



## Network analysis of schizotypal personality traits and their association with other subclinical psychiatric features

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### ABSTRACT

Schizotypal personality (SP) traits have been found to be correlated with autistic traits, obsessive-compulsive traits, depressive symptoms and anxiety symptoms. However, the overall pattern of the relationship remains unclear. The purpose of this study was to investigate the network structure between SP traits and other sub-clinical features (symptoms or traits) and test the replicability of these relationships. A total of 2204 college students completed measurements for SP traits, autistic traits, obsessive-compulsive traits, depressive symptoms and anxiety symptoms, and a validated subsample of 814 completed the same questionnaires again three months later. Using network analysis, we constructed the network structure of subclinical features and then tested its replicability. We found that interpersonal features were the bridge node connecting SP traits and autistic traits (social skill:  $r = 0.50$ ; attention switching:  $r = 0.14$ ; communication:  $r = 0.12$ ), while cognitive-perceptual (obsessing:  $r = 0.05$ ; neutralizing:  $r = 0.06$ ) and disorganization (obsessing:  $r = 0.11$ ) features were the SP traits associated with obsessive-compulsive traits. In addition to interpersonal features ( $r = 0.10$ ), disorganization ( $r = 0.12$ ) and cognitive-perceptual ( $r = 0.05$ ) features were also the overlap between depressive symptoms and SP traits. Anxiety symptoms only connected with interpersonal ( $r = 0.05$ ) but not cognitive-perceptual features of SP traits. The network showed high predictability (43%) and interpersonal features of SP traits had the highest expected influence (1.67) among all nodes, which may be a potential target for intervention. High similarities were found on network structure ( $r = 0.86$ ) and expected influence ( $r = 0.96$ ), and no significant difference on global connectivity was found between these two networks (difference value = 0.45,  $p = 0.135$ ), suggesting the replicability of the network structure.

### 1. Introduction

Over the past century, psychiatric disorders have been classified into separate categories with the assumption that there exist distinct aetiological factors behind observed symptoms. However, the categorical approach has been challenged recently (Cuthbert, 2014; Kotov et al., 2017). Indeed, recent genetic evidence from the world-wide Brainstorm Consortium found that psychiatric disorders share many common genetic risk factors (Brainstorm, 2018).

Schizophrenia spectrum disorder (SSD) is defined as an independent category in all widely-used classification systems, with main

manifestations of positive (e.g., delusion, hallucinations), negative (e.g., anhedonia, amotivation) and disorganization symptoms (American Psychiatric Association, 2003). However, SSD is often comorbid with mental disorders belonging to other categories, such as autism spectrum disorder (ASD), obsessive-compulsive disorder (OCD), depressive disorder and anxiety disorders (Chisholm et al., 2015; Fonseca-Pedrero et al., 2010; Lambert et al., 2018). More importantly, at the genetic level, genetic correlations have been observed between schizophrenia and ASD, OCD, major depressive disorder and anxiety disorders, indicating that schizophrenia and these disorders may share common aetiological factors (Brainstorm, 2018). However, at the

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phenotype level, how SSD and these disorders are connected and how they interact with each other remains unclear.

Some previous studies have reported potential connections between SSD and other comorbid disorders. For instance, the anhedonia-asociality dimension of SSD appears to be connected to ASD because these symptoms are comparable to ASD symptoms, such as impaired ability in social communication, social interaction and social cognition (Chisholm et al., 2015; Raju et al., 2019). Moreover, autistic traits and SP traits also share similar features in problems with social interaction (Dinsdale et al., 2013; Gong et al., 2017). The close link among obsessions, magical thinking and delusions suggests that positive symptoms of SSD may be the connection with OCD (Fonseca-Pedrero et al., 2010; Roth and Baribeau, 2000). Similarities between depressive symptoms and negative symptoms (anhedonia, social withdrawal and apathy) and the correlation between depressive symptoms and negative symptoms but not positive symptoms suggest that depressive symptoms may mainly interact with negative symptoms of SSD (Lambert et al., 2018; Uptegrove et al., 2017; Vrbova et al., 2018). On the contrary, anxiety symptoms are correlated with not only negative but also positive symptoms of SSD (Lewandowski et al., 2006; Temmingh and Stein, 2015; Vrbova et al., 2018). However, most of the aforementioned studies only included one or two comorbid disorders and did not control for other comorbidities, which may confound their findings. For instance, it is unclear whether impaired social abilities of ASD are directly associated with the anhedonia-asociality dimension of SSD or connected through depressive symptoms. Moreover, given that anxiety symptoms are associated with positive symptoms of SSD and OCD symptoms, it is not clear whether anxiety symptoms mediate the correlation between positive symptoms and OCD symptoms. The overall pattern of correlations between these symptoms has yet to be investigated, and a novel method which takes into account all related disorders and controls for confounding comorbid symptoms is needed.

Network analysis is a novel method that has been used to conceptualize the construct of psychosis (Fonseca-Pedrero et al., 2018), given that traditional classification systems have been challenged by the high heterogeneity among disorders and the absence of measurable underlying pathological mechanisms. Network analysis assumes that mental disorders develop from interactions between symptoms and measures the direct interactions between symptoms while controlling for the confounding effect of all other symptoms (Borsboom and Cramer, 2013; Fried et al., 2017). In this way, network analysis addresses the effect of confounding comorbid symptoms which is difficult to avoid in previous studies and a growing number of studies has successfully adopted this method to investigate the relationship between co-morbid symptoms (Afzali et al., 2017; Beard et al., 2016; Wang et al., 2017). More importantly, the network approach also benefits the understanding of the psychopathology of mental disorders by examining how symptoms interact with each other and which symptoms are most “influential” (Borsboom, 2017). The interactive pattern of symptoms shown by the network structure may help in the understanding of the emergence and development of mental disorders. To identify which symptoms are most “influential” in a network, the network approach calculates various indices such as expected influence (EI) and predictability, which may help in identifying potential targets for intervention. EI is the sum of edges of one node and it represents how impactful a node is in the network. Therefore nodes with a high EI may be a target to alter the network or a target for treatment (Fonseca-Pedrero et al., 2018c; Robinaugh et al., 2016). Predictability measures the variance of one node which is determined by its neighbours and it represents to what degree the node can be predicted by its neighbours (Haslbeck and Fried, 2017). Therefore, nodes with a high predictability may be easier to change, while nodes with a low predictability may be less dependent on the network. On the other hand, network analysis has also been criticized. Given that results from network analysis are mostly based on single samples and more importantly, they are not always consistent when conducted in different samples (Forbes et al., 2017), the

replicability of constructed networks remains controversial (Fried and Cramer, 2017; Verschuere et al., 2018). Network analysis using separate samples is therefore needed.

Mental disorders can be conceptualized as a continuum from healthy individuals to high risk populations and clinically diagnosed patients. Early detection of subclinical symptoms benefits the prognosis as well as the protection of clinical onset (Kaligis et al., 2018). Driven by the Hierarchical Taxonomy of Psychology (HiTOP), researchers have found that psychotic symptoms, SP traits and normal personality may share a common dimension (Cicero et al., 2019). SP traits, the subclinical features of SSD, may therefore provide a valuable framework for understanding the psychopathology of SSD (Kwapil and Barrantes-Vidal, 2015). Although there is a lack of agreement on the dimensions of SP traits, a three-factor model (cognitive-perception, interpersonal, disorganization) is well supported by previous studies (Fonseca-Pedrero et al., 2018c; Kwapil et al., 2018). Although the interpersonal features of SP traits cannot entirely represent the negative dimension of schizophrenia, the three-factor model still provides a viable model for investigating the different symptom dimensions of schizophrenia (positive, negative, disorganized). Investigating the correlation between SP traits and other subclinical features may enhance the understanding of the relationship between SSD and its comorbid disorders, without the confounding effect of illness chronicity and medication exposure. Moreover, it may shed light on the interaction pattern of subclinical features, and thus provide information for the identification of potential treatment targets.

In this study, we investigated the network structure between SSD and its commonly co-occurring traits by constructing a network consisting of SP traits, autistic traits, obsessive-compulsive traits, depressive symptoms and anxiety symptoms. Predictability and EI were calculated. Moreover, we compared the network pattern of the main sample and a validated sub-sample after a three-month interval to evaluate the replicability of the observed relationship. We hypothesized that SP traits would be connected to autistic traits and depressive symptoms by its interpersonal features and that the cognitive-perceptual features of SP traits would be the bridge node linking schizotypal and obsessive-compulsive traits. We also hypothesized that both interpersonal features and cognitive-perceptual features would be the connection between SP traits and anxiety symptoms (Chisholm et al., 2015; Fonseca-Pedrero et al., 2010; Lambert et al., 2018; Vrbova et al., 2018). Lastly, we hypothesized that the observed pattern found in the main sample would be replicated by the validated sub-sample.

## 2. Methods

### 2.1. Participants

We recruited participants from 130 cities of 34 provinces in mainland China via on-line advertisement. Participants who were willing to participate responded to on-line links, gave written informed consents and answered self-report questionnaires. A total of 2914 participants (from 130 cities) completed all measurements. The following exclusion criteria applied to all potential participants: 1) incomplete survey with missing data ( $n = 11$ ); 2) survey with repeated answers: 125 participants answered twice and their second answers were excluded; 3) completion time outliers: 144 participants were excluded because the completion time was shorter than 735 s (2.5th percentile) or longer than 6422 s (97.5th percentile); and 4) a lie detection score greater than 2 (the methodology of lie detection scoring can be found in the supplementary information;  $n = 430$ ). Applying these exclusion criteria, there are 2204 (645 males) valid participants in the final sample. Valid participants and invalid participants showed no age difference ( $t = 2.93$ ,  $df = 2901$ ,  $p = 0.77$ ), but valid participants contained fewer males than invalid participants ( $\chi^2 = 7.60$ ,  $df = 1$ ,  $p = 0.006$ ). All valid participants received 20 RMB in return for their participation. A validated sub-sample of 1118 participants completed the same

questionnaires again three months later. After removing invalid responses (two incomplete surveys, 34 repeated surveys, 80 time-outliers and 188 with a high lie-detection score), 814 (196 males) participants were retained in the validated sub-sample. Comparison information of participants who responded once (non-responders) and those who responded twice (responders) can be found in supplementary information (SI\_Table1).

This study was approved by the Ethics Committee of the Institute of Psychology, the Chinese Academy of Sciences (Ethics number: H15031).

## 2.2. Measures

The Schizotypal Personality Questionnaire (SPQ; Raine, 1991), which contains the cognitive-perceptual, interpersonal and disorganization factors was used to measure SP traits. The SPQ has been shown to possess good psychometric properties in previous studies and a recent international study recruiting more than 27,000 participants reported a high Cronbach's  $\alpha$  coefficient (0.73-0.94) for the SPQ across different countries (Fonseca-Pedrero et al., 2018b). The Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001), which includes the social skills, attention switching, attention to detail, communication and imagination factors was used to measure autistic traits. The Obsessive-Compulsive Inventory-Revised (OCI-R; Foa et al., 2002), which consists of the washing, obsessing, hoarding, ordering, checking and neutralizing factors was used to measure obsessive-compulsive traits. The Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001) and the Generalized Anxiety Disorder Questionnaire (GAD-7; Spitzer et al., 2006) were used to capture depressive symptoms and anxiety symptoms respectively. Detailed description of these measures can be found in the supplementary information.

## 2.3. Data analysis

### 2.3.1. Descriptive analysis

Descriptive analysis of demographic information and measurements were performed using the SPSS (Version 20.0). To compare the difference in age and gender between the main sample and the validated sub-sample, independent-sample *t*-test and Chi-square test were used.

### 2.3.2. Network analysis

Since the data did not meet the assumption of multivariate normality ( $W = 0.87$ ,  $p < 0.05$ , Shapiro-Wilk normality test), non-parametric transformation was applied for the normality assumption ( $W = 0.98$ ,  $p = 0.97$ , Shapiro-Wilk normality test) using the huge package (Zhao et al., 2012). A network was then constructed using the qgraph package (Epskamp et al., 2012). Sub-dimensions of each measurement were taken as nodes and Least Absolute Shrinkage and Selection Operator (LASSO) regularization was applied to construct an optimal network (Epskamp and Fried, 2018). EI and predictability were calculated for each node (Haslbeck and Fried, 2017; Robinaugh et al., 2016). Moreover, the mean predictability of the overall network and the mean predictability of each trait or symptom were calculated. The "Bootnet" package was used to calculate the stability of each network in edge and EI (Epskamp et al., 2018). Between-network replicability was tested using the "Network comparison test" package (van Borkulo et al., 2017). Moreover, the similarity of the two networks was estimated in terms of network structure and EI (Fonseca-Pedrero et al., 2018c). Details of network analysis can be found in the supplementary information. Using the same procedure, the network features based on all subscales of the SPQ and sub-dimensions of other measurements were also calculated. The results can be found in the supplementary information.

**Table 1**

Descriptive information of the main sample.

	Mean	SD	Min	Max
Age	21.71	2.74	18	30
Gender	M/F:645/1559			
SPQ sub-scores				
Cognitive-perceptual features	10.93	6.01	0	30
Interpersonal features	8.23	5.30	0	25
Disorganization features	4.93	3.68	0	16
AQ sub-scores				
Social skill	4.26	2.63	0	10
Attention switching	5.46	1.75	0	10
Attention to detail	4.99	2.19	0	10
Communication	2.97	1.98	0	9
Imagination	3.35	1.69	0	9
OCI-R sub-scores				
Washing	3.17	2.43	0	12
Obsessing	3.54	2.56	0	12
Hoarding	4.22	2.36	0	11
Ordering	4.39	2.53	0	12
Checking	3.47	2.51	0	12
Neutralizing	3.09	2.34	0	12
PHQ	7.27	4.95	0	27
GAD	5.86	4.37	0	21

Note: N = 2204. SPQ: schizotypal personality questionnaire; AQ: Autism-Spectrum Quotient; OCI-R: Obsessive-Compulsive Inventory-Revised; PHQ: Patient Health Questionnaire; GAD: Generalized Anxiety Disorder Questionnaire.

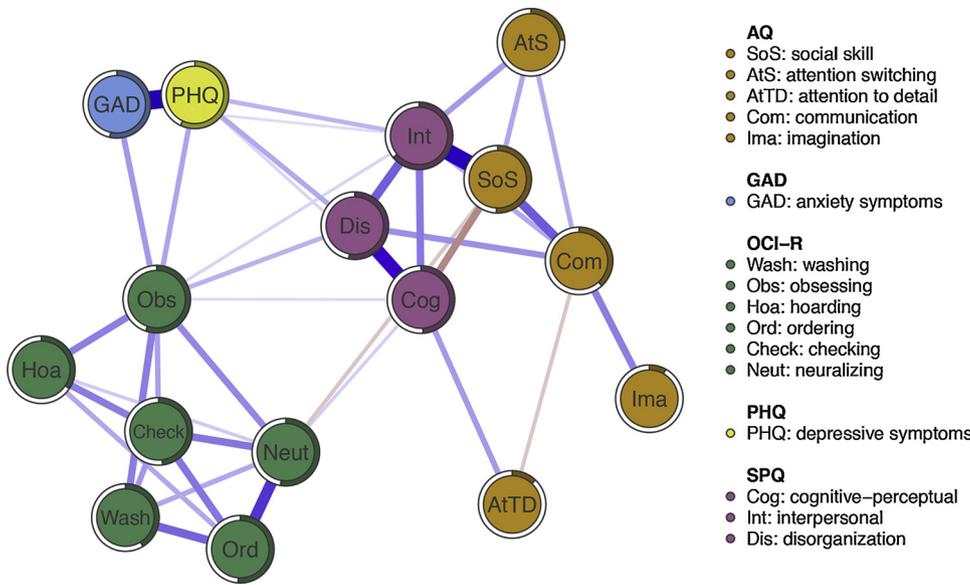
## 3. Results

### 3.1. Descriptive statistics

The main sample and the validated subsample were matched in age ( $t = -0.837$ ,  $df = 1560.13$ ,  $p = 0.403$ ). However, there were more males in the main sample than the validated sub-sample ( $\chi^2 = 7.95$ ,  $df = 1$ ,  $p = 0.005$ ). Table 1 shows the subclinical features of the main sample. The main sample reported similar levels of subclinical features as in previous studies (Fonseca-Pedrero et al., 2018a; Shi et al., 2017). The top 10th percentile cut-off SPQ score in the present study was 41, which was similar to typical cut-off scores of 38 in previous studies (Li et al., 2015). Moreover, 3.4% of the participants had an AQ score above its cut-off score of 32 (Baron-Cohen et al., 2001), 7.9% of the participants had a moderately severe level of depressive symptoms (PHQ\_9 scores > 15; Kroenke et al., 2001), and 14.9% of the participants reported severe anxiety (GAD\_7 scores > 10; Spitzer et al., 2006). Details on the difference between the main sample and the validated subsample can be found in the supplementary information (SI\_Table2).

### 3.2. Network pattern

The LASSO network is shown in Fig. 1. We found that SP traits were connected to autistic traits through interpersonal features, which was significantly correlated with social skills ( $r = 0.50$ ), attention switching ( $r = 0.14$ ) and communication ( $r = 0.12$ ). In the relationship between SP traits and obsessive-compulsive traits, obsessing was correlated with cognitive-perceptual features ( $r = 0.05$ ), interpersonal features ( $r = 0.06$ ) and disorganization features ( $r = 0.1$ ). Cognitive-perceptual features was correlated with neutralizing features ( $r = 0.06$ ). Moreover, SP traits were connected to depressive symptoms via interpersonal features ( $r = 0.10$ ), disorganization features ( $r = 0.12$ ) and cognitive-perceptual features ( $r = 0.05$ ). Anxiety symptoms was weakly correlated with interpersonal features ( $r = 0.05$ ). Edge values of the network can be found in supplementary information (SI\_Table3).



**Fig. 1.** The network structure between schizotypal personality traits, autistic traits, obsessive-compulsive traits, depressive symptoms and anxiety symptoms. Subclinical features are represented as nodes and lines between nodes indicated the partial correlation scores between each two nodes. The value of partial correlation was reflected by the thickness of lines, with higher values (stronger correlations) shown by thicker lines. Blue lines are positive correlations while red lines are negative correlations. The circle around nodes indicated predictability value.

**3.3. Predictability and EI**

The mean predictability of the overall network was 43%. The mean predictability of the various subclinical features was as follows: SP traits (55.3%), obsessive-compulsive traits (47.1%), depressive symptoms (57%), anxiety symptoms (53.5%) and autistic traits (26.6%). Interpersonal features also showed the highest predictability (0.639) in the network. Predictability value of each node can be found in the supplementary information (SI\_Table4). EI results are shown in Fig. 2. Interpersonal features had the highest EI (1.67) among all nodes, suggesting that interpersonal features were most influential in the network. Please see supplementary information (SI\_Table4) for details.

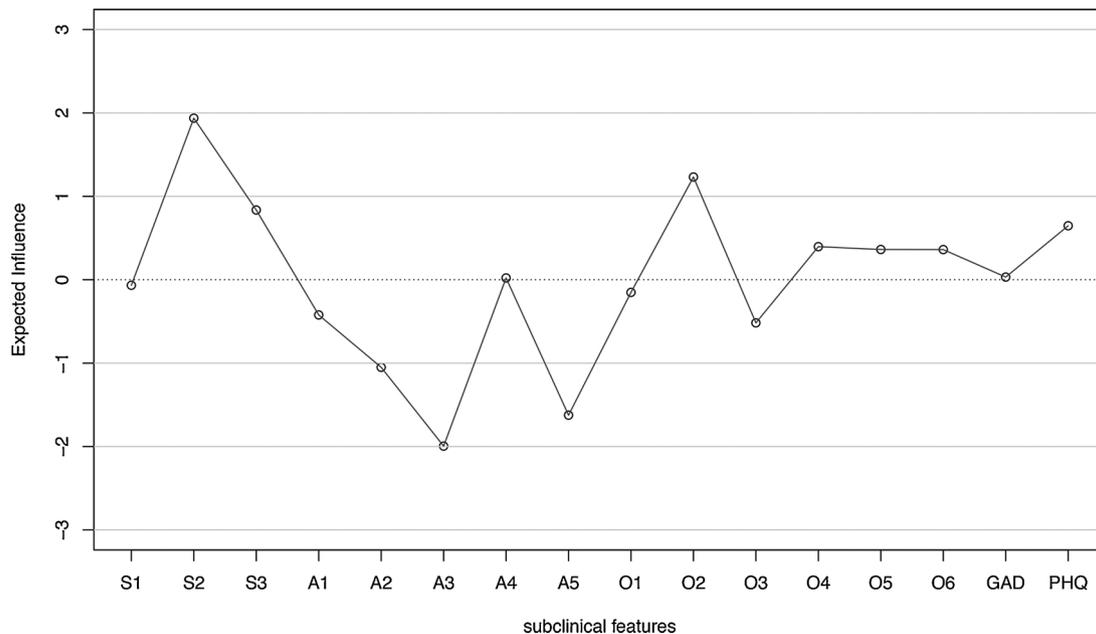
**3.4. Within-network stability**

Bootstrapping stability test of edge-weights showed that the

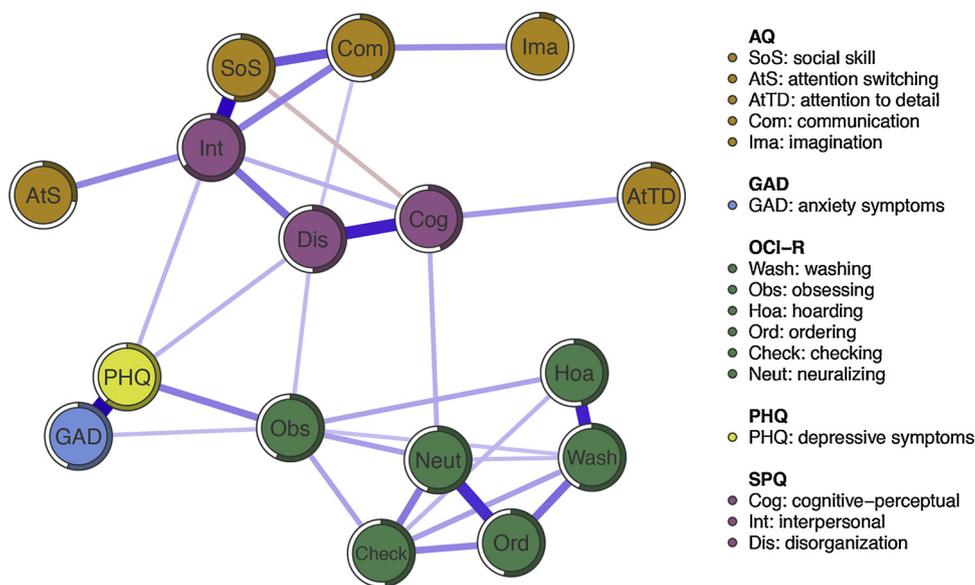
constructed network was stable. Using the default correlation level in bootnet ( $r = 0.70$ ), the Correlation Stability Coefficient (CS-coefficient) for EI was 0.75, which was higher than the recommended value of 0.5 (see supplementary information SI\_Figure 1 and SI\_Figure 2).

**3.5. Between-network replicability**

Network Comparison Test (NCT) showed no significant difference in global connectivity between the main network (NCT sum = 7.28) and the validated sub-sample network (NCT sum = 6.83; NCT difference = 0.45,  $p = 0.135$ ). The correlation coefficient was 0.86 for the network structure and 0.96 for the EI. Fig. 3 shows the network pattern of the validated sub-sample. The EI of the validated sub-sample is shown in Fig. 4.



**Fig. 2.** Expected influence of schizotypal personality traits, autistic traits, obsessive-compulsive traits, depressive symptoms and anxiety symptoms. S1: cognitive-perceptual; S2: interpersonal; S3: disorganization; A1: social skill; A2: attention switching; A3: attention to details; A4: communication; A5: imagination; O1: washing; O2: obsessing; O3: hoarding; O4: ordering; O5: checking; O6: neutralizing.



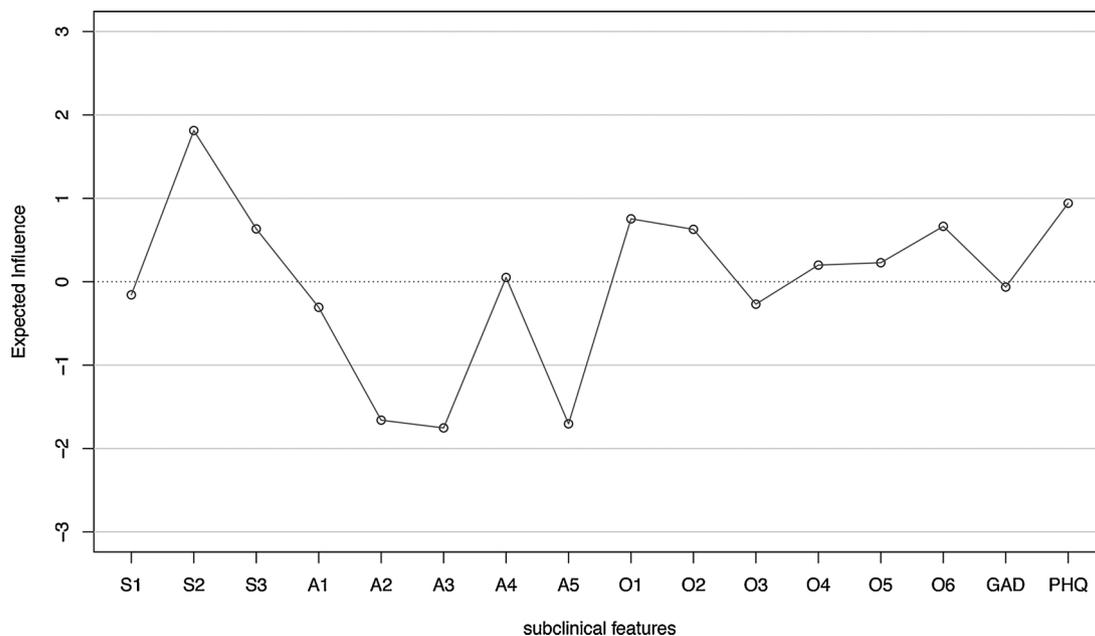
**Fig. 3.** The network structure between schizotypal personality traits, autistic traits, obsessive-compulsive traits, depressive symptoms and anxiety symptoms of the validated subsample. Subclinical features are represented as nodes and lines between nodes indicated the partial correlation scores between each two nodes. The value of partial correlation was reflected by the thickness of lines, with higher values (stronger correlations) shown by thicker lines. Blue lines are positive correlations while red lines are negative correlations. The circle around nodes indicated predictability value.

**4. Discussion**

Adopting network analysis, we modelled the network structure between various facets of SP traits and other subclinical features. For the network pattern, in line with our hypothesis, we found that interpersonal features of SP traits were the main connection between schizotypal and autistic traits, while cognitive-perceptual and disorganization features were the key nodes in the relationship between schizotypal and obsessive-compulsive traits. Depressive symptoms were correlated with all three dimensions of SP traits. Contrary to our hypothesis, anxiety symptoms only correlated with interpersonal features but not cognitive-perceptual features of SP traits. Our findings suggest that subclinical features of different psychiatric disorders are interconnected and that there is clear overlap at the phenotype level. High predictability was observed in the network, suggesting strong mutual dependence between nodes in the network. Interpersonal features

exhibit the greatest EI in the network. The main sample and validated sub-sample showed high similarity in terms of network structure and EI. Moreover, no significant difference in global connectivity was found between these two networks, confirming our hypothesis that the observed relationship is replicable.

Our finding that interpersonal features appeared to be the main connecting node between schizotypal and autistic traits is consistent with previous studies. Correlations between negative schizotypy and autistic traits have been reported in many previous studies (Claridge and McDonald, 2009; Gong et al., 2017; Hurst et al., 2007) and impaired social function is believed to be the shared impairment (Hurst et al., 2007; Russell-Smith et al., 2013). Interpersonal features may impact social abilities, such as social skills and communication, and interactions between interpersonal features and impaired social abilities may promote their respective development. Apart from social abilities and communication, correlations between interpersonal features and



**Fig. 4.** Expected influence of schizotypal personality traits, autistic traits, obsessive-compulsive traits, depressive symptoms and anxiety symptoms of the validated subsample. S1: cognitive-perceptual; S2: interpersonal; S3: disorganization; A1: social skill; A2: attention switching; A3: attention to details; A4: communication; A5: imagination; O1: washing; O2: obsessing; O3: hoarding; O4: ordering; O5: checking; O6: neutralizing.

attention switching were also observed, suggesting that attention switching could interact with interpersonal features independently. This may be determined by the shared genetic factors of the two disorders (Brainstorm, 2018).

We also observed that cognitive-perceptual features of SP traits were connected to Obsessing and Neutralizing features. This finding is consistent with a previous study which found that schizotypal individuals with obsessive-compulsive symptoms demonstrated more cognitive-perceptual features but less interpersonal features than schizotypal individuals without obsessive-compulsive symptoms (Suh *et al.*, 2006). Moreover, obsessive-compulsive symptoms have been found to be correlated with positive schizotypy scores, both in clinical (Norman *et al.*, 2011) and non-clinical samples (Lee and Telch, 2005). Obsessing features refer to uncontrollable thoughts which may be related to ideas of reference found in cognitive-perceptual features, while neutralizing features may reflect strange beliefs resembling odd beliefs or magical thinking found in cognitive-perceptual features. However, we also found that obsessing features were correlated with interpersonal features and disorganization features. This may be related to the content of uncontrollable thoughts, which are often about unsuccessful interpersonal relationships or eccentric behaviours.

Depressive symptoms were found to be correlated with all three dimensions of SP traits, which supports Kemp *et al.* (2018)'s findings that depressive symptoms were significantly correlated with positive schizotypy, negative schizotypy and disorganized schizotypy measured by the Multidimensional Schizotypy Scale (MSS). Relationship between interpersonal features of SP traits and depressive symptoms has been reported in previous studies. For instance, Beck Depression Inventory scores have been found to be correlated with negative schizotypy (Applegate *et al.*, 2009; Lewandowski *et al.*, 2006). Moreover, a recent network analysis based on clinical samples found that depressive symptoms are mostly connected to the anhedonia-asociality dimension of negative symptoms (van Rooijen *et al.*, 2017). Individuals with more interpersonal features are characterized by social anxiety and lack of close friends (Raine, 1991). Social anxiety may cause negative feelings during social activities while the lack of close friends suggests an inability to develop friendship and gain pleasure from friendships. As such, individuals with interpersonal SP features may experience less pleasure during social activities and develop depressive symptoms as a result. Besides, disorganization features were also found to be correlated with depressive symptoms, which is consistent with Fonseca-Pedrero group's finding (Fonseca-Pedrero *et al.*, 2011). Disorganization features are characterized by odd or eccentric behaviour and speech, which may impede social interactions, resulting in fewer friendships, lower self-confidence and depressive symptoms. The weak correlation between depressive symptoms and cognitive-perceptual features suggests that depressive symptoms can directly interact with positive dimensions of SP traits (Kemp *et al.*, 2018).

We only found significant correlation between anxiety symptoms and interpersonal features, but not with cognitive-perceptual features of SP traits. This is consistent with a recent study which found that anxiety symptoms are associated with negative schizotypy measured by the MSS (Kemp *et al.*, 2018). Our results suggest that anxiety symptoms can interact with interpersonal features directly, independent from depressive symptoms. However, we did not find any correlations between anxiety symptoms and cognitive-perceptual features. One possible reason is that anxiety symptoms are associated with the paranoia component of SP traits, which is a component of the four-factor SPQ (Gross *et al.*, 2014), but we adopted the three-factor SPQ in this study, which did not include the paranoia component. Another potential reason is the confounding effects of co-occurring features, such as obsessive-compulsive traits. Indeed, in the network pattern, anxiety symptoms were correlated with obsessive-compulsive traits, which were in turn correlated with cognitive-perceptual features. It is possible that the correlation between anxiety symptoms and cognitive-perceptual features came from obsessive-compulsive traits. However this

possibility should be tested in future studies.

Regarding network interconnectedness, the mean predictability of the network was 43%, indicating that 43% of the variation of nodes can be explained by other nodes in the network. The predictability of this network is higher than the average predictability (34%) of symptoms network, calculated by a meta-analysis based on 18 network studies (Haslbeck and Fried, 2017), indicating that interactions in this network is above the mean level of other mental disorders and therefore may be more suitable for intervention. Furthermore, high predictability was observed in SP traits (55.3%), obsessive-compulsive traits (47.1%), depressive symptoms (57%) and anxiety symptoms (53.5%), while the predictability of autistic traits was relatively low (26.6%). This finding suggests that autistic traits are more likely to be influenced by other factors such as environmental or genetic risks, which may not be amenable to intervention targeting subclinical features in this network.

At the node level, we found that interpersonal features showed the strongest EI among all nodes in the network. It is not surprising because interpersonal features are the main node that connected SP traits with autistic traits, depressive symptoms and anxiety symptoms. Our results suggest that interpersonal features may be the most influential node in the network and may be a potential target for intervention.

Comparison between networks indicates that the observed network is highly similar with the validated sub-sample network, both in network structure and EI. Moreover, the network comparison test results showed no significant difference in global connectivity between the two networks. Therefore, the network we found suggests that the relationship between SP traits and subclinical features of other mental disorders is valid. Compared with SP traits and obsessive-compulsive traits, connected pattern of autistic traits were relatively less stable, which may be due to the fact that the structure of the AQ is less well-designed than other instruments. For instance, the Cronbach's  $\alpha$  coefficient of the AQ was 0.68, which is relatively lower than other instruments (e.g., Cronbach's  $\alpha$  coefficient of SPQ: 0.92; Cronbach's  $\alpha$  coefficient of OCI-R: 0.91).

There are several limitations in this study. First, we only used total scores of the PHQ-9 and the GAD-7 to measure depressive and anxiety symptoms, without considering the sub-dimensions of depression and anxiety (e.g., physical or cognitive symptoms). Moreover, depressive symptoms and anxiety symptoms were states which may be less stable than traits. Secondly, we recruited non-clinical participants in this study and so whether the observed relationship can be generalized to patients with SSD still requires further investigation. Thirdly, only self-report data was included in the present study. Future studies using objective measurements to validate these results are needed. Moreover, we did not recruit an independent sample to validate the replicability of the network pattern. It is not clear whether the observed pattern could be generalized to other populations. Future studies should recruit a wider and more representative independent sample to validate and replicate our findings. Lastly, we did not measure the socio-economic features of the main sample which may influence mental health. Future studies should take the socio-economic features of participants into consideration.

Notwithstanding the above, to the best of our knowledge, this is the first study that comprehensively examines subclinical features using network analysis, in which all confounding effects of co-occurring features are controlled for. This finding echoes findings from a recent study in which different psychiatric disorders were found to display substantial genetic overlaps (Brainstorm, 2018). These findings at both the genotypic and phenotypic levels challenge the validity of the diagnostic boundaries presumed in the current psychiatric classification system. An alternative research strategy to study individual symptom dimensions on their own, rather than diagnostic categories, may be indicated. Specifically, interpersonal features of SP traits, due to its central role in the network, may be a potential target for focused research and intervention development. Moreover, high predictability of the network highlights the potential value of targeting intervention on

SP traits. Future studies could explore the pattern in clinical populations and verify if interpersonal features also occupies a central role in symptoms network.

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### Declaration of Competing Interest

None to be declared.

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### Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.ajp.2019.08.005>.

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