

## Schizotypal Traits, Psychopathology, and Reflective Functioning Impairments During Adolescence: A Bayesian Network Approach

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**Background:** New theoretical and measurement models related to Bayesian networks can usefully be implemented to enrich our understanding of psychosis risk. The present study aims to explore, using a directed acyclic graph (DAG), the putative causal relationship within schizotypal facets, as well as between schizotypal dimensions, psychopathology, and reflective functioning (RF) impairments, in a representative sample of non-clinical adolescents. **Study Design:** A sample of 1476 adolescents from the general population participated in a cross-sectional survey. The Oviedo Schizotypy Assessment Questionnaire-Revised, the Strengths and Difficulties Questionnaire, and the Reflective Functioning Questionnaire (RFQ) were used. **Study Results:** Schizotypal traits were positively associated with psychopathology and hypomentalizing. Putative causal relationships are presented between Reality distortion, Social disorganization, and Anhedonia. In addition, estimated DAG suggests that schizotypal dimensions influence psychopathology and RF impairments. **Conclusions:** The findings suggest different pathways connecting schizotypal traits, mental health problems, and RF impairments during adolescence. The use of probabilistic DAG may allow us to make more robust conclusions about the direction of causation and to unravel potentially complex causal chains in the study of psychosis risk.

**Key words:** schizotypy/reflective functioning/mentalization/network analysis/directed acyclic graphs/adolescence

### Introduction

Increased attention is currently directed to understanding the nature of risk for schizophrenia spectrum and other psychotic disorders (SSPDs).<sup>1,2</sup> The incorporation of new preventive, contextual, staging, and transdiagnostic approaches may help to improve the understanding of SSPDs.<sup>3</sup> New studies need to adopt dynamic, complex systems, and mechanism-based perspectives rather than static, common latent cause, and disorder-based approaches. Incorporating these approaches into the field of schizotypy may contribute to our knowledge of tentative etiological mechanisms of psychosis in order to develop preventive strategies.<sup>4</sup>

Schizotypy is defined as a latent personality organization reflecting a putative liability for schizophrenia spectrum disorders.<sup>5</sup> Schizotypy can manifest itself, at the phenotypic level, with a variety range of expressions, such as schizotypal traits, psychotic-like experiences, subclinical psychotic symptoms, psychotic symptoms, and psychosis-spectrum disorders.<sup>6,7</sup> Beyond representing a risk for schizophrenia spectrum disorders, schizotypy is a genuine manifestation of its latent liability.<sup>6</sup> Previous studies have found that schizotypal personality is a multidimensional phenotype, most often composed of three factors, like those found in individuals with psychosis. The three-factor model characterized by Positive (eg, hallucinations, ideas of reference, magical thinking, paranoid ideation), Interpersonal (eg, blunted affect, social anxiety, lack of

close friends), and Disorganized (eg, odd behavior and speech) dimensions has been replicated across samples and tools.<sup>8</sup>

Previous studies have demonstrated that schizotypal traits at the population level may represent the behavioral manifestation of distributed multifactorial risk for psychosis.<sup>9–12</sup> For instance, subtle, non-psychotic forms of perceptual aberrations or anhedonia are at an increased risk for SSPDs outcomes.<sup>13,14</sup> In this regard, Radua et al<sup>15</sup> conducted an umbrella review and found that the subclinical expression of the psychosis phenotype as an ultra-high risk state (UHR) for psychosis and trait anhedonia were among the main risk factors for psychosis with convincing or highly suggestive evidence of association. The predictive power of clinical interviews used in UHR samples is very comparable to that found in preventive medicine<sup>16</sup>; however, previous studies have found that childhood psychotic symptoms were not specific to a diagnosis of schizophrenia in adulthood.<sup>17</sup> The mere presence of schizotypal traits or psychotic-like experiences is neither necessary nor a sufficient condition for the later development of SSPDs outcomes, other mental problems (eg, depression), or poorer functioning.<sup>9,11</sup>

Novel theoretical and measurement models have to be tested and refined in order to capture the complexity of unfolding psychosis phenotype. A network theory of mental disorders has been proposed.<sup>18,19</sup> From this framework, mental disorders constitute emergent properties that arise from causal relations among symptoms (eg, behaviors, mental states, signs, traits). The network approach provides an alternative way to conceptualize psychosis and related phenomena (ie, schizotypal personality) as complex dynamic systems.<sup>20</sup> This interactional approach focuses on specific symptoms and signs and their interrelationships rather than latent diseases. According to network theory, dynamic interactions between symptoms of mental diseases play an important role in their formation and maintenance. Although network theory has frequently been contrasted with the paradigm of assuming common causes underlying symptoms of mental diseases and employing latent variable models, it has recently been proposed that the distinction between network and common cause models may not be as apparent as previously thought. Thus, the proposed latent network model has been provided to combine the latent variable model and the network model.<sup>21</sup> Emerging network analysis techniques provide new potential ways of modeling and understanding psychopathological processes and mental disorders,<sup>22,23</sup> in particular, psychosis phenotype.<sup>24–26</sup>

Several psychometric analyses are available to estimate networks.<sup>27,28</sup> However, in cross-sectional designs, estimated networks describe the predictive power and relative importance of distinct variables, but not causality. In this context, directed acyclic graph (DAG) models are tools for describing causal relationships and for guiding

attempts to learn them from data. Bayesian networks are probabilistic graphical models widely employed to understand dependencies in high-dimensional data, and even to facilitate causal discovery.<sup>29</sup> Causal graphs are based on strong assumptions (eg, causal sufficiency).<sup>30</sup> As a result, several studies have used DAGs in psychosis<sup>31–34</sup> and psychopathology research.<sup>35,36</sup> According to Moffa et al<sup>32</sup> probabilistic DAGs represent all the variables and links in a full picture of a unique network model, locating variables in a putative causal cascade in which upstream variables are potential causes of downstream variables.<sup>33</sup> DAGs can also provide better insight into potential causal and complex relationships between multiple variables (within and across domain levels) and better understand the complexity of the mechanisms that connect the variables. The logic behind using a DAG to depict hypothetical causal structures is explained elsewhere.<sup>37,38</sup>

Prior research has shown that emotional and behavioral symptoms are a key factor in all stages of psychotic phenomena (eg, prodrome, UHR, first episode).<sup>12,39,40</sup> It is already well documented that, along the extended psychosis phenotype, schizotypal traits, psychotic-like experiences, and subclinical psychotic symptoms have cross-sectional and longitudinal relationships with anxiety and depression symptoms.<sup>41–44</sup> For instance, individuals who meet the UHR criteria often have concurrent mood and/or anxiety disorders.<sup>45</sup> At the population level, those individuals who report schizotypal traits or psychotic-like experiences and who also refer to internalizing or externalizing psychopathology may indicate an underlying vulnerability to SSPDs or may be at risk for later psychosis.<sup>46,47</sup>

Reflective functioning (RF) may also play a relevant role in psychosis risk.<sup>48,49</sup> RF, or mentalizing, refers to the ability to understand others and the self in terms of internal mental states.<sup>50,51</sup> Mentalizing processes are more generally part of social cognitive processing. Mentalizing is thought to play a key role in preventing the development of mental health disorders such as psychosis, or attenuating their functional impact.<sup>48,52</sup> For example, good performance on the RF was found to be a predictor of attenuation of early risk symptoms such as delusional ideation in children with aberrant perceptual experiences.<sup>53</sup> On the other hand, low RF, characterized by an inability to understand behaviors in terms of mental states, has been associated with schizotypy and mental health problems.<sup>54</sup> Both emotional dysregulation and RF impairment may then serve as significant candidate targets for psychological treatments or prevention strategies for psychosis.<sup>49</sup>

To date, despite the large body of research, the functional relationship between schizotypal traits, psychopathology, and RF impairments, during adolescence through the lens of the Bayesian network approach has not been analyzed. Thus, the mechanisms by which schizotypal traits are related to emotional dysregulation or RF

impairments need to be further explored. In addition, further research is warranted to develop a better understanding of the facets of schizotypal and their associations with potential risk factors such as hypomentalizing or psychopathology, beyond the traditional categorical approach that has led to a simplified and incomplete view of psychological problems such as psychosis.

Within this research framework, the main goal of the present study was to explore, using a Bayesian network approach, the putative causal relationship within schizotypal facets, as well as between the schizotypal dimensions, psychopathology, and RF impairments, in a representative sample of non-clinical adolescents. The use of probabilistic DAG may allow for more robust conclusions about the direction of causation and provide a new perspective on this complex comorbidity. In addition, the Bayesian network model allows us to unravel potentially complex causal chains. Our intentions in this article were to demonstrate the potential of DAG in improving our understanding of schizotypy, as well as to characterize the functional relationships among schizotypal traits and psychopathology in the development of preventive interventions for individuals at risk for psychosis.

## Methods

### Participants

The total student population of La Rioja (a region in northern Spain) was sampled using stratified random sampling at class level. The students came from different public and non-public educational institutions, compulsory secondary education, and vocational training. Strata were developed based on the type of educational institution (public or non-public), as well as on the educational level. A total of 1476 students, 663 men (44.9%), and 813 (55.1%) women, from 34 schools and 98 classrooms participated in the study. The mean age was 16.13 years ( $SD = 1.36$ ), ranging from age 14 to 19 years (14 years,  $n = 200$ ; 15 years,  $n = 312$ ; 16 years,  $n = 366$ ; 17 years,  $n = 363$ ; 18 years,  $n = 167$ ; 19 years,  $n = 68$ ). The participants belonged to different nationalities: 89.9% were Spanish, 3.7% were Latin Americans (Bolivia, Argentina, Colombia, and Ecuador), 0.7% were Portuguese, 2.4% were Romanian, 1% were Moroccan, 0.7% were Pakistanis, and 2% were of other nationalities.

### Instruments

*The Oviedo Schizotypy Assessment Questionnaire-Revised.*<sup>55</sup> The Oviedo Schizotypy Assessment Questionnaire-Revised (ESQUIZO-Qr) is a self-report measure developed for the assessment of schizotypal traits in adolescents. It consists of 62 items with a Likert-type response format in five categories (from 1 “totally disagree” to 5 “totally agree”). Its 10 subscales are derived empirically by means of factor analysis, which in turn are

grouped into three general dimensions: Reality distortion/Positive schizotypy (eg, Ideas of reference, Magical thinking, Unusual perceptual experiences, and Paranoid ideation), Anhedonia (Physical anhedonia and Social anhedonia), and Social disorganization (Odd thinking and speech, Odd behavior, Lack of close friends, and Excessive social anxiety). Reliability estimates for the subscales ranged from 0.62 to 0.90. In addition, the ESQUIZO-Qr has been administered to representative samples of adolescents and its psychometric properties have been tested in relation to a number of psychometric indicators of mental health (eg, depression, personality disorders, emotional, and behavioral problems).<sup>41,56</sup>

*Reflective Functioning Questionnaire.*<sup>57,58</sup> The Reflective Functioning Questionnaire (RFQ) is an 8-item questionnaire that measures two subscales, the certainty (RFQc), and the uncertainty (RFQu) about mental states. The 8 questions are rated from 1 (“totally disagree”) to 7 (“totally agree”). Items were rescored based on the procedure described by the authors of the questionnaire, on a scale from 0 to 3 (for details, see Fonagy et al<sup>57</sup>). High scores on the uncertainty subscale indicate a lack of use of mental states. High scores on the certainty subscale indicate an adaptive level of certainty about mental states. The Spanish translation of the RFQ was used in the present study. Studies focusing on mental health and psychopathology have used the RFQu subscale.<sup>54,59</sup> In the present study, the reliability estimate of the RFQu total score was 0.78.

*The Strengths and Difficulties Questionnaire Self-report Version.*<sup>60</sup> The Strengths and Difficulties Questionnaire (SDQ) is a self-report questionnaire that is widely used for the assessment of various emotional and behavioral problems related to mental health in adolescents. The SDQ is comprised of a total of 25 statements divided into five subscales: Emotional symptoms, Conduct problems, Hyperactivity, Peer problems, and Prosocial behavior. The first four subscales result in a Total difficulties score. In this study, we used a Likert-type response format with three options (0 = “Not true,” 1 = “Somewhat true,” 2 = “Certainly true”). The validated Spanish version of the SDQ was used in the present study.<sup>61</sup> The Spanish version of the SDQ is available on the official website of the SDQ (<https://www.sdqinfo.org/py/sdqinfo/b0.py>).

*The Oviedo Infrequency Scale.*<sup>62</sup> The Oviedo Infrequency Scale (INF-OV) was administered to participants with the goal of identifying those who responded in a random, pseudorandom, or dishonest manner. The INF-OV is a self-report questionnaire composed of 12 items (eg, “The distance between Madrid and Barcelona is greater than the distance between Madrid and New York”) in a 5-point Likert-scale format (from 1 “completely disagree” to 5 “completely agree”). Students with more than



three incorrect responses on the INF-OV scale were excluded from the sample. The INF-OV has been used in previous studies.<sup>63–65</sup>

### Procedure

The study was approved by the Ethical Committee for Clinical Research of La Rioja (CEImLAR, PI 552). The survey was conducted in groups of 10–30 students, during school hours, in a specially equipped classroom, using personal computers. The administration was carried out under the supervision of researchers who had been trained in a standard protocol. There were no incentives for participation. Written parental consent was required for students. Participants were informed of the confidentiality of their responses as well as the voluntary nature of the study.

### Data Analyses

First, we calculated descriptive statistics for the measures. Second, considering all variables as continuous, Pearson correlations were calculated between the ESQUIZO-Qr dimensions, the SDQ subscales, and the RFQ uncertainty total score. The prosocial behavior subscale of the SDQ, which assesses strengths, was not used in the present study. Third, two DAGs were computed: (a) within the schizotypal subscales; and (b) between the schizotypal higher-order dimension, RFQ uncertainty, and SDQ subscales. A DAG is a mathematical object that provides the graphical representation of a Bayesian network. DAGs are graphical structures underlying Bayesian networks that model the overall dependence structure of multiple variables. The set of variables of interest is represented as nodes (eg, variables) connected by directed edges. A DAG is directed (from cause to effect) and acyclic (there is no path that starts from a node and returns to the same node, always following edges in the direction of the arrow).<sup>66</sup> An analysis based on DAGs has the advantage over one based on Markov random fields, in that it suggests explicit directions for the causal relationships among the variables used in the study. Given the assumptions and limitations of DAGs, upstream nodes are potential causes of downstream nodes. However, the direction of the arrows provides no information about the sign of the association, eg, we cannot take the simple network  $A \rightarrow B$  to necessarily imply that the presence of A increases the probability that B is also present, rather that it changes the probability of B being present, and could also decrease it. For the estimation of the DAG, in the present article, we used the approach and the scripts published by McNally et al,<sup>35</sup> using the hill-climbing algorithm from the R package *bnlearn*.<sup>67</sup> The hill-climbing algorithm uses a random procedure to go through models and evaluate their fit to the data until it finds one that fits best (locally). The procedure is not guaranteed to find a global optimum.

In order to draw more robust conclusions, we assessed the stability of the psychological networks. We bootstrapped 1000 samples and computed a network for each of them, and a consensus network of all 1000 networks to obtain the final, resultant estimated network. First, the strength of an edge does not typically refer to how often it appears in a bootstrapped (or even sampled) collection of DAGs, but rather to the magnitude of the coefficient in a structural equation model describing the probabilistic relationship of a node to its parents (ie, how strong the effect of one variable is on another). If an edge appeared in at least 85% of these networks, we retained it in the final consensus network. Second, we determined the probability direction of each edge in the 1000 bootstrapped networks. If an edge connecting two nodes was estimated in at least 51% of the fitted networks, this direction then appeared in the final network. Thus, all estimated edges in the final networks appeared in at least 85% of the fitted networks and were pointing in the given direction in a least 51% of the fitted networks. Further information on the analysis can be found elsewhere.<sup>35,66</sup> R scripts for the Bayesian network analysis of the study are shown in the [Supplementary material](#). Datasets can be found at the following link: <https://osf.io/h4eu7/>. SPSS 28 and R 4.3.2 version were used for statistical analyses.

## Results

### Descriptive Statistics

[Table 1](#) shows the descriptive statistics of the subscales and total scores for the entire sample. [Table 2](#) depicts the Pearson correlations of the variables used in the present study. Schizotypal facets, especially the Positive and Social disorganization dimensions, were moderately associated with psychopathology and RF impairments.

### DAG of Schizotypal Traits

[Figure 1](#) presents the estimated DAG for schizotypal traits. We can observe that Unusual perceptual experiences are placed at the top of the network as potential causes of downstream nodes related to the Social disorganization and Anhedonia facets. Anhedonia is placed at the bottom of the estimated network. The DAG also suggests that the Positive schizotypal nodes (ie, Unusual perceptual experiences, Magical thinking, Ideas of reference, and Paranoid ideation) have a putative causal relationship with Odd thinking and language and Anhedonia facets. Paranoid ideation and Odd behavior are directly related to Social anhedonia and also indirectly via Odd thinking and language and No close friends nodes. Thus, putative causal relationships are presented between Positive schizotypy and Social disorganization dimensions.

**Table 1.** Descriptive Statistics of the Measures

	Mean	SD	Skewness	Kurtosis	Min.	Max.
ESQ-Q Ideas of reference	6.74	2.89	1.14	1.03	4.00	20.00
ESQ-Q Magical thinking	8.28	3.28	1.20	1.44	5.00	25.00
ESQ-Q Unusual perceptual experiences	10.95	4.90	1.67	2.79	7.00	35.00
ESQ-Q Odd thinking and language	15.24	5.04	0.24	-0.45	6.00	30.00
ESQ-Q Paranoid ideation	8.33	3.50	1.27	1.65	5.00	25.00
ESQ-Q Physical anhedonia	16.35	4.05	0.24	-0.30	8.00	30.00
ESQ-Q Social anhedonia	17.23	4.55	0.91	1.05	10.00	37.00
ESQ-Q Odd behavior	7.59	2.98	1.09	1.18	4.00	20.00
ESQ-Q No close friends	10.11	3.90	0.30	-0.58	4.00	20.00
ESQ-Q Excessive social anxiety	17.25	5.70	0.46	-0.05	7.00	35.00
SDQ Emotional problems	3.55	2.45	0.49	-0.53	0.00	10.00
SDQ Conduct problems	1.97	1.65	0.91	0.81	0.00	9.00
SDQ Peer problems	1.51	1.56	1.36	2.07	0.00	9.00
SDQ Hiperactivity	4.31	2.17	0.10	-0.52	0.00	10.00
RFQ Uncertainty	3.89	3.57	1.25	1.49	0.00	18.00

*Note:* ESQ-Q, Oviedo Schizotypy Assessment Questionnaire-Revised; RFQ, Reflective Functioning Questionnaire; SDQ, Strengths and Difficulties Questionnaire.

### *DAG of Schizotypal Dimensions, Psychopathology, and Hypomentalizing*

Figure 2 presents the estimated DAG for schizotypal higher-order dimensions, psychopathology, and hypomentalizing. Several aspects should be noted: (a) the Social disorganization dimension is placed at the top of the network; (b) Hypomentalizing is placed at the bottom of the network; (c) the Social disorganization dimension shows a putative causal relationship with Positive schizotypy, psychopathology, and RF impairments; (d) Social disorganization shows a putative causal relationship with emotional and behavioral problems; (e) Social disorganization shows a putative causal relationship with RF impairments and also indirectly via other nodes; (f) Reality distortion dimension shows a putative causal relationship with externalizing psychopathology and RF impairments.

In addition, in order to test the robustness of the findings and to support the reliability of the results, the DAG of schizotypal higher-order dimensions, psychopathology, and certainty was estimated (see [Supplementary figure S1](#)).

### **Discussion**

Despite the large body of research on schizotypal traits, critical gaps, and caveats remain unsolved. For instance, few studies have employed the Bayesian network to gain insight into the possible directions of the interdependencies among the variables related to broadly defined mental risk states during adolescence. Thus, the present study examined the putative causal relationship within schizotypal facets, as well as between schizotypal dimensions, psychopathology, and reflective functioning (RF) impairments, in a representative sample of adolescents from the general population. This study is the first to use Bayesian networks to examine directional interdependencies among

schizotypal facets, psychopathology, and mentalizing impairments. This study may allow us not only to better understand schizotypal traits and its comorbidities with psychopathology and hypomentalizing, but also to explore tentative causal pathways to develop or refine prevention strategies for youth at increased risk for SSPDs outcomes.

First, as shown by the bivariate correlations, schizotypal traits were moderately related to internalizing and externalizing dimensions of psychopathology and to RF impairments during adolescence. On the one hand, Emotional problems were associated with Odd thinking and language and Positive schizotypy, whereas Social disorganization facets were closely related to Peer and Conduct problems. Previous studies have shown that schizotypal traits and psychotic-like experiences are associated with emotional dysregulation and behavioral problems.<sup>42,68–70</sup> On the other hand, Unusual perceptual experiences, Odd thinking and language, and Paranoid ideation showed the strongest relationship with hypomentalizing. Prior research conducted in adolescents has shown that schizotypal traits are related to RF difficulties.<sup>54,71</sup> For instance, Interpersonal schizotypal manifestations pertaining to Social anxiety are associated with high mentalizing uncertainty.<sup>54</sup> These results indicate that there is a moderate relationship between schizotypal traits, mental health problems, and RF impairments at a subclinical level. These mental health difficulties and RF impairments appear to be characteristic along the extended psychosis phenotype.<sup>40,52,72</sup>

Second, we have observed that the Positive schizotypal traits (eg, Magical thinking, Unusual perceptual experiences, and Paranoid ideation) were placed at the top of the estimated network, suggesting that these facets show putative causal relationships with the Social disorganization and Negative schizotypal facets. The directions of

**Table 2.** Pearson's Correlations Between Schizotypal Traits, Psychopathology, and Hypomentalizing

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ESQ-Q Ideas of reference (1)	1														
ESQ-Q Magical thinking (2)	0.507**	1													
ESQ-Q Unusual perceptual experiences (3)	0.561**	0.594**	1												
ESQ-Q Odd thinking and language (4)	0.342**	0.375**	0.450*	1											
ESQ-Q Paranoid ideation (5)	0.433**	0.457**	0.513**	0.415**	1										
ESQ-Q Physical anhedonia (6)	-0.048	-0.04	-0.019	-0.004	0.054*	1									
ESQ-Q Social anhedonia (7)	.225**	.186**	.296**	.301**	.388**	.203**	1								
ESQ-Q Odd behavior (8)	0.404**	0.357**	0.485**	0.409**	0.517**	-0.052*	0.462**	1							
ESQ-Q No close friends (9)	0.253**	0.266**	0.301**	0.387**	0.421**	-0.041	0.427**	0.429**	1						
ESQ-Q Excessive social anxiety (10)	0.203**	0.182**	0.267**	0.415**	0.282**	-0.024	0.377**	0.368**	0.343**	1					
SDQ Emotional problems (11)	0.222**	0.268**	0.337**	0.448**	0.344**	-0.068*	0.266**	0.333**	0.402**	0.510**	1				
SDQ Conduct problems (12)	0.243**	0.238**	0.320**	0.319**	0.404**	0.084**	0.209**	0.259**	0.250**	0.079**	0.182**	1			
SDQ Peer problems (13)	0.246**	0.199**	0.325**	0.273**	0.474**	-0.015	0.481**	0.502**	0.413**	0.336**	0.350**	0.244**	1		
SDQ Hyperactivity (14)	0.154**	0.198**	0.247**	0.550**	0.223**	0.02	0.091**	0.190**	0.177**	0.154**	0.217**	0.368**	0.122**	1	
RFQ Uncertainty (15)	0.261**	0.248**	0.364**	0.432**	0.339**	-0.05	0.170**	0.285**	0.332**	0.259**	0.416**	0.369**	0.239**	0.320**	1

Note: ESQ-Q, Oviedo Schizotypy Assessment Questionnaire-Revised; SDQ: Strengths and Difficulties Questionnaire; RFQ: Reflective Functioning Questionnaire.

\* $P < .05$ ,

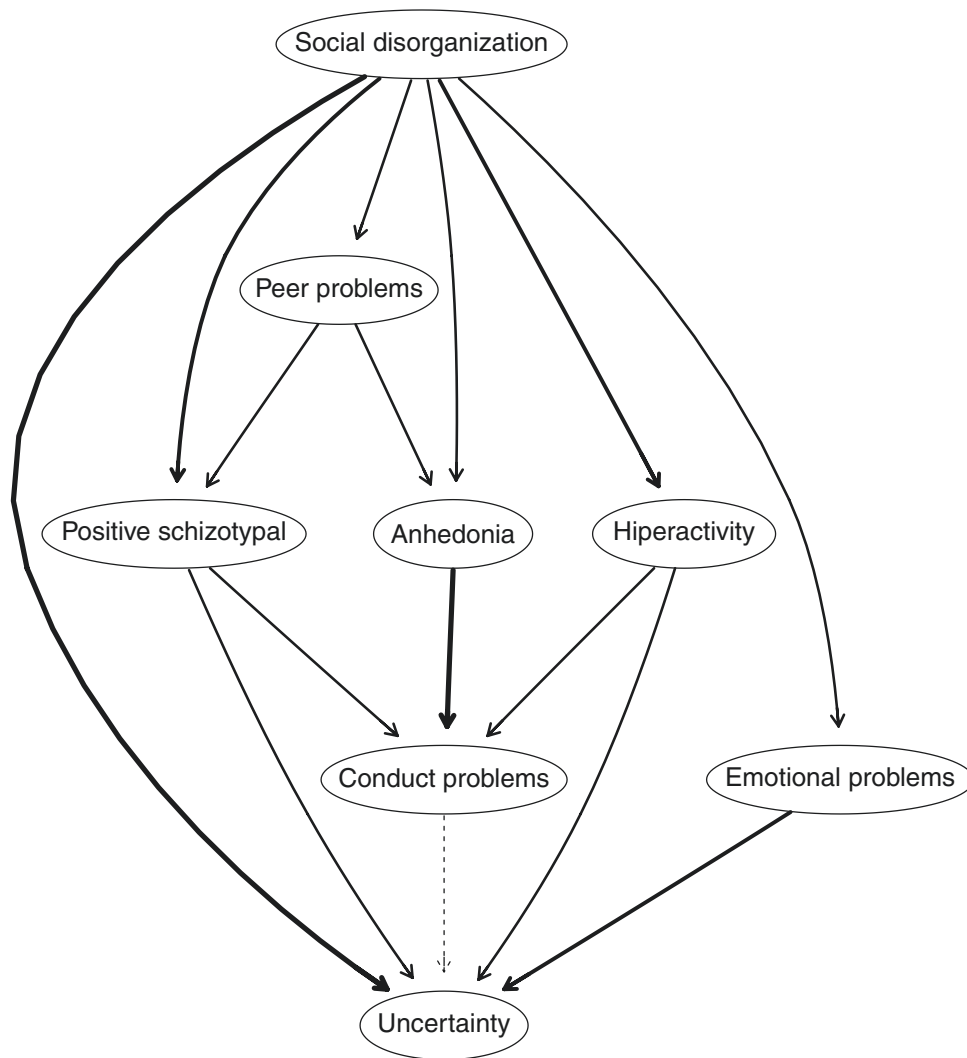
\*\* $P < .01$ .



**Fig. 1.** The directed acyclic graph (DAG) of schizotypal traits measured by the Oviedo Schizotypy Assessment Questionnaire-Revised. This graphical representation shows the consensus network of 1000 bootstrapped models. All estimated edges in the estimated network appeared in at least 85% of the fitted networks and were pointing in the given direction in a least 51% of the fitted networks. Thick arrows indicate high directional probabilities, and thin arrows indicate low directional probabilities.

the schizotypal traits give us clues as to which trait associations may be clinically significant. Thus, according to Lenzenweger,<sup>73</sup> it is important to determine whether one of the schizotypal facets has a genuine causal relationship

with another. Prior evidence suggests that critical interactions between schizotypal traits occur during adolescence and predict the unfolding of clinically significant psychotic symptoms.<sup>74–76</sup> For instance, Debbané et al,<sup>75</sup>



**Fig. 2.** The directed acyclic graph (DAG) of schizotypal higher-order dimensions, psychopathology, and hypomentalizing. Positive schizotypy (Ideas of reference, Magical thinking, Unusual perceptual experiences, and Paranoid ideation), Anhedonia (Physical anhedonia and Social anhedonia), and Social disorganization (Odd thinking and speech, Odd behavior, Lack of close Friends, and Excessive social anxiety). This graphical representation shows the consensus network of 1000 bootstrapped models. All estimated edges in the estimated network appeared in at least 85% of the fitted networks and were pointing in the given direction in a least 51% of the fitted networks. Thick arrows indicate high directional probabilities, and thin arrows indicate low directional probabilities.

in a longitudinal study, found that the relationship between disorganization features and positive schizotypy may play a central role in establishing risk for psychosis during adolescence. Other studies found that psychosis-like experiences were related to the development of secondary beliefs and appraisals.<sup>77</sup> These results are in line with the model proposed by Paul E. Meehl<sup>78</sup> who suggested that slippage (both cognitive and affective), rather than anhedonia, constitutes a key component of schizophrenia. These observations highlight a potentially critical relationship between Positive and Social disorganization schizotypal dimensions and an increased risk for psychosis during adolescence.

Third, probabilistic DAG suggested that the schizotypal dimensions were related to psychopathology and mentalizing impairments. As previously mentioned,

DAG allows us to capture the dependence structure of multiple variables and, when used appropriately, to draw inferences based on putative causal relationships.<sup>31</sup> In relation to schizotypal dimensions, previous work, using other approaches, has found similar results. For instance, in a 10-year follow-up study, Dominguez et al<sup>74</sup> found that early expression of negative/disorganized symptoms predicted psychotic experiences and subsequent clinical psychosis. The results also implied that the disorganized features were associated with psychotic disorder at the population level. In relation to schizotypal facets and RF, and according to Debbané and Barrantes-Vidal<sup>79</sup> cognitive and interpersonal aberrations in the context of schizotypal traits, may disrupt the normative development of RF processes during adolescence and impair the ability to understand mental states. Mentalizing is a capacity



that is acquired in social relationships, and its function is to facilitate social navigation through an understanding of mental states that govern behavior.<sup>80</sup> Interestingly, the Bayesian network lends evidence to the idea that mentalizing is a uniquely dependent regular, regulated, and reciprocal social interaction in order to appropriately develop itself.<sup>81</sup> This result is also in line with the idea that some facets of schizotypy may alter the development of mentalizing, which in turn augments the risk of the emergence of dysfunctional mental state attributions and the genesis of delusional belief systems.<sup>54,82</sup> Some recent clinical work suggests that intervening in mentalizing may serve as a protective factor for the functional impairments associated with risk for psychosis.<sup>48,49</sup> Critically, however, these developmental hypotheses need to be tested in longitudinal samples, and the first reports using such samples would appear to motivate further inquiry in relating disorganization through RF towards increased risk for psychosis. These findings allow for the possibility that different putative causal relationships may operate through different entry points in the network (eg, different stages of development), and this information may have useful implications for prevention and psychological treatments in both educational and clinical settings.<sup>83</sup>

Fourth, DAG using schizotypal traits (figure 1), found that Positive schizotypal traits are all above Social disorganization facets, while in the DAG (figure 2), Social disorganization is above Positive schizotypal traits. These results may have several tentative explanations. First, Bayesian networks are probabilistic graphical models widely employed to understand dependencies in high-dimensional data,<sup>29</sup> with strong assumptions and clear limitations and strengths. Second, in the first Bayesian network we use schizotypal facets at the subscale level, while in the second we use second-order dimensions of schizotypal personality. So, the level of analysis changes across DAGs. Third, in the second Bayesian network, psychopathology, and mentalization variables are introduced, an aspect that may affect the reconfiguration of the estimated network found. For example, mentalization might be closely related to Social disorganization. Hypothetically, if other facets had been introduced into the estimated network a different configuration would have been found. In this study, schizotypal traits have been characterized as a complex dynamic system in which symptoms (behaviors, affects, mental states, etc.), are directly connected to one another in a network structure and depend on the number and type of nodes introduced into the network.

Our study had some limitations. Due to the cross-sectional design used and the high potential for biases, particularly uncontrolled confounding variables (eg, causal sufficiency), causal conclusions cannot be drawn from this study. Secondly, the information was based on self-reported questionnaires only. The variables examined here depend on the instruments used (eg, Anhedonia is

measured by two subscales of the ESQUIZO-Qr), which limits the generalizability of our findings. In addition, measures used in the present study were created based on a latent variable framework.<sup>84</sup> Thirdly, learning DAGs from data and their causal interpretation rely on strong assumptions, such as causal sufficiency (no unmeasured confounders), faithfulness, and the causal Markov property.<sup>30</sup> Thus, drawing conclusions from the data may require caution. For instance, the hill-climbing-based procedure is not guaranteed to return DAGs from the same equivalence class with equal probability, potentially leading to biased results. These limitations, together with the heuristic nature of the procedure used, do not necessarily capture the distribution of the edges in the network. DAG models are powerful tools for improving communication and guiding research.

## Conclusions

This study is the first to comprehensively examine the Bayesian network structure within schizotypal traits as well as the relationships among schizotypal dimensions, psychopathology, and hypomentalizing during adolescence. This study also provides a deeper understanding of the schizotypal personality and its links to psychopathology and dysfunction in RF. Understanding the network structures of schizotypal traits, as an emergent property that arises from causal relations among facets (behaviors, cognitions, and emotions),<sup>85</sup> may help to prevent SSPDs and mental health disorders. Finally, studying the interrelationship between schizotypal traits, mental health problems or mentalizing impairments, prior to clinical disorders, may elucidate the mechanisms for the development of psychosis. Gaining a better understanding of schizotypes by adding new psychometric models opens the door to exploring the potential mechanisms involved in the etiology of psychosis, and thus, in its clinical approach.

## Supplementary Material

Supplementary material is available at <https://academic.oup.com/schizophreniabulletin/>.

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