

Article

Network and Exploratory Graph Analyses of Conduct Disorder and Oppositional Defiant Disorder Symptoms in Adolescents

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ABSTRACT

Initially, this study used network analysis to examine the network properties (centrality and edges) of Conduct Disorder (CD) symptoms and Oppositional Defiant Disorder (ODD) symptoms jointly. Following this analysis, it used exploratory graph analysis (EGA) to examine the dimensionality of the symptoms in this network model. Data were collected from the parents of 882 adolescents (age range 12 to 17 years) who rated their children's CD and ODD symptoms. Overall, of the five nodes with higher centrality values, three were from the CD aggression dimensions ("cruel to people", "fight", and "stolen with confronting"), while the other two were from the deceitfulness/theft dimension ("stolen—not confronting") and the anger/irritable mood dimension ODD ("temper"). In relation to edge weights, there were only modest associations between the nodes, especially between the CD nodes, and between the CD and ODD nodes. The CD symptom for "lies", and ODD symptoms for "annoys" and "defies" showed evidence of being bridge symptoms. The EGA indicated four dimensions, with three being comparable to the DSM-5-TR dimensions of CD aggression, CD serious rules violations, and ODD anger/irritable mood. The fourth dimension reflected anti-social behavior, with symptoms from across the different CD and ODD dimensions. These findings can be interpreted as suggesting that CD and ODD are related, but they are distinct disorders, and their symptom dimensions do not entirely align with the DSM-5-TR classifications.

Keywords: Conduct Disorder (CD); Oppositional Defiant Disorder (ODD); network analysis; exploratory graph analysis; adolescents; DSM-5-TR

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INTRODUCTION

According to the Diagnostic and Statistical Manual (DSM-5; [1], including its recent text revised edition (DSM-5-TR, [2]), Conduct Disorder (CD) and Oppositional Defiant Disorder (ODD) are two common child and adolescent disorders. CD refers to repetitive and persistent responses that violate the rights of others or societal norms, such as aggression to people and animals, destruction of property, deceitfulness or theft, and serious violations of rules [2], whereas ODD refers to a pattern of behavioral responses related to oppositionality, vindictiveness, argumentativeness, and irritability that cause conflict with adults and authority figures [1,2]. Studies have concluded that estimates for CD and ODD are approximately 3.5% [3] and 2.8% [4], respectively.

At present, there are robust findings that CD and ODD are highly comorbid [5–11], with some researchers suggesting that ODD is an earlier less serious form of CD or a precursor of CD [9,10,12,13]. However, whether CD and ODD are expressions of the same underlying disorder or independent disorders continues to be hotly debated [14–16]. Indeed, the findings by Diamantopoulou et al. [14] showed that CD and ODD symptoms develop in parallel.

In DSM-5-TR, there are 15 CD symptoms, grouped into four dimensions, namely aggression to people and animals, destruction of property, deceitfulness or theft, and serious rules violations. For ODD, there are eight symptoms, grouped into three dimensions, labelled anger/irritable mood, argumentative/defiant, and vindictiveness (see Supplementary Table S1). Thus, the DSM-5-TR consider both CD and ODD as multidimensional disorders [17–19]. To date, many studies have examined the factor structure of ODD symptoms. In general, while various models have been proposed for ODD, differing in terms of number and names of the dimensions (e.g., [16,20–23]), they all appear to have an affective dimension (e.g., irritability) and a behavioral dimension (e.g., defiant/headstrong). Although not always the case, in a number of studies, the spitefulness symptom (i.e., the only symptom in DSM-5-TR for the vindictiveness dimension) loaded on the affective dimension (e.g., irritability) [21,22].

Studies that have examined the structure of the DSM-IV CD symptoms (which are also the same in DSM-5/DSM-5-TR) have generally supported a two-factor structure, comprising factors for “aggressiveness” (e.g., initiating physical fights) and “delinquency/rule-breaking” (e.g., stealing without confrontation; [24]). However, an exploratory factor analysis by Janson and Kjelsberg [25] that did not include the symptoms for cruel to animals, robbery and forced sex (due to low frequencies), found support for three factors: aggression (bullies, fights, weapon, and cruel to people); delinquency (destroy property, breaks-in, lies, steal and run away); and rule breaking (out at night and truant). These dimensions were interpreted as corresponding to the overt, covert and authority conflict pathways proposed earlier in Loeber et al.’s [26] tripartite model of delinquency. It

is also worthy to note that, the aggression, and rule breaking factors appear to correspond to DSM-5-TR CD dimensions for aggression, and rule breaking. Notwithstanding this, according to Bezdjian et al. [27], the evidence for the structure of CD reflecting the four dimensions/clusters specified for CD in DSM-5-TR is limited [27].

Although a few studies employing Confirmatory Factor Analysis (CFA) have examined the dimensionality of CD and ODD symptoms together (e.g., [19,28]), the CD symptoms were depicted as a unidimensional construct. Thus, these studies were not able to reveal or test the validity of the factorial structure of CD and ODD together in terms of how they are specified in the DSM-5-TR. Consequently, the dimensionality of the CD and ODD symptoms jointly is an area that needs investigating.

At present, much of our current understanding of the psychometric properties (factor structure) of CD and ODD symptoms, and the inter-relations between them have come from latent variable models of psychopathology, in which a psychological disorder is viewed in terms of a latent (unobservable) construct (which is the disorder in question) that causes several observable responses (that are the symptoms of the disorder). An alternate approach to psychopathology is the network model. This proposes that what are traditionally considered to be the symptoms of a disorder interact with each other in meaningful ways, causing the disorder [29]. Relatedly, EGA [30,31], which is related to network analysis, can be used to identify dimensions of symptoms within the network.

To date, although network analysis models have been applied to understanding the properties of ODD symptoms [32–34], they have yet to be applied to CD symptoms, or to CD and ODD symptoms jointly. Given this gap, the current study used network analysis to examine the network properties of CD and ODD symptoms together in a group of adolescents from a psychology clinic. Additionally, it used EGA to examine the dimensionality of the CD and ODD symptoms together.

Network Theory, Model, Analysis, and Data

Network theory assumes that the indicators (or behaviors) traditionally considered to be part of a construct (or disorder) constitute a system, interacting with each other in meaningful ways, resulting in the “construct” (or disorder) in question [29]. In network analysis, the variables (or symptoms in the case of a disorder) making up the network are referred to as nodes. Although nodes are synonymous with symptoms, the use of the term symptom is incompatible with network theory as a node represents surface-level indicators of an underlying cause, and this is inconsistent with network theory [35]. The regression coefficient of a node with another node, controlling simultaneously for the influence of all other nodes in the model, is referred to as an edge. Expressed differently, edges are connections between the node pairs, controlling for all other connections in the model.

Network analysis is used to compute network models [29,36], and generally, correlations between nodes are estimated, while controlling for all other nodes in the network (resulting in a partial correlation structure). When the correlations are estimated using Markov Random Fields [37] with regularization, spurious correlations are suppressed [29,36], thereby producing a conditional independence structure, that reveals the more important relations between the nodes [29,38].

For interpretation of a network structure, the network analysis provides visual and quantitative information about the nodes and edges in the model [29,39]. Specifically, nodes can be examined in terms of centrality and nodes with higher centrality values are generally interpreted as having more influence on other nodes in the network. An edge reflects the strength (partial correlation) of the connection between two nodes, controlling for all other nodes in the network [29,39].

Related to network analysis, EGA [30,31] can be used to identify dimensions of symptoms within the network. In a network, dimensions (also referred to as clusters) are densely connected sets of nodes that form coherent subnetworks within the overall network. In this respect, EGA has several advantages over traditional methods for detecting dimensionality [40,41].

In the context of a network model that includes both the CD and ODD symptoms, the network analysis will show the interdependencies between individual CD and ODD nodes, jointly. It follows therefore, that such an analysis would provide a comprehensive understanding about the comorbidity of the two disorders at the node/symptom level. Additionally, as network based EGA has several advantages over traditional methods for detecting dimensionality [40,41] it can contribute in important ways to the current debate pertaining to whether CD and ODD are expressions of the same underlying disorder or are independent disorders [15]. Overall, therefore, network analysis has the potential to provide clinically and theoretically relevant information that is different to the information provided by the latent variable approach.

Many studies have used network analysis to examine the network properties of a range of disorders (e.g., [18,42–44]), including ODD [34,42]. For parent ratings of children, Gomez et al. [18] found that the first and second most central ODD symptoms were “anger”, and “argue”, respectively. “Anger” and “defy” were the first and second most central ODD symptoms for teacher ratings. Also, for both groups of respondents, there were at least medium effect size associations for “argue” with “temper” and “defy; annoy” “with “blames others”, and “angry” with “spiteful”. Also, for both parent and teacher ratings, the “spiteful” symptom was linked together relatively closely in one group with mainly irritability symptoms (for example high effect size association with “anger”), than headstrong symptoms (for example zero association with “blames others”). For preschool children, Smith et al. [34] also found relative stronger associations for “spiteful” with irritability symptoms of

“angry” and “loses temper” than with headstrong symptoms. These findings were interpreted as showing a novel understanding of ODD symptom structure. Of relevance to the current network study is that unlike previous factor analysis studies that showed mixed findings, in both the previous network analysis studies, the “spiteful” symptom has aligned more with irritability than headstrong symptoms.

To date, network models and EGA have not examined the interrelation of CD and ODD symptoms together. Consequently, there are no data on the network properties of CD and ODD symptoms together. Additionally, no study has examined the dimensionality of CD and ODD symptoms using EGA. The absence of such studies is a significant omission as they could contribute in important ways to theory, taxonomy, diagnosis, and treatment for CD and ODD. For example, when both CD and ODD nodes/symptoms are examined together in the same network, a better understanding of the links between CD and ODD at the symptom level may be possible. Strong relations between the CD and ODD nodes can be expected if CD and ODD are different variants of a common disorder. Conversely, absence and/or weak relations between the CD and ODD nodes might demonstrate they are distinct disorders. At a more general level, the network centrality hypothesis suggests that the more central nodes are the most influential in a network [29,45]. Relatedly, while some researchers disagree [46,47], it has been suggested that identifying the most central nodes (i.e., those with the greatest influence) can impact intervention outcomes [48–50]. That is, a network analysis of CD and ODD nodes might reveal novel findings pertaining to the relative influence of the different symptoms and the associations between them, which might in turn lead to more targeted interventions, and potentially better treatment outcomes.

Aims and Predictions of the Present Study

The first aim of the present study was to use network analysis to examine the network properties of CD and ODD symptoms together. The second aim was to use EGA to examine the dimensionality of the CD and ODD symptoms together. Given that CD is more often diagnosed during adolescence [51] and it is highly comorbid with not only ODD, but other common disorders, such as ADHD, depression, and substance abuse [52], we examined this in a group of adolescents, recruited from an Australian psychology clinic. The scores for CD and ODD symptoms as presented in the parent-report version of the Child and Adolescent PsychProfiler (CAPP-PRF; [53]) were used for this. For the network analysis, a network graph was produced and interpreted; and centrality and edges were examined. In addition, the robustness and stability of this network was checked. For the EGA, a graphical representation of the dimensions was examined, based on the Walk trap community detection algorithm approach.

Based on the argument presented by some researchers that ODD is a precursor (or not) of CD (for a review see [9,54]), we expected there would be close associations between the CD and ODD nodes, but not as strong as

those between the CD nodes. Based on DSM-5-TR conceptualization of CD and ODD, it can be speculated that the EGA would demonstrate CD dimensions reflecting aggression, destruction of property, deceitfulness/theft, and serious rules violations; and ODD dimensions reflecting anger/irritable mood, argumentative/defiant, and vindictiveness. Notwithstanding this, based on existing empirical findings we expected three CD dimensions, comparable to that reported by Janson and Kjelsberg [25]: aggression (symptoms that include bully, fights, weapon, and cruel to people), delinquency (symptoms that include destroy property, lies, steal and run away), and rule breaking (symptoms that include out at night and truant); and 2 ODD dimensions, comparable to that reported by Burke et al. [21]: an affective dimension (e.g., irritability) and a behavioral dimension (e.g., defiant/head strong), with the spitefulness symptom (i.e., the only symptom for the vindictiveness dimension) grouped with the other affective dimension symptoms. Relatedly, we included spitefulness to the affective dimension because, as pointed out earlier, previous network analysis studies have shown that this symptom has shown closer associations with irritability than headstrong symptoms [18,34].

METHOD

Participants

The initial sample, recruited from an Australian psychology clinic, comprised 951 adolescents. These were the same participants used in the previous validation study of the CAPP-PRF. While 69 of these participants (7.26%) had one or more missing data values, the missing value pattern indicated no evidence of monotonicity. Furthermore, there was no missing value pattern for each of the variables. Therefore, we used listwise deletion to remove participants with missing values, and this resulted in a final sample of 882 adolescents.

The mean age (*SD*, range) of the participants was 14.55 years (*SD* = 1.67 years; range = 12.01 years to 17.99 years). There were 533 (60.4%) males (mean age = 14.57 years, *SD* = 1.70 years) and 343 (38.9%) females (mean age = 14.51 years, *SD* = 1.62 years), and no gender information for 6 (0.7%) adolescents. There was no significant age difference across boys and girls, $t(df = 974) = 0.504$, $p = 0.614$. Most participants came from intact families, and their parents completed at least secondary education.

The scores for the CD and ODD symptoms were obtained from the parents of adolescents recruited from a psychology clinic using the parent version of the PsychProfiler (CAPP-PRF; [55]). Most of the participants were screened for psychological disorders using the CAPP-PRF at the time of recruitment. All items in the CAPP-PRF are rated on a six-point Likert scale (never = 0, rarely = 1, sometimes = 2, regularly = 3, often = 4, and very often = 5). When these ratings were re-coded in terms of those not at risk for the presence of the symptom (item ratings of 0, 1 and 2) and those at

risk for the presence of the symptom (item ratings of 3, 4 and 5), the frequencies of those at risk for ODD (based on at least a total of 4 symptoms considered present) was 32.7%, and those at risk for CD (at least a total of 3 symptoms considered to be present) was 8.4%. For these, 7.9% were at risk for both CD and ODD. As these thresholds align with DSM-5-TR thresholds for clinical diagnoses of these disorders, the sample examined in the study can be considered to include a sizable number of adolescents at high risk for CD and/or ODD.

Measure

The CAPP-PRF [55] that was used to obtain the scores for the CD and ODD symptoms can simultaneously screen for 14 of the most common psychiatric, psychological, and educational disorders in children and adolescents. In general, in the CAPP-PRF, the different disorders (including CD and ODD) are measured using items corresponding to the symptoms for the disorders (including wording in most instances), as presented in DSM-5-TR. Notwithstanding this, there were three CD symptoms that were not included in the CAPP-PRF. They were CD7 (“forced someone into sexual activity”), CD8 (“fire setting with intention to cause harm”), and CD10 (“breaking into someone’s house, building, or car”). These symptoms were excluded during its development as school principals objected to their inclusion in the CAPP. Thus, there are only 12 DSM-5-TR CD symptoms instead of the 15 DSM-5-TR CD symptoms in network analysis. All these 12 CD symptoms, and all 8 DSM-5-TR ODD symptoms, were present in network analysis.

According to the PsychProfiler Manual, the CAPP “was subjected to a rigorous psychometric analysis and was found to be reliable and valid” ([55], p. 51). In support of this, a more recent study of the parent ratings of 951 adolescents for the CAPP-PRF supported good fit for its factor structure, and for the internal reliability, and discriminant and criterion validity of all psychological disorders in it (citation withheld for double-blind review purpose). More directly relevant to the current study, the factors for CD and ODD showed acceptable reliability, with alpha coefficients of 0.87 and 0.93 for CD and ODD, respectively. Overall, therefore the findings for the CAPP-PRF CD and ODD factors have shown acceptable psychometric properties for adolescents.

Procedure

This study was approved by the Human Research Ethics Committee of (name withdrawn for blind review) (ROAP 2023/ET000965). All individuals were recruited from the same psychology clinic, located in Perth, in Western Australia. They were recruited over a period of three years. Individuals interested in online screening of DSM-5-TR psychological disorders can access the CAPP-PRF website (<https://www.psychprofiler.com> accessed 2 Oct. 2025). The primary users are psychologists, general practitioners, psychiatrists, pediatricians, and

interested members of the public. In this respect, caregivers were presented with the CAPP-PRF, and they had to rate the presence or absence of all the items (symptoms) in this questionnaire.

All parents of adolescents in the present study were those who provided data through this website. It is worth noting that on completion of the CAPP-PRF, individuals are requested to click a statement asking if their data can be used for future research and validation purposes. Thus, opt-in informed consent from parents was available for all adolescent participants involved in the study. Only adolescents with CAPP-PRF ratings for CD and ODD symptoms and parental consent were included in the study.

Statistical Analysis

The mean scores for the relevant CAPP-PRF CD and ODD symptoms were used in the network analysis. For the network analysis, we used the mean scores for these 12 CD symptoms and the 8 ODD symptoms in the model. Therefore, in the network analysis there were 20 symptoms or nodes. Thus, a total of 210 $((20) + (20 \times 19/2))$ parameters were estimated in our network analysis [56]. For a network analysis, sufficient power can be assumed if the sample size in the network is more than the number of estimated parameters. Given the sample size in the present study was 882 (after listwise deletion for missing values), it can be considered adequate for the network analysis.

The network analysis was conducted using the network module provided in Jeffreys' Amazing Statistics Program (JASP) version 0.14.1.0 (JASP Team, 2018). In JASP, the *botnet* package from R [37] is used to conduct network analysis, and the *qgraph* [57] package from R is used to network graphs. For the network analysis, we applied the Least Absolute Shrinkage and Selection Operator (LASSO) [58], with a hyperparameter set at 0.5, as recommended [37,59]. eLasso uses regression to compute associations between pairs of the nodes (symptoms), while partialling out the association between each node and all other nodes. Consequently, the network analysis produces a regularized partial correlation network, showing only the most important relationships or edges. For the network analysis, missing data were handled using the exclude listwise method.

Visually, the layout of our networks was based on the Fruchterman–Reingold algorithm that places the nodes with stronger and/or more connections closer together and the most central nodes into the center. Additionally, positive associations are depicted as blue lines, and negative associations are depicted as pink lines, with them being proportionally thicker and brighter with increasing strength.

Statistically, the network properties were examined in terms of centrality (the relative importance of the individual nodes in the network) and edge weights of the nodes (the correlation or partial correlation between two nodes; [60]). The centrality value of a node reflects how well it is connected, and they are often reported in terms of four indices:

closeness, betweenness, degree, and expected influence [61]. Closeness captures how close a node is to all other nodes by evaluating the inverse sum of the shortest paths between it and all other nodes. Degree captures how strongly a node is directly connected to other nodes, by summing the unsigned correlations between it and other nodes. Betweenness captures the average distance of a node to all other nodes with which it is connected. These three indices do not consider the direction of the edge (positive or negative). In contrast, the expected influence of a node, calculated as the sum of the signed correlations between it and other variables, considers this. As a node with a negative edge cannot be considered problematic because its activation diminishes activation in other nodes and thus reduces overall severity, betweenness, closeness, and degree/strength values can be misleading. Therefore, to avoid the interpretative challenges associated with these fit indices, we examined centrality using expected influence, as recommended by Robinaugh et al. [62]. It is important to note that centrality values are different from mean scores, used traditionally to infer the importance of symptoms [63]. According to network theory, when a node with high centrality is activated, its activation will spread or influence other nodes that are connected to it.

In addition to centrality, the network was examined for edge weights. Edges are connections or links between nodes. When edges are weighted, a numerical value (the “weight”) is associated with them, reflecting the strength of the relationships. For example, in a psychology networks, as in this study, a stronger correlation between two nodes would be represented by a weight specified in terms of a specific color that could be thicker and darker in a visualization. All edges displayed in the network can be considered worthy of interpretation. However, as there were many edges, and to allow a clear interpretation of the edges, the guidelines proposed by Christensen and Golino [40] for interpreting network effect sizes (negligible ≤ 0.14 , small = ≥ 0.15 to < 0.25 , moderate ≥ 0.25 to < 0.35 , and large ≥ 0.35) were used. In general, moderate and large effect sizes were considered as important.

In addition, network analysis can provide information on centrality bridge symptoms in the network that is being examined. These are centrality indices excluding intra-disorder node relationships to focus exclusively on inter-disorder node relationships. Therefore, they can reveal symptoms that bridge (or connecting pathways) for different disorders, which is our case is between CD and ODD. Expressed differently, this indicates influential symptoms that increase the likelihood of developing comorbidity between CD and ODD. In this respect, following suggestions outlined in Zarate et al. [64] we sought to identify bridge symptoms that may connect or serve as pathways between CD and ODD. Specifically, we observed bridge strength or the frequency of connections between symptoms across these disorders, and bridge expected influence or the sum of positive weighted edges across these disorders.

For network analysis, the reliability (accuracy and stability or the likelihood that the network results will be replicated) of the centrality and edge values need to be evaluated. The stability of the centrality indices was examined using case-dropping bootstrapping [57]. Briefly, this examines if the order of centrality indices remains the same after re-estimating the network with less cases (or nodes), quantified in terms of correlation stability coefficient. This coefficient reflects the correlation between the original centrality indices (based on the full data) and the correlation obtained from the subset of data representing different percentages of the overall sample. Although it has been suggested that a correlation stability coefficient of 0.7 or higher is the threshold, Epskamp et al. [57] recommend values above 0.25, with values above 0.50 indicating high robustness. We examined expected influence (used as our index of centrality) to interpret stability using strength centrality. The reliability of edge weights was evaluated using bootstrap 95% non-parametric confidence intervals (CIs). For this, narrower CIs suggest a more precise estimation of the edge [57]. In this study, edge weight accuracy and the stability of the centrality indices in the network were examined with 1000 bootstraps.

For the EGA, we used the Walktrap community detection algorithm within an EBIC-glasso framework [30,65,66] to identify the dimensions for the CD and ODD symptoms in the network. In brief, the Walktrap algorithm operates on the principle that random walks on a graph tend to get “trapped” within densely connected regions, which correspond to communities (nodes inside a community are densely connected). It uses the results of these random walks to merge smaller, separate communities in a bottom-up fashion until a final community structure is identified [67]. With this procedure, the dimensions from the EGA are presented graphically, with each dimension in a different color. However, the Walktrap community detection algorithm, based on the EGA net package, assigns each node to a single community, which may not align with the nature of CD and ODD symptoms. Thus, we also incorporate additional community detection algorithms, in particular the R package for Clique Percolation Algorithm [68]. This method allows for overlapping communities, which could provide a more nuanced understanding of symptom interactions and further validate the current conclusions.

RESULTS

Descriptive Scores and Bivariate Correlations of the CD and ODD Symptoms

Prior to the network analysis, the mean and standard deviation (*SD*) scores for the 12 CD symptoms, and the eight ODD symptoms were computed (see Supplementary Table S1). Brief descriptions of the nodes are also provided in this table. As shown, the mean scores for CD symptoms ranged from 0.12 (“cruel to animals”) to 1.82 (“lies”), and the mean scores for ODD symptoms ranged from 1.62 (“annoys”) to 2.48

(“touchy”). For CD symptoms, “lies” had the highest mean score, followed by “bully”. For ODD, “touchy” had the highest mean score, followed by “argues”. We also computed the bivariate correlations among the CD and ODD symptoms, and this is presented in Supplementary Table S2. As shown, all the symptoms were correlated significantly and positively with each other ($p < 0.01$).

Network Analysis

Visualization

The maximum number of edges in the network was 190. The EBIC-glasso estimation reduced the number of edges estimated to 112 (sparsity = 0.41). Figure 1 shows a visualization of the network structure for the CD and ODD nodes in this model. As can be seen, apart from ODD6 (“annoys others” in the argumentative/defiant dimension), all other ODD nodes were grouped together in one position, and all the CD nodes were grouped together in another position of the network. ODD6 (“annoys others” in the argumentative/defiant dimension) was somewhat in the center of the network, being relatively closer to the CD nodes than the ODD nodes. Therefore, it could be considered as bridging the CD and ODD nodes.

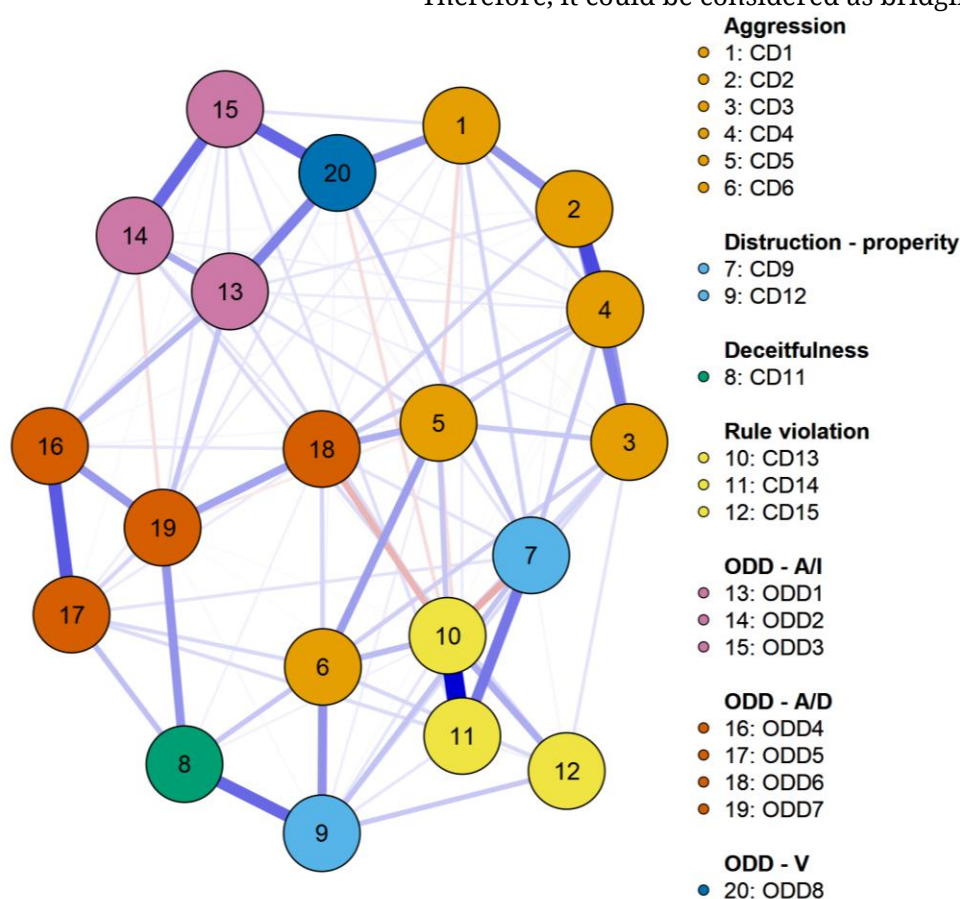


Figure 1. Network of the CD symptoms from network analysis of both CD and ODD symptoms together. ODD-A/I = Angry/Irritable Mood; ODD-A/D = Argumentative/Defiant Behavior; ODD-V = Vindictiveness. Note: Blue lines represent positive associations, and red lines negative associations. The thickness and brightness of an

edge indicate the association strength. The layout is based on the Fruchterman–Reingold algorithm that places the nodes with stronger and/or more connections closer together.

Supplementary Figure S1 presents the plot for these. The standardized estimates of the centrality indices for betweenness, closeness, strength, and expected influence are presented in Table 1. As shown in the table and supplementary Figure S1, in sequence, among the nodes with the highest expected influence values (used as our index of centrality) were “cruel to people” (CD 4 in the aggression dimension) and “stolen—not confronting” (CD 12 in the deceitfulness/theft dimension), “fight” (CD 2 in the aggression dimension), “stolen with confronting” (CD6 in the aggression dimensions), and “temper” (ODD1 in the anger/irritable mood dimension dimension).

For comparison, Table 1 also includes the means scores for the different symptoms. As will be noticed, the rank order of the expected influence and mean values varied considerably.

Table 1. Centrality indices for the CD and ODD symptoms from the network analysis.

Variable	Symptom	Centrality				Mean
		Betweenness	Closeness	Strength	Expected Influence	
CD1	bully	0.63	−0.15	−0.73	−1.16	0.89
CD2	fight	0.04	−0.38	0.09	1.05	0.51
CD3	weapon	−0.92	−0.91	0.01	0.55	0.23
CD4	cruel people	−0.68	−0.27	0.56	1.48	0.58
CD5	cruel animals	−1.04	0.23	0.35	−1.26	0.12
CD6	stolen—confronting	−0.68	−0.44	0.07	1.03	0.26
CD9	destroy	1.23	1.57	0.8	−0.21	0.65
CD11	lies	0.04	0.02	−0.5	−0.73	1.82
CD12	stolen—not confronting	0.51	0.58	0.14	1.12	0.46
CD13	out at night	0.16	0.8	2.86	−0.77	0.21
CD14	run away	0.04	1.07	0.53	0.72	0.57
CD15	truant	−1.4	−1.87	−2.48	−2.38	0.65
ODD1	temper	1.11	0.98	−0.08	0.84	2.26
ODD2	touchy	−0.92	−1.32	−0.79	−0.99	2.48
ODD3	angry	−0.44	−1.11	−0.53	0.28	2.09
ODD4	argues	−0.32	−0.76	−0.42	0.43	2.31
ODD5	defies	−1.16	−1.26	−0.89	−0.18	2.21
ODD6	annoys	0.04	1.15	0.23	−0.68	1.62
ODD7	blames	1.11	1.17	0.01	0.31	2.07
ODD8	spiteful	2.66	0.89	0.76	0.54	2.01

Note. Higher numbers indicate that the variable is more central to the network.

Bridge Symptoms

Supplementary Figure S2 shows the centrality bridge symptoms for all the ODD and CD symptoms in our network. As shown, bridge symptoms with the highest sum of positive weighted inter-disorder edges frequency of inter-disorder edges (i.e., expected influence) were CD11 (“lies”), ODD6 (“annoys”), and ODD5 (“defies”). Interestingly, the same nodes (CD11, ODD6 and ODD5) also showed the highest frequency of inter-disorder connections. Thus, symptoms can be seen as bridges between ODD symptoms and CD symptoms.

Edges

The edge weights for the nodes in network analysis are shown in Supplementary Table S3. There was a total of 190 edges across all the CD and ODD nodes. Of these, 12 (6.32%) were negative, and 89 (46.84%) were not connected. The remaining 89 (46.84%) were positive. For the CD nodes, 6 (9.09%) were negative, 24 (36.36%) were not connected, and the remaining 36 (54.55%) were positive. There were large effect size connections between “fight” (CD2 in the aggression dimension) and “cruel to people” (CD4 in the aggression dimension), and “out at night” (CD13 in the serious rule violations) and “runaway” (CD14 in the serious rule violations); and medium effect size connections between “fight” (CD2 in the aggression dimension) and “weapon” (CD3 in the aggression dimension), “lies” (CD11 in the deceitfulness/theft dimension) and “stolen not confronting” (CD12 in the deceitfulness/theft dimension), and “destroy” (CD9 in the destruction property dimension) and “run-away” (CD14 serious rule violations). For the ODD nodes, 7 (25.00%) were not connected, and the remaining 21 (75.00%) were positive. There was large effect size connection between “argues” (ODD4 in the argumentative/defiant dimension) and “defies” (ODD5 in the argumentative/defiant dimension); and medium effect size connections between “touchy” (ODD2 in the anger/irritable mood) and “angry” (ODD3 in the anger/irritable mood), “temper” (ODD1 in the anger/irritable mood) and “spiteful” (ODD8 in the vindictiveness dimension), and “angry” (ODD3 in the anger/irritable mood) and “spiteful” (ODD8 in the vindictiveness dimension). For nodes between CD and ODD symptoms, in all, there were 120 potential connections. Of these 6 (5.0%) edges were associated negatively, 58 (48.33%) were not connected, and the remaining 56 (46.67%) were connected positively.

Based on the guidelines proposed by Christensen and Golino [40] for interpreting network effect sizes (negligible ≤ 0.14 , small ≥ 0.15 to <0.25 , moderate ≥ 0.25 to <0.35 , and large ≥ 0.35), all significant connections were either negligible (≤ 0.14) or small (≥ 0.15 to <0.25). However, the edges weight value for both “bullying” (CD1 in the aggression dimension) and “spiteful” (ODD8 in the vindictiveness dimension), and “lies” (CD11 in the deceitfulness dimension) and “blames” (ODD7 in the argumentative/defiant dimension) were both at 0.24, i.e., very close to moderate effect size (≥ 0.25).

Reliability

The reliability or stability of the centrality indices, examined using case-dropping bootstrapping, is shown in Supplementary Figure S3. The figure shows this for expected influence and strength. As shown, there was appropriate stability (acceptable proportions of case-dropping to retain correlations of 0.7 in at least 95% of the samples) in edge-weights expected

influence (CS = 0.75) and strength (CS = 0.75), thereby indicating robustness in the stability for the strength centrality index [57].

Supplementary Figure S4 shows the accuracy of the edge weights estimated using bootstrap 95% non-parametric CIs. As shown, the 95% CI for most of the estimated edges were relatively narrow, thereby indicating robust stability of the edges in the network.

Exploratory Graph Analysis

Figure 2 shows the results of the EGA. As can be seen, the EGA identified 4 dimensions, and these dimensions are represented by different colors in Figure 2. Table 2 shows the nodes (symptoms) in these different dimensions. It also includes their brief descriptions. Of the four dimensions, the first dimension included CD1, CD2, CD3 and CD4 (i.e., four of the six symptoms for the CD dimension of aggression). The second dimension that included CD5, CD6, CD9, CD11, CD12, ODD4, ODD5, ODD6 and ODD7 included 2 symptoms for the CD aggression dimension, 1 CD symptom for the destruction of property dimension, 2 CD symptoms for the deceitfulness/theft dimension, and all 4 ODD symptoms for the argumentative/defiant dimension. The third dimension included CD13, CD14 and CD15 (i.e., all three symptoms in the CD serious rules violations dimension). The fourth dimension that included ODD1, ODD2, ODD3 and ODD8 included all three symptoms in the ODD anger/irritable dimension, and the symptom in the ODD vindictiveness dimension.

Supplementary Figure S5 shows the results of the community detection algorithms with the nodes assigned according to the Clique Percolating Algorithm. As shown, with $k = 3$, $I = 0.20$, no item overlapped between communities, suggesting relatively distinct CD vs ODD clusters despite several strong cross-construct edges [68]. Thus, the results from the EGA that used the Walktrap community detection algorithm can be interpreted confidently.

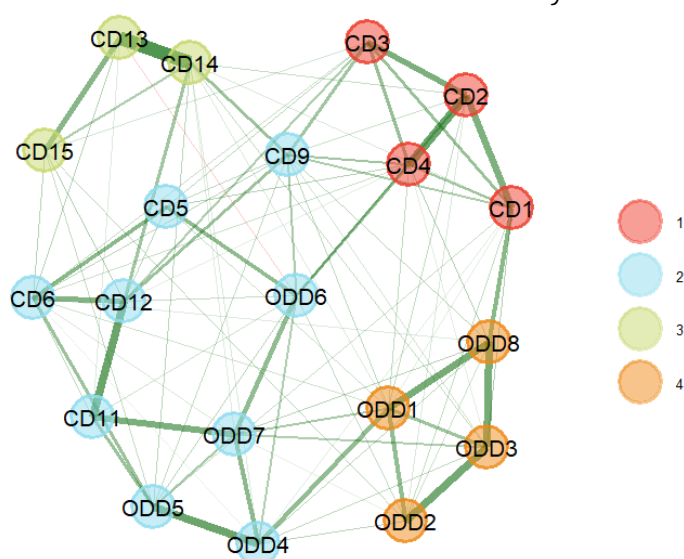


Figure 2. Results of the EGA for detecting dimensions for the CD and ODD nodes in the network.

Table 2. Dimensions produced in the EGA for the CD and ODD nodes.

DSM-5-TR		EGA	
Symptoms	Brief Description	DSM-5-TR Dimensions	Dimension
CD1	bully	Aggression	1(Aggression)
CD2	fight	Aggression	1 (Aggression)
CD3	weapon	Aggression	1 (Aggression)
CD4	cruel people	Aggression	1 (Aggression)
CD5	cruel animals	Aggression	2 (Anti-social behavior)
CD6	stolen—confronting	Aggression	2 (Anti-social behavior)
CD9	destroy	Destruction property	2 (Anti-social behavior)
CD11	lies	Deceitfulness/theft	2 (Anti-social behavior)
CD12	stolen—not confronting	Deceitfulness/theft	2 (Anti-social behavior)
ODD4	argues	Argumentative/defiant	2 (Anti-social behavior)
ODD5	defies	Argumentative/defiant	2 (Anti-social behavior)
ODD6	annoys	Argumentative/defiant	2 (Anti-social behavior)
ODD7	blames	Argumentative/defiant	2 (Anti-social behavior)
CD13	out at night	Serious rules violation	3 (Serious rules violation)
CD14	run away	Serious rules violation	3 (Serious rules violation)
CD15	truant	Serious rules violation	3 (Serious rules violation)
ODD1	temper	Anger/irritable mood	4 (Anger/irritable mood)
ODD2	touchy	Anger/irritable mood	4 (Anger/irritable mood)
ODD3	angry	Anger/irritable mood	4 (Anger/irritable mood)
ODD8	spiteful	Vindictiveness	4 (Anger/irritable mood)

DISCUSSION

Overall, of the five nodes with higher centrality values, three were from the CD aggression dimensions (“cruel to people”, “fight”, and “stolen with confronting”), while two were from the deceitfulness/theft dimension (“stolen—not confronting”) and the anger/irritable mood dimension ODD (“temper”). In relation to edge weights, approximately 50% of the nodes (especially between CD, and CD and ODD) were not connected as expected. For CD symptoms, only 7.58% of the edge weights were either large or medium; and for ODD symptoms, only 14.29% of the edge weights were either large or medium. None of the edge weights between CD and ODD symptoms were of large or medium effect size. However, the edge weights for CD1 and CD11 with ODD8 and ODD7, respectively, were very close to moderate effect sizes. The CD symptom for CD11 (“lies”), and ODD symptoms for ODD6 (“annoys”) and ODD5 (“defies”) showed evidence of being bridge symptoms. The results for the EGA showed a reasonable degree of comparability with the dimensions proposed in DSM-5-TR for the CD and ODD symptoms. Although, the composition of the dimensions was not identical to comparable dimensions in DSM-5-TR, there were dimensions for CD aggression, CD serious rule violations, and ODD anger/irritable. There was also a dimension that included symptoms from across the DSM-5-TR CD and ODD dimensions, characterized by broad anti-social behavior (delinquency/defiance). There were, however, no separate dimensions for CD deceitfulness/theft and ODD argumentative/defiant. Although our findings were not completely as hypothesized, they do offer novel theoretical and clinical implications that we discuss below. Prior to this discussion, we will compare our findings to existing findings.

Comparison with Previous Findings

In general, a network structure is dependent on the specific nodes included in the network analysis [57]. Although network analysis has previously been used to examine the structure of ODD symptoms, this has not been done for CD symptoms, or for ODD and CD symptoms jointly. Thus, there are no existing network studies with which we can compare our findings. Notwithstanding this, we compared our ODD network findings with previous studies that have examined networks for the ODD symptoms. First, for studies that have examined the network structure of the ODD symptoms, Gomez et al. [18] found that the most central ODD symptom was “anger”. This was also the case for pre-school children [34]. Since it was “temper” in the current study, it can be speculated that a different central symptom for ODD is revealed when ODD symptoms are considered with CD symptoms.

Although network analysis and factor analysis are different procedures, they are comparable [33,40]. Relatedly, virtually all factor analysis studies of ODD symptoms have supported an affective dimension (e.g., irritability) and a behavioral dimension (e.g., defiant/headstrong [42]), with a few studies showing that the spitefulness symptom (i.e., the only symptom in DSM-5-TR for the vindictiveness dimension) loads on the affective dimension (e.g., irritability; [21,22]). To some degree, the finding for the EGA for the ODD symptoms showed some support for such a separation. It showed that the symptoms for the behavioral dimension cluster together, although with several CD symptoms; and there was a cluster for the symptoms for the affective dimension. Also, the ODD spiteful symptom clustered together with the other ODD anger/irritable symptoms.

Past studies that have examined the structure of the DSM-IV CD symptoms (which are also the same in DSM-5/DSM-5-TR) have supported a two-factor structure, comprising factors for “aggressiveness” (e.g., initiating physical fights) and “delinquency/rule-breaking” (e.g., stealing without confrontation; [24]). This was also revealed in the EGA in the present study as two of the three CD symptoms reflected aggression, and delinquency/rule-breaking.

Although a few studies employing CFA have examined the dimensionality of CD and ODD symptoms together (e.g., [19,28]), the CD symptoms were depicted as a unidimensional construct. Unlike those studies, in the current study both CD and ODD symptoms were included. Consequently, we were able to reveal dimensionality of the CD and ODD when considered together. The findings revealed dimensions for aggression, antisocial behavior, serious rules violations, and anger/irritable. These dimensions contrasts with DSM-5-TR dimensions for aggression, destruction of property, deceitfulness/theft, argumentative/defiant, serious rules violation, anger/irritability, and vindictiveness.

Theoretical Implications

Given the centrality values for the nodes in network analysis the CD aggression nodes for “cruel to people”, “fight”, and “stolen with confronting”, and the deceitfulness/theft nodes for “stolen—not confronting”, and the ODD anger/irritable mood node for temper” can be considered as having relatively stronger influence on the other CD and ODD symptoms. Our findings showed that as much as approximately 50% of the CD nodes were not connected, and of this only 7.58% of the edge weights were either large or medium. For ODD symptoms only 14.29% of the edge weights were either large or medium, and none of the edge weights between CD and ODD symptoms, were of large or medium effect size. Considering these findings, it can be speculated that there were only modest associations between the nodes, especially between the CD nodes, and between the CD and ODD nodes.

Overall, therefore, despite existing robust findings that CD and ODD are highly comorbid [5–10,63], at the symptoms level, our edge weight correlations suggest they are likely separate diagnostic categories or disorders, as embraced in DSM-5-TR. Thus, although some researchers have combined CD and ODD to create an ODD/CD phenotype (e.g., [69]), our findings are more supportive of keeping them separate. Also, our findings do not provide compelling support [48] for the general view that ODD is a precursor of CD [10,43], or that ODD is an earlier less serious form of CD [14,48]. We base this argument on our findings that the ODD symptoms were not completely separate from the CD symptoms, and also as this was a cross-sectional study, the findings cannot provide compelling evidence to “support” or “not support” precursor relationships. As our findings are based on network analysis, not used previously, the findings in this study provide new and novel theoretical insights on the issue of whether CD and ODD are expressions of the same underlying disorder or independent disorders [15].

In relation to the EGA, the findings support four dimensions, with three being comparable to the DSM-5-TR dimensions of CD aggression, CD serious rules violations, and the remaining one with ODD anger/irritable. There were no separate dimensions for CD deceitfulness/theft and ODD argumentative/defiant. Indeed, the symptoms in these dimensions combined together in a separate dimension that also included symptoms from the CD dimensions for aggression and destruction to property. Thus, it can be speculated that when considered with ODD symptoms, the CD deceitfulness/theft cluster departs from that suggested in DSM-5-TR to reflect a broader dimension that includes ODD symptoms, characterized by anti-social behavior, in particular delinquency and defiance. This dimension is comparable to the “delinquency/rule-breaking” dimension(s) proposed in earlier studies [24,25].

Overall, therefore, the dimensions for CD and ODD symptoms did not correspond to the DSM-5-TR dimensions proposed for CD (aggression, destruction of property, deceitfulness/theft, and serious rules violations),

and ODD (anger/irritable mood, argumentative/defiant, and vindictiveness). It also differed somewhat from existing empirical findings that suggest CD dimensions for aggression, delinquency, and rule breaking [25,26]; and ODD dimensions for affectivity/irritability and defiant/headstrong [18]).

From a theoretical viewpoint, since the CD symptom for CD11 (“lies”), and ODD symptoms for ODD6 (“annoys”) and ODD5 (“defies”) showed evidence of being bridge symptoms, that may explain to some degree co-occurrence in CD-ODD comorbidity. Second, as ODD6 (“annoys others” in the argumentative/defiant dimension) was somewhat in the center of the network, thereby being relatively closer to the CD nodes than the ODD nodes, it can be considered as bridging the CD and ODD nodes. Third, although the ODD symptoms within the anger/irritability dimension and the argument/defiant dimension were grouped close to each other, they were in different locations. The spiteful symptom (the symptom for the vindictiveness dimension) was close to the set of anger/irritability symptoms (especially “temper” and “angry”), thereby raising the possibility that it could be part of the anger/irritability dimension. This concurs with the three-factor ODD model proposed by some researchers (e.g., [22]). Burke’s model proposes factors for negative affect, oppositional behavior, and antagonistic behavior. The negative affect and oppositional behavior dimensions are comparable to the angry/irritability and argumentative/defiant behavior dimensions in DSM-5-TR. As in Burke’s model, there is no equivalent DSM-5-TR factor for antagonistic behavior. Indeed, in Burke’s model, the ODD symptom for spitefulness that indexes the DSM-5-TR vindictiveness factor loaded on the negative affect dimension. Consistent with Burke et al’s. [22] model, our findings suggest the vindictiveness symptom for spitefulness could be grouped with the angry/irritable dimension, instead of being on a single-item separate dimension.

Diagnostic Implications

At one level, a clinically convenient method to infer the relative importance or severity of a symptom is its mean score [70], especially when the symptom is viewed from a dimensional viewpoint (see for example, [71]). In this present study, for CD symptoms, “lies” had the highest mean scores, followed by “bully”. In contrast, in the network analysis, the five symptoms (nodes) with the highest expected influence centrality score were “cruel to people”, “fight”, “stolen with confronting”, “stolen—not confronting”, and “temper”. Thus, when compared to mean scores, the findings from the network analysis indicated different core symptoms for CD. Therefore, clinicians may wish to pay particular attention to the presence and severity of those symptoms with high centrality values as they could be relatively more important for understanding, assessing and managing CD, OD and ODD-CD comorbidity.

Because it is not expected for symptoms in the same disorder to be associated negatively, our findings for a negative large effect size association for “run away from home” and “out at night” raises questions about the simultaneous use of either or both of these symptoms for diagnosing CD. Also, as our findings indicated negative associations for “bully” and “cruel to animals”, “destroy property” and “out at night”, and “run away from home” and “cruel to animals”, questions can also be raised about the utility of these symptoms for diagnosing CD. While we are not proposing that these symptoms are not relevant for a CD diagnosis, there is room for reconsideration of the role and appropriateness of approach for their use for the diagnosis of CD.

Treatment Implications

The network centrality hypothesis suggests that the more central nodes are the most influential in a network [29,35,45], and that intervening on the central nodes can potentially maximize the impact of an intervention, especially on those with which they are closely connected [45,48–50]. Therefore, given the more central nodes in the network analysis, it could be argued that intervening on the CD symptoms “cruel to people”, “fight”, and “stolen with confronting”, and “stolen without confronting”, and ODD symptom “temper” could have the potential (more than the other CD and ODD symptoms) to reduce CD and ODD. Thus, when both CD and ODD are present, they could be treated concurrently, with no need to treat them separately. As most of the CD symptoms were in the aggression dimension, it can be argued that at a more general level, prioritizing aggression behaviors when treating ODD with CD comorbidity is preferable. Additionally, as the edges between CD “bullying” and ODD “spiteful”, and CD “destroy” and ODD “blames” were very close to moderate effect sizes, these associations might also be valuable targets of intervention for CD/ODD comorbidity. In light of these findings, clinicians may wish to focus more on the presence of aggression symptoms and prioritize them when planning treatment for CD, ODD, and CD with ODD. At the practical level, a network-based based treatment approach could require clinicians to view the symptoms present in an individual in terms of their centrality (based on the findings reported here), and choose symptoms with higher centrality values to target, while also considering their connections to other symptoms (based on the findings reported here), and the individual’s clinical history and other disorders/psychological problems and needs [35].

Study Strengths, Limitations and Directions for Further Studies

This is the first study to use network analysis and EGA to examine the properties and dimensionality of CD and ODD symptoms concurrent in a large group of adolescents, recruited from a psychology clinic. Consequently, the study provides novel, and theoretically and clinically meaningful findings regarding the psychometric properties of CD and

ODD symptoms, and the relationships between these symptoms that are relevant to researchers and clinicians.

Despite the strengths, the results of the study must be interpreted in light of a number of limitations. Although the network centrality hypothesis suggests that the more central nodes are the most influential in a network [29,45], we used cross-sectional data and therefore we cannot infer causality. However, it is possible that the findings could be interpreted as eliminating spurious candidates for causal relations. Although participants in the study were from a psychology clinic, their clinical status was unknown. Furthermore, while ratings were recorded in terms of symptoms present or absent and this showed that 32.7% of the adolescents met the symptom threshold for ODD, 8.4% met the symptom threshold for CD, and 7.9% met the thresholds for both CD and ODD, there are limitations regarding the generalization of the findings to adolescents with a clinical diagnosis, including those with CD and ODD. Similarly, as data were obtained using the CAPP-PRF, they cannot be generalized to other measures. Only one sample was examined and therefore replication studies are needed. Moreover, the data collected were parent-report and therefore may be confounded from common method variance. It should also be acknowledged that DSM-5-TR has 15 CD symptoms, and we used only 12 because school principals objected to the inclusion of “forced someone into sexual activity”, “fire setting with intention to cause harm”, and “breaking into someone’s house, building, or car” in the CAPP-PRF-. Also, as CD and ODD are strongly comorbid with a wide range of other disorders (including anxiety, mood, neurodevelopmental, and eating), it is conceivable that the participants in this study comprised a mixed psychiatry sample with many comorbid disorders. This was not accounted for; therefore, the findings are likely to be confounded. Another point worthy of note is that this study was framed within the DSM-5’s structure. As the dimensional differences of ODD and CD vary significantly across theoretical frameworks, it might be helpful to include in future studies data that would enable comparisons with dimensions from other theories. Another limitation worthy of note is that although the frequencies of those at risk for ODD and Cd were high (i.e., 32.7% for ODD, 8.4% for CD, and 7.9% for both CD and ODD, they were not formally diagnosed. Overall, therefore, although the findings in the study might be viewed as compromised, these symptoms (especially forcing someone into sex and setting fire) occur at extremely low frequencies in the general and clinic populations [25,29]. Taken together, our findings challenge the assumption that CD and ODD are unitary constructs and suggest the need for diagnostic models that accommodate dimensional overlap and symptom-level variability. Future longitudinal network analyses are essential to test these structures over time and inform precision-based interventions.

ETHICAL STATEMENT

Ethical Approval

The present study was approved by (withheld for blind review) Human Research Ethics Committee (Approval Number—ROAP 2023/ET000965). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Informed consent was obtained from all parents and individual participants included in the study.

Declaration of Helsinki STROBE Reporting Guideline

This study adhered to the Helsinki Declaration. The Strengthening the Reporting of Observational studies in Epidemiology (STROBE) reporting guideline was followed.

SUPPLEMENTARY MATERIALS

The following supplementary materials are available online, Table S1: Descriptive of the DSM-5 CD and ODD symptoms used for the network models. Table S2: Intercorrelations among the Conduct Disorder (CD) Oppositional Defiant Disorder (ODD) symptoms. Table S3: Edge weights in the network analysis. Figure S1: Centrality plots (betweenness, closeness, degree, and expected influence) in the network for both CD and ODD symptoms together. Note. Values shown on the x-axis are standardized z-scores. Figure S2: Bridge symptom indices for the ODD and CD symptoms. Note. The horizontal axis represents sums of weights and frequency of bridge symptoms across ODD and CD. The vertical axis represents each ODD and CD symptoms. Figure S3: Stability of centrality indices by case dropping subset bootstrap. Note. The graph shows the average correlation between bootstrap centrality indices of networks sampled with node-dropping. A strong correlation after dropping a high percentage of participants indicate that centrality measures in the original network can be considered robust. Red lines indicate the average correlation between the expected influence in the original sample and the expected influence in the sample. Figure S4: Edge stability estimate for the CD symptoms in network analysis of both CD and ODD symptoms together. Note. The x-axis represents the edges, while every line on the y-axis represents a specific edge. The red line shows the estimate of the edge weights, and the grey bars the 95% confidence intervals for the estimates. Figure S5: Community detection with node assignment according to the clique percolating algorithm.

DATA AVAILABILITY

Data is available upon request to the first author.

AUTHOR CONTRIBUTIONS

RG: Conceptualization, Formal analysis, Methodology, Writing—original draft, Writing—review & editing all drafts. SL: Data curation, Writing—review & editing. DZ—Formal analysis; SH: Writing—ongoing review & editing.

CONFLICT OF INTERESTS

SL was employed by Psychological & Educational Consultancy Services. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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