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A Network Analysis of ADHD and ASD Symptoms in Chinese Children: Insights on Age and Gender Differences

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ABSTRACT

Objective: This study aimed to explore the transdiagnostic interactions between ADHD and ASD symptoms in Chinese children, identifying core and bridging symptoms, and examining differences in symptom networks across gender and age subgroups.

Method: Using data from a nationwide mental health survey of 71,217 Chinese children (mean age = 11.49, SD = 2.82), a symptom network analysis was conducted. ADHD and ASD symptoms were assessed via the Child Behavior Checklist (CBCL), with ASD items selected from an empirically derived CBCL autism scale. Network estimation was performed using the Glasso algorithm, and community detection was achieved through exploratory graph analysis (EGA). Network comparison tests (NCT) were used to evaluate differences in network structure and connectivity between gender (male vs. female) and age (younger vs. older) subgroups.

Results: Inattentive symptoms (I8 "Cannot concentrate," I78 "Inattentive/easily distracted") emerged as central bridging nodes linking ADHD and ASD symptoms. Three stable communities were identified: (1) an inattentive/internalizing cluster reflecting overlapping ADHD-inattentive and ASD features, (2) a hyperactive/impulsive and immature behavior cluster, and (3) a social withdrawal/low energy cluster representing core ASD features. Females exhibited significantly higher network connectivity than males (global strength: $S = 1.05$, $p = 0.03$), with tighter symptom interplay. Older children showed greater ADHD-ASD symptom overlap, though global strength differences were non-significant ($S = 0.70$, $p = 0.13$).

Conclusion: Two inattentive symptoms (I8 and I78) emerged as among the most strongly connected items in the combined ADHD–ASD symptom profile, suggesting that attentional difficulties could play an important role in the psychopathological mechanisms underlying both conditions. Nevertheless, this cross-sectional finding does not establish causality; longitudinal and intervention studies remain necessary. Screening approaches tailored to gender differences and local cultural context could improve identification of these symptoms in Chinese children and adolescents. The present findings may also guide future refinements in school mental-health support and related policy development.

The first two authors are joint first author.

1 | Introduction

Attention Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD) are two highly prevalent neurodevelopmental disorders in childhood and adolescence. Their complex symptomatology, high comorbidity rates, and long-term functional impairments pose significant challenges to global public health systems (Jonathan et al. 2020; Tomoya and Bryan 2023). ADHD is primarily characterized by inattention, hyperactivity, and impulsivity, with a pooled global prevalence of about 8.0% (95% CI: 6%–10%) in children and adolescents (Ayano et al. 2023). Beyond these core features, sex/gender and age shape clinical presentation—meta-analytic data show females with ADHD exhibit slightly lower mean severity of core symptoms and more internalizing features (Young et al. 2024), while longitudinal work indicates hyperactivity/impulsivity tends to decline with age whereas inattention is comparatively persistent (Shaw and Sudre 2021). This persistence significantly increases the risk of academic failure, social conflicts, and emotional disorders (Jonathan et al. 2020). In contrast, ASD is mainly defined by deficits in social communication, restricted and repetitive behaviors, and sensory processing abnormalities (Tomoya and Bryan 2023). Epidemiological studies indicate that ASD prevalence has approached 0.7%, with 50%–70% of individuals diagnosed with at least one additional psychiatric disorder, such as anxiety, ADHD, or intellectual disability (Alwin et al. 2025; Vahe et al. 2023). Critically, epidemiology suggests a male-to-female ratio closer to 3:1 (Loomes et al. 2017) and highlights camouflaging—particularly among females—which can alter observed phenotypes and contribute to under-recognition (Cook et al. 2021), and restricted/repetitive behaviors often attenuate with age (Esbensen et al. 2009).

Although ADHD and ASD have distinct diagnostic criteria, their symptoms frequently overlap in clinical practice. Studies suggest the total comorbidity rate of ADHD and ASD was 59% (Stevens et al. 2016). This overlap manifests not only in attentional and executive function deficits—such as ASD-related excessive focus on details being misinterpreted as ADHD-related distractibility—but also in emotional regulation difficulties, with both disorders exhibiting high impulsivity and low frustration tolerance (B. G. Nicole et al. 2021). Additionally, abnormalities in social interactions are observed in both conditions, as ADHD-related impulsivity may mask ASD-related deficits in social motivation. In ASD, repetitive/stereotyped behaviors are linked to cortico-striatal circuit imbalance, sensory over-responsivity, and cognitive inflexibility (Abbott et al. 2018); when routines are disrupted or sensory load is high, these factors can tax top-down control and lower inhibitory-control thresholds, plausibly amplifying impulsivity/disinhibition (Chen et al. 2024). Conversely, ADHD-associated attentional deficits can impede the acquisition and generalization of social rules in ASD, together perpetuating a vicious cycle of functional impairment (Parker et al. 2023).

This substantial symptom overlap underscores the intricate relationship between the two disorders. However, existing diagnostic frameworks such as the DSM-5 struggle to account for these complexities, leading to suboptimal treatment outcomes and, in some cases, exacerbation of symptoms (Regina et al. 2012). For example, when children with ADHD and comorbid ASD exhibit emotional outbursts, clinicians should avoid attributing these solely to ADHD impulsivity; although central nervous system stimulants (e.g., methylphenidate) are frequently—and often effectively—used to treat comorbid ADHD symptoms in ASD (Sturman et al. 2017), randomized trials and reviews show short-term reductions in hyperactivity without systematic exacerbation of core ASD features or stereotypies; nonetheless, because response rates are lower and adverse effects (e.g., decreased appetite, irritability, occasional anxiety/sensory reactivity) are more common than in ADHD-only (Autism 2005), careful assessment of sensory/anxiety triggers and cautious titration with close monitoring are warranted. Conversely, attributing attentional deficits in ASD purely to a lack of social motivation may delay the use of stimulant medications, which could otherwise mitigate ADHD-related executive dysfunctions such as working memory deficits, thereby impairing academic interventions (Camille et al. 2022). The interaction of ADHD and ASD symptoms and their clinical complexity has long been a central issue in psychopathology research.

To address the limitations of categorical diagnoses, researchers have employed Factor Analysis and Latent Class Analysis (LCA) to extract symptom dimensions or subtypes (Aneta et al. 2022). Cross-diagnostic factor analysis has identified a shared underlying factor ("behavioral dysregulation factor") linking ADHD-related hyperactivity-impulsivity and ASD-related repetitive behaviors, while attention deficits and social communication impairments appear to belong to separate dimensions (T. B. Nicole et al. 2023). However, these methods still rely on the assumption of latent variables, presuming that symptoms are driven by a common underlying cause, and fail to capture direct symptom interactions—such as how hyperactive behaviors exacerbate social withdrawal (Mojdeh et al. 2016).

Symptom Network Analysis conceptualizes psychiatric symptoms as dynamically interacting components of a complex system (Payton et al. 2019; Denny and Angélique 2013). By constructing direct interaction networks among symptoms (e.g., Bayesian networks, dynamic temporal networks), this method reveals how local causal relationships and feedback loops sustain disorder states (Jianqing et al. 2025). Its core advantages include: (1) Core Symptom Identification—centrality metrics (e.g., strength centrality, bridge centrality) help pinpoint hub nodes within trans-diagnostic networks, providing targets for precise intervention; and (2) Cross-Diagnostic Integration—breaking categorical diagnostic boundaries to elucidate shared and distinct symptom pathways (Richard 2020).

Several studies applied network analysis to investigate ADHD symptoms (Gomez and Houghton 2024), core autism symptoms (George et al. 2015), and the associations between core autism symptoms and obsessive-compulsive disorder (Laura et al. 2014), depression (Farhad et al. 2019), and anxiety (Farhad et al. 2018). One research utilized network analysis to explore the overlap between ADHD and autism symptoms (Farhat et al. 2022). This study revealed that symptoms tend to cluster within their respective disorders, with ADHD symptoms showing stronger intra-construct connections compared to the relatively sparse links observed between ADHD and autism symptoms. However, existing studies still have several limitations: (1) Most symptom-network studies to date derive from Western samples, limiting cross-cultural validation; despite China's substantial absolute ADHD/ASD burden—GBD analyses indicate China's ADHD age-standardized prevalence and DALYs exceed global levels (N. Li et al. 2025)—no mainland large-sample symptom-network study has specifically examined dual ADHD + ASD, although related work has been reported in Hong Kong SAR ($n \approx 2186$) (Suen et al. 2024). (2) Insufficient Heterogeneity Analyses—the effects of gender and age on symptom networks remain largely unexplored.

Thus, the present study applies network analysis to large-scale data from a nationwide Chinese child mental health survey to explore, for the first time, the interactive patterns of ADHD and ASD symptoms in Chinese children and adolescents. The primary research objectives are: (1) What are the core symptoms and transdiagnostic bridge symptoms in the ADHD-ASD symptom network among Chinese children? (2) Do symptom network structures differ significantly across gender and age subgroups?

2 | Method

The sample included for current study was extracted from a secondary data, which details of the sampling and survey procedure were reported elsewhere (F. Li et al. 2022). In short, the survey used a population-based, school sampling frame. Eligible participants were students aged 6–16 years enrolled in mainstream primary or secondary schools; by design, children outside this age range, not attending school, or placed in specialized education for severe learning/developmental disorders were not covered. We applied a multistage, stratified cluster random design. In 2015, approximately 72,000 students were sampled from general schools in five geographically diverse sites—Beijing municipality and the provinces of Liaoning, Jiangsu, Hunan, and Sichuan. The final sample size was 71,217; the mean age was 11.49 with a standard deviation of 2.82; female (n = 35,311) composed of 49.58% the total sample, see Table 1 for details. We identified a small number of participants (~0.5% of the total sample) who either did not respond to demographic questions or provided implausible responses (e.g., reporting an age outside the normal range). These participants were excluded from further analyses. Given the small proportion, their exclusion is unlikely to have affected the results.

2.1 | Variables

The Child Behavior Check List (CBCL) is a parent rating scale assessing mental and behavior problems in children, with good reliability and validity (Achenbach 2011). The original scale contains 113 items; the item is rated 0 (not true), 1 (somewhat/sometimes true), or 2 (very/often true); No skip structure is involved. In current analysis, items relevant to ADHD and ASD syndromes were selected from CBCL. The ADHD variables used the DSM oriented CBCL-ADH subscale, which contains 7 items (Zhongliang et al. 2023); the ASD variables applied a 15 items model that derived from another study (Julia et al. 2022). The item descriptions and endorsement (item score = 2) can be seen in Table 1.

2.2 | Network Estimation

An unregularized partial correlation network was estimated using glasso algorithm and stepwise model selection (ggmModSelect), which is a robust method for network estimation with large sample size (Adela-Maria and Sacha 2021). The polychoric correlation matrix was used as input to handle the potential issue of ordinal data and skewed distribution. Node statistics (e.g., strength, closeness, betweenness) and edge statistics were reported. Their stability was assessed using non-parametric bootstrapping with 3000 bootstrap samples. The correlation stability (CS) coefficient (range: 0–0.75) was used to evaluate the robustness of these statistics, with a CS coefficient of 0.50 or higher considered acceptable (Epskamp et al. 2018). Fruchterman Reingold algorithm (i.e., spring) was used to draw the network (Schönfeld and Pfeffer 2019); for ease of visual comparison, the layout of the network in general population was applied to sub networks.

2.3 | Exploratory Graphic Analysis (EGA)

The network community was estimated using the Glasso model and walkstrap algorithm (Pons and Latapy 2005). Dimension and item stability was evaluated through 1000 resampling iterations. Dimension stability is reflected by structural consistency, which is the proportion of certain structure is replicated in the iterations; item stability is reflected by the proportion of the node placement to certain dimension. For instance, a structural consistency of 0.65 indicates that the structure was replicated in 65% of the resampled datasets; an item stability of 0.65 for item 1 in dimension 1 indicates that item 1 was placed in dimension 1 in 65% of samples.

2.4 | Network Comparison Test (NCT)

The permutation test of network comparison was run to test the difference between two networks in network structure and connectivity (van Borkulo et al. 2023). The comparison was based on 2000 iterations. Findings from invariant global strength and omnibus tests were reported. The formal test compares sum of absolute edge weights of all edges to evaluate whether the two network differ in global connectivity; the latter decides whether the two networks differ in network structure (i.e., at least one edge is different between networks). Networks were compared between female and male as well as younger (6–11 years old) and older (12–16 years old) participants; network density was computed by the number of non-zero edges dividing the number of total edges of the network. Network density was computed by the number of non-zero edges dividing the number of total edges of the network. The average absolute edge weight (AAEW) was similarly reported for reference; it reflects the overall strength of associations

TABLE 1 | Descriptive statistics of the demographic and clinical information in general and subgroups.

	Total	Female	Male	Younger	Older
N/*n*	71,217	35,240	35,887	32,728	37,644
Age, *M* (SD)[a]	11.49 (2.82)	11.50 (2.82)	11.47 (2.82)	8.87 (1.55)	13.76 (1.28)
Female, %[b]	49.58	100	0	49.04	49.89
ADH, %					
I4: Fails to finish things they start	0.39	0.30	0.48	0.42	0.37
I8: Cannot concentrate, cannot pay attention for long	12.65	9.89	15.38	14.62	11.06
I10: Cannot sit still, restless, or hyperactive	7.80	5.66	9.93	10.70	5.38
I41: Impulsive or acts without thinking	1.53	1.35	1.72	1.21	1.84
I78: Inattentive or easily distracted	0.10	0.08	0.13	0.08	0.12
I93: Talks too much	5.32	4.82	5.81	6.26	4.56
I104: Unusually loud	3.19	3.40	2.98	3.42	3.02
ASD, %					
I1: Acts too young for his/her age	1.99	1.79	2.19	1.71	2.23
I5: There is little that he/she enjoys	0.93	1.42	0.61	0.65	1.17
I9: Cannot get his/her mind off certain thoughts; obsessions	2.76	2.33	3.18	1.71	3.67
I11: Clings to adults or too dependent	6.45	6.71	6.20	9.60	3.80
I17: Daydreams or gets lost in his/her thoughts	1.79	1.70	1.88	0.79	2.67
I25: Doesn't get along with other kids	0.99	0.79	1.18	0.91	1.07
I42: Would rather be alone than with others	3.83	3.92	3.74	1.49	5.85
I62: Poorly coordinated or clumsy	1.59	1.36	1.83	1.36	1.82
I64: Prefers being with younger kids	4.42	4.55	4.29	5.16	3.83
I66: Repeats certain acts over and over; compulsions	0.99	0.85	1.14	0.68	1.26
I75: Too shy or timid	5.86	6.04	5.69	6.92	4.98
I80: Stares blankly	1.12	1.14	1.11	0.32	1.82
I84: Strange behavior	0.35	0.31	0.37	0.18	0.49
I102: Underactive, slow moving, or lacks energy	1.25	1.08	1.42	0.86	1.59
I111: Withdrawn, doesn't get involved with others	1.15	1.13	1.17	0.56	1.67

[a]Missing value: general (n = 274), female (n = 110), male (n = 148); invalid response: general (n = 571), female (n = 271), male (n = 294).
[b]Missing value: general (n = 71), younger (n = 18), older (n = 23); invalid response: general (n = 19), younger (n = 12), older (n = 5).

among nodes in the network. These statistics can be interpreted as an index of global connectivity, with larger values indicating a denser symptom network (Epskamp et al. 2018).

2.5 | Statistics Software

R (version 4.3.1) was used for all analyses. Package *bootnet* (version 1.5.6) was applied for network estimation and evaluation via functions of *estimateNetwork* and *bootnet*. The visualizations of the networks and its centralities were performed by the qgraph (version 1.9.5). The EGA as well as bootstrapping was performed using the *EGAnet* (version 2.0.2) through the function of bootEGA. The NCT was conducted using the *NetworkComparisonTest* (version 2.2.2). The rest of the statistics was achieved by core functions of R.

3 | Result

3.1 | Network Interpretation

The final sample size and relevant descriptive statistics were summarized in Table 1 for general population and the subgroups. All networks exhibited excellent stability (CS coefficient = 0.75) in edge weights and node centralities except for the node closeness in network of younger participants (CS coefficient = 0.59).

The network in the general population was visualized in Figure 1. The I8 (Cannot concentrate) and I78 (Inattentive or easily distracted) appeared to be the important symptoms that bridging ADHD symptoms and possible ASD symptoms, and this finding has been replicated in the networks among subgroup population as well. The edge with highest weight in the network in general

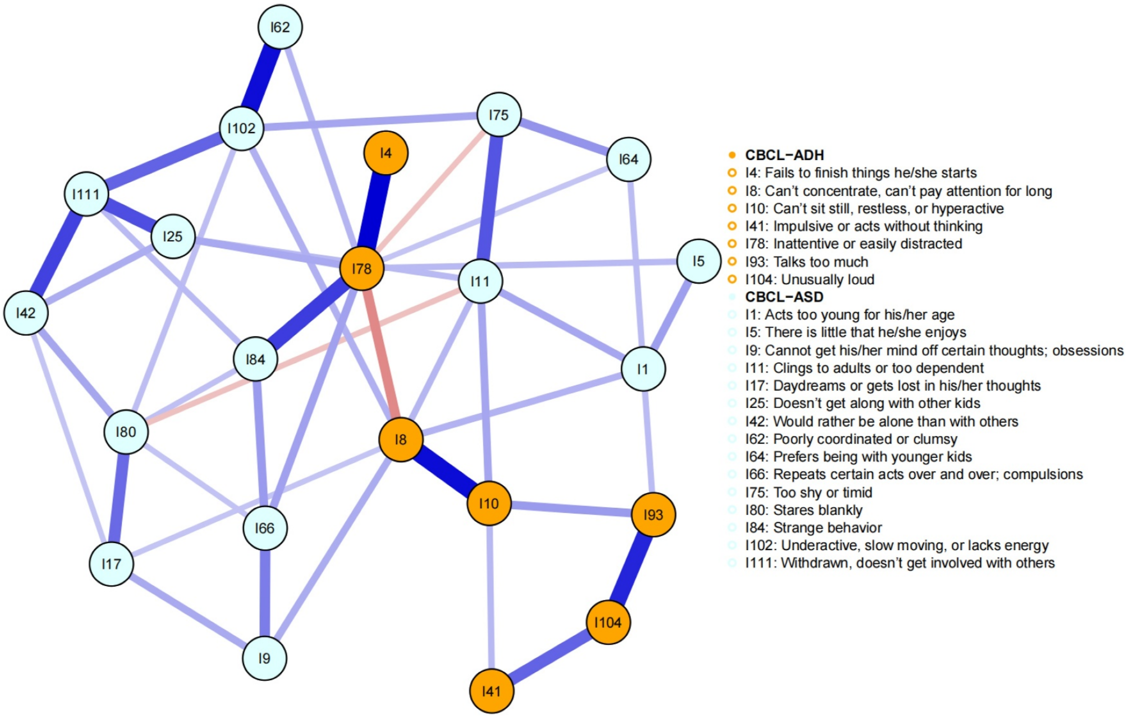

FIGURE 1 | Network structure of the selected variables in general population. The blue edges represent the positive relation between nodes; the red edges present negative relation between nodes. A threshold of edge weight was set to 0.1 to avoid spurious edges.

population was I4-I78 (W = 0.45, 95% BCI: 0.41–0.48); similar findings were found in all subgroups except for the network in male participants, which the edge was I62-I102 (W = 0.44, 95% BCI: 0.42–0.46). I66-I75 (W = 0.01, 95% BCI: −0.02–0.04) was the edge with the lowest weights in network, which was replicated in female network only. The edges with the lowest weights varied across networks, see Supporting Information S1: Tables 1 and 2a–d for details. The subgroup network plot is provided in Supporting Information S1: Figure 1a–b. It is worth noting that a negative edge was observed between ADHD symptoms I8 and I78 (W = −0.21, 95% BCI: −0.14 to −0.27), despite their conceptual overlap. The negative BCI indicates that this association was robust and likely reflected a suppression effect whereby variance shared with other items (e.g., I4) accounted for the expected positive relation.

The node with highest degrees of strength and betweenness in the general network was I78; node I8 exhibited highest level of closeness. Nodes with lowest level of centralities were as followings: strength (I64), closeness (I104), betweenness (I4). The I78 exhibited highest degree of all centralities in networks of all subgroups, as shown in Figure 2; the nodes with lowest degree of centralities tend to vary across the subgroups, see Supporting Information S1: Figure 2a–b for details.

3.2 | Network Community and Item Placement

The EGA identified three communities in the network of general population: community 1 (I4, I5, I9, I17, I66, I78, I80, I84), community 2 (I1, I8, I10, I11, I41, I64, I93, I104), and community 3 (I25, I42, I62, I75, I102, I111). All these communities exhibited excellent structural consistency; the item stability was robust, as shown in Figure 3. The structure has been replicated in networks of male, younger, and older participants with good item stabilities and structural consistency. In the network of female participants, I5 formed a community with items of community 2; and most of the items in this community were symptoms of ADHD, details of the statistics can be seen in Table 2.

3.3 | NCT Among Subgroups

The densest network in the subpopulations was the network in older participants (0.81), and then female (0.78), male (0.76) and younger (0.74) participants. The AAEWs for all networks in subpopulations were: female (0.07), male (0.06), younger (0.06) and older participants (0.07).

The NCT found significant difference in network connectivity and omnibus test between female and male as well as younger and older participants. After correction, the network of female exhibited higher global strength than that of male participants (S_0 = 1.05, p = 0.03); the omnibus test was significant (M = 0.21, p = 0.01), suggesting at least one edge was different between the two networks. The difference in global network strength was not significant (S_0 = 0.70, p = 0.13) between younger and older participants. However, the result of omnibus test was significant (M = 0.18, p = 0.04), see Supporting Information S1: Tables 3a–b for the edge statistics.

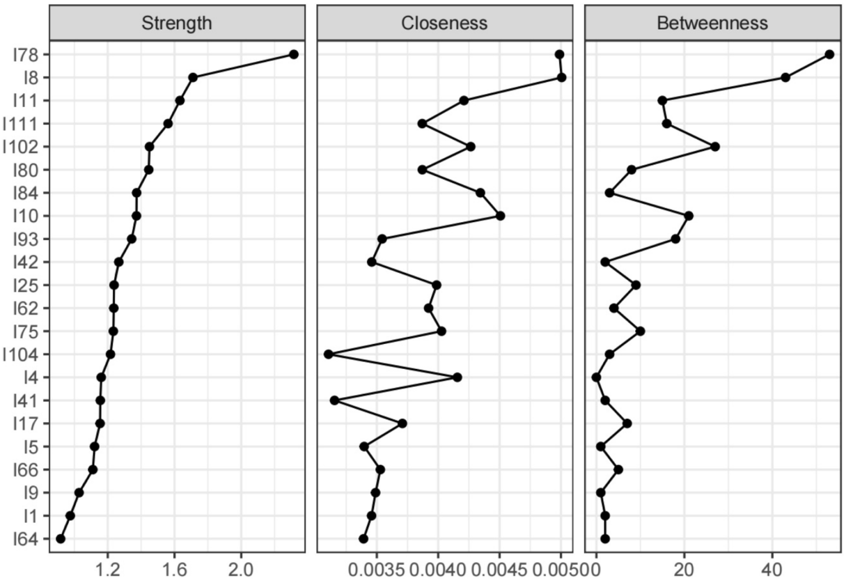

FIGURE 2 | The node centralities of the general network. I4: Fails to finish things he/she starts, I8: Can't concentrate, can't pay attention for long, I10: Can't sit still, restless, or hyperactive, I41: Impulsive or acts without thinking, I78: Inattentive or easily distracted, I93: Talks too much, I104: Unusually loud, I1: Acts too young for his/her age, I5: There is little that he/she enjoys, I9: Cannot get his/her mind off certain thoughts; obsessions, I11: Clings to adults or too dependent, I17: Daydreams or gets lost in his/her thoughts, I25: Doesn't get along with other kids, I42: Would rather be alone than with others, I62: Poorly coordinated or clumsy, I64: Prefers being with younger kids, I66: Repeats certain acts over and over; compulsions, I75: Too shy or timid, I80: Stares blankly, I84: Strange behavior, I102: Underactive, slow moving, or lacks energy, I111: Withdrawn, doesn't get involved with others; The scale for node strength was raw coefficients.

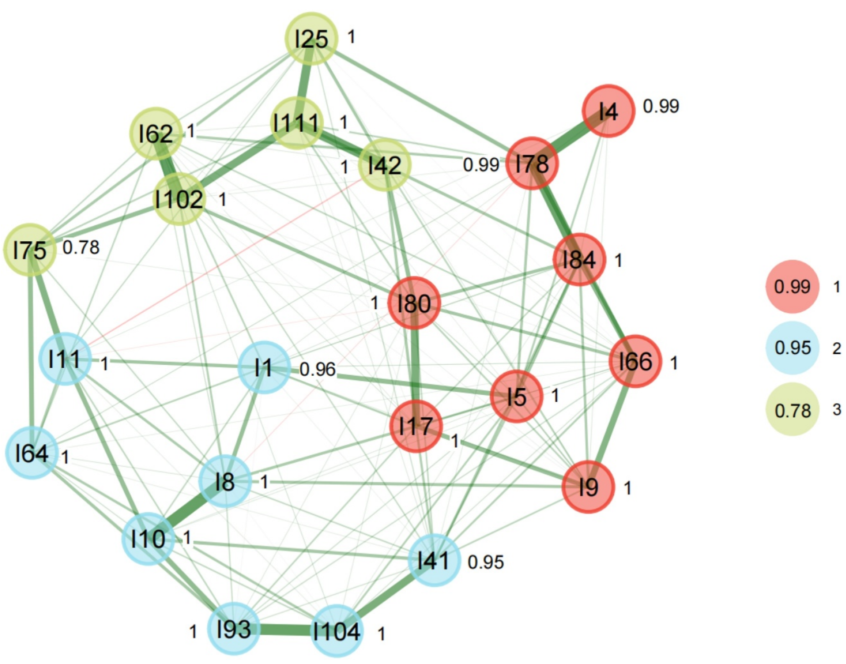

FIGURE 3 | Empirical network communities identified in general population. I4: Fails to finish things he/she starts, I8: Can't concentrate, can't pay attention for long, I10: Can't sit still, restless, or hyperactive, I41: Impulsive or acts without thinking, I78: Inattentive or easily distracted, I93: Talks too much, I104: Unusually loud, I1: Acts too young for his/her age, I5: There is little that he/she enjoys, I9: Cannot get his/her mind off certain thoughts; obsessions, I11: Clings to adults or too dependent, I17: Daydreams or gets lost in his/her thoughts, I25: Doesn't get along with other kids, I42: Would rather be alone than with others, I62: Poorly coordinated or clumsy, I64: Prefers being with younger kids, I66: Repeats certain acts over and over; compulsions, I75: Too shy or timid, I80: Stares blankly, I84: Strange behavior, I102: Underactive, slow moving, or lacks energy, I111: Withdrawn, doesn't get involved with others; The values displayed alongside the symptom nodes and within the dimension nodes on the left represent item stability and structural consistency, obtained from 1000 non-parametric iterations.

TABLE 2 | Structural consistency and item stabilities across the networks.

	Total			Female			Male			Younger			Older			
	Co 1	**Co 2**	**Co 3**	**Co 1**	**Co 2**	**Co 3**	**Co 1**	**Co 2**	**Co 3**	**Co 1**	**Co 2**	**Co 3**	**Co 1**	**Co 2**	**Co 3**	**Co 4**
SC	1	1	0.96	0.92	0.99	0.98	0.78	1	0.97	0.96	1	1	0.31	0.92	1	1
Items																
I4	**0.99**	0	0	**0.73**	0	0	**0.99**	0	0	**0.82**	0	0	0.34	0	**0.66**	0
I5	**1**	0	0	0.02	**0.98**	0	**1**	0	0	**0.98**	0.01	0	0	0.46	**0.54**	0
I9	**1**	0	0	**1**	0	0	**1**	0	0.01	**1**	0	0	0	0	**1**	0
I17	**1**	0	0	**1**	0	0	**0.56**	0	0.01	**0.99**	0.01	0	0	0	**1**	0
I66	**1**	0	0	1	0	0	**0.57**	0	0.01	**1**	0	0	0	0	**1**	0
I78	**0.99**	0	0	**0.73**	0	0	**0.99**	0	0	**0.94**	0	0	0.34	0	**0.66**	0
I80	**1**	0	0	**1**	0	0	**0.56**	0	0.01	**0.99**	0	0	0	0	**1**	0
I84	**1**	0	0	**1**	0	0	**1**	0	0	**0.99**	0	0	0.26	0	**0.74**	0
I1	0.04	**0.96**	0	0.01	**0.99**	0	0	**1**	0	0.01	**0.99**	0	0	**1**	0	0
I8	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0
I10	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0
I11	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0
I41	0.05	**0.95**	0	0.02	**0.98**	0	0	**1**	0	0.01	**0.99**	0	0	**0.78**	0.22	0
I64	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0
I93	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0
I104	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0
I25	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	0	**1**
I42	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	0	**1**
I62	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	0	**1**
I75	0	0.22	**0.78**	0	0.14	**0.86**	0	0.15	**0.85**	0	0	**1**	0	0	0	**1**
I102	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	0	**1**
I111	0	0	**1**	0	0	**1**	0	0	**1**	0	0	**1**	0	0	0	**1**

Note: Values in the item rows represent the replicability of each item within its respective community. The bolded value for each item indicates its empirical community, noted on the second row. The structural consistency (SC) of each community is presented below the community row.
Abbreviation: Co = community.

4 | Discussion

In the current study, the network analysis was conducted for ADHD and possible ASD symptoms in Chinese children. Specifically, the ADHD symptoms I8 and I78 were relatively central to the ADHD and possible ASD syndromes. Three network communities were identified in general as well as subpopulations. The network structure was different between female and male as well as younger and older participants; females had higher network connectivity than male participants. I8 and I78 serve as key bridging nodes linking ADHD and ASD symptoms, which aligns with findings from numerous existing studies (Parker et al. 2023). Several studies have shown that inattentive symptoms are prevalent in both ADHD and ASD, contributing to difficulties in maintaining focus across various contexts (Siqi et al. 2023). The prominence of I8 and I78 as core nodes may also provide symptom-level support for the hypothesis that ADHD and ASD share common neurocognitive deficits. One study highlighted that both ADHD and ASD exhibit functional abnormalities in fronto-striato-parietal networks related to sustained attention (Christakou et al. 2012). Nevertheless, we caution that these centrality findings should not be over-interpreted. Central symptoms in the network reflect statistical connectivity, not necessarily causal influence. Indeed, betweenness and closeness centrality can be poor indicators of a node's true importance in psychopathology networks. Thus, while I8 and I78 are statistically prominent bridges between ADHD and ASD, this does not automatically mean they are the optimal therapeutic targets or causal linchpins of comorbidity. We interpret their central role as highlighting their broad relevance across both conditions, rather than definitive evidence of them "driving" other symptoms. Additionally, Western studies have placed greater emphasis on the cross-diagnostic role of hyperactive-impulsive symptoms (e.g., I10 "restlessness") (Francesco et al. 2015), whereas in this study, hyperactive symptoms showed lower network centrality. This discrepancy may stem from cultural differences in symptom recognition. Chinese parents and teachers tend to focus more on academic-related attention problems (e.g., I8, I78), while externalizing behaviors (e.g., I10 "restlessness") may be more strictly managed in classroom settings, leading to earlier interventions and, consequently, underreporting of these symptoms (Yingkai et al. 2022).

The symptom network identified in this study can be divided into three stable communities, offering insights into distinct clinical profiles. Community 1 was characterized by internalizing behaviors (e.g., I5, I17, I80) and repetitive/compulsive behaviors (e.g., I9, I66), which are core features of ASD. The inclusion of attention-related items (I4, I78) suggests a potential overlap between ASD and ADHD in terms of attentional dysregulation. However, this community can also be viewed as reflecting an "Inattentive ADHD–like" profile, given that I4 and I78 are hallmark inattentive ADHD symptoms (formerly ADD) that frequently co-occur with internalizing problems. In other words, what we initially labeled an "ASD-core/internalizing" cluster likely captures the significant overlap of inattentive ADHD features and ASD-associated internalizing tendencies (Anna et al. 2018). The presence of internalizing symptoms (e.g., I80, I84) in this community further highlights the emotional burden that can accompany neurodevelopmental problems, which may exacerbate cognitive rigidity and social withdrawal (Sebastian 2013). Children fitting this Community 1 profile may benefit from therapies integrating cognitive-behavioral techniques addressing bothemotional regulation and attentional skills (e.g., exposure-response prevention for compulsivity) (Aldao et al. 2015). Community 2 predominantly captured hyperactive/impulsive behaviors (e.g., I8, I10, I41) and socially immature behaviors (e.g., I1, I11), consistent with the diagnostic criteria for ADHD. We interpret Community 2 as representing a "Hyperactive/Impulsive ADHD with social immaturity" profile. Here, the core symptoms center on motor disinhibition and impulsivity, while the presence of items like I1, I11, and I64 ("prefers younger peers") suggests that some social difficulties in this cluster may stem from delayed social development rather than autism-specific social deficits. The strong clustering of these items underscores the central role of hyperactivity/impulsivity in this community's structure. Notably, the inclusion of socially dependent or immature behaviors implies that ADHD-related social difficulties can arise from developmental lag in social cognition. This interpretation is supported by evidence that children with ADHD often have deficits in theory of mind (Szamburska-Lewandowska et al. 2021) and emotion regulation, which can lead to peer rejection and further social withdrawal (Levi-Shachar et al. 2021). Clinically, interventions for Community 2 should pair core ADHD behavior management with social-skills work (van der Oord and Tripp 2020). For preschoolers, meta-analyses show parent-focused programs (e.g., PCIT) reduce disruptive/externalizing problems with effects that can persist (Mingebach et al. 2018); in the early school years, behavioral classroom management improves disruptive behavior and classroom functioning (Chacko et al. 2024); and for autistic children with challenging externalizing behaviors, parent training and functional communication training reduce irritability/noncompliance and aggression/self-injury (Bearss et al. 2015). Community 3 was defined by social withdrawal (e.g., I25, I42, I111) and low energy (e.g., I102), which are hallmark features of ASD-related social impairment. Together, these characteristics indicate that Community 3 corresponds to a "Core ASD" symptom profile. The clustering of these behaviors suggests a distinct ASD subtype characterized more by passive social avoidance than active disruptive behavior. While the presence of low energy (I102) and poor motor coordination (I62) in this community could, in some cases, reflect secondary issues like co-occurring depressive symptoms or a broader developmental delay, our primary interpretation is that they are part of the ASD symptom spectrum in this group. This is consistent with research linking motor clumsiness and low initiative to ASD's neurodevelopmental profile, for example, studies implicating cerebellar dysfunction in both motor coordination problems and social-emotional processing deficits in ASD (Sivalingam and Pandian 2024). Clinically, children in Community 3 may require tailored interventions that address their social withdrawal and low activity levels, such as programs to gradually increase social engagement (through structured peer interactions) combined with occupational therapy to improve motor skills and energy levels (Balán et al. 2016).

The subgroup analysis revealed significant differences in network connectivity and global strength across gender and age groups, providing further insights into the heterogeneity of ADHD- and ASD-related behaviors. The network of female participants exhibited significantly higher global strength compared to males ($S = 1.05$, $p = 0.03$), suggesting that ADHD and ASD symptoms may be more tightly interconnected in females. This finding aligns with previous research indicating that females with ADHD and ASD often present with more internalizing symptoms (e.g., inattention, social withdrawal) rather than the externalizing behaviors (e.g., hyperactivity, impulsivity) typically seen in males (Oroian et al. 2023). The higher connectivity in females may reflect the diagnostic overshadowing of ADHD and ASD in this population, as their symptoms are often less overt and more difficult to distinguish. For example, girls with ASD may exhibit intense social anxiety or selective mutism, which can mask underlying ADHD-related inattention (Mao et al. 2024). This underscores the need for gender-sensitive diagnostic tools and interventions that address the unique symptom profiles of females (Susan et al. 2020).

Although the difference in global network strength between younger and older participants was not significant ($S = 0.70$, $p = 0.13$), the omnibus test indicated significant differences in edge weights ($M = 0.18$, $p = 0.04$). This suggests that the structure of symptom networks may change with age, with older participants exhibiting greater overlap between ADHD and ASD symptoms. One plausible selection account is that more prototypical/severe presentations are identified earlier (Visser et al. 2014)—particularly in ASD, where greater symptom severity and early communication/language deficits predict a younger age at diagnosis (Zwaigenbaum et al. 2019). Conversely, camouflaging and related measurement issues—reported more often in autistic females—are linked to delayed recognition (Cook et al. 2021). Accordingly, older subgroups may be enriched for less prototypical or more compensated phenotypes, yielding greater apparent cross-construct overlap. Additionally, the developmental trajectory of ADHD and ASD may contribute to this pattern, as some ADHD symptoms (e.g., hyperactivity) tend to diminish with age, while ASD-related social and cognitive challenges often persist or become more pronounced (Sainsbury et al. 2023). We present this as a hypothesis that warrants longitudinal confirmation.

This study highlights the centrality of inattentive symptoms (I8, I78) as transdiagnostic bridges between ADHD and ASD in

Chinese children, advocating for integrated interventions targeting attentional regulation and stratified approaches based on distinct symptom communities (internalizing/ASD-core, hyperactive/immature, withdrawal/low-energy). The heightened network connectivity in females and age-related symptom overlap underscores the need for gender-sensitive diagnostics and developmentally tailored strategies prioritizing subtle, internalizing presentations in older children. Culturally, findings emphasize adapting tools to address academic-focused inattention while improving recognition of underreported hyperactive behaviors in classroom settings. These insights call for policy reforms in school-based screening and multidisciplinary care models to address neurodevelopmental comorbidities holistically.

The current study employed a large sample size that is representative to Chinese children; a network analysis was adopted to reveal the connection between ADHD and ASD syndromes. However, the generalizability might be impaired by the following reasons. First, the ASD syndrome was selected from a data driven model, which is not quite consistent to the criteria of DSM and clinical practice. Furthermore, the CBCL is a parent rating scale, despite established validity and reliability, its capacity of capturing real psychopathology might be weaker than the clinician administered tools. Future studies with scales other than CBCL are merited to confirm the findings from current study. Finally, the ADHD and ASD populations might be more revealing and more appropriate to address this issue than the general population. Future studies could use patient data to explore the network mechanisms of ADHD and ASD syndromes in details.

5 | Conclusion

Two inattentive symptoms (I8 and I78) emerged as among the most strongly connected items in the combined ADHD–ASD symptom profile, suggesting that attentional difficulties could play an important role in the psychopathological mechanisms underlying both conditions. Nevertheless, this cross-sectional finding does not establish causality; longitudinal and intervention studies remain necessary. Screening approaches tailored to gender differences and local cultural context could improve identification of these symptoms in Chinese children and adolescents. The present findings may also guide future refinements in school mental-health support and related policy development.

Author Contributions

Jie Luo: formal analysis (lead), writing – original draft (lead), writing – review and editing (equal), visualization (lead). **Wen Shao:** methodology (lead), software (lead), formal analysis (supporting). **Yuanzhen Wu:** data curation (supporting), investigation (supporting). **Huanhuan Huang:** investigation (supporting). **Gaoyang Xu:** investigation (supporting). **Yanjie Qi:** data curation (lead), investigation (supporting). **Paul Overton:** writing – review and editing (equal), investigation (supporting). **Yi Zheng:** conceptualization (lead), supervision (lead), project administration (lead), funding acquisition (equal), validation (equal). **Fan He:** funding acquisition (equal), resources (equal), project administration (supporting).

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Ethics Statement

The project was approved by the Ethics Committee of Beijing Anding Hospital (201743FS-2) in 2017 and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All subjects and their parents signed an informed consent form before joining the trial.

Consent

Participants gave consent for data collected to be published in anonymous form in academic journals.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

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

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.
Supporting Information S1: mpr70042-sup-0001-suppl-data.docx.