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Research Article

Trait-Based Subtypes of ASD by the Multi-Dimensional Scale for PDD and ADHD (MSPA)

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Abstract

Background: This survey was conducted to classify Autism Spectrum Disorder (ASD) into subtypes based on childhood traits.

Method: To evaluate childhood traits, we used the Multidimensional Scale for Pervasive Developmental Disorder and Attention-Deficit/Hyperactivity Disorder (ADHD) (MSPA). The MSPA consists of 14 domains, is an assessment tool used for planning individual support by identifying the neurodevelopmental features. First, we checked the MSPA domains affecting the diagnosis of ASD by using the multiple logistic regression analysis. Then we conducted Principal Component Analysis (PCA) of the MSPA scores in 290 patients with ASD to figure out if the 14 MSPA domains can classify into aggregated groups.

Results: The multiple logistic regression analysis showed Group adaptability and Restricted interests/behaviors were the significant explanatory variables for ASD. We found four components as a result of PCA, with the initial eigenvalues> 1 and the explained variance 58.79%. The domains consisting of each component are as follows; Communication, Group adaptability, Empathy, Restricted interests/behaviors, and Language development for component 1, Hyperactivity, Impulsivity, and Inattention for component 2, Gross motor, Fine motor, and Learning for component 3 and Sensory, Stereotyped and repetitive motion, and Sleep cycle for component 4. Based on the traits constituting the four components, we classified ASD into "pure ASD," "overlapping with ADHD," "overlapping with developmental coordination disorder and learning disorder," and "disabilities associated with the reticular activating system."

Conclusions: These new subtypes from the aspect of traits in childhood may contribute to organizing effective supports for each patient of ASD and their surrenders.

Keywords: ASD; Co-Occurrence; MSPA; Trait; Subtype; Support

Trait-based subtypes of ASD by the Multi-Dimensional Scale for PDD and ADHD (MSPA)

Historically, the first case of autism was reported by Kanner (1943) [1], and the following year, Asperger (1944) [2] reported his cases that were later called as Asperger syndrome. Since the 1940s, several studies had been published discussing whether autism and childhood schizophrenia are the same or not [3-5]. After a few decades, the concept of autism was finally separated from childhood schizophrenia, and Pervasive Developmental Disorder (PDD) was then established through the Diagnostic and Statistical Manual of Mental Disorders (DSM)-III [6]. Furthermore, cases of specific Learning Disorder (LD), Developmental Coordination Disorder (DCD), and Attention-Deficit/Hyperactivity Disorder (ADHD) were reported [7-9], and the concept of each disorder was established..

In the revision of DSM-IV-TR [10] to DSM-5 [11] in 2013, PDDs including autism, Asperger's disorder, and Pervasive Developmental Disorder–Not Otherwise Specified (PDD-NOS), were integrated into Autism Spectrum Disorder (ASD), and the

diagnostic criteria were also changed. ASD, ADHD, LD, and DCD were all classified into one broad category of neurodevelopmental disorders. The co-occurrence of ASD, ADHD, and DCD has been permitted since this revision, possibly because of considerable case reports overlapping ASD and other neurodevelopmental disorders [12-16]. This revision indicates a complex pathology of neurodevelopmental disorders beyond each diagnostic category.

Individuals with ASD have a wide variety of clinical presentations. Several genetic studies identifying numerous responsible sites [17-19] have been reported in decades, supporting the idea of the complex background. The prognosis of ASD also varies widely. Landa (2012) [20] suggested a broader phenotype of ASD in children with good prognosis such as normative development; meanwhile, several studies brought up unfavorable prognosis such as the increase in mortality nearly twice more than that in the general population [21-23]. Waterhouse et al. (2016) [24] reviewed the validity of ASD for over 300 studies and specified the lack of evidence in a constant developmental course or life outcome in patients with ASD. Furthermore, they documented the lack of internal homogeneity to determine whether ASD has valid subtypes, despite the efforts from many aspects, such as gender subgrouping, brain-feature subgrouping, and behavior subgrouping.

To elucidate the question about prognosis and subtypes of ASD or how neurodevelopmental disorders extend and overlap each other, researchers need to collect enough number and information of individuals. However, when we tried to examine this question retrospectively, the difference of diagnostic criteria in each era would become one of the most challenging obstacles. The individual group with PDD-NOS in DSM-IV-TR may not be the same as that with ASD in DSM-5 [25-27].

Funabiki, Kawagishi, Uwatoko, Yoshimura, and Murai (2011) [16] developed the Multi-Dimensional Scale for PDD and ADHD (MSPA), which is an assessment tool for individuals who have neurodevelopmental disorders. This tool evaluates the severity of the traits associated with neurodevelopmental disorders by visualizing them in a radar chart for supporting them and their surroundings on the basis of their behaviors on early childhood. Most importantly, MSPA was developed as an evaluation tool for understanding their characteristics as they are, not as a diagnostic tool. Hence, it is not influenced by the change of diagnostic criteria, thereby solving the abovementioned problem, that is, the difficulty of evaluating individuals retrospectively due to the different diagnostic criteria. In addition, given that MSPA evaluates early childhood traits, it may also help us prevent overlooking the co-occurrence of neurodevelopmental disorders and distinguish traits from other complicating problems, such as secondary disorders. In the present study, we first checked the MSPA scores for organizing the overlapping features of each neurodevelopmental disorder. We clarified the distinctive traits of ASD, combined-ADHD (C-ADHD), inattentive-ADHD (I-ADHD), LD, and DCD. Next, we investigated the MSPA domains affecting the diagnosis of ASD. This survey aimed to classify ASD into subtypes to seek more suitable supports to individuals with ASD whose clinical presentations are diverse in each. For this goal, we focused on the aspect of childhood traits by using the MSPA scores.

Methods

Participants

We reviewed records of patients who had visited the neurodevelopment unit in our hospital or an educational support center in the community between 2006 and 2016. The inclusion criteria of participants were as follows: patients without intellectual disabilities (Intelligence Quotient [IQ] or Developmental Quotient [DQ] ≥ 70); those who had at least one diagnosis of ASD, I-ADHD, C-ADHD, LD, or DCD; those who had been assessed with MSPA; and those aged <50 years. We excluded patients aged ≥50 years because of the difficulty in gathering enough information about infancy and childhood. IQ or DQ was evaluated using the Kyoto Scale of Psychological Development [28] for children aged <6 years, the Wechsler Intelligence Scale for Children 3rd [29] or 4th [30] Edition for those aged 6–17 years, and the Wechsler Adult Intelligence Scale 3rd [31] Edition for those aged >17 years. A total of 396 patients (277 males and 119 females) were included according to the abovementioned criteria. The age of patients was 17.73 ± 11.45 (mean ± Standard Deviation [SD]) years. Their Full-Scale IQ (FIQ) was 99.75 ± 14.77, Verbal IQ (VIQ) was 103.37 ± 17.32, and performance IQ (PIQ) was 95.79 ± 14.38. The distribution of patients is presented in (Table 1). We rechecked their records retrospectively and reconstructed their diagnoses on the basis of DSM-5 wherein multiple diagnoses were allowed for one patient. Eventually, we found that 290 out of the 396 participants had been diagnosed with ASD. Furthermore, 138 had C-ADHD, 167 had I-ADHD, 75 had LD, and 122 had DCD. The percentage of co-occurrence of ASD and other neurodevelopmental disorders is listed in (Table 2).

	ASD	non-ASD	C-ADHD	I-ADHD	non-ADHD	LD	non-LD	DCD	non-DCD
n	290	106	138	167	91	75	321	122	274
male	209	68	114	98	65	49	228	85	192
female	81	38	24	69	26	26	93	37	82
age	18.71	16.79	13.46	21.01	20.32	17.19	18.43	20.36	17.25
	±11.81	±10.43	±10.22	±10.92	±12.06	±11.76	±11.42	±12.26	±11.01
FIQ	100.34	98.23	97.24	101.17	100.47	93.21	101.47	97.76	100.69
	±15.39	±12.95	±14.21	±15.23	±14.31	±11.16	±15.13	±14.78	±14.70
VIQ	104.29	100.63	±99.44	105.43	104.05	95.66	105.44	104.28	102.92
	±18.21	±14.10	±18.12	±16.15	±17.92	±14.79	±17.39	±17.45	±17.28
PIQ	96.03	95.04	94.86	96.33	95.85	91.63	96.90	92.94	97.23
	±15.26	±11.32	±14.64	±14.68	±13.68	±13.58	±14.41	±15.57	±13.55
Age, FIQ, VIQ, PIQ scores present mean ± SD The number of participants in ASD and non-ASD adds up to total participants (N=396) So as C-ADHD and I-ADHD and non-ADHD, LD and non-LD, DCD and non-DCD adds up to total participants.									

Table 1: Characteristics of sample (N = 396).

	n	%
ASD only	50	17.24
ASD + C-ADHD	97	33.45
ASD + I-ADHD	109	37.59
ASD + LD	54	18.62
ASD + DCD	107	36.90

Table 2: Classification of ASD.

Procedures and Materials

MSPA (Funabiki et al. 2011) [16] consists of the following 14 domains: Communication, Group adaptability, Empathy, Restricted interests/behaviors, Sensory, Stereotyped/repetitive motion, Gross motor, Fine motor, Inattention, Hyperactivity, Impulsivity, Sleep cycle, Learning, and Language development. Each domain was graded on a nine-rank scale according to the degree of difficulties based on their traits as follows: 1, no sign of developmental traits; 2, some signs of developmental traits but no need of support; 3, requiring support by supervisors in groups; 4, requiring special support by everyone in groups; and 5, facing difficulty despite full support from groups and requiring special supports individually. Conditions between adjacent scores were graded as 1.5, 2.5, 3.5, and 4.5 accordingly.

For MSPA evaluation, well-trained experts conducted a semi-structured interview to the individuals and their families in approximately 30 minutes, so that they could sufficiently assess the severity and the level of support needed for each trait. Before the interviews, the individuals and their families, caregivers, or teachers were required to answer questionnaires to help the interviewers know the state of the individual in multiple situations experienced from childhood to the present time. Through these procedures of MSPA, we could evaluate the details of their traits based on their behaviors in early childhood. This study was approved by the medical ethics of our hospital.

Data analysis

Descriptive statistics were conducted for gender, age, IQ (FIQ, VIQ, and PIQ), and the MSPA scores in each diagnosis of the neurodevelopmental disorder. In the respective analyses of ASD, LD, and DCD, we performed a chi-square test for gender and Student t-tests for age, FIQ, VIQ, PIQ, and the 14 domains of the MSPA scores between the groups with and without each disorder. Next, we conducted a one-way analysis of variance (ANOVA) to determine whether age, FIQ, VIQ, PIQ, and the 14 domains of the MSPA scores differed among the three groups, namely, C-ADHD, I-ADHD, and non-ADHD.

A multiple logistic regression analysis (the variable increasing method by likelihood ratio) was conducted to identify

the MSPA domains affecting the diagnosis of ASD. We used the dummy variables "1 = patients with the diagnosis of ASD" and "0 = patients without the diagnosis of ASD" as the dependent variables. The explanatory variables were the scores of the 14 MSPA domains. For the MSPA data of 290 patients with ASD, we conducted a principal component analysis (PCA) to summarize the developmental characteristics of the 14 domains. Oblique rotation (Promax rotation) was selected; this approach is commonly used in cases when a correlation is possibly present among factors [32].

Moreover, we used the Statistical Package for the Social Sciences (software version 22.0, IBM Corp. 2013) for statistical analysis.

Results

We found differences in age, gender, and IQ between the groups with and without each disorder. We excluded 11 patients from the analysis of age because their age data consisted of only school grade, not the exact age. The patients with C-ADHD were younger than those without C-ADHD ($F [2, 382] = 19.57$, $p < .001$). Male ratio was higher in C-ADHD than in I-ADHD ($\chi^2 [2] = 20.70$, $p < .001$). The scores of FIQ ($t [144.91] = 5.12$, $p < .001$) and VIQ scores ($t [277] = 3.95$, $p < .001$) were significantly lower in patients with LD than in patients without LD (Table 1).

The traits evaluated using the MSPA scores in each neurodevelopmental disorder are presented in (Table 3). MSPA scores of ≥3 indicate "requiring support" and traits requiring sufficient clinical attention. The number of such domains whose average scores were ≥3 was as follows: five domains in ASD, seven domains in C-ADHD, four domains in I-ADHD, five domains in LD, and six domains in DCD. These results are shown in (Table 3).

The group with ASD had significantly higher scores than that without ASD in the domains of Communication, Group adaptability, Empathy, Restricted interests/behavior, Sensory, Stereotyped/repetitive motion, and Gross motor, as shown by the result of t-test ($p < .001$). Furthermore, the group with ASD had significantly lower scores in the domain of Inattention than the group without ASD ($p < .001$). The group with LD had significantly higher scores in the domains of Fine motor and Learning than the group without LD ($p < .001$). Furthermore, the group with DCD had significantly higher scores in the domains of Communication, Group adaptability, Empathy, Restricted interests/behavior, Sensory, Stereotyped/repetitive motion, Gross motor, and Fine motor than the group without DCD ($p < .001$). Both groups with C-ADHD and I-ADHD had significantly higher scores in the domains of Inattention, Hyperactivity, and Impulsivity than the non-ADHD group, according to the ANOVA ($p < .001$). The C-ADHD group also showed higher scores of Hyperactivity and Impulsivity than the I-ADHD group, but Inattention had no statistically significant difference between the C-ADHD and I-ADHD groups.

	ASD	non-ASD		C-ADHD	I-ADHD	non-ADHD		LD	non-LD		DCD	non-DCD	
n	290	106		138	167	91		75	321		122	274	
Communication	**3.34**	2.46	#	**3.13**	**3.00**	**3.24**		**3.19**	**3.08**		**3.42**	2.96	#
	±0.57	±0.59		±0.74	±0.70	±0.59		±0.60	±0.71		±0.59	±0.69	
Group adaptability	**3.45**	2.40	#	**3.22**	**3.00**	**3.32**		**3.23**	**3.15**		**3.48**	**3.03**	#
	±0.51	±0.49		±0.78	±0.67	±0.52		±0.62	±0.70		±0.58	±0.69	
Empathy	**3.19**	2.33	#	**3.07**	2.88	2.93		2.94	2.96		**3.20**	2.85	#
	±0.61	±0.60		±0.73	±0.74	±0.64		±0.64	±0.74		±0.68	±0.71	
Restricted interests/ behaviors	**3.56**	2.52	#	**3.38**	**3.20**	**3.36**		**3.25**	**3.29**		**3.49**	**3.19**	#
	±0.53	±0.59		±0.74	±0.72	±0.63		±0.76	±0.71		±0.72	±0.70	
Sensory	2.39	1.75	#	2.29	2.21	2.12		2.27	2.21		2.52	2.08	#
	±0.93	±0.76		±0.97	±0.91	±0.89		±0.95	±0.93		±0.89	±0.91	
Stereotyped/ repetitive motion	1.61	1.24	#	1.68	1.47	1.33		1.52	1.51		1.77	1.40	#
	±0.80	±0.47		±0.86	±0.67	±0.61		±0.79	±0.73		±0.88	±0.64	
Gross motor	2.34	1.82	#	2.09	2.19	2.37		2.51	2.13		**3.20**	1.75	#
	±0.88	±0.76		±0.98	±0.84	±0.79		±0.81	±0.88		±0.46	±0.62	

Fine motor	2.13	1.87		2.20	2.04	1.88		2.38	1.98	‡‡	2.92	1.67	‡‡
	±0.89	±0.70		±0.93	±0.80	±0.77		±0.78	±0.84		±0.65	±0.60	
Inattention	**3.15**	**3.56**	‡‡	**3.73**	**3.60**	1.98	*a*	**3.51**	**3.20**		**3.34**	**3.22**	
	±0.93	±0.64		±0.55	±0.47	±0.56		±0.82	±0.89		±0.89	±0.88	
Hyperactivity	2.27	2.33		**3.34**	1.85	1.47	*b*	2.41	2.25		2.34	2.26	
	±0.99	±0.92		±0.55	±0.56	±0.58		±0.96	±0.97		±1.01	±0.95	
Impulsivity	2.66	2.62		**3.37**	2.40	1.99	*c*	2.66	2.64		2.67	2.64	
	±0.96	±0.89		±0.66	±0.81	±0.81		±1.01	±0.93		±1.01	±0.91	
Sleep cycle	1.96	1.95		1.97	2.08	1.71		1.81	1.99		2.00	1.94	
	±0.84	±0.90		±0.90	±0.84	±0.78		±0.80	±0.87		±0.86	±0.86	
Learning	1.95	1.98		2.00	2.03	1.77		**3.30**	1.62	‡‡	2.19	1.86	
	±0.85	±0.88		±0.84	±0.88	±0.84		±0.41	±0.56		±0.91	±0.82	
Language development	1.69	1.43		1.67	1.58	1.62		1.82	1.58		1.79	1.55	
	±0.71	±0.51		±0.72	±0.63	±0.68		±0.71	±0.66		±0.73	±0.64	

scores present mean±SD
‡‡ As the result of t-test, two groups deffered significantly ($p < .001$)
a As the result of ANOVA, none-ADHD group had significant low scores compared to both C-ADHD group and I-ADHD group
bc As the result of ANOVA, all three groups had significant difference among each other
Bold: mean of MSPA scores over 3 which means "requiring support"

Table 3: The MSPA scores of each neurodevelopmental disorder groups.

(Table 4) presents the domains affecting the diagnosis of ASD in the multiple logistic regression analysis (the variable increasing method by likelihood ratio). The omnibus test of the model coefficients was significant at the 0.1% level, guaranteeing the significance of the regression equation. The percentage correct was 94.2%. Given the possibility of multicollinearity, we examined the internal correlation between the explanatory variables and found no strong correlation ($|r| > 0.8$). The values of variance inflation factors were all <10, which suspects of no harmful possibilities of multicollinearity. Group adaptability and Restricted interests/behaviors were the significant explanatory variables for ASD. The multiple logistic regression model of the best battery is also presented in (Table 4).

	B	S.E.	Wald	Sig.	OR	95% CI for OR	
ASD						Lower	Upper
x_1: Group adaptability	4.634	.695	44.474	.000	102.898	26.361	401.650
x_2: Restricted nterests/behaviors	3.318	.544	37.251	.000	27.605	9.511	80.119
Constant	-22.260	3.046	53.398	.000			
model chi-square test: $p < .001$, Percentage Correct: 94.2 % The logistic regression model of the best battery: $\ln(P/(1-P)) = -22.260 + 4.634\ x1 + 3.318\ x2$							

Table 4: Logistic regression analysis in ASD.

The correlation matrix analyzed in 290 patients of ASD is shown in (Table 5a). We did not find extremely strong correlations ($|r| > 0.9$) to suspect possibilities of multicollinearity.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Communication	-	.65**	.48**	.30**	.13**	.17**	.21**	.29**	.11	.16**	.08	.05	.13*	.38**
2. Group adaptability		-	.49**	.44**	.23**	.28**	.23**	.26**	.11	.27**	.18**	.10	.12	.33**
3. Empathy			-	.38**	.21**	.22**	.13**	.15*	.25**	.28**	.32**	.05	.00	.22**
4. Restricted interests/behaviors				-	.29**	.13**	.11	.11	.16**	.28**	.33**	.10	.08	.16*
5. Sensory					-	.31**	.21**	.22**	.15*	.22**	.27**	.12*	.05	.06
6. Stereotyped/ repetitive motion						-	.23**	.26**	.20**	.29**	.19**	.15*	.10	.08
7. Gross motor							-	.62**	.07	.00	.01	.09	.21**	.15*
8. Fine motor								-	.25**	.23**	.12*	-.02	.27**	.18**
9. Inattention									-	.54**	.47**	.14*	.25**	.12
10. Hyperactivity										-	.63**	.13*	.22**	.20**
11. Impulsivity											-	.10	.13*	.14*
12. Sleep cycle												-	-.05	.08
13. Learning													-	.18**
14. Language development														-

* p <.05, ** p <.01

Table 5a: Pearson Correlation in 290 participants with ASD.

(Table 5b) presents the PCA result. The Cronbach's alpha coefficient for testing the reliability was.77. Four components were selected on the basis of the criterion that the initial eigenvalues were >1. The explained variance was 58.79%, which is less than the satisfactory 60% proposed by Hair (2014) [33]. Therefore, we adopted initial eigenvalues> 1 based on Guttman (1954) and Kaiser (1960) rule [34,35]. The pattern matrix is depicted in (Table 5c). All of the 14 MSPA domains were categorized into four components without overlapping or missing. Component 1 was accounted for 27.40% of the variance and consisted of the following five domains: Communication, Group adaptability, Empathy, Restricted interests/behaviors, and Language development. Component 2 was accounted for 12.20% of the variance, with the three following domains: Hyperactivity, Impulsivity, and Inattention. Component 3 was accounted for 10.67% of the variance, also with the three following domains: Gross motor, Fine motor, and Learning. Component 4 was accounted for 8.52% of the variance, with the three remaining domains: Sensory, Stereotyped/repetitive motion, and Sleep cycle.

Total Variance Explained							
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.84	27.40	27.40	3.84	27.40	27.40	3.08
2	1.71	12.20	39.60	1.71	12.20	39.60	2.70
3	1.49	10.67	50.27	1.49	10.67	50.27	2.17
4	1.19	8.52	58.79	1.19	8.52	58.79	1.71
5	0.97	6.94	65.73				

6	0.82	5.83	71.56				
7	0.77	5.48	77.04				
8	0.72	5.11	82.15				
9	0.58	4.16	86.31				
10	0.51	3.65	89.96				
11	0.47	3.32	93.28				
12	0.35	2.48	95.76				
13	0.33	2.33	98.09				
14	0.27	1.91	100.00				

Table 5b: Principal axis factor analysis of ASD and 14 domains (Promax rotation).

	Component			
	1	2	3	4
Communication	0.88			
Group adaptability	0.83			
Empathy	0.70			
Language development	0.56			
Restricted interests/behaviors	0.53			
Hyperactivity		0.83		
Impulsivity		0.80		
Inattention		0.80		
Gross motor			0.85	
Fine motor			0.83	
Learning			0.48	
Sensory				0.66
Stereotyped/repetitive motion				0.55
Sleep cycle				0.51
Pattern loadings ≥.40 are reported.				

Table 5c: Pattern Matrix of the MSPA domains in ASD.

Discussion

This survey focused on the severity of childhood traits as an additional aspect to various approaches in ASD subtyping, as expressed by MSPA. The MSPA scores well presented the individual features of individuals with neurodevelopmental disorders who consulted the experts for diagnosis. Patients with ASD had significantly higher scores in the MSPA domains related to the diagnosis criteria of ASD than those without ASD. The well matching of the high MSPA scores and the diagnostic criteria was also noted in C-ADHD, I-ADHD, LD, and DCD. Meanwhile, patients with LD had significantly higher scores in Fine motor

domain than those without LD. This result matches well to the previous report noticing fine motor deficiency in children with LD [36]. From the mean MSPA scores, we found that patients with LD required support in the domains of Communication, Group adaptability, Restricted interests/behavior, and Inattention, as well as Learning, possibly suggesting the highly frequent overlap of LD with ASD or ADHD.

Patients with DCD also showed higher mean scores in the MSPA domains of Communication, Group adaptability, Empathy, Restricted interests/behavior, and Inattention, similar to patients with LD. Hence, when patients with LD or DCD visit the experts for diagnosis, they may have difficulties in not only motor function or learning skills but also traits from the co-occurrence of ASD or ADHD. Thus, MSPA could help more in recognizing other traits than the main diagnosis, thereby supporting individuals with neurodevelopmental disorders comprehensively in their daily lives. According to the multiple logistic regression analysis, the MSPA domains that significantly affected the diagnosis of ASD were Group adaptability and Restricted interests/behaviors in the order of influence. The ASD diagnosis in DSM-5 has two major criteria stated as follows: A. persistent deficits in social communication and social interaction and B. restricted, repetitive patterns of behavior, interests, or activities. The most affected domain in our analysis met the criteria A, and the second most affected domain met the criteria B. These two domains appeared to be specific features of ASD even compared with other neurodevelopmental disorders constituting the non-ASD group in this study. The other typical ASD domains such as Communication and Empathy, which are also included in the criteria A, were not specific features of ASD when compared with other neurodevelopmental disorders. Both average scores of Communication and Empathy were >3, which indicates "requiring support." However, in this study, these domains did not have a significant effect on the diagnosis of ASD. Hence, Communication and Empathy might be shared symptoms in other neurodevelopmental disorders at clinical settings.

Thus, we compared the MSPA rating with the diagnosis of ASD in DSM-5 and found features specific to the diagnosis. Considering that MSPA focuses on the traits from behaviors on early childhood and evaluates them in multiple situations, the rating is not influenced by the revision of diagnostic criteria. The PCA for the MSPA data of 290 patients with ASD revealed four components. The five MSPA domains constituting component 1 were as follows: Communication, Group adaptability, Empathy, Restricted interests/behaviors, and Language development. Restricted interests/behaviors domain is in the diagnostic criteria B and the three other domains are in the diagnostic criteria A of ASD in DSM-5. Delayed language development is one of the earliest symptoms in individualss with ASD [37] and was used to be one of the diagnostic criteria of autism before development of DSM-5 [11]. These five domains are a set of core symptoms of ASD, and we consider these domains of component 1 as traits related to an aspect of "pure autism."

The MSPA domains constituting component 2 were three, namely Hyperactivity, Impulsivity, and Inattention. These domains are features of the diagnostic criteria of ADHD and may indicate frequent overlaps between ASD and ADHD. Thus, component 2 is an aspect of "overlapping with ADHD." The percentage of patients with ASD who have a co-occurrence of ADHD in our survey was 71.0%, which matches well with previous reports by Leitner (2014) and Yoshida (2004) [13,38]. Leitner (2014) [38] reviewed over 150 studies of ASD and ADHD co-occurrence and reported the percentage range of recorded cases at 37%–85%. Yoshida (2004) [13] also noted that PDD has 67.9% overlap with ADHD. In our survey, the subjects had IQ of ≥70, and this finding is consistent with that of Yoshida's report.

Component 3 consisted of three MSPA domains, namely, Gross motor, Fine motor, and Learning. These domains are considered to be a group overlapping with DCD or LD or both. Although clumsiness is excluded in the DSM-5 criteria for ASD, motor problems such as motor delay or deficits in coordination, movement preparation and planning, praxis, gait, and balance are well known as ASD-associated features [39]. Green (2009) [40] reported that the difficulty of motor skills was up to 79% in children with ASD, specified that the impairment was severer in low-IQ groups, and concluded that it might arise from a severer neurological damage. Our participants had an IQ over 70, and DCD accompanied approximately 40% of them. Co-occurrence with DCD might increase when we focus on patients with both ASD and low IQ. When DCD was not allowed to be diagnosed with ASD until the establishment of DSM-5, LD was one of the diseases that could already be diagnosed with ASD in DSM-IV. The co-occurrence of ASD and LD is reported to be between 65% and 85% [41]. Hence, component 3 is a mass of traits "overlapping group with DCD and LD." Furthermore, we already recognized a group of patients having symptoms of DCD, LD, and ADHD, which are collectively known as deficits in attention, motor control, and perception (DAMP) syndrome [42,43]. In addition, the high frequency in the co-occurrence of DAMP and ASD has already been suggested [43]. From the results of components 2 and 3, we can conclude that the symptoms of neurodevelopmental disorders closely overlap each other.

Meanwhile, component 4 had three MSPA domains: Sensory, Stereotyped and repetitive motion, and Sleep cycle. Individuals with ASD have unusual sensory patterns [44]. Stereotyped and repetitive motion is also one of the early signs of ASD [45,46], thereby related to the severity of ASD [47]. Sleep problems are also frequently observed in individuals with ASD [48,49]. Furthermore, these three traits may be predictors of social skill or communication problems [50]. These traits may occur from more primitive

brain functions, indicating syndromes related to the reticular activating system. The reticular activating system is responsible for controlling the sleep–wake pattern [51]. It is also known as the pathway where sensory information is integrated and projected. In addition, it plays roles in muscle toning, exercise regulation, and rhythm generation (pattern generator). Some individuals with ASD have the disability of these functions. Thus, component 4 is considered as "disabilities associated with the reticular activating system." These interpretations based on domains with high scores do not imply that the results are exclusive of other domains that entered in the model and relatively small sample size.

The four components presented from the results of this study indicate the complex overlapping with other neurodevelopmental disorders and variations of ASD; such variations may be called as subtypes. Given that this survey focused on the aspect of the MSPA scores evaluating the severity of "requiring support," these subtypes might well present the ways of supports they need. Furthermore, considering that MSPA is well designed to support individuals with neurodevelopmental disorders throughout their lifetime on the basis of their traits, it is also useful and supportive for those who turned out to have difficulties in their adulthood. In the future, more effective supports for each subtype are expected to be determined and organized.

Limitation

The target population of the present study included patients diagnosed with neurodevelopmental disorders. Considering that they consulted the experts for diagnosis regarding their difficulties experienced in their daily lives, their MSPA scores tend to be higher than those of the undiagnosed population. A comparative study involving a community group is needed for further discussions. There is no comprehensive support tool like the MSPA. For this reason, it is necessary to verify external validity by finding tools that evaluate similar characteristics even if the purpose is different for each domain, which is a future work.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

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

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