

Cluster-derived profiles of parental reports of Autism and ADHD traits and their associations with diagnoses: EPINED study

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Abstract

Autism and attention-deficit/hyperactivity disorder (ADHD) frequently co-occur and show substantial phenotypic overlap, challenging categorical diagnostic frameworks. Person-centred approaches may better capture heterogeneity, but the consistency and external validity of these profiles across informants remain unclear. Using data from the EPINED population-based study in Tarragona, Spain, we identified symptom-based clusters from parent reports in preschool-aged (n=1805) and school-aged (n=1930) children, examined concordance with teacher-derived clusters, and evaluated associations with diagnoses. Parent-reported cluster analyses yielded a four-cluster solution across both age groups: low/no symptoms (Parent-CP-1/Parent-CS-1), sub-autism+sub-ADHD traits (Parent-CP-2/Parent-CS-2), social communication problems (Parent-CP-3/Parent-CS-3), and ADHD-dominant profiles (Parent-CP-4/Parent-CS-4). Although structures were comparable, parent-teacher agreement was low ($\kappa=0.03-0.05$). Across both age groups, clinical diagnoses were primarily concentrated within ADHD-related behavioural clusters, with other clusters showing lower and more variable representation across diagnostic groups. In preschool-aged children, Parent-CP-4 clusters were associated with autism across both parent (ORs: 4.55-7.46) and teacher reports (ORs: 6.09-6.51). In school-aged children, only teacher-reported Teacher-CS-4 (ORs: 11.96-20.50) predicted autism diagnoses, while parent-reported behavioural features, higher thought problems and lower rule-breaking behaviour were significant contributors. For ADHD, parents (Parent-CP-4; preschool-aged ORs: 19.74-20.58, school-aged ORs: 25.22-27.63) and teachers (Teachers-CP-2; preschool-aged ORs: 20.80-20.94, school-aged ORs: 2.66-3.10) were significant contributors, although the parent-cluster effect attenuated to non-significance after inclusion of teacher report. Data-driven profiles explained variance in related clinical measures beyond diagnostic categories. Overall, parent-reported clustering identified meaningful behavioural phenotypes, but cross-informant discrepancies highlight context-dependent symptom expression. The findings underscore the clinical importance of multi-informant and multidimensional assessment approaches to better capture heterogeneity within neurodevelopmental conditions.

Introduction

Autism and attention-deficit/hyperactivity disorder (ADHD) are among the most prevalent neurodevelopmental conditions in childhood, with traits typically emerging early in life. Both conditions are characterised by marked heterogeneity in behavioural presentation, severity, and functional impact^[1]. In recent years, increasing attention has been directed toward the substantial phenotypic overlap between autism and ADHD traits, including difficulties in social communication, emotional regulation, attention, impulsivity, and behavioural control^[2,3]. A population-based study conducted in Spain reported a co-occurrence of autism and ADHD symptoms of 3.2% and 2.6% based on parent and teacher reports, respectively^[4]. Among diagnostic groups, comorbidity was non-reciprocal, 31.4% of children with autism and 32.8% with subthreshold autism met criteria for ADHD, whereas autism was present in 5.7%–9.8% of children with ADHD or subthreshold ADHD. This overlap challenges traditional categorical diagnostic frameworks and highlights the need for approaches that more effectively capture the dimensional and transdiagnostic nature of neurodevelopmental symptoms in community populations^[5,6].

In response to these limitations, person-centred, data-driven analytical approaches have gained prominence in developmental psychopathology research^[6]. Cluster analysis allows for the identification of relatively homogeneous subgroups of individuals based on shared behavioural characteristics, without imposing a priori diagnostic boundaries^[7]. Such approaches are especially valuable in large population samples, where they can reveal naturally occurring behavioural phenotypes that reflect varying combinations of autism and ADHD traits^[5,8]. By capturing symptom patterns rather than diagnostic labels, clustering methods may enhance early identification efforts and improve understanding of heterogeneity within neurodevelopmental risk profiles^[9].

Assessment of neurodevelopmental traits in childhood typically recommends obtaining reports from multiple informants, most commonly parents and teachers^[10,11]. Since each informant observes the child in distinct contexts and under different environmental demands, they contribute unique and complementary perspectives. Teachers are particularly well-positioned to evaluate behaviours related to attention, hyperactivity, and peer interaction within structured classroom settings^[12]. Whereas, parents can observe their children across a broader range of daily situations, including less structured environments that may elicit emotional and social behaviours not evident

at school^[13]. As a result, discrepancies between parent and teacher reports are frequently reported in the assessment of autism and ADHD symptoms^[14,15].

Previous research has demonstrated low to moderate levels of agreement between parent and teacher ratings, particularly for behaviours influenced by contextual factors such as emotional lability, social engagement, and internalising symptoms^[16]. These discrepancies are not necessarily indicative of measurement error but rather reflect genuine situational variability in behavioural expression^[17]. Nevertheless, most studies examining informant agreement have relied on variable-centred approaches, focusing on correlations between symptom scores rather than on whether different informants identify comparable subgroups of children when using person-centred methodologies. In this context, cluster-based approaches can offer a valuable framework for examining informant concordance at the level of behavioural profiles rather than individual symptom dimensions^[7].

Within the framework of the Neurodevelopmental Disorders Epidemiology Project (EPINED), cluster analysis of teacher-reported behavioural traits was previously conducted in a large population-based sample of preschool-aged and school-aged children^[12]. Based on standardised measures of autism-related traits (including social communication difficulties and repetitive behaviours) and ADHD traits (including inattention, hyperactivity, restless-impulsivity, and emotional lability), four distinct behavioural clusters emerged across both age groups. These clusters reflected different levels of neurodevelopmental symptomatology, ranging from low-symptom profiles to more complex patterns characterised by elevated autism and/or ADHD traits. The findings supported the utility of teacher-based cluster analysis for identifying meaningful behavioural subgroups in community samples. Parent-reported data were not examined, and therefore, it remains unclear whether similar behavioural clusters can be identified based on parent observations using the same methodological framework. Moreover, the degree to which parent and teacher-derived cluster memberships converge or diverge at the individual level has not yet been systematically evaluated. Addressing these gaps is essential for advancing multi-informant assessment strategies and for understanding how behavioural phenotypes manifest across home and school contexts.

Therefore, the present study aimed a) to identify symptom-based clusters of autism and ADHD traits using parent-reported measures in a large population-based sample of preschool-aged and

school-aged children (EPINED project), b) to examine the degree of concordance between parent-derived clusters and previously identified teacher-based clusters, thereby evaluating cross-informant agreement at the level of behavioural phenotypes. Importantly, c) further assess the structural coherence and external (clinical) validity of the parent-derived and previously identified teacher-derived clusters by examining their associations with ADHD and autism diagnoses; and their explanatory value relative to diagnostic categories and dimensional symptom measures. By integrating person-centred clustering with multi-informant comparison and diagnostic validation across developmental stages, the study sought to clarify the extent to which behavioural heterogeneity in neurodevelopmental traits is context-dependent while maintaining clinical relevance.

Methods

Study design

The EPINED project was carried out between 2014 and 2019 across the province of Tarragona, Catalonia (Spain). This two-phase population-based study aimed to estimate the prevalence of autism and ADHD in the region. In Phase-1 (screening), information was collected from teachers (n=6894; preschool-aged=3374, school-aged=3520) and parents (n=3735; preschool-aged=1805, school-aged=1930) on autism and ADHD symptomatology. Symptoms were assessed in preschool-aged (4-5 years) and school-aged (10-11 years) children using standardised screening instruments (EDUTEA, CAST, and Conners). In Phase-2 (diagnosis; n=781), children who screened positive for the likelihood of autism and/or ADHD symptoms from Phase-1 (preschool-aged n=899; school-aged n=1216), as well as those who screened negative, were selected and matched in a 1:2 ratio (positive:negative). These children underwent comprehensive diagnostic assessments conducted by trained psychiatrists and psychologists, through the administration of the Autism Diagnostic Observation Schedule-2nd (ADOS-2)^[18] and the Autism Diagnostic Interview-Revised (ADI-R)^[19]. Subthreshold autism was defined as scoring one or two points below ADI-R and ADOS-2 cut-offs. The Kiddie Schedule for Affective Disorders and Schizophrenia for School-Aged Children (K-SADS-PL)^[20] was used to confirm ADHD criteria and their presentations. Diagnoses were based on DSM-5 criteria and re-evaluated at follow-up.

Children's emotional and behavioural problems were also assessed with the Child Behaviour Checklist (CBCL1½-5 for preschool-aged or CBCL6-18 for school-aged)^[21,22]. Cognitive functioning was assessed using the Wechsler scales WPPSI-IV^[23] for preschool-aged and WISC-IV^[24] for school-aged children. A detailed description of the study design and procedures has been previously described^[4,25]. The teacher-derived four-cluster solution was as follows: preschool-aged children, Cluster 1 (Teacher-CP-1), children with no autism/ADHD symptoms; Cluster 2 (Teacher-CP-2), sub-ADHD; Cluster 3 (Teacher-CP-3), sub-autism; and Cluster 4 (Teacher-CP-4), children with autism+ADHD. For school-aged children: Cluster 1 (Teacher-CS-1) no autism/ADHD symptoms; Cluster 2 (Teacher-CS-2) sub-ADHD; Cluster 3 (Teacher-CS-3) sub-autism+ADHD; and Cluster 4 (Teacher-CS-4) children with autism+ADHD. A comprehensive overview is available in Kaur et al. (2024)^[12].

Autism and ADHD Screening Measures

The *Childhood Autism Spectrum Test (CAST)* is a 37-item parent-report questionnaire designed to screen for characteristics associated with autism in children aged 4-11 years^[26]. Each item requires a yes/no response, assessing behaviours related to social communication, social interaction, and restricted or repetitive behavioural patterns. For clustering, we used the Spanish 28-item short CAST version with a cut-off score of 13, which showed internal consistency ($\alpha=0.84$) and high sensitivity (85.7%) and specificity (91.2%). CAST measured two factors: social interaction and communication problems (**SCP**; 14 items) and restrictive patterns of behaviour and pragmatic impairments (**RRB**; 13 items)^[27].

The *Conners Early Childhood Global Index (EC GI)* and the *Conners 3 ADHD Index (AI)*^[28,29] were rated by parents who assessed behavioural and emotional difficulties observed over the previous month in children aged 2-6 years and 6-18 years, respectively. Both are rated on a 0-3 Likert scale (0="never," 1="occasionally," 2="often," 3="very often") and include cut-off thresholds for elevated scores ($T=65-69$) and highly elevated scores ($T\geq 70$). For the Conners EC GI, two main factors are identified: restless-impulsiveness (**RI**; 6 items, $\alpha=0.88$) and emotional lability (**EL**; 4 items, $\alpha=0.81$). For the Conners AI, the measure is divided into hyperactivity-impulsivity (**HI**; 3 items, $\alpha=0.97$) and inattention (**INA**; 7 items, $\alpha=0.99$). The Spanish parent and teacher versions demonstrated excellent reliability: $\alpha=0.92$ and 0.97 for the EC GI, and $\alpha=0.96$ and 0.98 for the AI, respectively^[30].

Statistical Analysis

The autism-related (SCP, RRB) and ADHD-related (RI, EL for preschool-aged; HI, INA for school-aged) traits derived from CAST and Conners items were standardized (z-scores) before cluster analysis. ***Hierarchical clustering***, using Euclidean distance and the Ward's D² linkage method, was first applied to determine the optimal number of clusters, followed by k-means clustering to refine subgroup classification. This clustering procedure was identical to that used to derive the teacher-report clusters^[12]. To examine agreement between parent- and teacher-derived cluster memberships, *Chi-square tests and Cohen's Kappa* coefficients were used, together with *Pearson correlations* between parent- and teacher-reported subdomain scores.

Furthermore, to assess the external (diagnosis) validity of the cluster solutions, logistic regression analyses were conducted with ADHD and autism+subthreshold autism diagnoses as binary outcome variables (diagnosis vs control). Cluster membership was entered as a categorical predictor, with the cluster characterised by the lowest symptom burden serving as the reference category (cluster 1). Analyses were conducted in three sequential steps: 'a' unadjusted model including parent clusters membership only, 'b' models adjusted for demographic covariates (sex: male vs female, SES: low, medium, high, and ethnicity: Spanish vs others), and 'c' model adjusted for teacher report-based clusters and 'd' models additionally adjusted for continuous CBCL symptom subscales to examine incremental validity beyond dimensional symptom measures. CBCL subscales in model 'd' were for preschool-aged children: emotional reactivity, anxiety/depression, somatic complaints, withdrawn, sleep problems, and attention problems. Whereas, for school-aged children, included anxiety/depression, somatic complaints, withdrawal, social problems, attention problems, thought problems, and rule-breaking behaviour. Aggressive behaviour was excluded from both age-specific models due to evidence of multicollinearity (VIF>5). No multicollinearity was observed among other covariates, including teacher-identified clusters (VIF=1). Odds ratios (ORs) with 95% confidence intervals (CIs) were reported. Additionally, to evaluate whether cluster membership captured clinical heterogeneity beyond diagnostic category, linear regression models were used with each CBCL subscale as the outcome, comparing the variance explained (adj. R²) by diagnostic category (no NDD, autism, ADHD,

autism+ADHD), cluster membership, and both jointly; nested F-tests evaluated the incremental contribution of cluster membership over diagnostic category.

Hierarchical logistic regression analyses further examined whether parent- and teacher-reported cluster membership improved prediction of diagnostic status beyond the z-standardised parent- and teacher-reported symptom subscales, with model improvement assessed using likelihood ratio tests. Statistical significance was set at $p < 0.05$, and a conservative correction for multiple comparisons of $p < 0.01$ was applied. All analyses were conducted using IBM SPSS Statistics (Version 29.0) and JASP (Version 0.95.3.0).

Results

Based on the parents' reports, a four-cluster solution was identified, yielding homogeneous subgroups across both informant sources. For preschool-aged children, Cluster 1 (Parent-CP-1) children with no autism and/or ADHD symptoms; Cluster 2 (Parent-CP-2) sub-autism+sub-ADHD symptoms; Cluster 3 (Parent-CP-3) with social communication difficulties; and Cluster 4 (Parent-CP-4) children with ADHD+repetitive/restrictive traits. A similar pattern was observed for school-aged children: Cluster 1 (Parent-CS-1) had no autism and/or ADHD symptoms; Cluster 2 (Parent-CS-2) had sub-autism and ADHD symptoms; Cluster 3 (Parent-CS-3) had social communication difficulties; and Cluster 4 (Parent-CS-4) had ADHD+sub-autism.

The agreement between teacher- and parent-reported groupings was statistically significant for both preschool-aged and school-aged samples (χ^2 , $p < 0.001$), although the chance-corrected agreement was low, with $\kappa = 0.045$ and 0.033 , respectively. The agreement varied by domain: ADHD-related dimensions, assessed with the same instrument family across informants, showed consistent positive associations (strongest for inattention in school-aged children, $r = 0.51$, $p < 0.001$), whereas the autism-related social/communication subdomain showed inverse parent-teacher correlations in both age groups ($r = -0.35$ and -0.24 , $p < 0.001$) and restricted/repetitive behaviours showed modest positive agreement (Supplementary Table S1). Furthermore, overall, most children were classified into the teacher low-symptom cluster (Teacher-CP-1/Teacher-CS-1), representing 71.4% (1288/1805) of preschool-aged children and 73.0% (1408/1930) of school-aged children. In addition, children in the parent social-communication cluster (Parent-CP-3/Parent-CS-3) were predominantly reassigned to the teacher low-symptom cluster, with 83.9% of

preschool-aged and 87.1% of school-aged children classified as Teacher-CP-1 and Teacher-CS-1, respectively (Supplementary Table S2).

Tables 1 and 2 show that parents' report-based clusters differed significantly on all behavioural measures in both age groups, and perceived profiles of ADHD. Sex distribution varied across clusters, with a higher proportion of males in ADHD-related clusters (Parent-CP-4; Parent-CS-4) and relatively more females in sub-autism/ADHD and social communication clusters (Parent-CP-2/3; Parent-CS-2/3). Socioeconomic status also differed, with ADHD clusters (Parent-CP-4; Parent-CS-4) overrepresented among lower SES and underrepresented among higher SES, whereas social communication clusters (Parent-CP-3; Parent-CS-3) showed the opposite pattern.

Table 1: Characteristics of preschool-aged children by cluster: cluster-defining, sociodemographic, and emotional-behavioural profiles

Preschool-aged (<i>N</i> =1805)		Parent-CP-1 (<i>n</i> =418)	Parent-CP-2 (<i>n</i> =617)	Parent-CP-3 (<i>n</i> =559)	Parent-CP-4 (<i>n</i> =211)	<i>p</i>*
Behavioural		No autism/ADHD	Sub- autism+sub- ADHD	Social Communication Problems	ADHD+repet itive/restricti ve traits	
CAST, M(SD)	SCP	10.59(1.68)	12.19(1.43)	12.74(1.06)	10.11(3.03)	<0.001
	RRB	2.80(1.06)	4.01(1.53)	2.56(0.97)	7.14(1.80)	<0.001
	Total	13.39(1.82)	16.20(2.10)	15.30(1.36)	17.25(3.97)	<0.001
Conners	RI	54.87(7.79)	68.44(10.41)	50.98(8.63)	78.07(12.68)	<0.001
EC GI, M(SD)	EL	58.98(8.16)	70.29(12.83)	49.47(6.38)	75.27(12.95)	<0.001
	Total	56.19(6.70)	69.74(9.19)	50.36(6.81)	77.84(9.93)	<0.001
Sociodemographic						
Age, M(SD)		4.72(0.58)	4.63(0.44)	4.65(0.50)	4.64(0.43)	0.480
Sex, %(n)	Male	54.8(229)	44.1(272)	51.5(288)	53.6(113)	<0.001
	Female	45.2(189)	55.9(345)	48.5(271)	46.4(98)	
SES, %(n)	Low	10.8(45)	18.6(113)	11.1(61)	28.2(59)	<0.001
	Medium	62.9(261)	60.4(366)	52.2(288)	61.2(128)	
	High	26.3(109)	21.0(127)	36.8(203)	10.5(22)	
Ethnicity, %(n)	Spanish	87.1(364)	80.7(498)	87.3(488)	68.2(144)	<0.001
	Other	12.9(54)	19.3(119)	12.7(71)	31.8(67)	
Emotional-behavioural profiles						<i>p</i>^o
CBCL-1½-5, M(SD)		(<i>n</i> =48)	(<i>n</i> =90)	(<i>n</i> =50)	(<i>n</i> =98)	
Emotional Reactivity		55.17(7.43)	58.73(8.49)	52.16(4.01)	65.41(10.68)	<0.001
Anxiety Depression		56.90(6.85)	58.32(7.24)	52.84(4.17)	62.66(8.96)	<0.001
Somatic Complaints		55.83(5.67)	56.14(6.49)	53.52(5.26)	60.14(7.79)	<0.001
Withdrawn		60.35(8.44)	58.72(8.66)	52.98(4.09)	66.51(9.80)	<0.001

Sleep Problems	54.19(5.12)	55.89(6.32)	53.14(5.45)	57.87(7.88)	<0.001
Attention Problems	59.19(6.69)	60.41(6.49)	54.16(5.77)	64.31(7.52)	<0.001
Aggressive Behaviours	54.21(5.53)	58.72(6.71)	51.68(2.94)	65.36(10.16)	<0.001

Abbreviations: CBCL-1½-5: Child Behaviour Checklist for preschool-aged; SCP: social interaction and communication problems; RRB: restrictive patterns of behaviour and pragmatic impairments; RI: restless-impulsiveness; EL: emotional lability. *Post-hoc: clusters (1-2, 1-3, 1-4, 2-4, 3-2) for behavioural profiles were $p<0.001$, except for the cluster between CAST SCP (1-4), 0.194. ^aPost-hoc: CBCL-1½-5 in supplementary Table-S3.

Table 2: Characteristics of school-aged children by cluster: cluster-defining, sociodemographic, and emotional-behavioural profiles

School-aged (<i>N</i> =1930)		Parent-CS-1 (<i>n</i> =226)	Parent-CS-2 (<i>n</i> =677)	Parent-CS-3 (<i>n</i> =605)	Parent-CS-4 (<i>n</i> =422)	<i>p</i> *
		No autism/ADHD	Sub- autism+sub- ADHD	Social Communication Problems	ADHD+sub- autism	
Behavioural						
CAST, M(SD)	SCP	9.08(1.06)	11.54(1.84)	12.13(1.08)	10.21(2.46)	<0.001
	RRB	2.32(0.64)	4.11(2.03)	2.46(0.78)	5.11(2.08)	<0.001
	Total	11.39(1.20)	15.66(2.78)	14.59(1.15)	15.32(2.81)	<0.001
Conners	HI	0.73(0.92)	3.51(1.86)	0.86(1.05)	5.63(2.73)	<0.001
AI, M(SD)	INA	2.24(2.20)	6.90(3.74)	3.24(2.80)	14.39(3.98)	<0.001
	Total	46.23(5.14)	63.40(14.52)	48.11(6.94)	86.45(7.23)	<0.001
Sociodemographic						
Age, M(SD)		10.62(0.42)	10.61(0.47)	10.62(0.46)	10.66(0.46)	0.190
Sex, %(n)	Male	49.6(112)	45.9(311)	37.0(224)	60.2(254)	<0.001
	Female	50.4(114)	54.1(366)	63.0(381)	39.8(168)	
SES, %(n)	Low	14.2(31)	21.7(143)	12.1(72)	22.3(93)	<0.001
	Medium	61.2(134)	58.8(388)	58.0(345)	63.5(265)	
	High	24.7(54)	19.5(129)	29.9(178)	14.1(59)	
Ethnicity, % (n)	Spanish	85.0(192)	80.1(542)	90.9(550)	86.5(365)	<0.001
	Other	15.0(34)	19.9(135)	9.1(55)	13.5(57)	
Emotional-behavioural profiles						<i>p</i> ^a
CBCL-6-18, M(SD)		(<i>n</i> =26)	(<i>n</i> =142)	(<i>n</i> =82)	(<i>n</i> =216)	
Anxiety Depression		53.44(5.22)	55.75(6.92)	54.71(5.52)	60.68(8.58)	<0.001
Somatic Complaints		54.84(6.18)	56.49(6.83)	56.15(6.51)	58.73(6.92)	<0.001
Withdrawn		56.92(8.55)	56.40(7.79)	56.35(6.77)	60.67(9.55)	<0.001
Social Problems		53.08(5.27)	55.00(6.01)	53.57(4.88)	60.20(7.57)	<0.001
Thought Problems		51.48(3.15)	54.13(6.46)	52.66(3.92)	58.54(7.88)	<0.001
Attention Problems		51.24(1.85)	57.13(7.47)	53.74(5.95)	65.07(9.78)	<0.001
Rule-Breaking Behaviour		50.48(1.46)	54.25(5.28)	52.12(3.03)	57.56(7.04)	<0.001

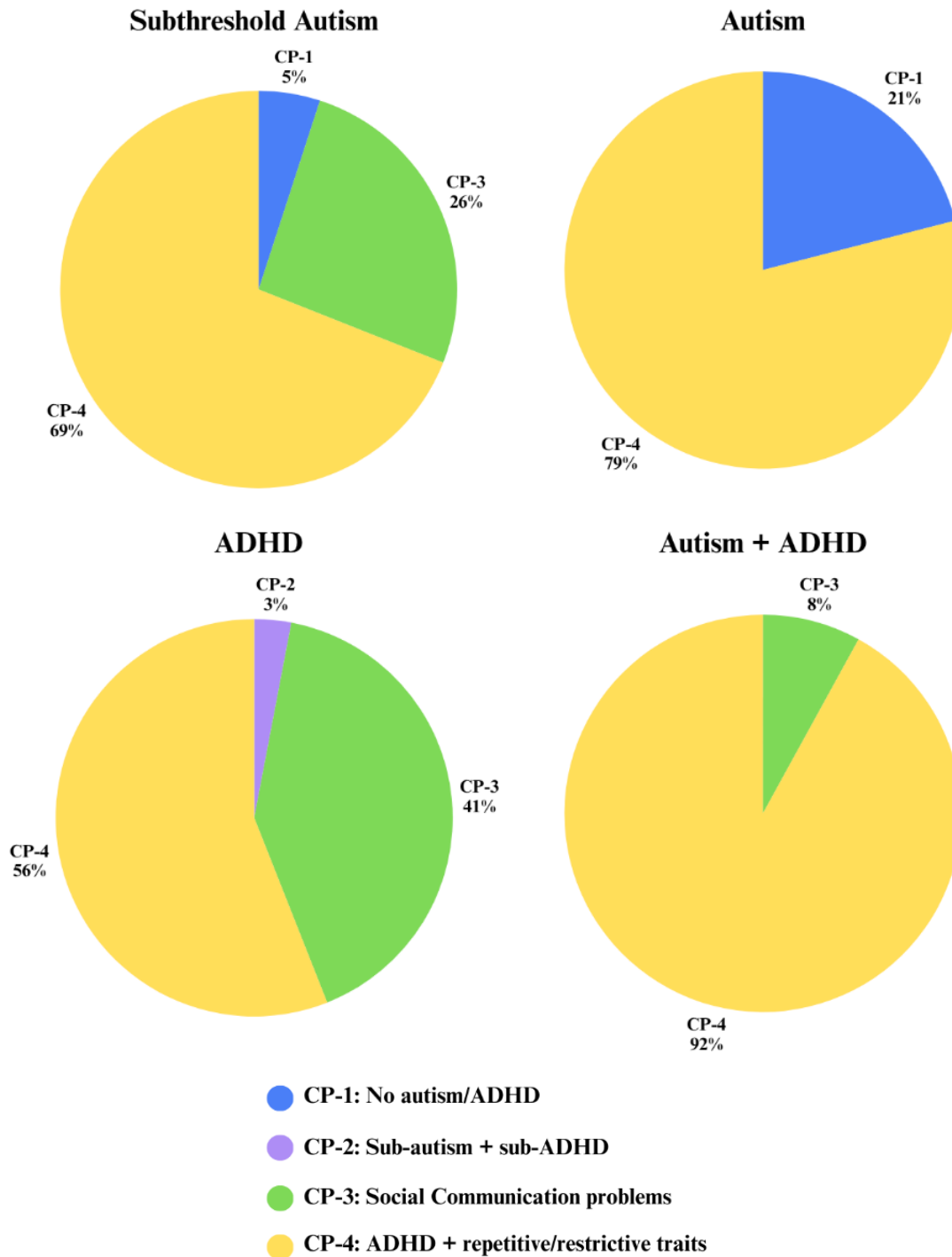
Abbreviations: CBCL-6-18: Child Behaviour Checklist for school-aged; SCP: social interaction and communication problems; RRB: restrictive patterns of behaviour and pragmatic impairments; HI: hyperactivity-impulsivity; INA: inattention. *Post-hoc: clusters (1-2, 1-3, 1-4, 2-3, 3-4) for behavioural profiles were $p<0.001$, except for cluster between CAST RRB (1-3) 0.049; CAST Total (2-4) 0.281; Conners HI (1-3) 0.328. ^aPost-hoc: CBCL-6-18 in supplementary Table-S6.

Distribution of Diagnoses Across Clusters

Figures 1 and **2** show the distribution of clinically diagnosed cases across behavioural clusters in preschool- and school-aged children (Phase-2). Across both age groups, diagnoses were predominantly included in the ADHD symptoms-related clusters (Parent-CP-4; Parent-CS-4). Among preschool-aged children, Parent-CP-4 was present in 79% of those with autism, 69% with subthreshold autism, and 92% with co-occurring autism and ADHD, compared to 56% of those with ADHD alone. Similarly, in school-aged children, Parent-CS-4 was observed in 79% of those with autism, 95% with autism+ADHD, and 75% of ADHD cases. Clusters Parent-CP-3 and Parent-CS-3 also showed notable representation, particularly among ADHD-related groups. In preschool-aged children, Parent-CP-3 included 41% of ADHD cases, 26% of subthreshold autism cases, and 8% of autism+ADHD cases, with no representation in the autism-only group. In contrast, among school-aged children, Parent-CS-3 was less prevalent, accounting for 7% of subthreshold autism, 3.7% of autism, and 3% of ADHD cases.

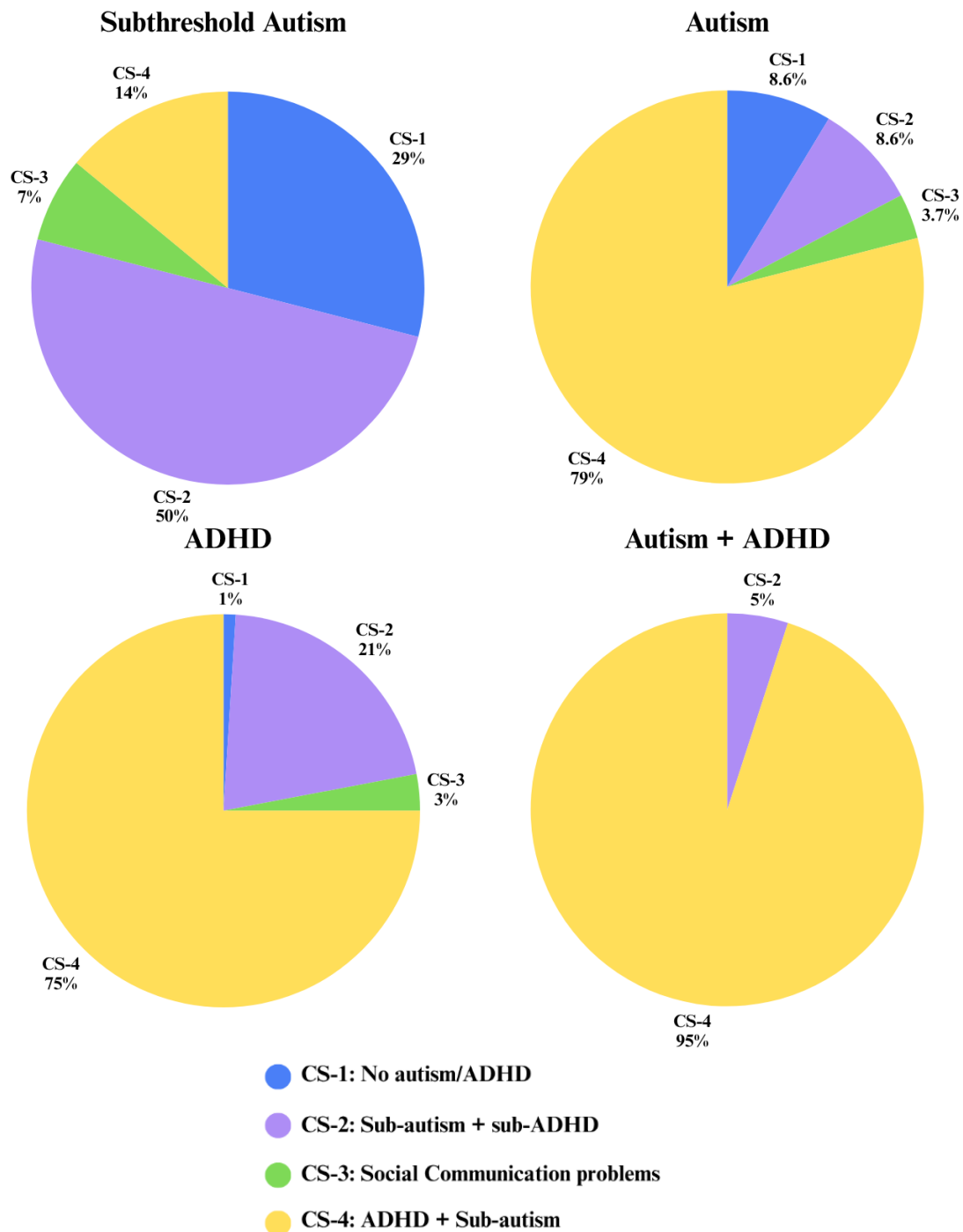
The remaining clusters were less prominent. In preschool-aged children, Parent-CP-1 was observed in 21% of autism cases and 5% of subthreshold autism cases, while Parent-CP-2 (3%) appeared only in ADHD cases. In school-aged children, Parent-CS-2 was most represented in subthreshold autism (50%), followed by ADHD (21%) and autism (8.6%). Parent-CS-1 was present in 29% of subthreshold autism cases, 8.6% of autism cases, and 1% of ADHD cases. A complete descriptive statistic and post-hoc comparisons are provided in Supplementary Tables S3-S5.

Figure 1: Distribution of clinically diagnosed cases across behavioural clusters in preschool-aged children (Phase-2)



Note: *Autism:* also includes autism and autism with sub-ADHD; *Autism+ADHD:* also includes ADHD with sub-autism.

Figure 2: Distribution of clinically diagnosed cases across behavioural clusters in school-aged children (Phase-2)



Note: *Autism:* also includes autism and autism with sub-ADHD; *Autism+ADHD:* also includes ADHD with sub-autism.

External Validity of Cluster Solutions

Logistic regression analyses (Table 3; full models in supplementary Table S6) examined whether parent-derived cluster membership predicted autism+subthreshold autism diagnosis. In preschool-aged children, autism+subthreshold autism diagnosis was consistently associated with the parent-derived Parent-CP-4 cluster (ORs: 4.55-7.46, $p<0.01$) and the teacher-derived Parent-CP-4 cluster (OR: 6.09-6.51, $p<0.01$). Higher CBCL withdrawn behaviour significantly predicted odds of autism diagnosis in the final model (OR= 1.20, $p<0.001$), whereas female sex was associated with lower odds in intermediate models.

In school-aged children, parent-derived clusters showed somewhat limited and variable associations with autism+subthreshold autism diagnosis. No significant association was observed for parent-derived clusters after applying multiple corrections. Whereas Teacher-reported CS-4 membership was the strongest predictor of autism+subthreshold autism diagnosis (OR: 11.90-20.50, $p<0.001$). In the final model, higher CBCL thought problems (OR: 1.12-1.13, $p<0.001$) increased the odds, whereas rule-breaking behaviour (OR: 0.82-0.83, $p<0.001$) decreased the odds of autism+subthreshold autism diagnosis.

Table 3: Preschool-aged and school-aged logistic regression predicting autism+subthreshold autism diagnosis

Preschool-aged	Model a	Model b	Model c	Model d
Parent-CP-2	0.50(0.16-1.55)	0.56(0.18-1.76)	0.60(0.15-2.48)	0.66(0.14-3.03)
Parent-CP-3	0.00(0.00-0.00)	0.00(0.00-0.00)	0.00(0.00-0.00)	0.00(0.00-0.00)
Parent-CP-4	4.55(1.97-11.95)	5.43(2.25-14.86)	6.31(1.94-23.78)	7.46(2.03-32.15)
Sex	-	0.36(0.16-0.75)	0.30(0.11-0.76)	0.41 (0.14-1.15)
Teacher-CP-4	-	-	6.51(2.30-20.32)	6.09(1.72-24.73)
CBCL Withdrawn	-	-	-	1.20(1.11-1.31)
Nagelkerke R ²	0.31	0.37	0.51	0.70
School-aged	Model a	Model b	Model c	Model d
Parent-CS-2	0.31(0.10-1.06)	0.33(0.11-1.17)	0.23(0.06-0.94)	0.29(0.06-1.33)
Parent-CS-3	0.21(0.05-0.86)	0.24(0.05-1.00)	0.18(0.04-0.88)	0.34(0.06-1.82)
Parent-CS-4	0.71(0.27-2.23)	0.75(0.27-2.39)	0.25(0.07-1.01)	0.35(0.08-1.64)
Sex	-	0.33(0.15-0.69)	0.26(0.11-0.62)	0.43(0.16-1.03)
Teacher-CS-4	-	-	11.96(5.10-30.01)	20.50(7.00-67.09)
CBCL Thought Problems	-	-	-	1.13(1.06-1.22)
Rule-breaking Behaviour	-	-	-	0.82(0.74-0.90)
Nagelkerke R ²	0.05	0.08	0.27	0.50

Bold: significance after multiple corrections, $p<0.01$

Clusters 1 were used as reference category for logistic regression models.

Preschool-aged children: Parent-CP-1: no autism/ADHD; Parent-CP-2: sub-autism+sub-ADHD; Parent-CP-3: social communication difficulties; Parent-CP-4: ADHD with repetitive/restrictive traits. School-aged children: Parent-CS-1: no autism/ADHD; Parent-CS-2: subclinical autism+ADHD; Parent-CS-3: social communication difficulties; Parent-CS-4: ADHD+sub-autism; SES: socioeconomic status (reference: low); sex (reference: male), and ethnicity (reference: Spanish); CBCL: Child Behaviour Checklist, Teacher-CP-1: no autism/ADHD; Teacher-CP-2: sub-ADHD; Teacher-CP-3: sub-autism; Teacher-CP-4: autism+ADHD. School-aged children, Teacher-CS-1: no autism/ADHD; Teacher-CS-2: sub-ADHD; Teacher-CS-3: sub-autism+ADHD; Teacher-CS-4: autism+ADHD

Logistic regression analyses predicting ADHD diagnosis are presented in Table 4 (full models in supplementary Table S7). In preschool-aged children Parent-CP-4 (OR: 19.74-20.58, $p<0.01$) was associated with increased odds of ADHD diagnosis in the demographic-adjusted model, but these effects were no longer observed in further models. Teacher-derived cluster membership, Parent-CP-2, was strongly associated with ADHD diagnosis (ORs: 20.94-20.80, $p<0.01$). Higher CBCL attention problems (OR=1.18, $p<0.001$) were consistently associated with increased odds of ADHD diagnosis.

In school-aged children, Parent-CS-4 was associated with increased odds of ADHD diagnosis in initial models (ORs: 25.22-27.63, $p<0.01$), but this association was attenuated in further adjusted models. In the fully adjusted model, teacher-derived clusters Parent-CS-2, CS-3, and Parent-CS-4 were significantly associated with ADHD diagnosis (ORs: 2.38-3.64, $p<0.01$), together with higher CBCL attention (ORs=1.11, $p<0.001$).

Table 4: Preschool-aged and school-aged logistic regression predicting ADHD diagnosis

Preschool-aged	Model a	Model b	Model c	Model d
Parent-CP-2	8.68(1.67-159.81)	9.28(1.73-172.40)	0.00(0.00-0.00)	0.00(0.00-0.00)
Parent-CP-3	0.9 (0.04-25.25)	0.84(0.03-21.87)	0.00(0.00-0.00)	0.00(0.00-0.00)
Parent-CP-4	19.74(4.01-357.39)	20.58(4.07-375.96)	0.00(0.00-0.00)	0.00(0.00-0.00)
Ethnicity	-	0.09(0.01-0.33)	0.11(0.02-0.44)	0.12(0.02-0.50)
Teacher-CP-2	-	-	20.94(4.01-386.80)	20.80(3.19-425.23)
CBCL Attention Problems	-	-	-	1.18(1.09-1.29)
Nagelkerke R ²	0.18	0.28	0.38	0.54
School-aged	Model a	Model b	Model c	Model d
Parent-CS-2	5.88(1.17-107.27)	6.58(1.29-120.41)	2.23(0.41-41.58)	2.12(0.38-40.18)
Parent-CS-3	1.25(0.17-25.06)	1.46(0.20-29.33)	0.67(0.09-13.96)	0.72(0.09-15.31)
Parent-CS-4	25.22(5.21-454.26)	27.63(5.64-499.68)	4.24(0.78-79.07)	3.53(0.63-66.79)
Sex	-	0.56(0.35-0.89)	0.38(0.21-0.66)	0.43(0.24-0.76)
Teacher-CS-2	-	-	2.66(1.47-4.85)	3.10(1.53-6.42)
Teacher-CS-3	-	-	2.38(1.31-4.38)	2.39(1.19-4.84)
Teacher-CS-4	-	-	3.64(1.77-7.59)	2.61(1.08-6.31)

CBCL Attention Problems	-	-	-	1.11(1.07-1.16)
Nagelkerke R ²	0.25	0.28	0.32	0.53

Bold: significance after multiple corrections, $p < 0.01$

Clusters 1 was used as the reference category for logistic regression models.

Preschool-aged children: Parent-CP-1: no autism/ADHD; Parent-CP-2: sub-autism+sub-ADHD; Parent-CP-3: social communication difficulties; Parent-CP-4: ADHD with repetitive/restrictive traits. School-aged children: Parent-CS-1: no autism/ADHD; Parent-CS-2: subclinical autism+ADHD; Parent-CS-3: social communication difficulties; Parent-CS-4: ADHD+sub-autism; SES: socioeconomic status (reference: low); sex (reference: male), and ethnicity (reference: Spanish); CBCL: Child Behaviour Checklist, Teacher-CP-1: no autism/ADHD; Teacher-CP-2: sub-ADHD; Teacher-CP-3: sub-autism; Teacher-CP-4: autism+ADHD. School-aged children, Teacher-CS-1: no autism/ADHD; Teacher-CS-2: sub-ADHD; Teacher-CS-3: sub-autism+ADHD; Teacher-CS-4: autism+ADHD

Additional analyses evaluated the external validity of the profiles. Cluster membership explained significant incremental variance beyond diagnostic category for most CBCL subdomains, with ΔR^2 values ranging from 0.09- 0.14 in preschool-aged children and from 0.04- 0.06 in school-aged children (Supplementary Table S8). In contrast, hierarchical logistic regression models showed that cluster membership did not explain additional variance in either autism or ADHD diagnosis beyond the continuous symptom dimensions from which the clusters were derived (all likelihood-ratio $p > 0.05$; Supplementary Table S9).

Discussion

The present study applied a person-centred, data-driven approach to identify behavioural clusters of autism and ADHD traits based on parent reports in a large population-based sample. Several key findings emerged. First, parent-reported data yielded a four-cluster solution across both preschool and school-aged groups that closely resembled previously identified teacher-based profiles. Second, despite this structural similarity, agreement between parent- and teacher-derived cluster membership at the individual level was low. Third, parent-derived clusters showed limited independent predictive value for clinical diagnoses once teacher-derived clusters and dimensional psychopathology were considered. Furthermore, teacher-derived clusters consistently demonstrated stronger associations with both autism and ADHD diagnoses^[12].

The scrutiny of cross-informant agreement revealed low concordance between parent- and teacher-derived clusters. This finding is consistent with extensive literature documenting low to moderate agreement between informants in the assessment of childhood psychopathology^[16,17,31,32]. Notably, when comparing informant-derived clusters with clinical diagnoses, teacher-based clusters demonstrated higher prediction accuracy as compared to parent-based clusters. Importantly, such

discrepancies could be reflecting genuine context-dependent variability in behavioural expression. Teachers observe children in structured academic and peer environments, where attentional control and behavioural inhibition demands are high, whereas parents observe children across broader and less structured contexts, where emotional regulation and family-based social interactions may be more salient^[11,12]. Although differences in scale structure and response format may have contributed to symptom variability, direct examination of cross-informant agreement suggested that measurement characteristics alone could not explain the observed discrepancies. Parent-teacher correlations were domain-specific: restricted/repetitive behaviours showed positive agreement, whereas social/communication problems showed inverse correlations across both age groups. Because these subdomains derive from parent and teacher instruments, their divergence **likely not attributable** to response format alone and **may reflect** context-dependent expression of social behaviour. Consistently, children in the parent social-communication cluster were predominantly reassigned to the teacher low-symptom cluster, locating cross-informant discrepancy specifically within the social-communication domain.

Nevertheless, methodological differences between assessment instruments may have contributed to the observed discrepancies. Teacher-rated measures of autism and ADHD symptoms (e.g., EduTea, Conners) employ Likert-type response scales, whereas the parent-rated CAST utilises dichotomous (yes/no) responses. Also, the EduTea test was created based on DSM symptoms, which may increase its sensitivity to clinically relevant behaviours compared to broader screening tools^[33]. Differences in scale structure and response format may have influenced symptom variability and, consequently, cluster formation. By deriving clusters separately for each informant, the present study preserved this contextual variability rather than imposing artificial consensus across settings.

Furthermore, we also observed some developmental differences. Cross-informant agreement shifted from restless-impulsiveness in preschool-aged children to inattention in school-aged children, suggesting that attention-related behaviours become more consistently recognised across settings with age. Person-centred clusters explained more variance than diagnostic category for emotional and internalising problems in preschool-aged children, whereas diagnostic category was more informative in school-aged children, indicating that clusters capture greater heterogeneity earlier in development. Agreement on the absence of symptoms was also higher in school-aged

children, possibly reflecting more consistent behavioural expectations across home and school settings.

The assessment of diagnostic outcomes revealed that ADHD-related clusters were predominantly represented across ADHD, autism, and subthreshold autism cases in both age groups. This pattern highlights the prominence of behavioural characteristics such as impulsivity, inattention, and emotional dysregulation as perceived by parents, particularly in preschool-aged children, rather than reflecting ADHD-specific diagnostic categorisation alone. These behaviours, likely due to their impact on family functioning, may contribute to increased identification and reporting by parents and should be considered as part of the broader clinical heterogeneity of autism, including borderline presentations. Accordingly, rather than indicating condition-specific risk, these findings suggest that the likelihood of challenges in behavioural regulation, particularly impulsivity, hyperactivity, and emotional lability, may represent a cross-cutting dimension spanning neurodevelopmental conditions. Additionally, the cluster characterised by social communication problems was predominantly represented across diagnostic groups in preschool-aged children, potentially reflecting a subgroup with more general communication difficulties, behavioural inhibition (i.e., hypoactivity and low dysregulation), and increased attentional disengagement. These emotional and behavioural difficulties are known to influence referral pathways and contribute to functional impairment in both ADHD and autism^[34,35], which may help explain the prominence of this profile. Similarly, authors have identified an autism subgroup characterised by elevated behavioural problems despite relatively lower core autistic symptoms severity^[36]. Furthermore, the presence of clinically confirmed autism cases within the low-symptom parent cluster (Parent-CP-1) is consistent with the central observation that parent-derived profiles do not map directly onto diagnostic categories; it is further compatible with the dichotomous CAST response format, which offers limited resolution for borderline social-communication presentations, such that some diagnosed children present low parent-rated screening symptomatology. Extending this work, the present findings indicate that when ADHD and autism traits are modelled jointly, clusters characterised by behavioural dysregulation may capture a substantial proportion of clinically identified cases across diagnostic categories.

When evaluated against related clinical measures, the data-driven profiles explained variance in CBCL subdomains beyond that accounted for by diagnostic categories in most domains across

both age groups, indicating that person-centred profiles capture heterogeneity not reflected by categorical diagnosis. However, when cluster membership was tested against the continuous subdomains from which it was derived, it did not account for additional variance in diagnostic outcomes. Taken together, these findings suggest that clustering serves a primarily descriptive and organisational function, capturing multivariate symptom patterns more comprehensively than diagnostic labels, rather than providing incremental predictive value beyond dimensional measures.

Furthermore, logistic regression analyses indicated that preschool-aged children, parent-derived clusters predicted autism+subthreshold autism diagnoses, with an association observed for CBCL withdrawn behaviour. In contrast, in school-aged children, clusters did not predict these diagnoses; instead, autism+subthreshold autism were associated with CBCL domains of thought problems and rule-breaking behaviour, highlighting the importance of a holistic behavioural assessment. These findings suggest that autism identification is better captured by dimensional behavioural features that reflect its clinical heterogeneity rather than by categorical cluster membership alone, consistent with dimensional and transdiagnostic models of neurodevelopmental psychopathology^[3,6]. In contrast, in both preschool-age and school-aged ADHD diagnoses showed a more symptom-specific pattern, with attention problems consistently predicting outcome. This finding supports the predictive capacity of the CBCL Attention Problems subscale, as previously observed, particularly in school-aged children^[37]. Although parent-derived clusters were associated with ADHD diagnosis in initial models, these effects diminished after accounting for teacher-derived clusters and CBCL symptoms. Whereas, teacher-derived clusters remained significant predictors, in line with previous evidence highlighting the stronger association between teacher reports and clinically significant impairment, particularly for ADHD-related behaviours^[38,12]. This pattern highlights the relative specificity of ADHD-related symptom profiles compared to the broader and more heterogeneous behavioural presentation of autism and ADHD.

Strengths and Limitations

This study has several notable strengths. First, it draws on a large population-based sample spanning both preschool-aged and school-aged children, enhancing generalizability across

developmental stages. Second, the use of parallel age groups allowed for developmentally informed comparisons. Third, the integration of multi-informant data and diagnostic validation analyses strengthens the clinical relevance of the findings. Importantly, the inclusion of dimensional CBCL scales in the predictive models enabled the examination of incremental validity, showing that dimensional psychopathology can complement neurodevelopmental cluster-based profiles in reflecting clinical heterogeneity. Moreover, the application of person-centred cluster analysis enabled the identification of meaningful heterogeneity within the population, an essential consideration for understanding complex neurodevelopmental conditions such as ADHD and autism.

However, several limitations should also be acknowledged. First, the response rate for parent reports was lower than for teacher reports, which may introduce selection bias and limit representativeness. Second, although cluster analyses were conducted separately for each informant to preserve contextual specificity, the cross-sectional design prevents conclusions regarding the longitudinal stability of cluster membership across developmental transitions. Moreover, we observed wide confidence intervals in some regression estimates, likely reflecting the relatively small number of diagnoses within certain clusters, and cluster solutions are inherently sample-dependent, which may limit generalisability to other populations or cultural contexts. Future studies should examine whether these behavioural profiles remain stable over time and whether they predict later functional outcomes. Finally, reliance on questionnaire-based measures may not fully capture the contextual and behavioural complexity of clinically relevant functioning. Incorporating multimethod assessments, including observational and performance-based measures. Therefore, future research should also prioritise the development and validation of dimensionally sensitive assessment tools, particularly for use at early ages, capable of capturing the clinical heterogeneity and predictive trajectories.

Conclusion

In conclusion, this study shows that parent-reported data can identify meaningful and developmentally consistent clusters of autism and ADHD traits in a population-based sample, closely mirroring teacher-derived profiles. However, low agreement between informants

highlights the context-dependent nature of behavioural expression and identification. While parent-derived clusters were useful for capturing behavioural profiles, their contribution to predicting autism diagnosis was largely accounted for by dimensional symptom measures, and their predictive value for ADHD remained limited. In contrast, dimensional behavioural measures and teacher-derived cluster membership demonstrated more consistent associations with diagnostic outcomes. These findings highlight the importance of assessing behavioural symptoms dimensionally and across contexts. Once dimensional measures were considered, associations with diagnostic outcomes were better explained by specific domains such as behavioural dysregulation, attention, and emotional symptoms, possibly reflecting that parent reports capture more observable behavioural outcomes, while less overt underlying features may be less readily detected. Overall, the findings underscore the clinical importance of multi-informant and multidimensional assessment approaches and support the use of person-centred methods to characterise heterogeneity within neurodevelopmental conditions.

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