Network structure of psychotic-like experiences in adolescents: links with risk and protective factors

Journal:	*Early Intervention in Psychiatry*
Manuscript ID	EIP-2019-146.R2
Manuscript Type:	Original Article
Date Submitted by the Author:	n/a
Complete List of Authors:	Fonseca-Pedrero, Eduardo ; Universidad de la Rioja, Department of Educational Sciences Muñiz, José García-Portilla, Paz ; University of Oviedo, Psychiatry Bobes, Julio
Keywords:	psychosis risk, psychotic-like experiences, Adolescents, network analysis, extended psychosis phenotype

Network structure of psychotic-like experiences in adolescents: links with risk and protective factors

Running title: Network structure of psychotic-like experiences

Abstract

Background: The main goal was to analyze the network structure of psychotic-like experiences (PLEs) in a large sample of adolescents. In addition, the network structure between PLEs and putative risk (mental health difficulties, suicide ideation and behavior, depression symptoms) and protective factors (prosocial behavior, subjective well-being, and self-esteem) for psychosis was analyzed.

Method: Participants were made up of 1,790 adolescents (M=15.7 years; SD=1.26), 816 men (45.6%), selected by stratified random cluster sampling. Various tools were used to measure PLEs, general psychopathology, suicide ideation and behavior, depression symptoms, prosocial behavior, subjective wellbeing, and self-esteem. The Gaussian graphical model for continuous variables and Ising model for binary variables were used for network estimation.

Results: The PLEs estimated network was strongly interconnected. Unusual perceptual experiences were among the most central nodes. The average predictability of this network was 16.41%. The PLEs and risk and protective factors estimated network showed a high degree of interconnectedness between psychotic experiences and psychopathology domains. PLEs, behavioral problems, and emotional symptoms were among the most central nodes. The mean predictability of this network was 43.46%. The results of the stability and accuracy analysis indicated that networks were accurately estimated.

Conclusions: At population level, extended psychosis phenotype can be conceptualized as a network of interacting cognitive, emotional, and behavioral features. The network model allows us to understand psychosis risk, at the same time opening new lines of study in the mental health arena.

Keywords: psychosis risk; network analyses; psychotic-like experiences; extended psychosis phenotype; adolescents

Psychotic-like experiences (PLEs) are often viewed as phenotypic indicators of the diathesis for psychotic disorders (Linscott & van Os, 2013). Previous follow-up studies have showed that adolescents and young adults who report subclinical expressions of psychosis phenotype (e.g., PLEs, schizotypal traits) have a greater probability of clinical outcome, mainly non-affective psychoses (Debbané et al., 2015; Kaymaz et al., 2012, Zammit et al., 2013). The positive predictive values estimated however are too low (Livny et al., 2018; Sullivan et al., 2020; Zammit et al., 2013). In addition, it must also be noted that PLEs are moderately common during adolescence. The median prevalence is 7.5% (Kelleher et al., 2012). While PLEs are usually transient in about 80% of adolescents and young adults, around 20% go on to develop persistent psychotic experiences, and 7% go on to develop a psychotic disorder (annual transition rate of 0.5-1%) (van Os & Linscott, 2012). These findings converge to suggest that attenuated psychotic experiences, as a tentative index of the behavioral expression of vulnerability for psychotic disorders, may be useful for understanding the etiological mechanisms as well as for developing prevention strategies (Fonseca Pedrero & Debbané, 2017; McGorry, Ratheesh, & O'Donoghue, 2018).

Several risk factors have been associated with psychotic disorders, displaying different levels of evidence (Keskinen, et al., 2019; Linscott & van Os, 2013; Oliver et al., 2019; Radua et al., 2018). In particular, subclinical expression of psychosis phenotype (e.g., clinical high-risk states for psychosis, PLEs, and schizotypal traits) have shown to be one of the main risk factors for psychosis. In order to improve our prevention capacity, we need to incorporate known risk factors within and between multiple levels of analysis (e.g., genetic, psychophysiological, cognitive, psychopathological, demographic). At a phenotypic level, the link between psychotic experiences and a later psychotic disorder, may be stronger depending on the concomitant presence of affective dysregulation, family history of a mental disorder, and lower socio-economic status (Klrll, et al., 2019; Pries et al., 2018; van os & Linscott, 2012). In addition, previous research has shown that PLEs are also associated bidirectionally, amongst others, with emotional and behavioural problems, suicidality, non-suicidal self-injury, depression, and substance use (Armando et al., 2010; Bolhuis et al., 2018; Fonseca-Pedrero, Inchausti, Pérez-Albéniz, & Ortuño-Sierra, 2018;

Fonseca-Pedrero et al., 2019; Yung et al., 2006). In this sense, evidence suggests that the combination of well-known risk factors such as cannabis use, psychopathology, childhood adversity, and urbanicity, in interaction with proxy measures of genetic risk, may facilitate the onset of psychosis (e.g., Radhakrishnan, et al., 2019).

Risk factors for psychosis have been extensively investigated. It must be noted however, that protective factors as a variable associated with a decrease in the likelihood of developing illness (that are not reciprocal to risk factors), are understudied. To date, no protective factors have shown a convincing level of evidence in the prevention of psychosis (Keskinen et al., 2018; Oliver et al., 2019; Radua et al., 2018). For instance, Radua et al. (2018), after conducting an umbrella review, identified no protective factors with a strong level of evidence. According to Oliver et al. (2019) the analysis in new studies of protective factors such as self-esteem, social support, and resilience in this arena is relevant. It is therefore crucial to analyse the role of protective factors in symptom formation and prognosis in order to develop effective preventive intervention.

In order to provide new insights into the psychosis field, the incorporation of new approaches such as the network model is relevant in the complementation of the traditionally DSM categorical approach to psychopathology. Basically, the network model is evolving as an alternative to the biomedical model, which is commonly used by the leading nosological systems and based on a common cause model (Borsboom, 2017; Borsboom & Cramer, 2013; Fried et al., 2016). From a network perspective, mental disorders such as psychosis can be seen as emergent properties that arise from mutual interactions between symptoms (signs, traits, mental states, etc.) (Borsboom, 2017; Fonseca-Pedrero, 2017a; McNally et al., 2014; Schmittmann et al., 2013).The network model has been argued within the psychosis field. Specifically, Van Os and Linscott (2012) introduced a network model onset of psychotic disorders which, in line with previous research, can be used to outline that psychosis phenotype, at both a clinical and non-clinical level, can be seen as network systems of interacting cognitive, emotional, behavioral, and social traits (e.g. Fonseca-Pedrero, et al., 2018; Isvoranu, Borsboom, van Os, & Guloksuz, 2016; Isvoranu et al., 2019; Wüsten et al., 2018).

A wide variety of issues remain to be resolved in the extended psychosis phenotype research. To date, for instance, there has been no in-depth examination into the network structure of PLEs and their relationship with cognitive, emotional, and behavioral indicators during adolescence. Interestingly, no previous studies have analyzed simultaneously the role of known protective factors and risk factors in the extended psychosis phenotype from a network perspective. It is therefore necessary to gain a deeper understanding of the nature and structure of the multidimensional psychosis liability at population level, going beyond diagnostic systems and traditional approaches (e.g., based on macrophenotypes, categorical diagnosis, common cause model, and static viewpoint). In addition, adolescence is considered as a crucial developmental stage during which the first psychotic experiences and mental health difficulties may emerge (e.g., Bolhuis, et al., 2018; Dalsgaard et al., 2019, Fusar-Poli, 2019). Thus, it is relevant to understand etiological mechanisms as well as risk and protective factors for psychosis, in order to improve the likelihood of positive outcomes and develop effective youth mental health services.

Within this research framework, the main goals of the present study were: a) analyse the network structure of PLEs in a large sample of adolescents; and b) examine the network structure between PLEs, putative risk (mental health difficulties, suicide ideation and behaviour, and depression symptoms), and protective factors (prosocial behaviour, subjective well-being, and self-esteem) for psychosis. In light of the available evidence, it can be hypothesised that PLEs show a high degree of interconnectedness. In addition, PLEs would be positively associated with risk factors and negatively associated with protective factors.

Method

Participants

The sample was selected using stratified random cluster sampling, with the classroom as the sampling unit, from students of La Rioja (region located northern Spain). The students belonged to different public and charter Secondary and Vocational Training Schools, and to different socio-economic levels. The layers were created as a function of the geographical zone and the educational stage. The study was conducted in 2019.

The initial sample consisted of 1,881 students, eliminating those participants who presented a high score on the Oviedo Infrequency Response Scale (more than 3 points) (n = 104), an age older than 18 (n = 170) or did not complete the tests battery (n = 101). Participants were 1790 students, 816 males (45.6%), 961 (53.7%) females, and 13 (0,7%) other gender identity. The mean age was 15.7 years (SD = 1.26; age range = 14 to 18 years old). Distribution by age was: 14 years, n= 342; 15 years, n=511; 16 years, n=410; 17 years, n=399; and 18 years, n=198.

Nationality distribution of the participants was as follows: 89.9% Spanish; 3.7% Latin American (Bolivia, Argentina, Colombia, and Ecuador); 2.4% Romanian; 1% Moroccan; 0.7% Portuguese; 0.7% Pakistani, and 2% other nationalities.

Instruments

The Prodromal Questionnaire–Brief (PQ-B) (Loewy, Pearson, Vinogradov, Bearden, & Cannon, 2011). The PQ-B is a self-report tool designed for the evaluation of PLEs and subclinical psychosis symptoms. This tool consists of a total of 21-items with a dichotomous response system (true/false). The PQ-B asks additional questions regarding extent/severity of impairment and distress, rated on a Likert-type (1= “Strongly disagree”, 5= “Strongly agree”). The validation of the PQ-B into Spanish has shown adequate psychometric properties (Fonseca-Pedrero, Inchausti, Pérez-Albéniz, & Ortuño-Sierra, 2018).

The Paykel Suicide Scale (PSS) (Paykel, Myers, Lindenthal, & Tanner, 1974). The PSS is an instrument developed to measure suicidal ideation and behaviour in the last year. It consists of a total of five items with a dichotomous response system of Yes/No. The PSS has shown adequate psychometric properties in samples of Spanish adolescents (Fonseca-Pedrero et al., 2018).

The Strengths and Difficulties Questionnaire (SDQ) *self-report version* (Goodman, 1997). The SDQ is a tool used to measure prosocial capacities and emotional and behavioural difficulties in adolescents. It can be used as a measure of general psychopathology. It consists of a total of 25 items with a Likert-type response format (0 = “Not true”, 1 = “Somewhat true”, 2 = “Certainly true”). SDQ items are grouped in five subscales (Hyperactivity, Conduct problems, Peer problems, Emotional symptoms, and Prosocial behaviour). The psychometric

properties of the SDQ Spanish version have been exanimated in previous studies (Ortuño-Sierra, Chocarro, Fonseca-Pedrero, Riba, & Muñiz, 2015).

The Personal Wellbeing Index-School Children (PWI-SC) (Cummins & Lau, 2005). The PWI-SC contains eight items of satisfaction, corresponding to different quality of life domains: standard of living, personal health, achievement in life, personal relationships, personal safety, feeling part of the community and future security. Each item is rated on a 0- to 10-scale (0 = Very Sad; 10 = Very Happy). Item "How happy are you with your life as a whole" was used in the present study. Previous studies have demonstrated that this instrument has adequate psychometric properties in Spanish adolescents (Fonseca-Pedrero, 2017b).

The Reynolds Adolescent Depression Scale-Short From (RADS-SF) (Reynolds, 2002). The RADS-SF is a self-report developed to measure depressive symptoms during adolescence. Brief RADS includes a total of 10 items rated on a 4-point Likert-type response scale (1 = almost never, 4 = almost always). The version validated into Spanish has been used in the present study (Ortuño-Sierra et al., 2017).

The Rosenberg Self-esteem Scale (Rosenberg, 1965). This self-report tool is a one-dimensional scale that allows us to assess self-esteem. It is composed of 10 items that should be scored on a Likert scale of 4 points (1 = Strongly disagree and 4 = Strongly agree). The Spanish version that has shown adequate psychometric properties has been used (Fonseca-Pedrero, 2017b).

The Oviedo Infrequency Scale (INF-OV) (Fonseca-Pedrero, et al., 2009). INF-OV was used in order to detect those participants who responded in a dishonest manner. The INF-OV is a self-report tool composed of 12 items rated on a 5-point Likert-type response scale (1 = "Completely disagree"; 5 = "Completely agree"). Adolescents with more than 3 incorrect responses were removed from the study. (Example item: "*The distance between Madrid and Barcelona is greater than the distance between Madrid and New York*"). The Spanish version of INF-OV has been used in previous research (Fonseca-Pedrero et al., 2019).

Procedure

The Research Ethics Committee of La Rioja (CEImLAR) has approved the present research. The instruments were administered collectively via personal computers in classrooms of 10 to 30 students during a standard one-hour session and in rooms particularly prepared for this goal. For individuals under the age of 18, parents were asked to provide written informed consent. Participants were free to withdraw from the study at any time. No incentive was provided for their participation. Confidentiality was guaranteed to all participants.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data analyses

First, the descriptive statistics of PQ-B items and all measures used were computed.

Second, two networks were estimated. First, network of PLEs. Second, network of PLEs and risk (general psychopathology, suicide ideation and behavior, and depression symptoms) and protective factors (subjective well-being, prosocial behavior, and self-esteem). Due to the dichotomous nature of the PQ-B items, we estimated an Ising model for the PLEs network. For the second network, due also to the continuous nature of the measures, we estimated a Gaussian Graphical Model (GGM) (Epskamp & Fried, 2018). In this network, sum scores of instruments rather than individual items were used. The details of network analysis were documented in-depth elsewhere (Epskamp, Borsboom, & Fried, 2018; Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012).

A network consists of nodes (here PQ-B items or subscales and total scores of each measuring instrument) and edges (unknown statistical relationships between nodes that need to be estimated). Partial correlations were used: if two nodes are connected in the resulting graph via an edge, they are statistically related after controlling for all other variables in the network; if they are unconnected, they are conditionally independent. For the layout, the Fruchterman-Reingold algorithm was used, placing the strongly connected nodes

closer to each other and the least connected nodes far apart (Epskamp et al., 2012).

Concordantly to previous studies examining network (e.g., Fonseca-Pedrero, Ortuño et al. 2018), we estimated two inference measures: Expected Influence (EI) and predictability. EI identifies the most important nodes within a network graph (Robinaugh, Millner, & McNally, 2016). We use EI instead of strength centrality in order to avoid possible problems associated with centrality measures (Haslbeck & Fried, 2017; Opsahl, Agneessens, & Skvoretz, 2010). Strength centrality uses the sum of absolute weights (i.e., negative edges are turned into positive edges before summing), which distorts the interpretation if negative edges are present (such as in the present article). The predictability of each node indicates the shared variance of a node with all the other nodes with which it is connected. In the visualization of the networks, the circles around the nodes can be interpreted as the R^2 (the explained variance of the node). The predictability was computed using the *mgm* package (Haslbeck & Fried, 2017).

Network stability and accuracy were estimated using the bootstrapping analysis implemented in the *bootnet* package in *R* (Epskamp, Borsboom, & Fried, 2018).

We employed SPSS 22.0 (IBM Corp Released, 2013) and *R* (R Core Team, 2016) to perform data analyses.

Results

Descriptive statistics

The descriptive statistics of PQ-B items are shown in the supplementary material (Table S1). The descriptive statistics of all measures are depicted in Table 1. 87.7% of the adolescents responded positively to at least one statement of the PQ-B. In addition, 18.8% of the individuals scored equal or higher than nine points on the total frequency score of the PQ-B.

----------Insert Table 1 about here ----------

Network structure of psychotic-like experiences

The PLEs estimated network showed a high degree of interconnectedness. All associations between edges were positive (see Figure 1). Figure 2 depicts standardized EI values. The most central nodes in terms of

EI were items 10 (“Do you sometimes feel suddenly distracted by distant sounds that you are not normally aware of?”) and 11 (“Have you had the sense that some person or force is around you, although you couldn’t see anyone?”). Predictability ranged from 0% (item 3, “Do things that you see appear different from the way they usually do (brighter or duller, larger or smaller, or changed in some other way”) to 41% (item 8, “Do you feel that other people are watching you or talking about you?”) (see Figure 1). The average predictability of this estimated network was 16.52%.

----------Insert Figures 1 and 2 about here ----------

Network structure of psychotic-like experiences and putative risk and protective factors for psychosis

Figure 3 shows the estimated network for PLEs and risk and protective factors for psychosis. First, this network showed a high degree of interconnectedness, with strong edges between psychotic experiences and risk factors (psychopathology domains). Second, when the effect of all variables in the network were controlled, no clear associations between PLEs and protective factors (prosocial behaviour, self-esteem, and subjective well-being) were found. Third, protective factors were more closely related with each other and, at the same time, inversely related with risk factors. The central nodes in terms of standardized EI were PLEs, behavioral problems, and emotional symptoms. Results are depicted in Figure 4. Predictability ranged from 7.4% (PLEs distress) to 72.9% (depression symptoms). The average predictability of this estimated network was 43.46%. Figure 5 depicts a flow diagram showing how PQ-B node is connected to all other nodes of the network.

---------- Insert Figures 3, 4 and 5 about here ----------

Network stability

The results of the stability and accuracy analysis (Epskamp et al., 2018) indicated that PLEs network was accurately estimated. Stability analysis indicate that this network is accurately estimated, with moderate confidence intervals

around the edge weights. Details are accessible in supplementary material (Figures S1-S4).

Discussion

To date, the network structure of PLEs, using the PQ-B (Loewy et al., 2011), and its link with some tentative risk and protective factors for psychosis has not been clearly delimited in community-derived samples of adolescents. To the best of our knowledge, this is the first work to examine the empirical network structure of PLEs and its association with a large number of cognitive, affective, and behavioural psychometric indicators. Thus, the present study used network analysis to examine the extended psychosis phenotype (e.g., specific symptom-symptom associations) during adolescence, a relevant stage of human development where there is an increasing incidence of mental disorders and psychopathological symptoms (e.g., Bolhuis, et al., 2018; Dalsgaard et al., 2019, Fusar-Poli 2019).

At symptom level, the psychotic experiences were positively interconnected. Unusual perceptual experiences were among the most central nodes in this network. The average predictability was 36.27%, implying that substantial variability remained unexplained. These results are also congruent with previous studies that have conducted network analysis across the different manifestations of extended psychosis phenotype, as schizotypy (Fonseca Pedrero, et al., 2020; Christensen, Kenett, Aste, Silvia, & Kwapil 2018), schizotypal personality traits (Fonseca-Pedrero, Ortuño et al., 2018), and PLEs in adults (Murphy, McBride, Fried, & Shevlin, 2018 Wüsten et al., 2018). For instance, Murphy et al. (2018) found that estimated network showed strong interconnectivity between PLEs, where nodes indicating paranoia were among the most central. In another, multinational study, Wüsten et al. (2018) found that the network of PLEs was significantly less connected in low- and middle-income countries (i.e., PLEs had less clinical relevance) compared to high-income countries.

The results found in the present study allow us to improve our understanding of extended psychosis phenotype. Network analysis conducted at experiences/symptoms level also allow for a fine-grained examination of extended psychosis phenotype at population level. In this sense, network

analyses provide an informative way to describe the complex relationships between a set of key variables (e.g., PLEs), by focusing on the local interactions at the level of smaller units that compose the psychological problems, and not at a disorder level. For instance, we found that unusual perceptual experiences played a relevant role in the PLEs estimated network. In fact, perceptual abnormalities and bizarre experiences reported by adolescents may be more malignant forms of psychotic symptoms compare to others such as magical thinking (Yung et al., 2006). Overall, these results might serve as an informant of early detection and prevention strategies in targeting, for instance, unusual perceptual experiences in adolescents of the general population.

At domain level, differential associations between psychotic experiences and putative risk and protective factors for psychosis were found. In particular, suicide ideation and behaviour, emotional and behavioural problems, and depression were positively associated with PLEs. The most central nodes were PLEs, emotional symptoms, and behavioral problems, which may be relevant targets in order to develop preventive strategies in this sector of the population. Interestingly, protective factors like prosocial behaviour, self-esteem, and subjective well-being were more closely associated with each other and, at the same time, negatively related with psychopathology domains. However, contrary to our previous expectations, when the effect of all nodes in the network were controlled (i.e., partial correlations), protective factors showed no clear association with PLEs (frequency or distress scores). To this regard, several issues have to be mentioned. First, in this network the nodes have a very different meaning than the nodes that represent PLEs (occurrence and distress). In fact, they capture different concepts (compared to symptomatology) and also span different time-ranges (e.g., well-being seems to represent a much more stable concept than volatile PLEs). Second, protective factors might impact directly on the PLEs expression and severity or indirectly throughout other variables and mechanisms (e.g., emotional dysregulation). Third, it is plausible to argue that a good subjective quality of life, prosocial behavior, or self-esteem might act as protective factors; however, this is a tentative hypothesis because protective factors research within the extended psychosis phenotype is limited (e.g., Oliver et al., 2019; Radua et al., 2018), and highlights the need for more research.

To the best of our knowledge, no previous studies have analyzed the network structure of PLEs and their links with known risk and protective factors for psychosis using multiple psychometric indicators in a large sample of adolescents. That being said, these results are consistent with previous studies conducted in both adolescents (Fonseca-Pedrero et al., 2020) and adult populations (Zhang et al., 2019). For example, Fonseca-Pedrero et al. (2020), using a network analysis in a representative sample of adolescents, found that PLEs frequency and associated distress were the most central nodes in the estimated network. Psychotic experiences were also strongly associated with schizotypy and psychopathology. In adult populations, for example, Zhang et al. (2019), investigated the network structure between schizotypal traits and autistic traits, obsessive-compulsive traits, depressive symptoms, and anxiety symptoms in a college sample. They found that schizotypal features were highly overlapped with depressive symptoms. Furthermore, the results found here are congruent with those studies that show that PLEs during adolescence are associated, amongst other, with emotional and behavioural problems, suicidality, and depression (Armando et al., 2010; Bolhuis et al., 2018; Fonseca-Pedrero et al, 2018; Fonseca-Pedrero et al., 2019; Kelleher et al., 2013; Schimanski, Mouat, Billinghurst, & Linscott, 2017; Yung et al., 2006). Overall, the results add empirical support to the extended psychosis phenotype indicating that PLEs (occurrence and associated distress) are directly associated with emotional dysregulation and psychopathology in adolescent populations.

These findings are congruent with the modern paradigms to promote a multidimensional, dynamic, transdiagnostic, preventative, and staging approach where interacting factors at multiple levels may influence in the liability for psychopathology and clinical outcomes (e.g., Fusar-Poli, McGorry, & Kane, 2017; McGorry & van Os, 2013; van Os & Guloksuz, 2017; van Os & Reininghaus, 2016). In addition, these results can be understood under the umbrella of the psychosis proneness-persistence-impairment model (van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009) and the network model of onset psychotic disorders (Linscott & van Os, 2012). From this approach PLEs may causally impact on each other over time. In addition, if these network-type dynamic interactions are associated, amongst others, with psychopathology dimensions (e.g., emotional dysregulation), environmental exposures (e.g.,

trauma) and/or genetic background (e.g., family members with psychosis), psychotic experiences may become persistent and lead then to clinical impairment. These network interactions can be viewed as a fundamental part of the psychosis risk picture. In fact, from an integrated network model (Looijestijn et al., 2015), psychosis may be the outcome of the dynamic interplay within and between multiple scale levels of organization (e.g., genetic, brain, cognitive, psychopathology, cultural), that are changing over time and across individuals. Finally, as Lenzenweger (2010) pointed out, psychosis (and mental disorders) represent complex configural outcomes of multiple interacting systems that cannot be reduced to a mere collection of constituent parts. Future research may integrate the multitude of data across levels found in psychosis as well as psychopathological processes into a single network model.

A number of limitations of the present study must be acknowledged. First, in this study estimated networks were based only on positive PLEs. Future studies must also consider negative and disorganization dimensions of the extended psychosis phenotype. Second, we used self-report measures which are associated with well-known limitations. Third, this study was not a follow-up design, so we cannot make cause-effect interpretations. In this regard, and according to previous studies (Murphy et al., 2018) the current data did not allow an opportunity to assess PLEs prospectively or temporally in order to examine dynamic interactions. Fourth, here we have considered the psychometric indicators as index of risk or protective factors for psychosis, however it is also plausible that these variables (e.g., suicide behaviour) could be seen as another domain of psychopathology, or even as an outcome. Fifth, the structure of the estimated networks is clearly limited by the tool used and constructs measured. Finally, network modelling is currently in its initial stages (Guloksuz, Pries, & van Os, 2017). Although it is shown as a promising tool in obtaining information in a number of research fields, there remain to be limitations and resolution issues (Jones, Heeren, & McNally, 2017; Letina et al. 2019).

Conclusions

The present study aimed to use network analyses to gain insight into the relationships between PLEs themselves and their links with putative risk and protective factors for psychosis. The results found that at symptom level, PLEs

showed a high degree of interconnectedness. PLEs were also positively associated with psychopathology domains. No clear associations between PLEs and protective factors were found.

New approaches such as network model, may provide new insights into the conceptualization, assessment, and prevention in the field of psychosis. Future studies require to further explore the temporal dynamics between the PLEs and risk and protective factors across multiple levels in order to understand the underlying mechanisms and identify potential treatment targets. The network model allows us to understand mental health problems such as psychosis from a different lens, opening new lines of study.

Financial support

This research was supported by FEDER La Rioja 2014-2020 (SRS 6FRSABC026).

Conflict of interest

The authors have declared that there are no conflicts of interest in relation to this study.

References

Armando, M., Nelson, B., Yung, A. R., Ross, M., Birchwood, M., Girardi, P., & Nastro, P. F. (2010). Psychotic-like experiences and correlation with distress and depressive symptoms in a community sample of adolescents and young adults. *Schizophrenia Research*, *119*, 258–265. doi: 10.1016/j.schres.2010.03.001.

Bolhuis, K., Koopman-Verhoeff, M. E., Blanken, L. M. E., Cibrev, D., Jaddoe, V. W. V., Verhulst, F. C., … Tiemeier, H. (2018). Psychotic-like experiences in pre-adolescence: what precedes the antecedent symptoms of severe mental illness? *Acta Psychiatrica Scandinavica*, *138*, 15-25. https://doi.org/10.1111/acps.12891

Borsboom, D. (2017). A network theory of mental disorders. *World Psychiatry*, *16*, 5–13. doi: 10.1002/wps.20375.

Borsboom, D., & Cramer, A. O. (2013). Network analysis: an integrative

approach to the structure of psychopathology. *Annual Review of Clinical Psychology*, *9*, 91–121. doi: 10.1146/annurev-clinpsy-050212-185608.

Cummins, R. A., & Lau, A. L. D. (2005). *Personal Well-being Index – School Children* (3rd Edition). Melbourne: Deakin University.

Christensen, A.P., Kenett, Y.N., Aste, T., Silvia, P.J., & Kwapil, T.R. (2018). Network structure of the Wisconsin Schizotypy Scales–Short Forms: Examining psychometric network filtering approaches. *Behavior Research Methods, 50*, 2531–2550. doi:10.3758/s13428-018-1032-9.

Debbané, M., Eliez, S., Badoud, D., Conus, P., Flückiger, R., & Schultze-Lutter, F. (2015). Developing psychosis and its risk states through the lens of schizotypy. *Schizophrenia Bulletin*, *41*, S396-407. doi: 10.1093/schbul/sbu176.

Dalsgaard, S., Thorsteinsson, E., Trabjerg, B.B., Schullehner, J., Plana-Ripoll, O., … Pedersen, C.B. (2019). Incidence rates and cumulative incidences of the full spectrum of diagnosed mental disorders in childhood and adolescence. *JAMA Psychiatry*, doi: 10.1001/jamapsychiatry.2019.3523

Epskamp, S., & Fried, E. (2018). A tutorial on regularized partial correlation networks. *Psychological Methods*, *23*, 617-634. doi: 10.1037/met0000167

Epskamp, S., Borsboom, D., & Fried, E. I. (2018). Estimating psychological networks and their accuracy: a tutorial paper. *Behavior Research Methods*, *50*, 195-212. doi: 10.3758/s13428-017-0862-1.

Epskamp, S., Cramer, A., Waldorp, L. J., Schmittmann, V. D., & Borsboom, D. (2012). Qgraph: Network visualizations of relationships in psychometric data. *Journal of Statistical Software*, *48*, 1–18. https://doi.org/10.18637/jss.v048.i04

Fonseca-Pedrero, E. (2017a). Network analysis: A new way of understanding psychopathology? *Revista de Psiquiatria y Salud Mental*, *10*, 206-215. https://doi.org/10.1016/j.rpsm.2017.06.004.

Fonseca-Pedrero, E. (2017b). *Bienestar emocional en adolescentes riojanos [Personal wellbeing in adolescents from La Rioja]*. La Rioja: Universidad de La Rioja.

Fonseca-Pedrero, E., Inchausti, F., Pérez, L., Aritio, A., Ortuño-Sierra, J., Sánchez-García, A., … Pérez de Albéniz, A. (2018). Suicidal ideation in a community-derived sample of Spanish adolescents. *Revista de Psiquiatria y Salud Mental*, *11*, 76-85. doi: 10.1016/j.rpsm.2017.07.004.

Fonseca-Pedrero, E, Lemos-Giráldez, S., Paino, M., Villazón-García, U., & Muñiz, J. (2009). Validation of the Schizotypal Personality Questionnaire Brief form in adolescents. *Schizophrenia Research*, *111*, 53–60.

Fonseca-Pedrero, E., Inchausti, F., Pérez-Albéniz, A., & Ortuño-Sierra, J. (2018). Validation of the Prodromal Questionnaire–Brief in a representative sample of adolescents: Internal structure, norms, reliability, and links with psychopathology. *International Journal of Methods in Psychiatric Research*.

https://doi.org/10.1002/mpr.1740

Fonseca-Pedrero, E., Ortuño-Sierra, J., Muñiz, J., & Bobes, J. (2019). Latent profile analysis of psychosis liability in a community-derived sample of adolescents: Links with mental health difficulties, suicidal ideation, bipolar-like experiences and psychotic-like experiences. *Early Intervention in Psychiatry, 13*, 1111-1120. doi: 10.1111/eip.12741.

Fonseca-Pedrero, E., Ortuño-Sierra, J., Inchausti, F., Rodríguez-Testal,J.F., & Debbané, M. (2020). Beyond clinical high-risk state for psychosis: the network structure of multidimensional psychosis liability in adolescents. *Frontriers Psychiatry*, 10, 967. doi: 10.3389/fpsyt.2019.00967

Fonseca-Pedrero, E., Ortuño, J., Debbané, M., Chan, R. C. K., Cicero, D., Zhang, L. C., … Fried, E. I. (2018). The network structure of schizotypal personality traits. *Schizophrenia Bulletin*, *44*, S468–S479. https://doi.org/10.1093/schbul/sby044

Fonseca Pedrero, E., & Debbané, M. (2017). Schizotypal traits and psychotic-like experiences during adolescence: An update. *Psicothema*, *29*, 5–17. doi: 10.7334/psicothema2016.209.

Fried, E. I., van Borkulo, C. D., Cramer, A. O. J., Boschloo, L., Schoevers, R. A., & Borsboom, D. (2016). Mental disorders as networks of problems: a review of recent insights. *Social Psychiatry and Psychiatric Epidemiology*, *58*, 7250–7257. https://doi.org/10.1007/s00127-016-1319-z

Fusar-Poli P. (2019). Integrated mental health services for the developmental period (0 to 25 years): a critical review of the evidence. *Frontiers in psychiatry, 10*, 355. https://doi.org/10.3389/fpsyt.2019.00355

Fusar-Poli, P., McGorry, P., & Kane, J. (2017). Improving outcomes of first-episode psychosis: an overview. *World Psychiatry*, *16*, 251-265. doi: 10.1002/wps.20446.

Goodman, R. (1997). The strengths and difficuties questionnaire: a research note. *Journal of Child Psychology and Psychiatry*, *38*, 581–586.

Guloksuz, S., Pries, L.-K., & van Os, J. (2017). Application of network methods for understanding mental disorders: pitfalls and promise. *Psychological Medicine*, 1–10. https://doi.org/10.1017/S0033291717001350

Haslbeck, J. M. B., & Fried, E. I. (2017). How predictable are symptoms in psychopathological networks? a reanalysis of 17 published datasets. *Psychological Medicine, 47*, 2767-2776. doi: 10.1017/S0033291717001258

Huang, X., Fox, K. R., Ribeiro, J. D., & Franklin, J. C. (2018). Psychosis as a risk factor for suicidal thoughts and behaviors: A meta-analysis of longitudinal studies. *Psychological Medicine*, *48*, 765-776. https://doi.org/10.1017/S0033291717002136

IBM Corp Released. (2013). *IBM SPSS Statistics for Windows, Version 22.0*. Armonk, NY: IBM Corp.

Isvoranu, A.-M., Borsboom, D., van Os, J., & Guloksuz, S. (2016). A network approach to environmental impact in psychotic disorder: brief theoretical framework. *Schizophrenia Bulletin*, *42*, 870–873. https://doi.org/10.1093/schbul/sbw049

Isvoranu, A.M., Guloksuz, S., Epskamp, S., van Os, J., Borsboom, D., & GROUP Investigators. (2019). Toward incorporating genetic risk scores into symptom networks of psychosis. *Psychological Medicine,* doi: 10.1017/S003329171900045X. [Epub ahead of print]

Jones, P. J., Heeren, A., & McNally, R. J. (2017). Commentary: A network theory of mental disorders. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.01305

Kaymaz, N., Drukker, M., Lieb, R., Wittchen, H. U., Werbeloff, N., Weiser, M., … van Os, J. (2012). Do subthreshold psychotic experiences predict clinical outcomes in unselected non-help-seeking population-based samples? A systematic review and meta-analysis, enriched with new results. *Psychological Medicine*, *42,* 2239-2253. doi: 10.1017/S0033291711002911.

Kelleher, I., Connor, D., Clarke, M. C., Devlin, N., Harley, M., & Cannon, M. (2012). Prevalence of psychotic symptoms in childhood and adolescence: a systematic review and meta-analysis of population-based studies. *Psychological Medicine*, *42,* 1857-1863. doi: 10.1017/S0033291711002960

Kelleher, I., Corcoran, P., Keeley, H., Wigman, J. T., Devlin, N., Ramsay, H., … Cannon, M. (2013). Psychotic symptoms and population risk for suicide attempt: a prospective cohort study. *JAMA Psychiatry*, *70*, 940–948. doi: 10.1001/jamapsychiatry.2013.140.

Keskinen, E., Marttila, R., Koivumaa-Honkanen, H., Moilanen, K., Keinänen-Kiukaanniemi, S., Timonen, M., … Jääskeläinen, E. (2018). Search for protective factors for psychosis – a population-based sample with special interest in unaffected individuals with parental psychosis. *Early Intervention in Psychiatry*, *12*, 869-878. doi: 10.1111/eip.12380.

Klrll, U., Binbay, T., Drukker, M., Elbi, H., Kayahan, B., Gökçelli, D. K., … Van Os, J. (2019). DSM outcomes of psychotic experiences and associated risk factors: 6-year follow-up study in a community-based sample. *Psychological Medicine*, *49*, 1346-1356. doi: 10.1017/S0033291718001964.

Lenzenweger, M. F. (2010). *Schizotypy and schizophrenia: The view from experimental psychopathology*. New York: Guilford Press.

Letina, S., Blanken, T.F., Deserno, M.K., & Borsboom, A.C. (2019). Expanding network analysis tools in psychological networks: minimal spanning trees, participation coefficients, and motif analysis applied to a network of 26 psychological attributes. *Complexity.* Article ID 9424605, https://doi.org/10.1155/2019/9424605

Linscott, R. J., & van Os, J. (2013). An updated and conservative systematic

review and meta-analysis of epidemiological evidence on psychotic experiences in children and adults: on the pathway from proneness to persistence to dimensional expression across mental disorders. *Psychological Medicine*, *43*, 1133–1149. doi: 10.1017/S0033291712001626

Livny, A., Reichenberg, A., Fruchter, E., Yoff, R., Goldberg, S., Fenchel, D., … Weiser, M. (2018). A population-based longitudinal study of symptoms and signs before the onset of psychosis. *Amercian Journal of Psychiatry*, *175*, 351-358. doi: 10.1176/appi.ajp.2017.16121384.

Loewy, R. L., Pearson, R., Vinogradov, S., Bearden, C. E., & Cannon, T. D. (2011). Psychosis risk screening with the Prodromal Questionnaire--brief version (PQ-B). *Schizophrenia Research*, *129*, 42-46. doi: 10.1016/j.schres.2011.03.029.

Looijestijn, J., Blom, J. D., Aleman, A., Hoek, H. W., & Goekoop, R. (2015). An integrated network model of psychotic symptoms. *Neuroscience and Biobehavioral Reviews*, 59, 238–250. https://doi.org/10.1016/j.neubiorev.2015.09.016

McGorry, P. D., Ratheesh, A., & O'Donoghue, B. (2018). Early intervention—an implementation challenge for 21st century mental health care. *JAMA Psychiatry*, *75*(6), 545–546. https://doi.org/10.1001/jamapsychiatry.2018.0621

McGorry, P., & Van Os, J. (2013). Redeeming diagnosis in psychiatry: Timing versus specifi city. *The Lancet*, *381*(9863), 343–345. https://doi.org/10.1016/S0140-6736(12)61268-9

McNally, R. J., Robinaugh, D. J., Wu, G. W. Y., Wang, L., Deserno, M. K., Borsboom, D., … Borsboom, D. (2014). Mental disorders as causal systems : a network approach to posttraumatic stress disorder. *Clinical Psychological Science*, *3*(6), 1–14. https://doi.org/10.1177/2167702614553230

Murphy, J., McBride, O., Fried, E., & Shevlin, M. (2018). Distress, impairment and the extended psychosis phenotype: A network analysis of psychotic experiences in a US general population sample. *Schizophrenia Bulletin*, 44, 768-777. doi: 10.1093/schbul/sbx134.

Oliver, D., Reilly, T. J., Baccaredda Boy, O., Petros, N., Davies, C., Borgwardt, S., … Fusar-Poli, P. (2019). What causes the onset of psychosis in individuals at clinical high risk? a meta-analysis of risk and protective factors. *Schizophrenia Bulletin*. https://doi.org/10.1093/schbul/sbz039

Opsahl, T., Agneessens, F., & Skvoretz, J. (2010). Node centrality in weighted networks: Generalizing degree and shortest paths. *Social Networks*, *32*(3), 245–251. https://doi.org/10.1016/j.socnet.2010.03.006

Ortuño-Sierra, J., Aritio-Solana, R., Inchausti, F., De Luis, E. C., Molina, B. L., De Albéniz, A. P., & Fonseca-Pedrero, E. (2017). Screening for depressive symptoms in adolescents at school: New validity evidences on the short

form of the reynolds depression scale. *PLoS ONE*, *12*(2). https://doi.org/10.1371/journal.pone.0170950

Ortuño-Sierra, J., Chocarro, E., Fonseca-Pedrero, E., Riba i Riba, S., & Muñiz, J. (2015). The assessment of emotional and Behavioural problems: Internal structure of The Strengths and Difficulties Questionnaire. *International Journal of Clinical and Health Psychology*, *15*(3), 265–273. https://doi.org/10.1016/j.ijchp.2015.05.005

Paykel, E. S., Myers, J. K., Lindenthal, J. J., & Tanner, J. (1974). Suicidal feelings in the general population: A prevalence study. *The British Journal of Psychiatry*, *214*, 460–469.

Pries, L. K., Guloksuz, S., Ten Have, M., De Graaf, R., Van Dorsselaer, S., Gunther, N., … van Os, J. (2018). Evidence that environmental and familial risks for psychosis additively impact a multidimensional subthreshold psychosis syndrome. *Schizophrenia Bulletin*, *44*, 710-719. doi: 10.1093/schbul/sby051

R Core Team (2016). *R: A Language and Environment for Statistical Computing*. Vienna, Austria.

Radua, J., Ramella-Cravaro, V., Ioannidis, J. P. A., Reichenberg, A., Phiphopthatsanee, N., Amir, T., … Fusar-Poli, P. (2018). What causes psychosis? An umbrella review of risk and protective factors. *World Psychiatry*, *17*, 49–66. https://doi.org/10.1002/wps.20490

Radhakrishnan, R., Guloksuz, S., Ten Have, M., De Graaf, R., Van Dorsselaer, S., Gunther, N., … van Os, J. (2019). Interaction between environmental and familial affective risk impacts psychosis admixture in states of affective dysregulation. *Psychological Medicine, 49*, 1879-1889. doi: 10.1017/S0033291718002635.

Reynolds, W. M. (2002). *Reynolds Adolescent Depression Scale – 2nd Edition. Professional manual.* Odessa: Psychological Assessment Resources, Inc.

Robinaugh, D. J., Millner, A. J., & McNally, R. J. (2016). Identifying highly influential nodes in the complicated grief network. *Journal of Abnormal Psychology*, *125*(6), 747–757. https://doi.org/10.1037/abn0000181

Rosenberg, M. (1965). *Society and adolescent self- image*. Princenton: University press.

Schimanski, I. D., Mouat, K. L., Billinghurst, B. L., & Linscott, R. J. (2017). Preliminary evidence that schizophrenia liability at age 15 predicts suicidal ideation two years later. *Schizophrenia Research*, *181*, 60–62. https://doi.org/10.1016/j.schres.2016.08.030

Schmittmann, V. D., Cramer, A. O. J., Waldorp, L. J., Epskamp, S., Kievit, R. A., & Borsboom, D. (2013). Deconstructing the construct: A network perspective on psychological phenomena. *New Ideas in Psychology*, *31* 43–53. https://doi.org/10.1016/j.newideapsych.2011.02.007

Sullivan, S., Kounali, D., Cannon, M., David, A., Fletcher, P., Holmans, P., …

Zammit, S. (2020). A population-based cohort study examining the incidence and impact of psychotic experiences from childhood to adulthood, and prediction of psychotic disorder. *American Journal of Psychiatry.* doi: 10.1176/appi.ajp.2019.19060654.

van Os, J., Linscott, R. J., Myin-Germeys, I., Delespaul, P., & Krabbendam, L. (2009). A systematic review and meta-analysis of the psychosis continuum: Evidence for a psychosis proneness-persistence-impairment model of psychotic disorder. *Psychological Medicine*, *39*, 179–195.

van Os, J., & Guloksuz, S. (2017). A critique of the "ultra-high risk" and "transition" paradigm. *World Psychiatry*, *16*(2), 200–206. https://doi.org/10.1002/wps.20423

van Os, J., & Linscott, R. J. (2012). Introduction: The extended psychosis phenotype - Relationship with schizophrenia and with ultrahigh risk status for psychosis. *Schizophrenia Bulletin*, *38*, 227–230. https://doi.org/10.1093/schbul/sbr188

van Os, J., & Reininghaus, U. (2016). Psychosis as a transdiagnostic and extended phenotype in the general population. *World Psychiatry*, *15*, 118–124. https://doi.org/10.1002/wps.20310

Wüsten, C., Schlier, B., Jaya, E. S., Fonseca-Pedrero, E., Peters, E., Verdoux, H., … Lincoln, T. M. (2018). Psychotic experiences and related distress: a cross-national comparison and network analysis based on 7141 participants from 13 countries. *Schizophrenia Bulletin*, *44*, 1185–1194. https://doi.org/10.1093/schbul/sby087

Yung, A.R., Nelson, B., Baker, K., Buckby, J.A., Baksheev, G., & Cosgrave, E.M. (2006). Psychotic-like experiences in a community sample of adolescents: implications for the continuum model of psychosis and prediction of schizophrenia. *Australian & New Zealand Journal of Psychiatry, 43,* 118-128. doi: 10.1080/00048670802607188.

Zammit, S., Kounali, D., Cannon, M., David, A. S., Gunnell, D., Heron, J., … Lewis, G. (2013). Psychotic experiences and psychotic disorders at age 18 in relation to psychotic experiences at age 12 in a longitudinal population-based cohort study. *American Journal of Psychiatry*, *170*, 742–750. doi: 10.1176/appi.ajp.2013.12060768.

Zhang, R., Zhou, H., Wang, Y., Yang, Z., Wang, Y., So, S., … Chan, R. (2019). Network analysis of schizotypal personality traits and their association with other subclinical psychiatric features. *Asian Journal of Psychiatry, 44*, 209–216. doi: 10.1016/j.ajp.2019.08.005.

Table 1. Descriptive statistics for the measures used.

	M	SD	Skewness	Kurtosis	Min.	Max.
PQ-B Frequency	5.32	4.28	0.70	-0.29	0	18
PQ-B Distress	4.54	12.46	2.88	8.19	0	85
Self-esteem	30.83	5.56	-0.62	0.31	10	40
SDQ Emotional	3.44	2.41	0.55	-0.38	0	10
SDQ Conduct problems	1.74	1.55	1.07	1.28	0	8
SDQ Peer problems	1.45	1.59	1.63	3.54	0	10
SDQ Hiperactivity	4.36	2.17	0.07	-0.49	0	10
SDQ Prosocial	8.56	1.42	-1.16	1.53	2	10
RADS-SF	16.40	4.49	1.53	3.12	10	40
PSS	0.58	1.12	2.24	4.66	0	5
PWI-SC	7.75	1.86	-1.15	1.80	0	10

Note. PQ-B= The Prodromal Questionnaire–Brief; SDQ= The Strengths and Difficulties Questionnaire; RADS-SF= The Reynolds Adolescent Depression Scale Short From; PSS= The Paykel Suicide Scale; PWI-SC= The Personal Wellbeing Index-School Children.

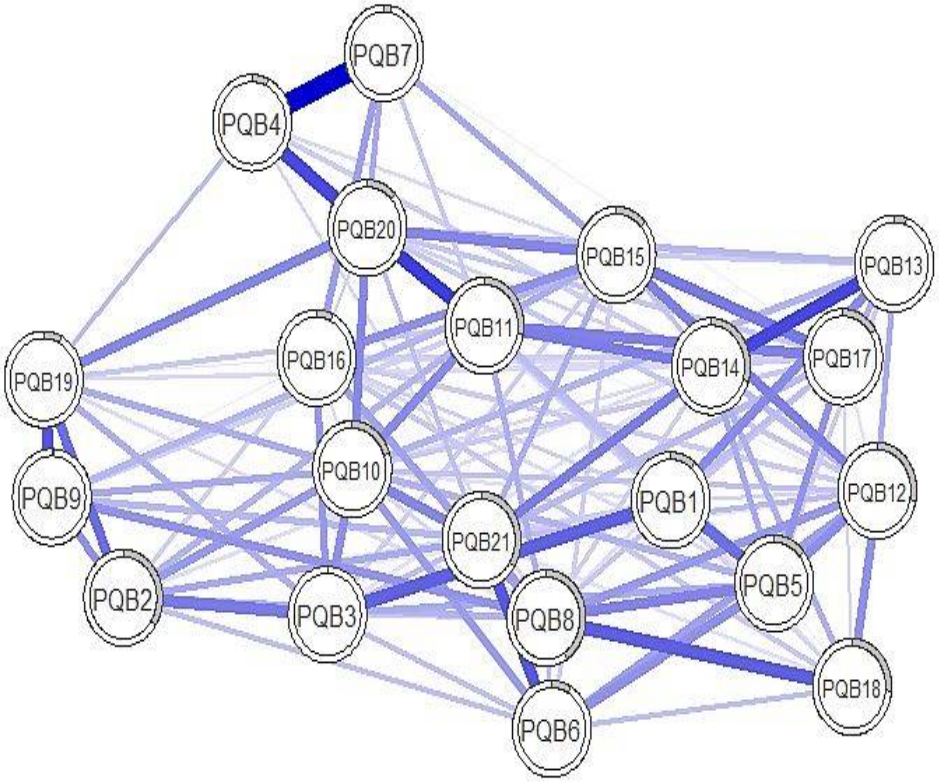

Figure 1. Psychotic-like experiences estimated network.

Note. PQ-B: Prodromal Questionnaire-Brief. Blue edges represent positive associations. Thickness and saturation of edges indicate the strength of associations. The filled part of the circle around each node shows the predictability of each node, representing the variance of the nodes explained by all nodes with which it is connected.

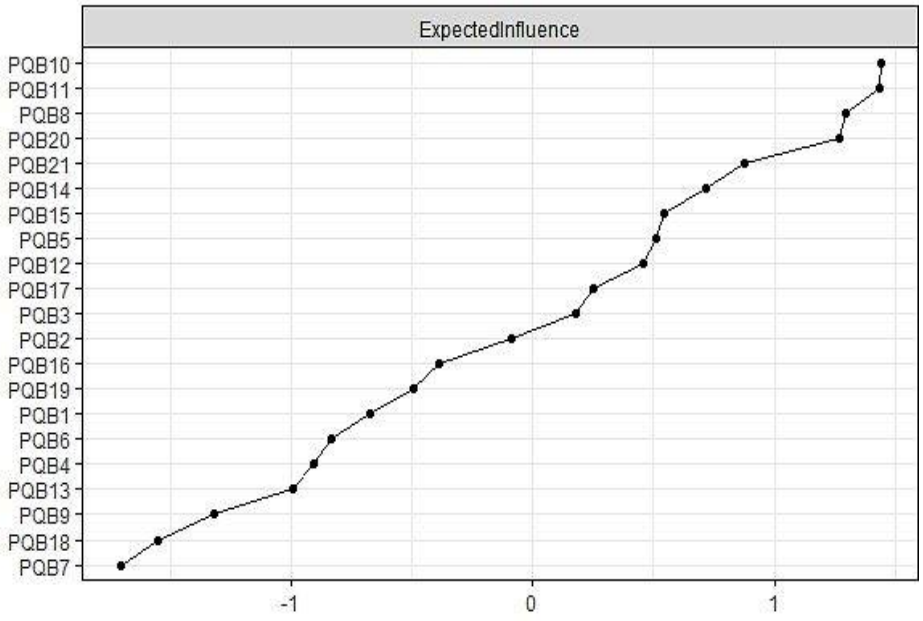

Figure 2. Expected Influence values of the psychotic-like experiences network.

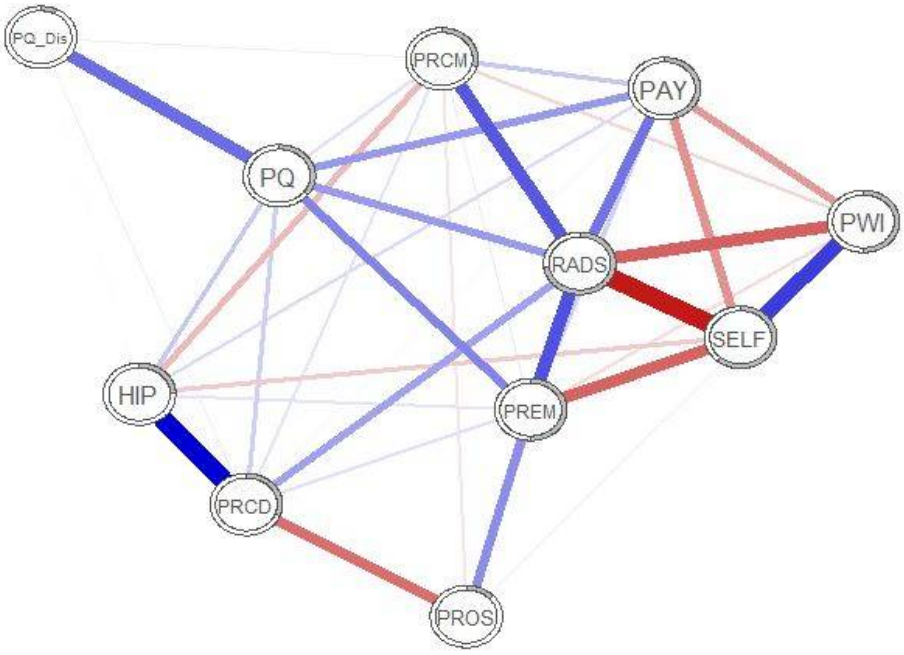

Figure 3. Multidimensional extended psychosis phenotype estimated network.

Note. Blue edges represent positive associations; red edges represent negative associations. Thickness and saturation of edges indicate the strength of associations. The filled part of the circle around each node shows the predictability of each node, representing the variance of the nodes explained by all nodes with which it is connected.

Note. PQ= The Prodromal Questionnaire-Brief (frequency score); PQ Dis= The Prodromal Questionnaire-Brief distress score; PREM=Emotional Symptoms of SDQ, PRCD= Conduct problems of SDQ; PRCM=Peer Problem of SDQ, HIP=Hyperactivity of SDQ; PROS=Prosocial behavior of SDQ; RADS= The Reynolds Depression Scale short version; PWI= The Personal Well Being Index-School version; PAY= The Paykel Suicide Scale; SELF= The Rosenberg Self-esteem Scale.

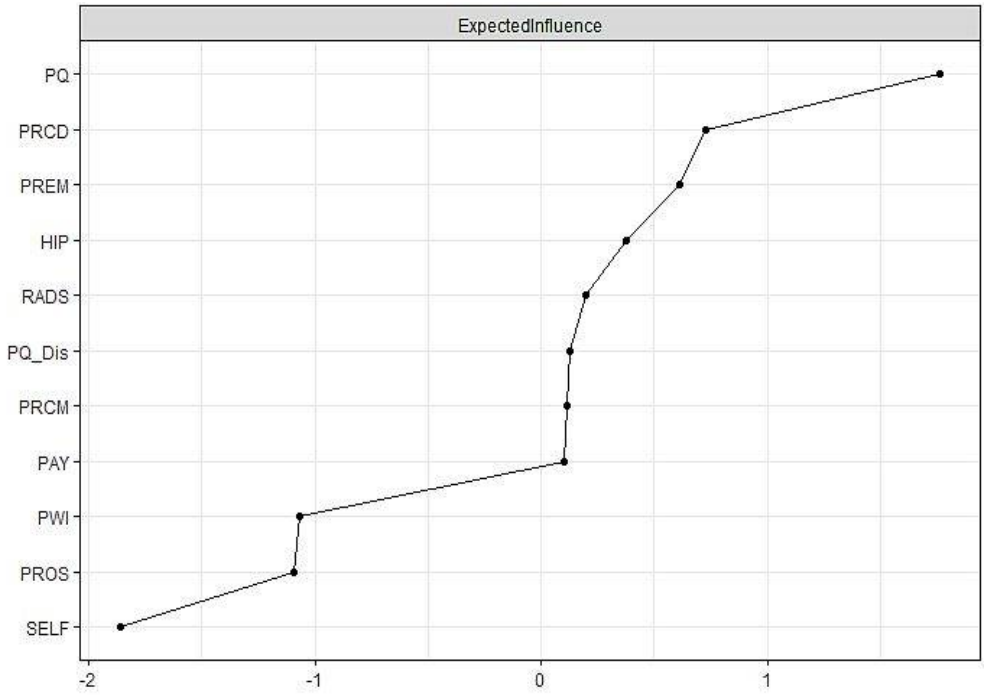

Figure 4. Expected Influence values of the extended psychosis phenotype estimated network.

Note. PQ= The Prodromal Questionnaire-Brief (frequency score); PQ Dis= The Prodromal Questionnaire-Brief distress score; PREM=Emotional Symptoms of SDQ, PRCD= Conduct problems of SDQ; PRCM=Peer Problem of SDQ, HIP=Hyperactivity of SDQ; PROS=Prosocial behavior of SDQ; RADS= The Reynolds Depression Scale short version; PWI= The Personal Well Being Index-School version; PAY= The Paykel Suicide Scale; SELF= The Rosenberg Self-esteem Scale.

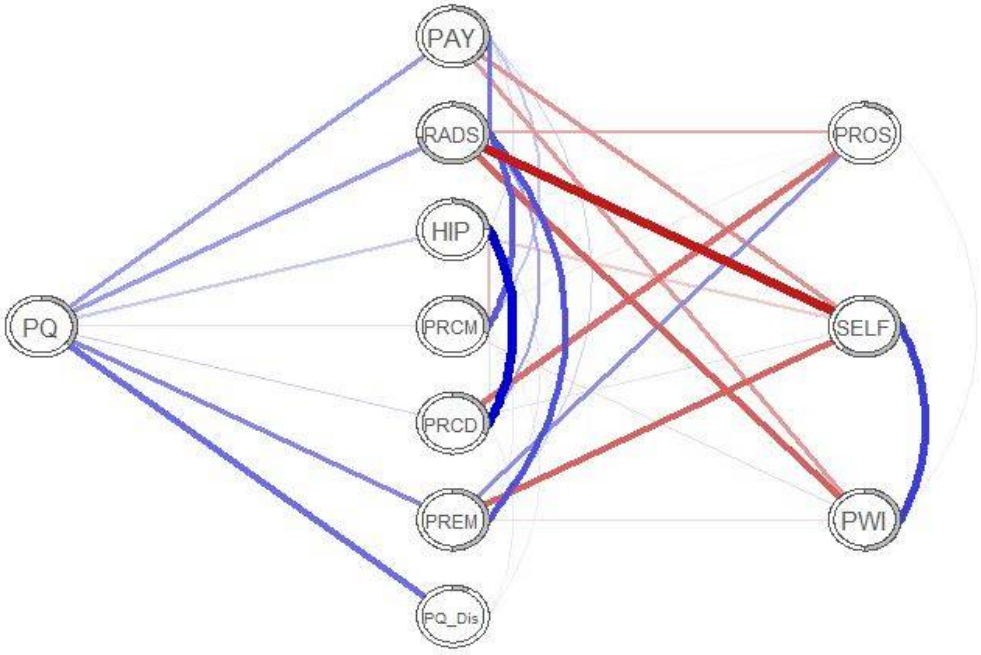

Figure 5. Extended psychosis phenotype estimated network. PQ node (node of interest) on the left and all other nodes in vertical levels to the right.

Note. Blue edges represent positive associations; red edges represent negative associations. Thickness and saturation of edges indicate the strength of associations. The filled part of the circle around each node shows the predictability of each node, representing the variance of the nodes explained by all nodes with which it is connected.

Note. PQ= The Prodromal Questionnaire-Brief (frequency score); PQ_dis= The Prodromal Questionnaire-Brief distress score; PREM=Emotional Symptoms of SDQ, PRCD= Conduct problems of SDQ; PRCM=Peer Problem of SDQ, HIP=Hyperactivity of SDQ; PROS=Prosocial behavior of SDQ; RADS= The Reynolds Depression Scale short version; PWI= The Personal Well Being Index-School version; PAY= The Paykel Suicide Scale; SELF= The Rosenberg Self-esteem Scale.