Journal of Autism and Developmental Disorders (2023) 53:2409–2420
https://doi.org/10.1007/s10803-022-05533-y

ORIGINAL PAPER

Cluster Analysis of Clinical Features of Children Suspected to Have Neurodevelopmental Disorders

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Accepted: 15 March 2022 / Published online: 28 March 2022

Abstract

Early identification of neurodevelopmental disabilities (NDDs) is critical to a good prognosis. Several factors such as overlapping diagnoses can complicate this process and thus delay access to services. This study sought to identify meaningful clinical profiles, beyond diagnostic labels, in 194 children with NDDs referred to an assessment clinic. Cluster analyses were applied to eight selected behavioral and cognitive variables. Results suggested a cluster structure in which three homogenous groups differed significantly from one another: children who presented either (1) heterogeneous diagnoses and ambiguous profiles, (2) a clinical profile closely aligned to a classic presentation of ASD, and (3) emotional and behavioral challenges. These distinct profiles may have implications for assessment and clinical practices.

Keywords Cluster analysis · Autism · Intellectual disability · Neurodevelopmental · Clinical profile · Diagnosis

Early identification of neurodevelopmental disabilities (NDDs), such as autism spectrum disorder (ASD), intellectual disability (ID), global development disorder (GDD) and specific learning and communication disorders, is critical for the prognosis of children and the well-being of their family because a formal diagnostic label is often required to access early intervention and support (Guralnick, 2019; Johnson et al., 2007; Lipkin et al., 2020). Together, NDDs are observed in up to 10% of children (NICE, 2019). Their prevalence has increased continuously over the last decades, which translates into a growing demand for evaluation and intervention and, consequently, delays to access adequate services (see Rivard et al., 2021). In parallel, both the scientific literature and practice settings have questioned the validity of diagnostic evaluation processes that rely exclusively on category-based systems as the *Diagnostic and Statistical Manual of Mental Disorders* (DMS-5; American Psychiatric Association (APA), 2013) to capture the heterogeneity of needs in the NDD population (Astle et al., 2022). Similarly, there has been growing concern about the appropriateness of exclusively diagnosis-based service provision systems, where a diagnosis is required to access interventions and there is little latitude to individualize supports according to the diverse needs and clinical profiles (e.g., co-occurring conditions) within a given NDD (Astle et al., 2022; Miller et al., 2016). These systems pose challenges for families' prompt access to adequate services that are attributable to (1) delays in obtaining diagnosis from qualified specialists; (2) complex clinical profiles or the presence of delays or atypicality that fail to meet diagnostic thresholds or do not find within a discrete diagnostic category; (3) heterogeneous profiles (in terms of symptom severity or variety of co-occurring conditions) and, thus, clinical needs within the same diagnosis; (4) shared service needs among families who are nevertheless placed on different service trajectory due to their child's different NDD diagnosis. These concerns have led to the suggestion that children's functional characteristics (e.g., adaptive and social behavior, learning or academic achievement, and cognitive functioning) may better explain child and family outcomes than the diagnosis itself, and that grouping or categorizing children on the basis of these characteristics (and, thus, needs) would better support service provision in NDDs (Astle et al., 2022; Kushki et al., 2019; Miller et al., 2016). The present study sought to address some of these issues and contribute to the

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advancement of our understanding of clinically meaningful subgroups that may exist across NDDs, beyond diagnostic labels. To do so, it employed a data-driven approach (i.e., cluster analysis), based on eight behavioral and cognitive variables (i.e., functional characteristics), to identify NDD subgroups in 194 children referred for assessment.

Challenges to Diagnostic and Category-Based System in NDDs During Early Childhood

Several factors complicate the diagnostic process when NDDs are suspected in early childhood and these have impacts on the references for adequate interventions and services. First, the constantly changing and evolving nature of development during the early years makes diagnostic decision-making more challenging, as children's behavior and profile may change drastically over short period of times. However, even in the absence of an official, definitive ("fixed") diagnosis, children in their families may require support and interventions in relation to developmental delays or atypicality observed in early screening. This is a serious concern inasmuch as delays of up to two years are observed between an initial referral for evaluation and a final diagnosis (Rivard et al., 2021). Furthermore, the evaluation of possible NDDs in very young children needs to account for risk factors that may be present in the family environment (e.g., early deprivation or being from a disadvantaged socioeconomic background) which can also impact timely access to assessments (Astle et al., 2022; McLaughlin et al., 2011). It is therefore advisable to adopt a dynamic approach to assessment and early intervention when such risk factors are present. Indeed, it may be pertinent to examine whether services can promote the child's development prior to making a definitive determination as to whether their clinic profile is consistent with a NDD diagnosis (Haute autorité de santé, 2020). This creates a circular problem: an official diagnosis is often required to access the very interventions that could make a difference in whether a child will be diagnosed with a given disorder. The scientific literature has consistently identified social inequalities in the assessment process, which in turn translate into delays in obtaining a diagnosis and interventions, and eventually into disparate outcomes for children (see Astle et al., 2022; Rivard et al., 2021). It is thus important to continue investigating how demographic socioeconomic factors relate to different profiles and groupings within NDDs.

Second, there is a questioning on the validity of diagnostic classification systems such as the DSM to effectively capture the service needs of all children presenting signs of atypical or delayed development. They may require significant support in various domains (e.g., learning, cognitive, behavioral, and social) yet their clinical profile may not meet the threshold for diagnostic criteria, and thus the criteria to receive needed interventions (Astle et al., 2022). Thus, children with subthreshold or non-classical presentations of NDD will experience inequalities in access to assessment and intervention.

The third and fourth concerns stem from the fact that symptoms and support and intervention needs within a given diagnosis may vary more substantially within a same NDD diagnosis than between two distinct diagnoses. The third concern, overlap between diagnoses under the larger umbrella of NDDs poses challenges for differential diagnosis (Gillberg et al., 2014). The currently prevailing taxonomy systems do not fluidly accommodate overlap between what are supposedly discrete disorders (Caoghill & Sonuga-Barke, 2012). Fourth, as noted by Astle et al. (2022), these same systems are also poorly suited to the substantial variability in symptoms among children who receive the same diagnosis. Thus, the reliance on discrete diagnostic labels to orient services, guide interventions, and or make referrals for NDDs may be inappropriate. Indeed, Gillberg et al. (2014; see also Fernell et al., 2014) have stated that NDDs are almost never "one problem only" and that overlap, comorbidity, or co-existence are the rule. Yet public agencies may dispense only diagnosis-oriented interventions (i.e., which target diagnostic criteria only and are predicated upon the child having received a given diagnosis) as opposed to services that focus on the needs of children and their family (e.g., support in managing challenging behaviors, which transcend diagnostic categories). Furthermore, in a context where families wait several years to obtain a diagnosis (i.e., 2–3 years in the United Kingdom, United States, and Canada; Austin et al., 2016; Crane et al., 2016; Rivard et al., 2021), a service delivery model that requires official diagnostic labels delays and hinders families' access to support they might need as soon as the child displays significant difficulties. All these raise concerns about the exclusive reliance on categorical diagnostic systems to orient families toward services (Astle et al., 2022; Gargaro et al., 2011; Gillberg et al., 2014; Kalyva et al., 2016; Klopper et al., 2017; van der Meer et al., 2012).

Categorical Versus Transdiagnostic Systems in NDDs

Categorical, international diagnostic frameworks and systems such as the DSM-5 (APA, 2013) are extensively used by clinicians to categorize delays and atypicality into discrete NDD diagnostics, determine families' eligibility for services, and inform intervention decisions (Astle et al., 2022; Lipkin et al., 2020; Rivard et al., 2021). In research, as mentioned by Astle et al. (2022), the reliance on these systems could lead to highly

selective samples that limit the external validity of studies. Indeed, studies often adopt the presence of a discrete diagnosis as inclusion criterion and simultaneously excludes participant with co-occurring conditions or problems. Samples created with these fixed inclusionary and exclusionary criteria misrepresent the reality in NDDs, where co-occurring diagnoses and difficulties are very prevalent (e.g., between 65 and 85% in autism; Gillberg & Coleman, 2000). The authors challenged the assumption built into theories and research practices (e.g., recruitment and data analysis), i.e., that diagnostic criteria reflect an underlying reality.

The authors further argued that weaknesses of exclusively category-based approaches in research and real-life service provision for NDDs underscore the value of also integrating transdiagnostic or dimensional approaches that center on child functional characteristics (Astle et al., 2022; see also Sonuga-Barke et al., 2016). A transdiagnostic approach holds that disorders share a set of behavioral and cognitive processes that contribute to maintaining the disorder or deficits and that a framework to categorize disorders should be based on needs rather than discrete categories and labels (Dalgleish et al., 2020; Nolen-Hoeksema & Watkins, 2011). In NDDs, two transdiagnostic approaches have been proposed as alternatives to categorical systems: dimensional and clustering methods. Both methods recommend a broad assessment of important functional variables in children, that is, meaningful and measurable features of difficulties experienced in NDDs that are associated to risk factors and later outcomes for children and their families. A range of transdiagnostic measures may be used to capture children's cognitive processes, learning or educational achievement, behavior, and social functioning.

A dimensional approach to individual differences proposes the examination of multiple clinical features to generate continuous scales (ranging from typical to atypical) that represent a person's functional needs (Astle et al., 2022). Transdiagnostic clustering adopts a data-driven approach to identifying subgroups based on functional characteristics or other variables associated with child and family outcomes. Thus, cluster analyses use individuals' scores on a range of dimensional measures to determine their membership within subgroup (i.e., cluster) with a similar clinical profile in terms of needs (Astle et al., 2022; Lombardo et al., 2016; Stevens et al., 2000).

Objectives

In response to extant challenges in the early identification and differential evaluation of ASD, ID, GDD and other NDDs and to guide clinical evaluation and intervention practices, the present study sought to identify the potential meaningful clustering of clinical profiles, beyond diagnostic labels, among children referred to a neurodevelopmental assessment clinic. To this end, data from their clinical evaluation records were analyzed to answer the following questions:

1. Do the profiles of children suspected of NDDs comprise cohesive subgroups, or clinical clusters, based on selected clinical features (i.e., autism severity, intellectual functioning, adaptive behavior, comorbidities, and internalized and externalized challenging behaviors), beyond the diagnostic label they ultimately received at the clinic?
2. Are contextual or family factors (e.g., income, number of siblings, etc.) associated with these profiles and linked to their membership within a given clinical cluster?
3. How is clinical cluster membership related to the diagnoses made by the assessment clinic?

Method

This study was part of a larger longitudinal project (2016–2021) to support and evaluate a new neurodevelopmental assessment center established in a large Canadian city to address several organizational and clinical challenges associated with access to quality diagnosis and intervention services for families of children suspected of having NDDs. The four broad objectives of the research project established in parallel with the pilot clinic were to (1) support the development of a model for an assessment center and assess the quality of its implementation (Morin et al., 2020, 2021; Rivard et al., 2018); (2) evaluate the face validity of this clinical model from service users' (i.e., parents) perspective (Morin et al., accepted); (3) conduct a longitudinal follow-up of parents' experience and appraisal of the quality of their service trajectory following the child's diagnosis and leading up to their enrollment in school (Rivard et al., 2021); and (4) describe the profiles of children and families at the moment of the diagnosis and over time. Thus, the present study corresponded to the fourth objective and sought, more specifically, to describe the profiles of children referred for NDD assessment. These findings should not only inform the diagnostic evaluation process, but also to orient families toward services as soon as the child is referred for assessment. The longitudinal project received ethical approval from the institutional review board for human subjects research of [Université du Québec à Montréal].

Participants

Parents of 259 children took part in larger research project, which represented a 23.5% participation rate relative to the total number of families who received services from the pilot assessment center between 2016 and 2020. For the present study, data from 194 children were included in cluster analyses. In order to be included in the present study, parents had to speak English or French, children had to be of preschool age (i.e., under seven years), had to have received a complete evaluation from the clinic, and have complete data on all of the measurements listed in the following section. The first column of Table 1 presents the sociodemographic characteristics of all participating families and children. At the time of the diagnosis, children's ages ranged between 2.2 and 7.1 years and 159 (74.1%) were boys.

Measures

Sociodemographic Information

A sociodemographic questionnaire was used to collect the following information on families: (1) the child's age, sex, and gestation period; (2) yearly income of the family; (3) type of family; (4) number of siblings; (5) diagnoses and comorbidities (e.g., physical or motor disorder, ADHD, language delay) among the child's siblings or parents.

Intellectual Functioning

The Wechsler Preschool and Primary Scale of Intelligence-Fourth Edition (WPPSI-IV; Wechsler, 2012), the Bayley Scales of Infant & Toddler Development-Third Edition (BSID-III; Bayley, 2006), and the Leiter International Performance Scale-Third Edition (Leiter-3; Roid et al., 2013) were used to assess children's intellectual functioning depending on the child's age, verbal ability, and level of cooperation. For young children (ages 2:6–3:11), the global test–retest reliability of the WPPSI-IV ranges from .72 to .84; its internal consistency ranges from .83 to .93. For older children (ages 4:0–7:7) these coefficient ranges are .71 to .86 and .75 to .94, respectively (Soares & McCrimmon, 2013).

The BSID-III has ranges of .79 to .98 for test–retest reliability and .83-to 94 for internal consistency (Albers & Grieve, 2007). The Leiter-3 has an internal consistency of .96 (Kranzler & Floyd, 2013). For the purposes of the present study, the full-scale IQ from the WPPSI-IV, the Cognitive Composite from the BSID-III, or the Leiter-3 nonverbal IQ were used to assess children's intellectual functioning. Because the clinic used the most appropriate instrument for each child, scores on each measure were converted to *z*-scores to provide a scaled indicator of cognitive functioning that could be used across the entire sample.

Adaptive Behavior

The parent/primary caregiver form (ages 0–5) of the Adaptive Behavior Assessment System-Second Edition (ABAS-II; Harrison & Oakland, 2003) was used to measure children's adaptive behavior. This instrument assesses the Conceptual, Social, and Practical domains and provides a General Adaptive Composite. The instruments' internal consistency (.98–.99) and test–retest reliability ($r = .90$) attest to its high reliability (Harrison & Oakland, 2003). The measure

Table 1 Sociodemographic information for the study sample and individual clusters

Variables	All ($N = 194$)		Cluster 1($n = 59$)		Cluster 2 ($n = 71$)		Cluster 3 ($n = 64$)		*p*	Group differences
	n	%	*n*	%	*n*	%	*n*	%		
Age in years (*M, SD*)	4.4	(1.1)	4.66	(1.1)	3.9	(0.9)	4.6	(1.2)	< .001	1, 3 > 2
Pregnancy weeks (*M, SD*)	39.3	(1.9)	39.06	(2.1)	39.3	(1.6)	39.4	(2.0)	.657	
Sex (male)	159	74.1	44	74.6	59	83.1	56	87.5	.168	
Family (nuclear)	137	70.6	39	70.9	55	79.7	43	70.5	.400	
Siblings (*M, SD*)	1.3	(1.6)	1.20	(1.1)	1.2	(1.1)	1.4	(1.3)	.329	
Diagnostic in family										
Siblings	41	21.1	9	17.0	17	26.2	15	25.0	.453	
Father	27	13.9	7	12.3	5	7.5	15	24.6	.020	3 > 2, 1
Mother	20	10.3	4	7.3	5	7.6	11	17.7	.107	
Income in CAD									.338	
10–49 k	84	48.0	17	33.3	37	26.4	30	38.5		
50–89 k	46	26.3	15	29.4	18	12.9	13	16.7		
90–139 k	33	18.9	13	25.5	7	5.0	13	16.7		
140 +	12	6.9	6	11.8	3	2.1	14	17.9		

CAD Canadian dollar

also displayed high correlations (.70 to .84) with the Vineland Adaptive Behavior Scale, a converging measure (Harrison & Oakland, 2003).

Internalizing and Externalizing Problem Behaviors

The preschool version (ages 1.5–5) of the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2000) was used to assess problem behaviors. The checklist yields seven syndrome scores, which combine to form broadband measures of internalizing behaviors (emotional reactive, anxious/depressed, somatic complains, withdrawn) and externalizing behaviors (attention problems, aggressive behavior); a Total Problems score may also be computed. The clinical threshold on the Internalizing and Externalizing measures is a *T*-score of 63 (60–63 = borderline). The internal consistency and factor structure of this instrument have been validated among children with ASD (Pandolfi et al., 2009).

Autism Symptom Severity

The Autism Diagnostic Observation Schedule-Second Edition (ADOS-II; Lord et al., 2012) is a protocol for the observation of children's and adults' social and communication behaviors in standardized situations. This instrument can be used to diagnose ASD and to qualify behaviors associated with ASD. It includes five modules which enable its use with individuals of any age. The ADOS-II presents good reliability, with interrater reliability ranging from .79 to .98 and test–retest reliability between .64 and .92 (Lord et al., 2012; McCrimmon & Rostad, 2014). Internal consistency ranged from .47 to .92 (McCrimmon & Rostad, 2014).

Procedure

Data collection began in January 2016 and ended June 2020. All families who received a complete evaluation from the assessment center were invited take part in the longitudinal study. During an in-person follow-up meeting that took place approximately two weeks after their child's assessment was completed, the family services coordinator (employed by the assessment center) provided families with information about the research process. Those who expressed interest were contacted by a research assistant to schedule an in-person data collection appointment (either at their home or at the assessment center, or at the affiliated university). The only data collected during this visit used in the present study pertained to sociodemographic information. When parents provided written consent to participate in the study, they also gave the study team permission to use their child's evaluation records from the clinic. All other assessments (i.e., ABAS-II, CBCL, ADOS-II, WPSSI-IV, Leiter-3, or Bayley-III), were administered during the course of the diagnostic evaluation at the clinic and were shared with the study team.

Analyses

Eight variables were used in the cluster analysis carried out in JASP 0.14.1. These were selected to reflect children's broad behavioral and cognitive profile while maximizing sample size (i.e., minimizing omitted cases due to missing data): the Conceptual, Social, and Practical domain scores of the ABAS-II; the Social Affect and Restricted/Repetitive Behavior scores from the ADOS-II: the Externalized and Internalized Behavior scales from the CBCL, and intellectual functioning score (obtained through either the WPPSI-IV, Bailey-III, or Leiter-3). All variables were transformed into *z*-scores for the cluster analysis.

For the first objective, a cluster analysis was conducted to group children into homogeneous subgroups of children based on the selected variables. First, to determine the appropriate number of homogeneous clusters present in the sample, we obtained a dendrogram via a hierarchical cluster analysis using the Ward minimum variance method (D^2 linkage) with Euclidean distances. This graph provides a visual depiction of differences between children and is used to visually determine the number of homogeneous subgroups in the sample. Once an appropriate number of clusters was determined, a *k*-means cluster analysis was conducted to assign each child to a cluster. In *k*-means clustering, each child belongs to the cluster with the nearest centroid (i.e., multivariate mean), which minimizes within-cluster variance and thereby yields homogeneous subgroups.

For the second and third objectives, clinical records and sociodemographic data were compared between clusters using analyses of variance (ANOVA) for numerical data and χ^2 for categorical data. To establish which clusters were significantly different from one another, post-hoc analyses were conducted using Tukey's HSD (numerical data) and standardized residuals (categorical data).

Results

Although the dendrogram strongly suggested a three-cluster structure, a two- and four-cluster structure were also examined through *k*-means clustering analyses. A three-cluster structure was ultimately selected because it resulted in the most homogeneous subgroups based on variable distributions (see the density plots in Fig. 1).

The sociodemographic and clinical profiles of children within each cluster are described below and detailed in Tables 1 and 2. Table 3 displays the representation of diagnoses within each cluster. The density plots in Fig. 1

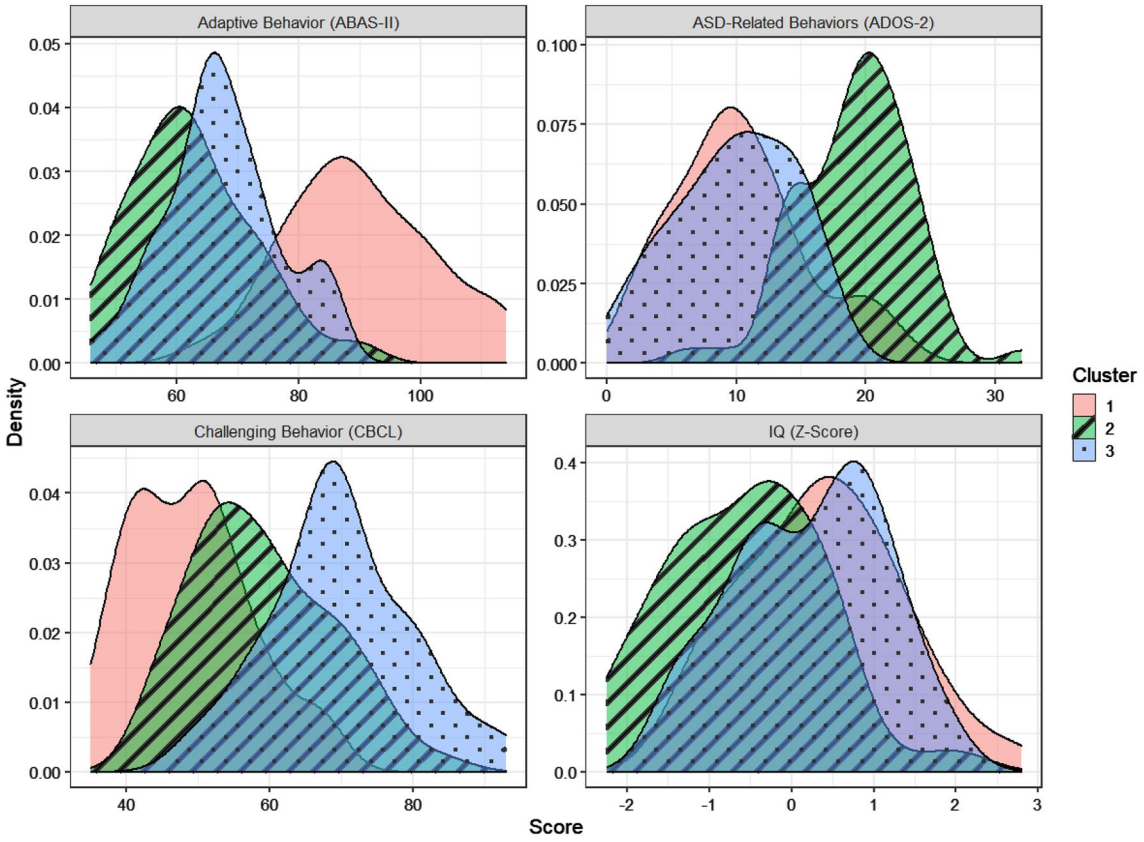

Fig. 1 Variable distributions (density) for each clinical variable used for clustering children into homogeneous subgroups

provide a visual depiction of these results, which are also summarized in Table 4. Children in Cluster 1 ($n=59$) tended to present neurodevelopmental disorders diagnoses other than ASD and ID such as language delay (10.3%), physiological disorders (8.2%), ADHD (5.7%) and motor disorders (2.1%). These children had higher levels of adaptive behavior and lower levels of both internalizing and externalizing challenging behavior. Children in Cluster 2 ($n=71$) were significantly younger and more likely to have a dual diagnosis of ASD and ID. They displayed lower levels of intellectual functioning and lower adaptive behavior. The children in this cluster presented higher levels of challenging behavior than those in Cluster 1, but less than those in Cluster 3. Compared to other clusters, children in Cluster 2 have more autism-related behavior. Children in Cluster 3 ($n=64$) were more likely to have a father who had received

Table 2 Descriptive statistics for clinical measures across the study sample and within individual clusters

Clinical measures	All ($n=194$)		Cluster 1 ($n=59$)		Cluster 2 ($n=71$)		Cluster 3 ($n=64$)		p	Group differences
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*		
Intellectual functioning (*z*-score)	− 0.0	(1.0)	0.36	(1.0)	− 0.6	(0.9)	0.2	(0.9)	< .001	1, 3 > 2
ABAS-II conceptual	73.6	(15.7)	90.4	(12.2)	64.2	(10.4)	70.1	(9.9)	< .001	1 > 3 > 2
ABAS-II social	73.9	(15.9)	89.4	(11.1)	65.4	(11.7)	70.9	(13.1)	< .001	1 > 2, 3
ABAS-II practical	74.6	(17.6)	92.6	(14.0)	65.8	(12.5)	69.7	(12.7)	< .001	1 > 2, 3
CBCL internalizing	59.2	(11.8)	49.1	(10.8)	59.1	(7.7)	68.3	(8.2)	< .001	3 > 2 > 1
CBCL externalizing	55.7	(12.4)	46.2	(8.0)	53.9	(9.1)	66.9	(10.1)	< .001	3 > 2 > 1
ADOS social affect	9.6	(5.2)	7.3	(4.0)	14.1	(4.1)	6.7	(3.5)	< .001	2 > 1, 3
ADOS restricted/repetitive	3.8	(1.9)	3.1	(1.8)	5.2	(1.5)	3.3	(1.9)	< .001	2 > 1, 3

ABAS-II Adaptive Behavior Adaptive Assessment System-II, *CBCL* Child Behavior Checklist, *ADOS-II* Autism Diagnostic Observation Schedule

Table 3 Frequency of diagnoses across the study sample and within individual clusters

	All ($N=194$)		Cluster 1 ($n=59$)		Cluster 2 ($n=71$)		Cluster 3 ($n=64$)		p	Group differences
	n	%	n	%	n	%	n	%		
Diagnosis									< .001	
ASD	105	54.1	35	59.3	28	39.4	42	65.6		1, 3 > 2
ID or GDD	7	3.6	5	8.5	0	0.0	2	3.1		1 > 2, 3
ASD and ID/GDD	55	28.5	3	5.1	42	59.2	10	15.6		2 > 3 > 1
Other	27	13.9	16	27.1	1	1.4	10	15.6		1 > 3 > 2

ASD Autism spectrum disorder, *ID* intellectual disability, *GDD* global developmental disorder, *other* language delays, attention deficit/hyperactivity disorder, or complex motor disorders

Table 4 Summary of the characteristics that distinguish each cluster

	Cluster 1 ($n=59$)	Cluster 2 ($n=71$)	Cluster 3 ($n=64$)
Demographic and family background		Younger	Family NDD diagnosis (father)
Diagnosis	Other NDDs	ASD, ID/GDD	
Intellectual functioning		Lower	
Adaptative behavior	Higher	Lower	Intermediate
Challenging behavior	Lower	Intermediate	Higher
Autism symptoms severity		Higher	

NDD neurodevelopmental disorder, *ID* intellectual disability, *ASD* autism spectrum disorder

a neurodevelopmental disorder diagnosis such as attention deficit (8.3%) learning disorder (7.2%), language delay (6.2%) or mental health disorders as mood disorder (7.3%). Children in this cluster had the highest rates of challenging behavior.

Discussion

Assessment practices and research in the field of NDDs are largely based upon both data on symptoms that confirm (or refute) the presence of a condition associated with a given DSM-5 diagnostic category as well as a differential evaluation of other disorders in childhood and adolescence (Lipkin et al., 2020). The rapidly changing and evolving nature of early childhood development, the variability in clinical profile and service needs within NDD diagnoses as well as the frequent overlap between these along with co-occurring conditions all contribute to challenges in diagnosing children using categorical systems. These issues also raise concerns about the validity of service delivery models that rely solely on diagnostic labels (Astle et al., 2022; Miller et al., 2016). On its own, a NDD diagnosis such as ASD may not be as strong a predictor of a child's outcomes, in contrast to comorbid conditions or the challenging behaviors that tend to co-occur with it (Astle et al., 2022; Miller et al., 2016). In real-life settings, clinicians must reconcile the theoretical diagnostic categories for NDDs according to the DSM-5 (or other categorical taxonomies) with a clinical reality that is not always as straightforward. Every day, the teams who assess children are left with many questions, such as: when should early symptoms, screening results, a diagnosis or co-occurring/comorbidities be used to orient interventions, and which interventions (diagnosis-oriented or services needs-oriented)? Are there early clinical indicators (beyond specific diagnostic criteria) that could prompt referral to services to meet intervention or support needs before or during the assessment process? Some authors have suggested that categorical (e.g., as in the DSM-5) and transdiagnostic approaches are both useful, with neither approach being sufficient by itself, to understand, evaluate, and intervene with children with NDDs (Gargaro et al., 2011; Gillberg et al., 2014; Kalyva et al., 2016; Klopper et al., 2017). However, the integration of these approaches requires further study of the clinical profiles of children within and across diagnostic categories.

In this vein, data-driven, exploratory techniques such as cluster analysis can be used to identify cohesive subgroups based on selected clinical features and, consequently, intervention needs, within large and heterogeneous diagnostic categories (Astle et al., 2022; Klopper et al., 2017). This approach has seldom been used in ASD, and even more rarely under the umbrella of childhood NDDs (Astle et al., 2022). Different subgroups within autism (e.g., with or

without co-occurring ID or attention-deficit/hyperactivity disorder [ADHD]) will have different outcomes (Miller et al., 2016; Paynter et al., 2018; Perry et al., 2011). This is also true within other NDD labels or diagnoses (Bathelt et al., 2021; Miller et al., 2016). Consequently, the current, exclusive focus on fixed diagnostics in early screening and intervention may be limiting. Children's prognosis may be better predicted by comorbidities and specific clinical features, but also by children's strengths and resources (Astle et al., 2022; Bathelt et al., 2021; Miller et al., 2016). A cluster analytic approach to clinical profiles in NDDs may thus provide valuable, additional information. With the goal to contribute to a better understanding of a potential transdiagnostic approach of NDDs, the present study aimed to identify data-driven NDD subgroups. Cluster analysis techniques were applied to eight behavioral and cognitive variables selected to reflect functional characteristics in children referred to an assessment center for NDDs.

Our analyses resulted in three subgroups (i.e., clusters) which differed significantly from one another in terms of key variables considered in the assessment process. The first subgroups was more heterogeneous in terms of the diagnoses children ultimately received at the clinic (e.g., attention deficit disorder, learning disorder) and presented fewer classical symptoms of autism. This cluster falls under the broad umbrella of NDDs, but presents more ambiguous and diversified profiles. These children presented, on average, less pronounced deficits in social functioning (compared to the two other clusters) as well as in IQ and adaptive behavior. This suggests that these children may require fewer individualized supports in cognitive and adaptive functioning domains at school or in daycare and may generally function well in everyday life. However, longitudinal studies (such as the ongoing project with this cohort) would yield more accurate information about outcomes for this group over time and taking development into account. Due to the presence of conditions such as language or motor problems or other neurodevelopmental particularities, the children in this cluster may particularly benefit from multidisciplinary assessment. Indeed, the participating assessment clinic had reported challenges when evaluating these less typical cases that are milder in terms of ASD- and ID-related symptoms. These tended to require lengthier evaluations and a clinical team with diversified areas of expertise (Astle et al., 2022; Rivard et al., 2018).

The second subgroup reflected a clinical profile closely aligned with the classical presentation of ASD as described in the DSM-5, that is, in terms of the core symptoms used to diagnose autism. These children showed signs of ASD earlier and were thus diagnosed earlier, which explains the lower mean age of this cluster. Following an early diagnosis of ASD, these children will gain access to evidence-based interventions such as parental coaching program or early intensive behavioral intervention (EIBI) that are adapted to their diagnosis (Makrygianni et al., 2018; Prior et al., 2011; Reichow et al., 2018; Warren et al., 2011; Weitlauf et al., 2014). Overall, these children showed the highest levels of ASD symptomatology and more deficits in terms of intellectual functioning and adaptive behavior, such that rapid access to more intensive interventions would be needed to improve their outcomes. Given the present issues with waiting lists for diagnostic evaluations and EIBI within the public system, the use of screening tools for ASD such as the M-CHAT could serve to rapidly orient children in this cluster toward interventions (Janvier et al., 2016; Moore et al., 2017). A child with this profile could therefore receive needed services in parallel to a lengthier assessment to reach an official diagnosis, (e.g., Haute autorité de santé, 2020). This is consistent with current recommendations to orient children suspected of having ASD during screening toward early intervention services to minimize the negative effects of delays on the effectiveness of these behavioral interventions (Penner et al., 2015; Perry et al., 2011). Furthermore, observations of the child's response to ongoing interventions could provide useful information in the diagnostic evaluation process.

The third subgroup included children with emotional and behavioral challenges, difficulties that often co-occur with and exacerbate NDDs such as ASD. Children in this cluster were more likely to have fathers with a neuropsychological or mental health diagnosis. This observation, alongside elevated levels of challenging behavior, suggests that these cases cluster due to other factors that are peripheral to classical ASD symptoms diagnosis. These behavioral and family factors would have warranted a referral for evaluation and the identification of behavioral challenges as a clinical priority. Children in this cluster would likely benefit from interventions focused on the management of challenging behavior, parenting practices, and psychosocial support for the family (see, e.g., parent coaching programs for socio-emotional and behavioral in young children with NDDs; National Institute for Health & Care Excellence, 2013; Rivard et al., 2021).

As discussed by Klopper et al. (2017), we conclude that distinctions between diagnoses and grouping based on dimensions of clinically meaningful subgroups, which takes into account the overlap between NDDs, are both useful guides to clinical practice. For instance, the three clusters identified in the present study are relevant for the screening procedures in place within healthcare and social services and could provide professionals with valuable indicators to seek out. While screening for ASD does not in itself yield a final clinical diagnosis, it can help to detect atypical development suggestive of autism or of other NDDs for which further assessment is needed. However, screening practices should also include tools that can detect early signs of other

clinical profiles (beyond ASD-specific screeners) associated with different intervention needs and outcomes. Importantly, screening should set families on a path toward support according to the child's clinical features, i.e., multidisciplinary evaluation and intervention for children whose profile resembles Cluster 1; ASD-specific evaluation and intervention for those in Cluster 2; psychosocial support along with behavior management and diagnosis-specific interventions for children within subgroup 3. This would stem from an organized screening program at community health centers where screen-positive children receive in-depth assessment and interventions that are consistent with their difficulties.

The current knowledge, new trends in recent research, and recent discussions around categorical and transdiagnostic approaches following changes to the DSM and recent questions on diagnostic- and transdiagnostic-based intervention and services (e.g., in the field of applied behavioral analysis, including acceptance and commitment therapy intervention models) have led us to analyze behavioral and developmental measures associated with later outcomes and the lived experiences of children who received a NDD diagnostic. Our research was also motivated by a growing body of research suggesting that diagnostic labels are not necessarily good predictors of prognoses. Our attempt was also motivated by a desire to support the participating assessment center identifying intervention and family support practices to provide throughout the diagnostic evaluation process. This approach is informed by the notion that a diagnosis-based service trajectory has its limits, e.g., in terms of access to intervention for children with NDDs other than ASD or in cases for which lived experience and challenges are more closely connected to comorbid conditions than to the primary diagnosis. Our data suggest that even at the diagnostic evaluation stage of children and families' services trajectories, support and services could be oriented towards different indicators of services needs rather than, as was the case in the province where the present study took place, exclusively based on official diagnoses and offer a specific treatment according to specific modalities, and for a specific period of time. Other recent studies have identified similar issues internationally and have highlighted the importance of research that would support data-driven, needs-based service allocation (see, e.g., Astle et al., 2022). A transdiagnostic approach to NDDs that focuses on the clinical profile and needs of children would lead to a more individualized, family centered approach. It may also help to reduce inequalities in access to services between NDDs diagnoses and for children who do not meet diagnostic criteria. As stated by Astle et al. (2022):

> The potential benefits of a transdiagnostic framework for the identification of child's needs have the potential to translate into intervention. The shift from a diagnosis-centred to a child-centred perspective means characteristics that are most impactful for the child become the focus for support and remediation. (p. 15)

The authors also pointed out that a transdiagnostic approach provides a framework from which to build on children's strengths and family resources in providing interventions.

Limitations and Future Studies

Because this study represents, to our knowledge, one of the few attempts to identify clusters of clinical profiles of children with a range of neurodevelopmental diagnoses (i.e., not limited to ASD but have been suspected to have one; e.g., González-Cortés et al., 2019; Klopper et al., 2017; Rixon et al., 2021; Stevens et al., 2000), its findings of three specific subgroups should be treated as tentative. Indeed, because cluster analysis is an unsupervised (i.e., data-driven) approach, its results are contingent on the characteristics of the dataset on which it was performed. For instance, cluster analytic approaches in ASD research have yielded clusters that varied in number and composition as a function of the sampled population and measures (e.g., González-Cortés et al., 2019; Klopper et al., 2017; Rixon et al., 2021; Stevens et al., 2000). As such, it would be important to replicate these analyses in other samples of children suspected of, or diagnosed with, NDDs, and with variations on the battery of assessments used by the participating clinic. However, despite this need for future replication, the clusters identified in the present study are meaningful in the clinical context in which they were observed and can be translated into practical recommendations for screening and access to interventions. Our next steps for research into this topic will be to examine links between screening data and subsequent cluster membership, as well as and following clusters longitudinally to assess the continuity and variability of clinical profiles over time along with the outcomes associated with each cluster.

Conclusion

By relaxing the adherence to strict diagnostic categories and basing service allocation on functionally defined needs, a transdiagnostic approach to NDDs could help to alleviate four major challenges discussed in the present paper and elsewhere, namely: (1) a need for rapid access to services in spite of delayed access to diagnostic evaluation by qualified teams; (2) the difficulty in orienting toward services for children with more complex clinical profiles, delays, or atypicalities that do not meet diagnostic thresholds or do not fit a discrete diagnostic category; (3) the heterogeneous profiles and, by extension, of intervention

and support needs observed among individuals with the same diagnosis; and (4) the presence of similar needs across families of children with different NDD diagnoses who are nevertheless placed on different service trajectories based on their respective diagnostic labels. A data-driven method to identify groupings and profiles within NDDs may be closer to clinical reality and be a more useful way to identify pathways for effective interventions. The transdiagnostic perspective on NDDs adopted in the present study exemplifies a step toward a more flexible approach to clinical practices regarding diagnosis and assessment. Specifically, this strategy was informed by real-world observations and difficulties stemming from the heterogeneity within, and overlap between, disorders when practitioners must reach an accurate diagnostic/needs evaluation conclusions and determine what best to support families. It resulted in the identification of clusters of individuals with a common set of characteristics and service needs which could inform and guide intervention and support practices as early as screening and referral for assessment. This data-driven method could also help to capture developmental change and shifts in cluster membership over time and development, in contrast to fixed diagnostic labels. Our next step in this larger initiative will focus on the longitudinal follow-up of participants in this study and the outcomes of each cluster in meaningful behavioral and developmental domains.

Author Contributions Prof. MR conceptualized, designed the study (all the steps including the data collection instruments, initial analyses) and acquired the funding, insured the supervision of the research team for the data collection, drafted the initial manuscript, and reviewed and revised the manuscript. ZM carried out the analyses and contributed to the initial draft, reviewed and revised the manuscript. Dr DM contributed to conceptualize, design the study and in acquiring the funding, reviewed and revised the manuscript. Dr. CP supervised the analyses and the redaction of the results part. Prof. CM contributed to the design of the data collection instruments, translated the drafted the initial manuscript, reviewed and revised the manuscript. Dre MM supervised the research team and collected data, carried out the initial analyses, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Funding This study was funded by Grants from the Ministère de la Santé et des Services Sociaux du Québec and the Fondation Marcelle et Jean-Coutu. Additional financial support to Mélina Rivard was provided by the Fonds de Recherche du Québec—Santé (research scholar—junior1) and the Fondation Sandra et Alain Bouchard. The redaction of this manuscript was also support by the fundings of the Institut universitaire de recherche en déficience intellectuelle et trouble du spectre de l'autisme.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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