2021) is not in the References list. Please add this reference.

Response: Thanks for picking up on this – we have now added the Knoelle reference in the reference list. We have also reworded the sentences, now on p5.

Page 5 2nd paragraph (the one to introduce the network analysis) line 4: What does "comparison across interactions" mean?

Response: Thanks for your question. This pertains to comparing pairs of variables and how they interact across other pairs of interactions in the network.

Page 6 the 2nd hypothesis "the social network"?

Response: Thanks for picking this up. This should say psychological network, which has been corrected.

Methods:

Page 7 line 2 "two waves of data collection" should be "three waves"

Response: Thanks, yes, we have corrected this typo.

Page 8 2.2.1 Why the total score of the SPQ-B ranges from 0-44 (not 0-22)? Also for the loneliness questionnaire, why the score range is 20-77 but not 20-80? Please check.

Response: We have corrected these typos in the main text. The reviewer is correct that the SPQ-B ranges from 0-22 and loneliness questionnaire scores range from 0-80.

When calculating the internal consistency of all the scales in this study, which wave of the data did the authors use?

Response: The internal consistency of all scales was based on Wave 1 data of which we had the largest sample for.

Page 10 2.3 Data analysis The authors showed bivariate relationships for Wave 2 data in Table3. It should be the results of Wave1, right?

Response: Thanks for spotting this typo. Yes, it should be for Wave 1.

Page 11 NCT paragraph – "The significance threshold was set at p or adjusted p< 0.05"?

Response: Thank your. Yes, for the invariance tests of network structure and global strength, we did not apply multiple comparison correction, so threshold was set at $p < 0.05$. Whereas for the comparisons between nodal strength and edge-weights, threshold was set at adjusted $p< 0.05$.

Results:

For table 4 and 5, please add in the notes what the **BOLD** characters indicate.

Response: Thank you. Bold characters indicate significant differences after multiple comparisons. We have added this in the notes for Table 4 and Table 5.

Page 17-18: "network structure invariance test: M; global strength invariance: S" Should clearly state what the M and S referred to.

Response: Thank you. M refers to the value of maximum difference of the connection strength matrices of networks from two groups. S refers to the difference on global strength between two networks.

Discussion:

Page 21 "Whether this is purely due to the COVID easing of restrictions taking place during time 3…." It is unclear what "this" refers to in this sentence.

Response: Thank you. We have now clarified the sentence ("Whether changes in levels of schizotypy and paranoia are purely due to the COVID.." (p.23).

Page 22 Ill-formed sentence: "This may suggest that there are individual differences **in the length of lockdown on self-perceived levels of loneliness**……"

Response: Thank you. We have now amended this sentence to more accurately reflect our ideas: "This may suggest that there are individual differences variations on self-perceived levels of loneliness (but not for other mental health variables) as lockdown duration progresses, perhaps alternative factors that we have not assessed in this study tha may come into play including an individual's ability to cope and access financial and emotional support during the lockdown period (Fekih-Romdhane, Dissem, & Cheour, 2021)."

Page 22 the last line: "This was not measures…." Should be "measured"

Response: This has been removed and the sentence has been rephrased.

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

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Abstract (249/250)

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 and depression), yet fewer longitudinal studies have compared across background factors and other psychological variables to identify vulnerable sub-groups in the general population. This study tests to what extent higher levels of schizotypal traits and paranoia are associated with 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 (time 3). 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 feelings of loneliness, suggesting that increasing social/community cohesion may improve individuals' mental wellbeing in the long run.

Keywords: Network Analysis; Schizotypy; Paranoia; 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 April 2022, a total of 435,422 publications on coronavirus have been published[1], with medical and health sciences being a key area of research interest. Large birth cohort study findings reporting pre- and post-pandemic comparisons – investigating how forced lockdown restrictions have impacted individual's environments in which they play, work and learn – have been particularly valuable in assessing change. However, many more findings from new cross-sectional cross-country/-population-specific studies have also been pivotal in our understanding of the mental health prevalence under the pandemic conditions. This latter set of studies has often limited the definition of mental health to 'internalizing' problems such as anxiety and depression, 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 lack control groups. 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 have been limited due to COVID restrictions, although there are a few exceptions in timeseries studies.[2] Understanding how environmental factors, such as the imposed national lockdown restrictions (e.g., physical distancing and social isolation) on mental health (Carollo et al., 2021), are important in 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 schizotypal personality traits and paranoia. It is conceivable that COVID-19 an airborne 'invisible killer' that has infected over 502 million people – many of whom are asymptomatic – and caused 6.19 million deaths and counting globally,[3] has instilled doubt and distrust in all aspects of society. We know from existing research that the unfounded fixed belief that others cause intentional harm, or paranoia (Freeman & Garety, 2000), is a key symptom of mental health disorders and

[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 as of 14 April 2022.

schizophrenia-spectrum disorders like schizotypal personality disorder - both paranoia and schizotypy 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 xenophobic aggression towards people of Asian descent (Dhanani & Franz, 2021). Fear of others not social distancing, fear of catching COVID, lack of control over the restrictions, and 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 paranoia compared to their peers, and higher levels of paranoia may be correlated with mental health issues, including anxiety, depression, aggression as well as loneliness and COVID related stress.

Compliance with government physical distancing and lockdown restrictions, though necessary in reducing the spread of COVID, may perpetuate other health issues. For example, recent studies have shown that lockdown duration (by weeks) can likely increase feelings of loneliness over the course of forced stay-at-home mandates and fuel anxiety and depression (Carollo et al., 2021). Similarly, higher levels of loneliness are found to be comorbid with other mental health issues in patients with psychosis (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). In a large representative sample of UK adults in April 2020, mistrust and belief in conspiracy theories were associated with lower compliance in government restrictions, antibody testing and vaccine adoption (Freeman et al., 2020). Another large study of US adults also found that high levels of paranoia are also associated with more endorsements of conspiracy theories generally (e.g., QAnon theories), conspiracies around mask-wearing and potential vaccines (Suthaharan et al., 2021). Thus, more than ever, research understanding paranoia and its correlates are of utmost importance in informing public health and policy during the COVID pandemic. From past studies, we also know that paranoia and schizotypal traits are associated with higher levels 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).

To the author's knowledge, four studies have investigated schizotypal personality traits of which paranoia is a key symptom, in relation to mental health during the pandemic. Study findings have been mixed. In one study comparing the UK and Germany adults conducted between 27 April and 31 May 2020, respondents reported experiencing schizotypal traits for the first time (UK = 4.4%, Germany = 3.5%), increases in schizotypal traits (UK = 4.8%, Germany = 4.1%), and a larger group reported unchanged symptom levels (UK = 14.7%, Germany = 14.2%) (Knoelle, Ronan, & Murray, 2021). No country or gender differences were found despite differences in lockdown restrictions at the time of data collection. By October 2020, the same researchers recruited an additional sample and found that an increase in schizotypal traits was associated with higher levels of loneliness, use of drugs, and financial burden and this was particularly true of UK and not Germany respondents (Daimer et al., 2021). These changes were thought to be due to sudden changes in environment as a result of national lockdown restrictions and physical distancing measures. In another cross-sectional survey of Tunisian university students conducted between 1 June and 15 July 2020, students self-identified as being 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 traits group (bottom-10%) (Fekih-Romdhane, Dissem, & Cheour, 2021). Contrastingly, in an online survey of French adults conducted 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, studies thus far are limited in the scope of mental health variables, follow-up duration and cross-sectional designs which preclude the understanding of specific target variable(s) for intervention and changes in relative associations over time.

One way to fill these gaps is to conduct a network analysis (NA) on all variables and across three timepoints. Mental health variables such as anxiety, depression, aggression, are often correlated with each other and with schizotypal traits, stress, and insomnia, yet traditional

bivariate correlations only focus on the association between two variables each time and preclude comparison across interactions and the identification of influential variables in the network. NA addresses this by estimating a network structure, where *'nodes'* represent the variables and *'edges'* represent the partial correlations between each pair of variables (Borsboom & Cramer, 2013; McNally, 2021; Wang et al., 2020). The '*centrality index*' of nodes reflects the influence of a node in the network and the '*strength*' of the centrality indices is the summed weight of all edges connected to a node in the network, which are important in identify which variables and relationships are most influential. Mapping the nodes and estimating the edges between pairs of nodes within a network provides a holistic view of all inter-variable relationships and helps identify influential variables for intervention whilst controlling for the effects of all the other variables and associations in the network. Using a network comparison technique, we are able to test invariance of the network structure and strength between variables across networks (age, sex, income, country, timepoints, and high vs. low schizotypal trait groups). Furthermore, this study crucially includes a 12-month follow-up at time 3 which allows us to perform the cross-lagged panel network analysis and examine the longitudinal relationships such as how variables in the previous timepoint predicts a future timepoint of nodes across two timepoints.

This prospective study tests to what extent higher levels of schizotypal traits relate with various mental health variables at 6- and 12-months from 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 lockdowns 1, 2 and 3, and the easing of restrictions respectively. Given the country differences in lockdown restrictions at the time of data collection, we will test to see whether country differences are observed in our outcome variables. As 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 levels of schizotypal traits and paranoia have varied 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:

1. Mean levels of schizotypal traits, paranoia, and mental health variables will be different across three timepoints but schizotypal traits and paranoia will be positively associated with poorer mental health symptoms across the three timepoints.
2. The overall network structures will be different for participants across different sex (F=M), age (stronger in <35 vs. 35+ years), countries (stronger in the UK vs Others), income levels (stronger in low vs medium vs high groups), and timepoints (strongest in time 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). Study preregistration can be found: https://osf.io/fe8q7/. 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 three timepoints of data collection are presented in **Table 1**. The analytic sample for this study consisted of data from participants at 3 time-points: time 1 (N_1=1599; 17 April to 14 July 2020), time 2 (N_2=774; 17 October 2020 to 31 January 2021), and time 3 (N_3=586; 17 April to 31 July 2021).

2.2. Measures

2.2.1. Schizotypal Personality Traits and Paranoia

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 22 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 behaviors 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).

2.2.4 Feelings of Loneliness

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 80. A higher score denotes higher levels of loneliness. The internal reliability for this study was excellent (α = .94).

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. 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.

2.2.7. 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**). 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 were categorized and included in our between-group analyses.

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 conducted to examine the group differences between age (older vs. younger), gender, country (UK vs. other counties) and socioeconomic status (low, medium, high). Paired sample *t*-tests were conducted to examine the changes in all psychological variables between two timepoints. SPSS 19.0 was for aforementioned statistics with significant threshold set at $p < 0.05$.

Network Estimation. Psychological networks were estimated in the whole sample collected at the first timepoint to examine the direct links between psychological variables including anxiety (GAD), depression (PHQ), sleep, COVID-related levels of stress, loneliness (Lone), aggressions (RPQ), paranoia (SMS) and the three factors of the schizotypy subscales (SPQ-B: Factor 1, 2, 3). In this study, nodes were defined as participants' scores on each of the variables and edges were calculated using partial correlations between pairs 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 the Gaussian graphical model and to construct networks. Furthermore, to investigate the importance of each node in the network, the strength of each node was examined by summing up all connections of the node. Out of all the centrality indices, we mainly report on the index of "*strength*" as all connections are positive and the nodes are total or subscale scores of psychological variables. 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 to construct the networks and the "*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 the 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 group by age, gender, countries and income levels, as well as individuals with high and low schizotypal traits, we estimated networks for each subset of data and then

conducted the NCT respectively using two-tailed permutation tests at 10,000 times (van Borkulo et al., 2017). To cater for multiple comparisons of invariance tests of edge-weights and nodal strength, false discovery rate (FDR) correction was applied to correct for the estimations. The significance threshold was set at p or adjusted $p < 0.05$.

Cross-lagged panel network (CLPN) analysis. Longitudinal relationships of nodes were estimated using cross-lagged panel network modeling（Funkhouser et al., 2021). As there are three timepoints, we performed CLPN analysis separately for two timepoints at a time, to examine which variables in the earlier time-point were most predictive of the variables at the later timepoint (e.g. predict variables at Time 2 based on Time 1). The CLPN was estimated using a series of nodewise linear regression models to compute autoregressive (i.e., the coefficient of a node at Time 1 predicts itself at Time 2 after controlling for all other nodes at Time 1) and cross-lagged effects (i.e., coefficient of a node at Time 1 predicts another node at Time 2 after controlling for all the other nodes at Time 1). Regression coefficients were regularized using LASSO with 10-fold cross-validation tuning parameter selection to shrink small regression coefficients to exactly zero. Regularized regressions were estimated using "glmnet" package in R (https://cran.r-project.org/web/packages/glmnet/index.html).

Network stability and accuracy. The stability and accuracy of each estimated network were examined with reference to a tutorial paper by 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. Comparison of proportions using https://www.medcalc.org/calc/comparison_of_proportions.php found no significant differences in participants in time 1 and 3 on age, sex, and income ($p > 0.1$).

Table 1. Demographic statistics of all study variables.

	Time 1	**Time 2**	**Time 3** 17 April to 31 July 2021

	17 April to 14 July 2020 (N_1=1599)		17 October 2020 to 31 January 2021 (N_2=774)		(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**.**

Time 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
Time 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
Time 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 Time 1.

	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 Time 1

Independent samples *t*-tests were conducted to test for groups differences between younger and older groups, males and females, countries (UK vs. Other countries) as well as socioeconomic status. 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 (<35 years) reported higher levels of schizotypal traits, aggression, depression, stress, and anxiety, as well as more sleep problems compared to older participants (35+years); 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 aggressive behaviors. High income was a protective factor for schizotypal traits, negative affect, and loneliness compared to the individuals in the medium- or low-income bands.

Table 4. Comparisons across age, gender, countries and income groups at Time 1

	Age		**Gender**		**Countries**		**Levels of Income**		
Time 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. Numbers in bold indicate significant group differences after 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 Time 1 and 2, as well as between Time 2 and 3, respectively. The results suggested that participants reported lower levels of aggressive behaviors and more sleep problems at Time 2 compared to Time 1. In the last timepoint, participants had lower levels of schizotypal traits and stress caused by COVID. These changes were significant even after multiple comparison corrections with adjusted $p < 0.0045$ were applied.

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. Numbers in bold indicate significant group differences after multiple comparisons.

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

In the whole sample of Time 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 for all other variables in the network with thicker lines representing stronger bivariate connections. Strong connections were observed between schizotypal traits, paranoia and mental health variables. For example, SPQ-B Factor 1 was linked with anxiety, aggression, and paranoia, while SPQ-B Factor 2 was correlated with depression through loneliness.

Figure 1 details the strength of all study variables from Time 1. Depression, anxiety and loneliness are seen to be the most influential nodes in the network as they have relatively high nodal strength. According to the network, anxiety, depression and stress from COVID were closely correlated to each other, while sleep problems were only connected with depression. More interestingly, we found that loneliness was connected to multiple nodes in the network, including schizotypal traits (SPQ-B Factor 2 and Factor 3), paranoia and depression. This finding suggests that loneliness may serve as a bridge connecting schizotypal traits/paranoia with poor mental health.

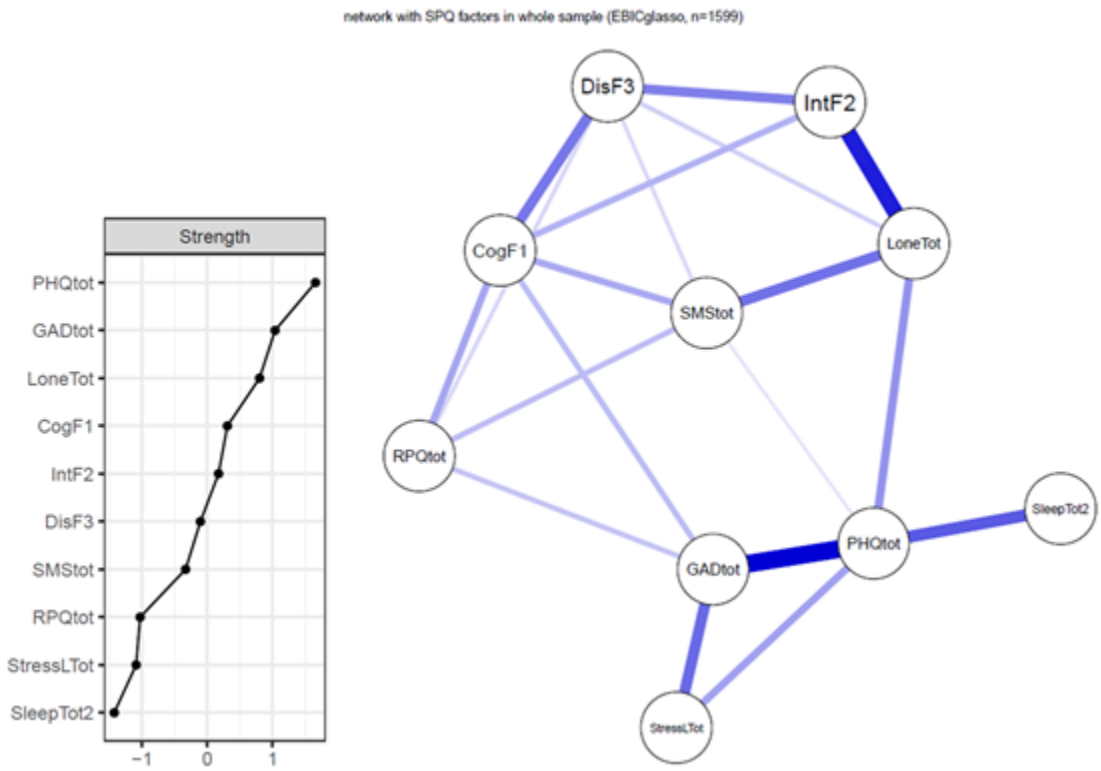


Figure 1. Estimated network structure of Time 1 using SPQ factor scores (right) and nodal strength (left). All of the blue lines in the network represent positive partial correlations. A thicker line represents a stronger correlation. SPQ-B: Schizotypal Personality Questionnaire – Brief, SMStot: Social 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.

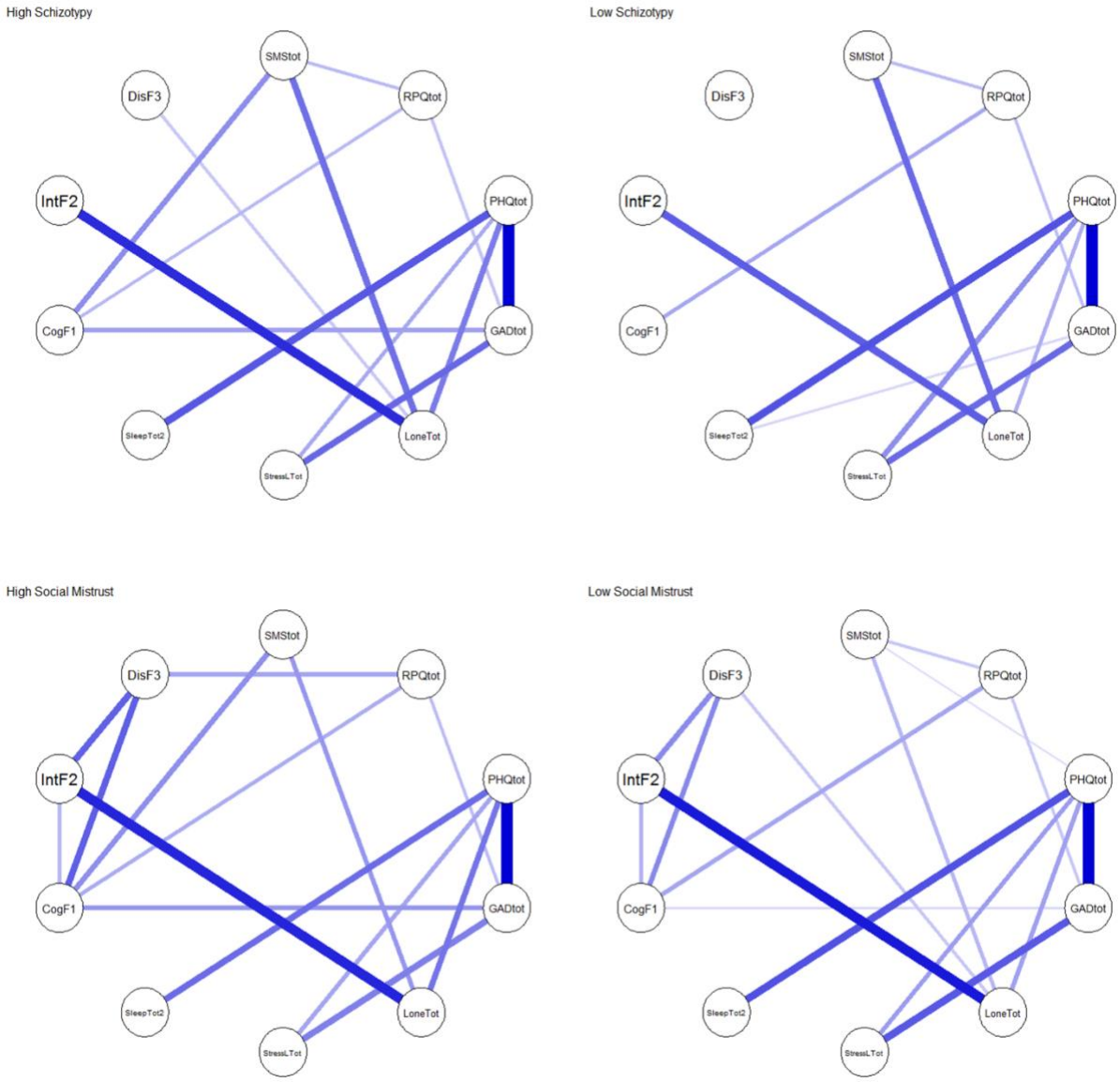
3.5 Network comparisons test (NCT) across groups

At Time 1, network comparisons were conducted across groups by age (<35 years, 35+years), gender (male vs. female), countries (UK vs others) and levels of income (low, medium, high). NCT analyses did not show significant differences in 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). Given differences in sample sizes, we repeated the NCT 100 times using random subsamples of younger participants and found that only 1% and 16% of the invariance tests for network and global strength were found to be significant – confirming our null finding. No **gender differences** were found between males and females (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 – again confirming out null finding. In terms of **networks of UK and other countries**' responses, again, 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). Comparing networks across groups with **low, medium and high levels of income** also resulted in no significant differences (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 (i.e., invariant) across different groups: age, gender, countries and levels of income.

Furthermore, we also performed network comparisons between **high vs. low schizotypy/paranoia** groups. The network structures between groups with high and low SPQ-B scores were different ($M = 0.21$, $p < 0.001$). Compared with the low schizotypy group, individuals in the high schizotypy group showed significantly stronger correlations between paranoia and SPQ-B Factor 1(adjusted $p = 0.005$), anxiety and SPQ-B Factor 1 (adjusted $p = 0.027$), and loneliness and SPQ-B Factor 2 (adjusted $p < 0.001$). The global strength of the high schizotypy group was also stronger 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 paranoia, individuals in the high paranoia group also showed a different network structure compared with those in the low paranoia group ($M = 0.183$, $p = 0.004$). Stronger network connections were found between paranoia and SPQ-B Factor 1 (adjusted $p < 0.05$) and loneliness (adjusted $p < 0.001$) in the high SMS group compared with the low SMS group. The global strength for the high SMS group was significantly higher than that of the low SMS group which, 3.82 vs 3.30 respectively ($S = 0.53$, $p < 0.05$, see networks in Figure 2).

Figure 2. Networks of all study variables by high-/low-schizotypy groups (top) and high-/low-paranoia groups (bottom).



3.6 Network comparisons across timepoints and longitudinal relationships

We performed the network comparisons to test the invariance of network structure and global strength across three timepoints with each other (Figure 3). Compared to the Time 1

network, Time 2 network had comparable network structure (M = 0.11, p = 0.153) and global strength (S = 0.02, p = 0.879, 3.99 for Time 1 and 4.02 for Time 2), suggesting that no significant differences in the networks were found across two timepoints. Similarly, the networks of Time 2, and Time 3 are similar with no significant differences (M = 0.08, p = 0.983; S = 0.07, p = 0.519, global strength is 4.02 for Time 2 and 3.95 for Time 3). These findings indicate that network structure and partial correlations among variables were similar across the three timepoints.

The results of CLPN were shown in Figure 4. The SPQ-F2 and social mistrust at Time 1 could predict the scores on stress and loneliness respectively at Time 2, while SPQ-F2, SPQ-F1 and Depression at Time 2 predicted the loneliness and stress at Time 3. All these cross-lagged effects survived after applying a threshold of 0.35.

Figure 3. Invariance test of network structures across three time-points.

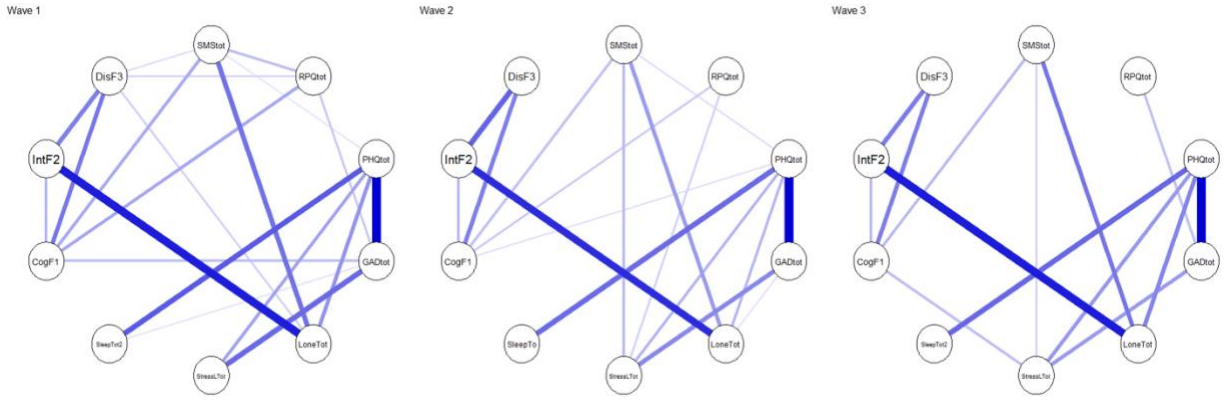
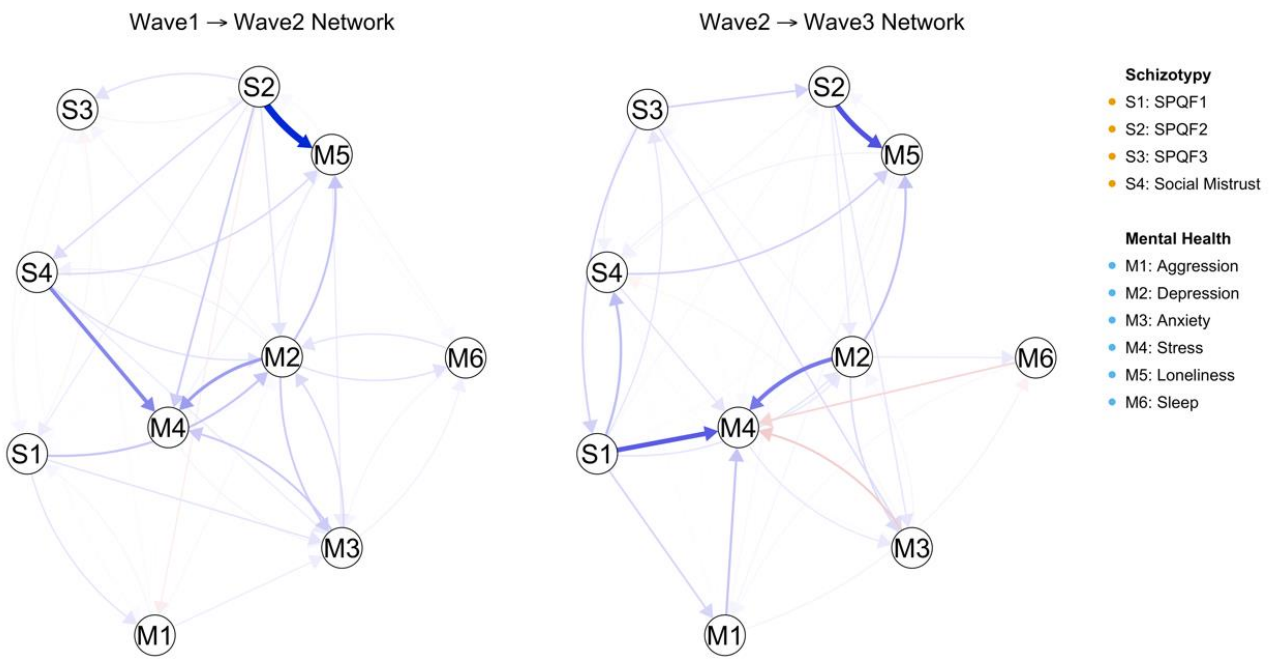


Figure 4. The results of cross-lagged panel network (CLPN) analysis. Arrows represent unique longitudinal relationships which was calculated by the regression analysis across data from different time-points. Blue edges indicate positive relationships, and red edges indicate negative relationships. Thicker edges represent stronger relations. Autoregressive edges were excluded.



4. Discussion

4.1. Main Findings

In this three timepoint network analytic study of the associations between paranoia and schizotypal traits in relation to anxiety, depression, loneliness, aggression, COVID-related stress, and poor sleep, we found that both paranoia and schizotypal traits were positively associated with depression and associated relationships with anxiety, stress, and poor sleep primarily through self-perceived loneliness. Specifically, interpersonal and disorganized features were particularly associated with loneliness and depression – a key relationship observed 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 and schizotypal traits were uniquely associated with aggression. Interestingly, there were no network structure differences across sex, age groups, countries, and income level, indicating that no single vulnerable group could be identified but rather the effects were similar on the whole. On the contrary, we found significant differences of networks between high and low schizotypal traits/social mistrust groups with high schizotypal trait/mistrust group showed stronger connected network compared to their counterparts. 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. This is in line with the changes in country lockdown restrictions at the time – in the UK, US, Italy, and Greece where the majority of respondents contributed from – lockdown restrictions were easing, shops were reopening, and physical distancing was still in place but group gathering limitations were being lifted. On balance, these findings tentatively suggest that reductions in self-perceived loneliness - an influential variable across all participant groups may have taken place due to the improved environmental situation during the easing of lockdown – and this in turn may have reduced concurrent negative associations between paranoia/schizotypy and mental health symptoms to a large degree.

Although the empirical evidence for why schizotypal traits is associated with loneliness remains sparse, it is conceivable that individuals with schizotypy feel anxious in social situations (F2), often have few close friends, anhedonia, and this in turn are features that may also prevent other people from interacting with the individual and precipitate feelings 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), with effects replicated for both positive and negative symptoms of schizotypy (Badcock *et al.*, 2016). Conversely, these study findings are 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, or paranoia, coupled with an individual's odd behaviors, and social anxiety can lead an individual to keep to themselves more, avoid from social situations altogether, which in turn can lead to reduced interactions with others and spiral into a vicious cycle where alternative positive interactions are not possible, and self-perceived detachment from others, loneliness, ensues. Whether the causal direction of changes in levels of schizotypy and paranoia are purely due to the COVID easing of restrictions taking place during time 3 (April to July 2021), natural acclimatization to the pandemic, and/or existing poor social support/earlier childhood experiences may be disputed as we do not have pre-pandemic baseline measures of paranoia. Drawing on developmental research comparing suspicious and non-suspicious children, highly suspicious 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), suggesting that negative changed in an environment may also be a cause of the loneliness and schizotypy/paranoia relationship.

Over a 12-month period (time 1 and time 3), schizotypal traits and paranoid ideations have reduced over time, yet we only see reductions in levels of loneliness between time 2 and 3 (p<.002) synced with easing of lockdown and not between time 1 and time 2 (p=.273) (see Table 5). Two explanations may account for this: first, levels of loneliness were generally felt and sustained for the large majority of the sample given that the UK was in full national lockdowns coinciding with time 1 and time 2 data collection, uncertainty around coronavirus was high, and worldwide travel restrictions were in place. For most people, this unprecedented forced separation from the world is a first. By time 3, mean levels of self-perceived loneliness reduced, which coincided with the initial easing of lockdown restrictions (e.g., reopening of shops, going out was possible, yet physical distancing 2-metre rule was 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 stabilize or decline 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%) was 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 et al., 2017). This finding perhaps suggests that government and community efforts to reduce feelings of loneliness may be beneficial for the large 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 responded to the survey at different times of the lockdown period, and our assessment at 6 and 12 months may have been too long to capture smaller in-person fluctuations. As we know from our Time 1 findings that the levels of self-perceived loneliness follow an inverted U-shape in relation to lockdown duration in weeks: respondents to the survey at the beginning and end of the lockdown period reported significantly higher mean 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 variations on self-perceived levels of loneliness (but not for other mental health variables) as lockdown duration

progresses, perhaps alternative factors that we have not assessed in this study that may come into play including an individual's ability to cope and access financial and emotional support during the lockdown period (Fekih-Romdhane, Dissem, & Cheour, 2021). 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 analysis.

Controlling for other variables in the network, study network analyses failed to 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 and symptoms (e.g., depression, anxiety, poor sleep, covid-related stress). This finding is consistent with previous studies showing that reductions in loneliness through a weekly positive psychology interventions or social prescribing can improve psychological wellbeing for older adults (Chen & Feeley, 2014), patients with psychosis (Lim, Penn, Thomas, & Gleeson, 2019), and increase neighbourhood's identification and social belonging (Fong, Cruwys, Robinson, & Haslam, 2021). Thus investing in community services that prevent social isolation as part of the pandemic recovery strategy may be key in reducing feelings of loneliness for the general population (Windle, Francis, & Coomber, 2011). When splitting all participants at Time 1 into high and low schizotypy/paranoia groups, we observed stronger connected network for the high schizotypy/paranoia group compared to individuals with low level of schizotypy/paranoia, this is consistent with our expectation as the network theory (Borsboom, 2017) assumes that individuals with severe symptoms would have more nodes activated and manifest a stronger connected network. Hence, it is very important to identify some nodes in the network which would be great influential to the other variables and relatively easy to manipulate. Based on our findings, loneliness would be a promising node that could be consider for future intervention.

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 uniquely relate 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 mental health variables included in the network,

schizotypal traits were associated with more aggressive behaviors, specifically reactive retaliatory aggression and not proactive instrumental aggression. This suggests that individuals with high schizotypal traits are more likely to report retaliatory aggression as a result of social interactions with others (not proactive aggression), and thus more likely to perhaps avoid social situations, engage in reclusive behaviors and report higher feelings of loneliness, that individuals in the low-trait group. Particularly attention to helping individuals with high levels of paranoia and schizotypy reintegrate into communities post-pandemic may be warranted.

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 schizotypal traits and paranoia together and internalizing and externalizing symptoms using a network analytic approach to identify the variable(s) of influence for intervention and across a 12-month period during the pandemic. Our study was able to examine macro and micro associations, test for group contrasts, and across timepoints that coincided with national lockdowns and easing periods in the UK and to a large extent, abroad as well. This analytic technique though not commonly used across timepoints may be particularly valuable when applied to big data to glean a holistic understanding of the web of comorbid relationships that are often observed in mental health research.

This study is however, 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 comparative studies 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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Supplementary Tables/Figures

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

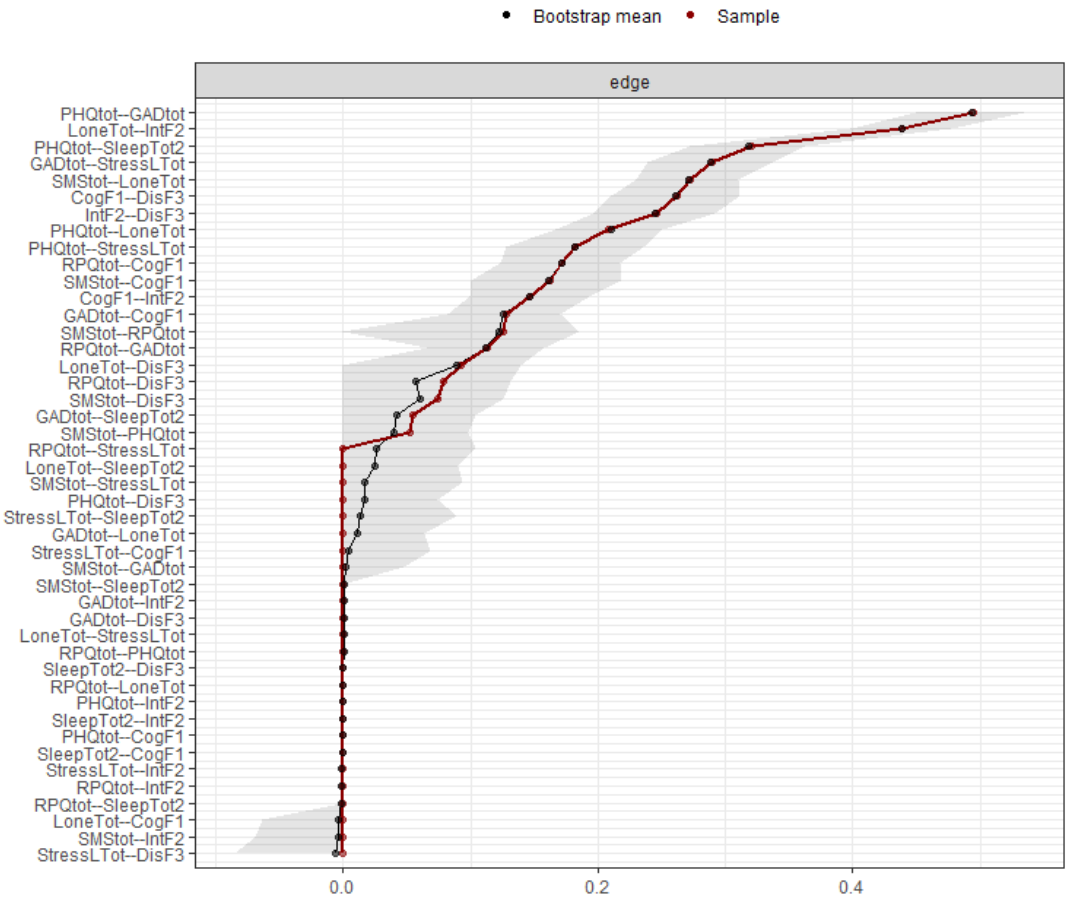

Figure S1. Bootstrapped CIs of estimated edge-weights for the estimated network. The red line indicates the sample values and the grey area indicates the bootstrapped CIs. Each horizontal line represents one edge of the network ordered by edge-weights.

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.

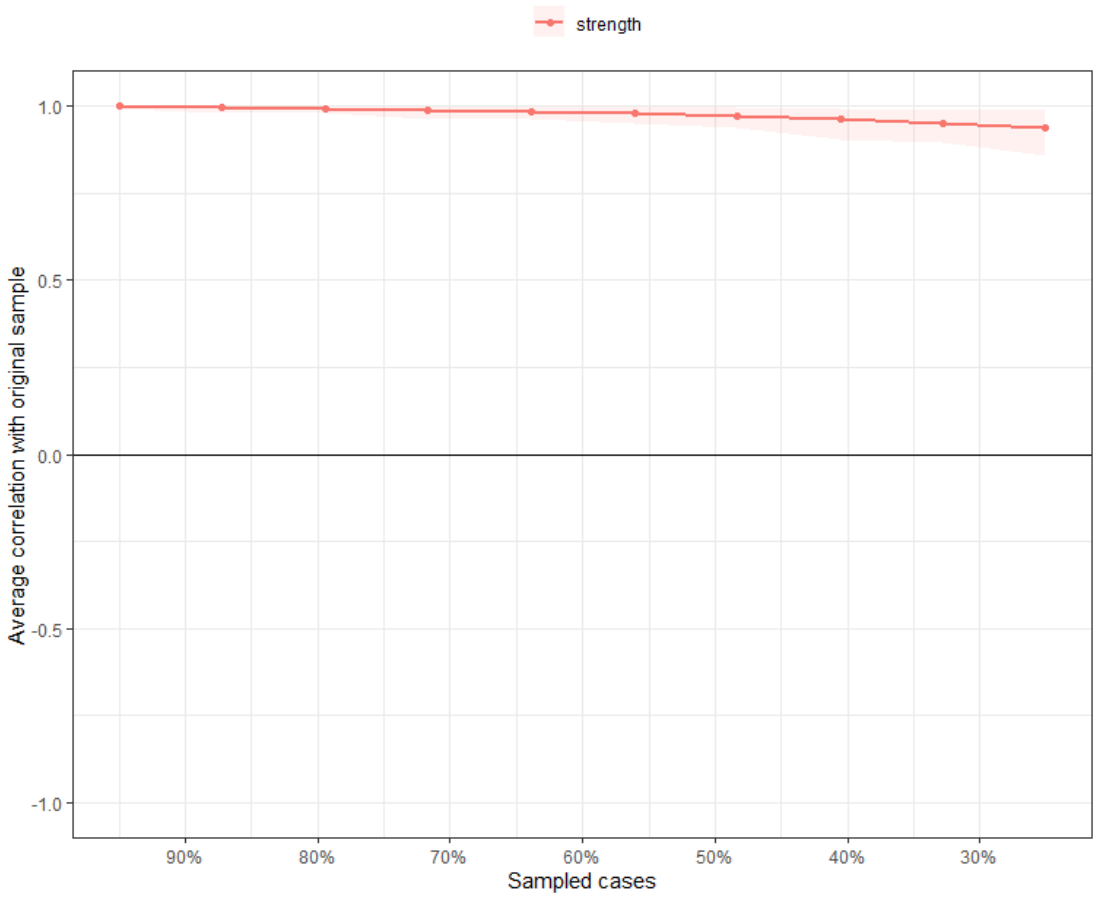

Figure S2. Average correlations between strengths of networks estimated with sampled participants and original sample. Lines indicate the means and areas indicate the range from the 2.5th to the 97.5th percentile.

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.

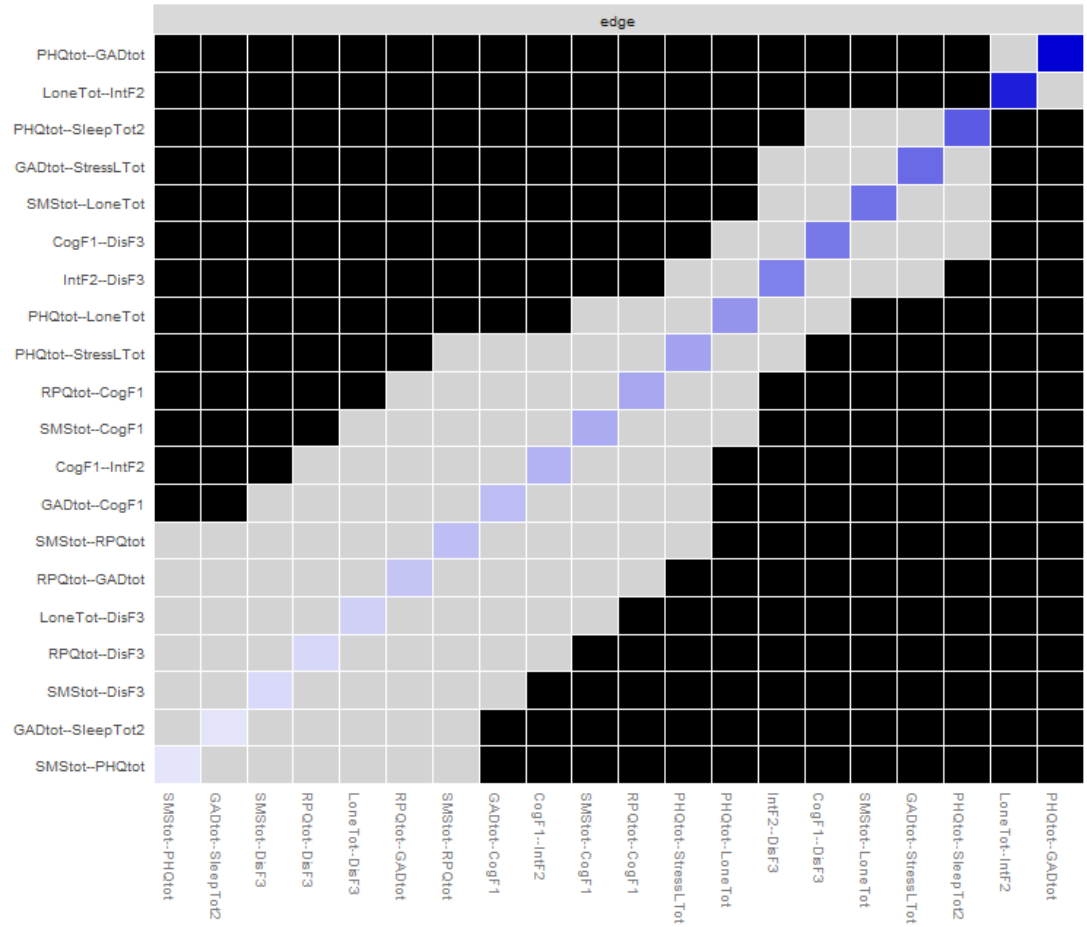

Figure S3. *Bootstrapped difference tests on the non-zero edge-weights of the estimated network. Black boxes indicate edges that differ significantly from other corresponding edges in the matrix. Coloured boxes in the edge-weight plot correspond to the colour of edges in the estimated network.*

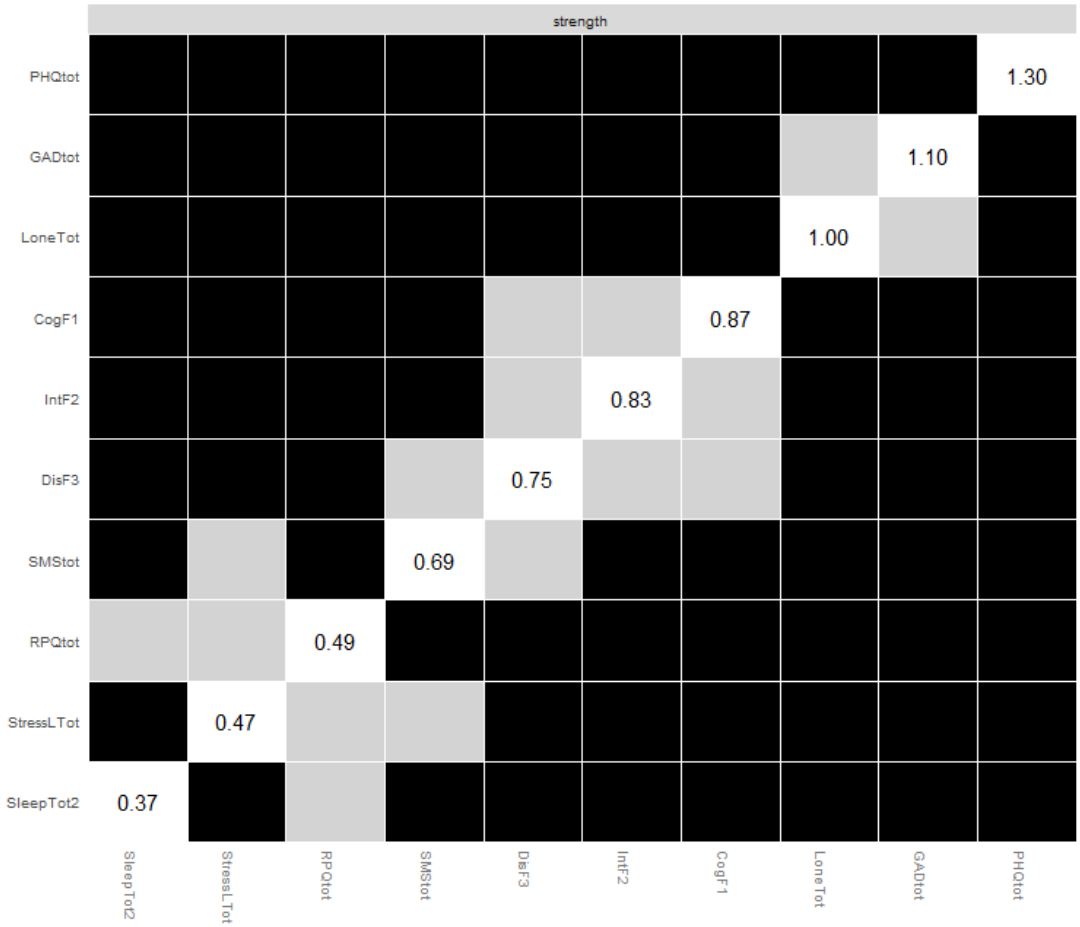

Figure S4. *Bootstrapped difference tests on the nodal strength of all the variables in the network. Black boxes indicate nodes that differed significantly from another corresponding node in the matrix. Numbers in white boxes in the centrality plot show the strength of the corresponding node.*

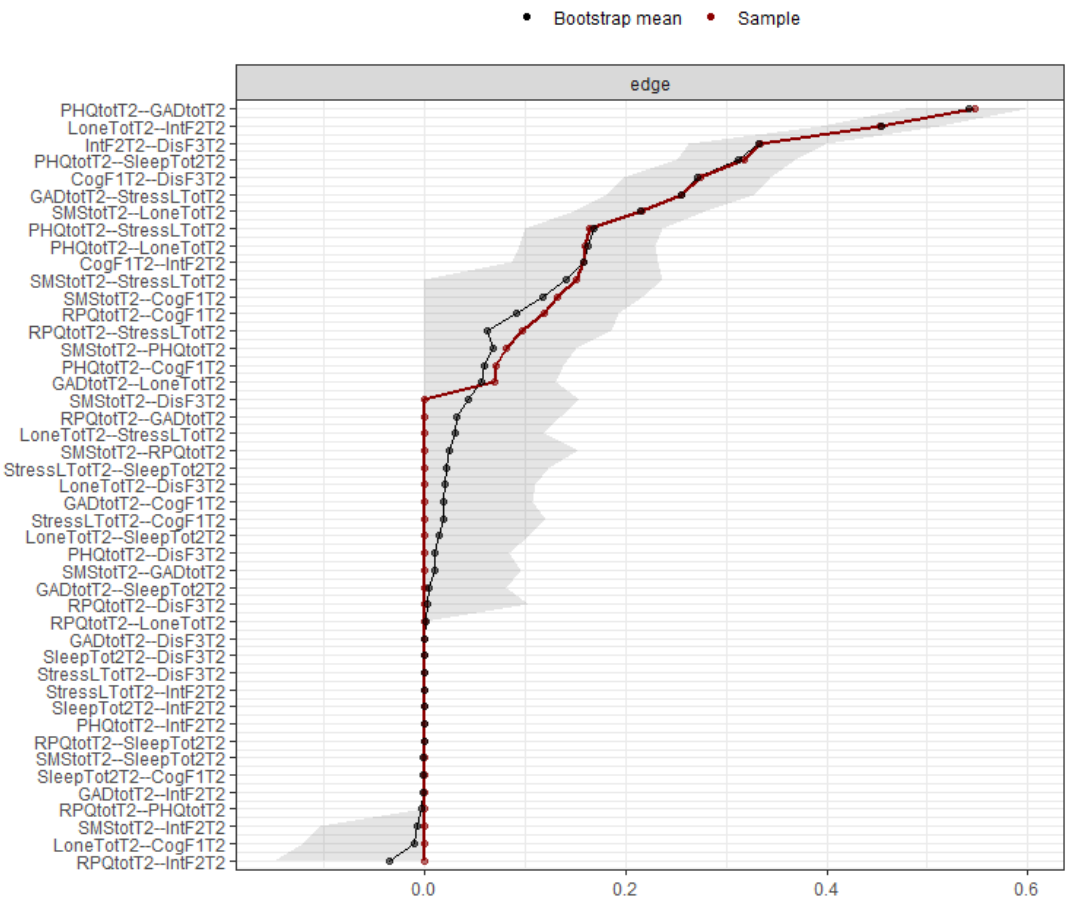

Figure S5. Bootstrapped CIs of estimated edge-weights for the estimated network at Time 2. The red line indicates the sample values and the grey area indicates the bootstrapped CIs. Each horizontal line represents one edge of the network ordered by edge-weights.

2.2 Centrality stability

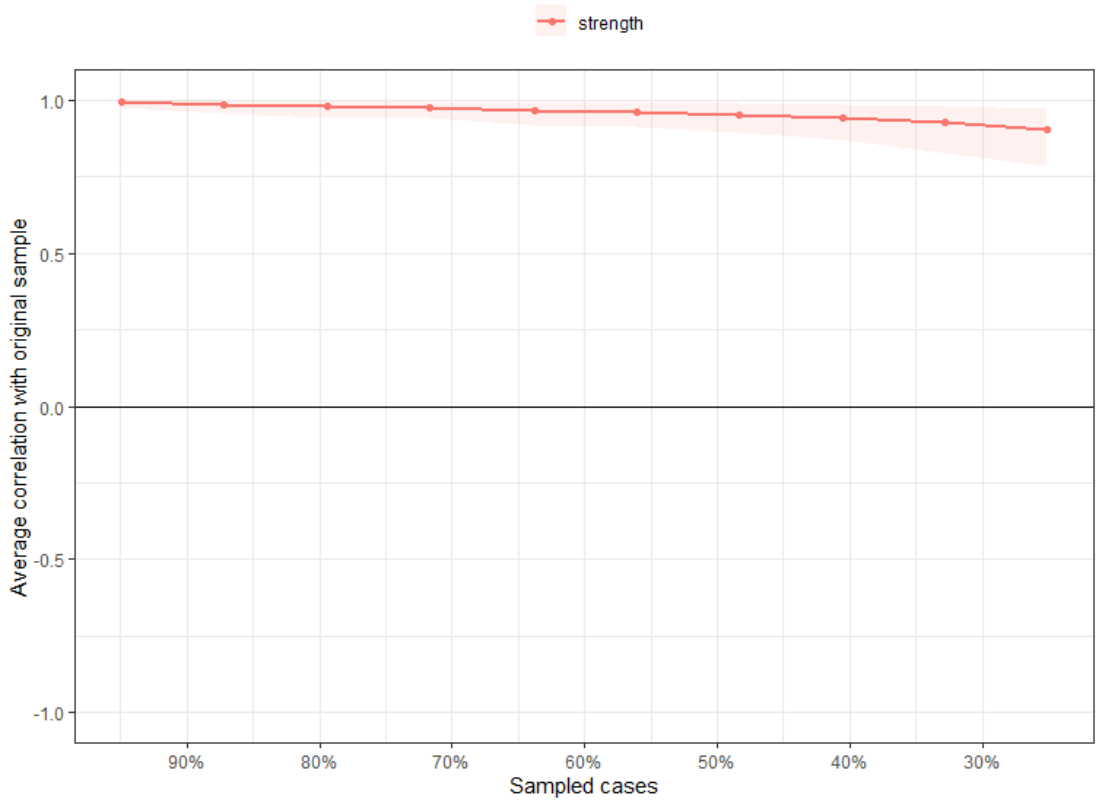

Figure S6. Average correlations between strengths of networks estimated for Time 2 with sampled participants and original sample. Lines indicate the means and areas indicate the range from the 2.5th to the 97.5th percentile. The CS-coefficient for strength (CS (cor=0.7) = 0.749) is higher than 0.5 suggesting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

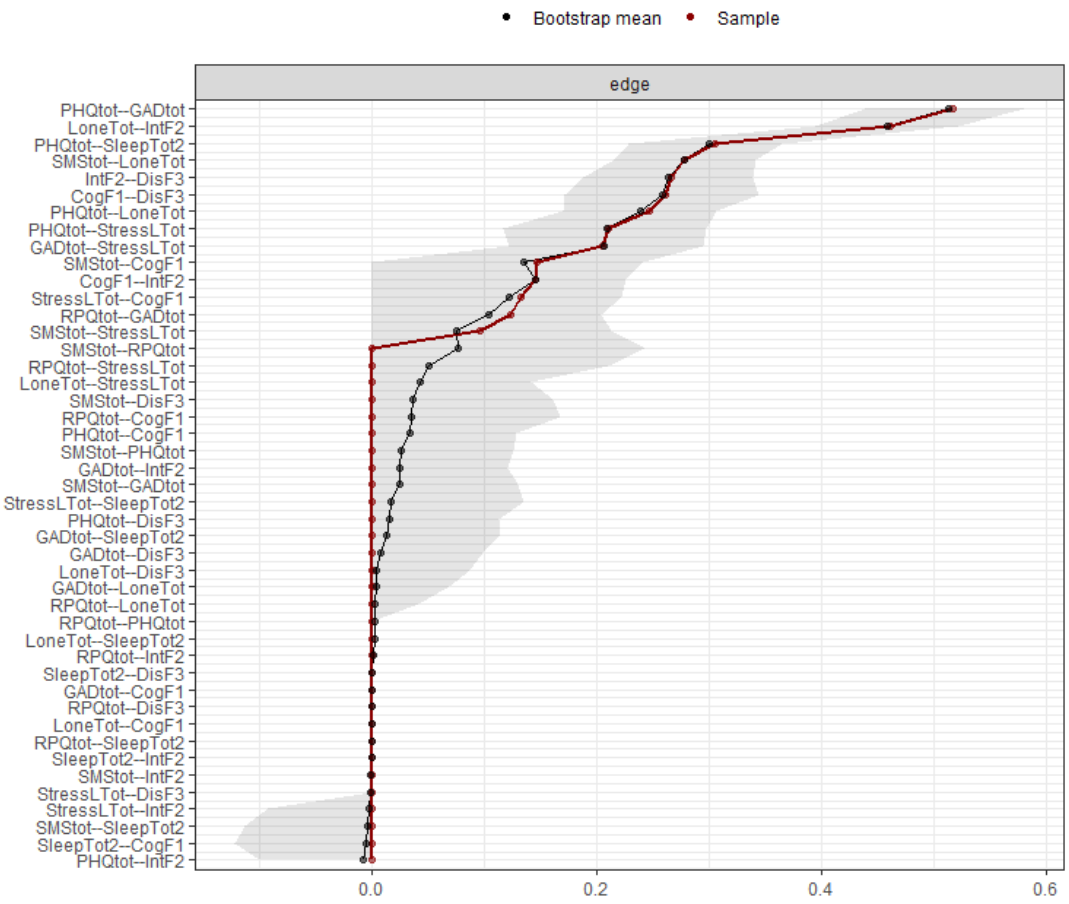

Figure S7. Bootstrapped CIs of estimated edge-weights for the estimated network at Time 3. The red line indicates the sample values and the grey area indicates the bootstrapped CIs. Each horizontal line represents one edge of the network ordered by edge-weights.

5.2 Centrality stability

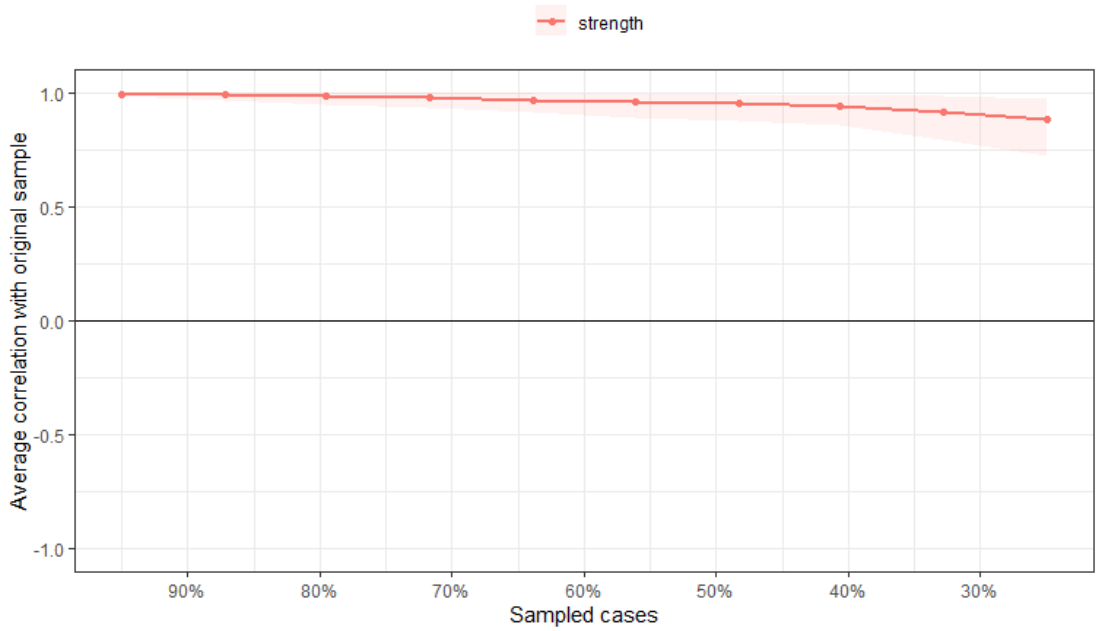

Figure S8. Average correlations between strengths of networks estimated for Time 3 with sampled participants and original sample. Lines indicate the means and areas indicate the range from the 2.5th to the 97.5th percentile. The CS-coefficient for strength (CS (cor=0.7) = 0.751) is higher than 0.25 suggesting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