Can Autism, Language and Coordination Disorders Be Differentiated

Based on Ability Profiles?

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Abstract

Children with autistic disorder (AD), mixed receptive-expressive language disorder (RELD), or developmental coordination disorder (DCD) have impairments in common. We assess which abilities differentiate the disorders. Children aged 3 to 13 years diagnosed with AD (n = 30), RELD (n = 30), or DCD (n = 22) were tested on measures of language, intelligence, social cognition, motor coordination, and executive functioning. Results indicate that the AD and DCD groups have poorer fine and gross motor coordination and better response inhibition than the RELD group. The AD and DCD groups differ in fine and gross motor coordination, emotion understanding, and theory of mind scores (AD always lower), but discriminant function analysis yielded a non-significant function and more classification errors for these groups. In terms of ability scores, the AD and DCD groups appear to differ more in severity than in kind.

Key Words: Autism, Receptive-Expressive Language Disorder, Coordination Disorder

Autistic Disorder (AD), Mixed Receptive-Expressive Language Disorder (RELD) and Developmental Coordination Disorder (DCD) have distinctive DSM-IV diagnostic criteria (4 53). But DSM rules indicate that RELD and DCD cannot be diagnosed if criteria for AD are met, which means that overlap among persons with AD, RELD or DCD is to be expected. High rates of co-morbidity between these and other disorders mean that deviance is seldom specific to one ability domain. The defined distinction between disorders may not match actual patterns of impairment among children with these developmental disorders (27 30). Given the extent of overlap between AD, RELD and DCD, which abilities or disabilities reliably differentiate each disorder from the others?

Research consistently indicates that children with AD, RELD or DCD underachieve relative to age peers across a broad range of ability domains, including language, intelligence, social cognition, motor coordination, and executive functioning.

Language

Children with AD, RELD and DCD all have communication problems. AD children show impaired speech and language comprehension (19 53), with comprehension more impaired than expression (8) and expressive language ranging from mutism to fluency (6). By definition, there is impaired receptive and expressive language development in RELD, with expressive language worse than receptive (31). DCD children have language problems, including problems with speech (11 39). Comparative studies of AD/language disorder show similar language problems in the two groups (53). What may distinguish them is that in AD, deficits may be more profound/deviant (4 5). Whether this applies to AD and RELD (as opposed to a broader set of language disorders) is unknown, and we know of no direct comparisons between AD and DCD.

Intelligence

IQ deficits are common in children with AD, RELD or DCD. In AD, ability ranges from normal to severely disabled (29 58), and about 75% of AD children have Mental Retardation (29 52). In general, AD children perform better on performance than verbal tasks (33). Language

disordered children appear unimpaired on tasks involving visuo-spatial processing (27), but this may be an artefact of RELD being defined by language abilities substantially lower than nonverbal intelligence. DCD children have poor visuo-spatial skills (46), are more impaired on performance than verbal intelligence tasks (25), and underachieve educationally (13 20). High-functioning AD children and RELD children are comparable on non-verbal tests (4). On verbal tests, the two groups do not consistently differ (31 65).

Social Cognitive Ability

Delay in acquiring a theory of mind is common in AD (57), and 40 to 80% of persons with AD fail theory of mind tests (3 50). They also have difficulty discriminating and interpreting social and emotional cues (41 62). Language disordered children lack insight into social relations (7 58) and are poor at identifying vocal emotion cues (10). DCD children show deficits in recognizing facial expressions of emotion (12). Theory of mind impairment in AD is more severe and more common than in language disorders (32 44 66), but the impairment in emotion recognition ability may be less severe in AD than in language disorders (9).

Motor Coordination

Children with AD, language disorders and DCD are delayed in achieving motor milestones (4). About 40% of AD children show gross motor problems, and about 30% show fine motor problems (2 22). Language disordered children have problems with gross motor and visuo-spatial processing (27 40). By definition, DCD children have a range of motor impairments. Language disordered children may have better motor ability than AD children, but a large proportion of them have movement difficulties comparable to DCD (26 27).

Executive functioning

Children with AD, RELD, or DCD have deficits in executive functioning, with the frequency of deficits as high as 96% in the AD group (34 42). Children with language disorders have deficits in attention (27), while DCD children may have problems with inhibitory function and working memory (36 47). DCD children also show impaired attention (13 48 49). On

executive functioning tasks, high functioning AD children made more perseverative errors than language disordered children, but the groups did not differ on total errors (34).

Research Aims

The deficits of children with RELD or DCD are more pervasive than current definitions imply, and there is substantial overlap in affected ability domains. What is not clear is the relative severity of observed deficits. Do the defining language deficits in RELD, or the motor skills deficits in DCD, exceed other deficits? Are deficits other than the defining ones of sufficient severity that diagnostic criteria misrepresent the characteristics of persons with language or motor skills disorders? Also, which deficits, if any, differentiate disorders which share defining characteristics? Do children with RELD or AD only share language deficits and children with DCD or AD only share motor skills deficits? We aim to answer these questions. In order to ensure that our assessment is comprehensive, we assess ability in 11 domains that are important to defining developmental disorders. To ensure that ability scores are comparable across domains, we use tests which have been renormed on a single representative sample.

Method

Participants

A state autism register and research connections were used to recruit an initial sample of 42 participants with a clinical diagnosis of AD, and 30 children (male = 23) aged from 3 years, 10 months, to 13 years, 3 months (mean = 8.47 years, $sd = 2.68$ years) met criteria for inclusion in the AD group. Each obtained a score > 13 on the Social Communication Questionnaire (54) and obtained Autism Diagnostic Interview - Revised (35) scores indicating abnormal functioning prior to age 3 years, and scores > 9 on social items, > 7 on communication items, and > 2 on restrictive and repetitive behavior items. Based on parents' reports, 15 children with AD had between 1 and 8 additional physical or mental disorders. Comorbid mental disorders included 9 cases of ADHD or ADD, 3 of sleep disorder, 2 of mental retardation, 1 of mixed

receptive-expressive language disorder, and 1 of depression. Significant physical disorders likely to affect performance included 1 case of epilepsy and 1 of cerebral palsy.

The RELD group were 30 children (male = 22) aged 3 years, 10 months to 12 years, 3 months (mean = 6.78 years, $sd = 1.85$) recruited through Language Development Centres. Each child had been diagnosed by a pediatrician, psychologist or speech pathologist based on standardized testing of receptive language, expressive language, and intelligence, and based on parent/teacher reports of significant impairments in social and academic functioning. Parents were asked to report any other disorders that had been diagnosed. In 7 cases, an additional mental disorder was reported, including 3 cases of ADD, 3 of dyspraxia, and 1 of learning disorder. No significant physical disorders likely to affect performance were reported.

The DCD group were 22 children (male = 14) aged 5 years, 0 months to 13 years, 1 month (mean = 8.55 years, $sd = 2.07$) recruited through special education teacher and occupational therapist referrals. We confirmed that all referred children had coordination problems by testing them with the Movement Assessment Battery for Children (25); each child scored at the 5th percentile or lower. Parents were asked to report any other disorders that had been diagnosed. In 2 cases, ADD was reported. No significant physical disorders likely to affect performance were reported.

Measures

Ability Measures

Detailed information on the validity and reliability of the ability tests used in this study is reported in Dyck et al. (18).

Intelligence was measured with 4 scales from the 3rd edition of the *Wechsler Intelligence Scale for Children* (61)—Vocabulary, Information, Block Design, and Picture Completion. Tests were selected because they represent verbal comprehension and perceptual organization and provide a good estimate of full-scale IQ. Each test is reliable and both criterion and concurrent validity are established (61).

Language ability was estimated with 4 scales from the 3rd edition of the *Clinical Evaluation of Language Fundamentals* (55)—Concepts and Directions, Word Classes, Recalling Sentences, and Formulated Sentences. This test has been standardized across a wide age range. Specific scales are suitable across age ranges and sample receptive (Concepts and Directions, Word Classes) and expressive (Recalling Sentences, Formulated Sentences) language. These scales have acceptable internal consistency, test-retest reliability, and concurrent validity (55).

Motor coordination was assessed with the *McCarron Assessment of Neuromuscular Development* (38). The test comprises 10 tasks: 5 assess fine motor skills (e.g., putting beads in a box) and 5 assess gross motor skills (e.g., heel to toe walking). These tasks have acceptable test-retest reliability, criterion validity, and concurrent validity (38).

Social Cognition. Social cognitive ability was estimated with a combination of 3 1st-order and 1 2nd order theory of mind tasks, an advanced theory of mind task, and 6 *Emotion Recognition Scales* (16). First order *theory of mind* tasks included the *Sally Ann* (3), *Smarties* (44 64), and *Ella the Elephant* tasks (24). The 2nd order task was the *John and Mary icecream story* (45). We treated these tasks as items on a 4-point theory of mind scale. The *Strange Stories Test* is an ‘advanced’ theory of mind task and assesses the ability to provide context-appropriate mental state explanations for non-literal (irony, sarcasm, lies) statements (23).

The *Emotion Recognition Scales* (15 16) include 3 measures of emotion understanding ability (*Emotion Vocabulary Test*, *Comprehension Test*, *Unexpected Outcomes Test*) and 2 measures of emotion recognition ability (*Fluid Emotions Test*, *Vocal Cues Test*). The *Emotion Vocabulary Test* measures the ability to define emotion words (what does the word angry mean). The *Comprehension Test* measures the ability to understand the emotional consequences of exposure to an emotion-eliciting context (Susan is given a new bicycle for her birthday. What will Susan feel?). The *Unexpected Outcomes Test* measures the ability to explain incongruities between an emotion-eliciting context and the emotion elicited by the context. The *Fluid Emotions Test* (15) measures the ability to recognize static and changed/changing (morphed

over 4 seconds) facial expressions of emotion (37). Two scales were used: initial Accuracy (the number of static emotion pictures correct); and Speed Given Accuracy. The latter scale is based on the speed of accurate responses to changed/changing emotion pictures. The *Vocal Cues Test* measures the ability to recognize vocal intonations specific to different emotions. We used its *Unreal* scale in which emotions are expressed using non-semantic content: numerals, letters, nonsense syllables. The Emotion Recognition Scales have acceptable internal consistency. The social cognition measures used in this study are more strongly related to a child's parent-rated social and behavioral disturbances than are intelligence, motor coordination, language or executive functioning measures (17).

Executive functioning was assessed with 3 tasks. *Response inhibition* was measured with the *Go/No-Go Task*, a modified version of a task (56) designed to assess simple motor inhibition. This test consistently discriminates between ADHD and non-ADHD children (43 56). *Working memory* was assessed with the *Trailmaking/Memory Updating Task* and the *Goal Neglect Task*. Trailmaking is a simplification of a more complex task (51) and is designed to assess working memory and behavioral inhibition. Goal Neglect measures the ability to formulate and respond to goal-directed plans, and has been positively related to age and IQ (14).

Procedure

Children were tested individually at each child's home, school or a university, depending on parental preference. Testing was conducted in 3 sessions (2.5 hours, 2.5 hours, 1.25 hours) over 2 or 3 days.

Data Transformations

To ensure that all measures had the same scale, we used data from a representative sample (17) to create age-standardized scores for each variable, i.e., each participant's score was subtracted from the mean score of same-aged participants in the representative sample, and the difference was divided by the standard deviation of the same-aged participants in the representative sample to yield a *z*-score. The *z*-scores were multiplied by 15, and 100 was added

to the product to create standard scores with a mean = 100 and $sd = 15$. These scores were used to create composite indices, unweighted averages of tests that define each ability domain, as follows: *receptive language ability* was the average of standard scores on Concepts and Directions and Word Classes; *expressive language ability* was Formulating Sentences and Recalling Sentences; *perceptual organization* was Wechsler Block Design and Picture Completion; *verbal comprehension* was Wechsler Vocabulary and Information; *emotion recognition ability* was Accuracy, Speed Given Accuracy, and Vocal Cues Test; *emotion understanding ability* was Comprehension Test, Emotion Vocabulary Test, and Unexpected Outcomes Test; *theory of mind ability* was the false belief tasks and Strange Stories Test; *fine motor coordination* was 5 fine motor tasks and *gross motor coordination* was 5 gross motor tasks; *response inhibition* was two go/no go trials; *working memory* was 2 trials of the trailmaking and the goal neglect task.

Composite indices were restandardized (based on normative sample) so that each index had a mean of 100 and a sd of 15. This ensures that composites have the same distribution in the population, but in clinical samples it yields a larger range than does conventional scoring. To ensure that very low scores would not substantially reduce group means, we set a minimum of 20 for all composites. This restricts the range of scores and makes statistical tests more conservative.

Results

Descriptive statistics are reported in Table 1, and indicate that means are typically 1 sd or more below the population mean of 100. There were a few exceptions—RELD on fine motor coordination, AD or DCD on response inhibition, and DCD on expressive language, emotional understanding and theory of mind.

Our interest was whether group ability profiles differ. We used analyses of variance to test group differences. Univariate analyses ensured that list-wise deletion of cases with missing data would not reduce statistical power. Where groups differed, we tested equality of variances

between groups, and conducted Bonferroni (list-wise alpha was set at .05) tests where variances were equal (emotion recognition, theory of mind, receptive language, expressive language, working memory, gross motor coordination) and Dunnett T3 tests otherwise (emotion understanding, response inhibition, perceptual organization, verbal comprehension, fine motor coordination).

The groups differ in expressive language [$F(2, 61) = 4.640, p = .013$], emotion understanding [$F(2, 76) = 8.331, p = .001$], theory of mind [$F(2, 75) = 5.870, p = .004$], fine motor coordination [$F(2, 79) = 20.038, p < .001$], gross motor coordination [$F(2, 79) = 18.157, p < .001$], and response inhibition [$F(2, 51) = 7.875, p = .001$]. *Post-hoc* tests (see Table 1) show each group differs from each other group on two variables: fine and gross motor coordination. RELD obtain the highest scores, DCD obtain intermediate scores, and AD obtain the lowest scores. Otherwise, DCD differs from RELD in obtaining higher emotion understanding, theory of mind, expressive language and response inhibition scores. DCD differs from AD in obtaining higher emotion understanding and theory of mind scores. RELD differs from AD in obtaining lower response inhibition scores.

Each group differs from the others on 3 or more variables, but within-group variability raises the question: can individuals be reliably sorted into groups based on ability profiles? We tested this with discriminant function analysis using all 11 variables. The first function (see Table 2, Analysis 1) accounted for 80.5% of variance [$\chi^2(22) = 49.83, p < .001$], and both functions accurately classified 67.1% of cases. Six AD children were misclassified as DCD and 2 as RELD, 3 RELD children were misclassified as AD and 4 as DCD, and 8 DCD children were misclassified as AD and 4 as RELD.

We conducted 3 follow-up analyses (see Table 2, Analyses 2, 3, 4) to assess how well each group can be discriminated from each other group. When AD and RELD were included, the function was significant [$\chi^2(11) = 30.34, p < .001$] and 88.3% of cases were correctly classified. When DCD and RELD were included, the function was significant [$\chi^2(11) = 23.33, p$

= .016] and 90.4% of cases were correctly classified. However, when AD and DCD were included, the function was not significant [$\chi^2(11) = 14.32, ns$] and 76.9% of cases were correctly classified: 8 DCD were misclassified as AD, and 4 AD were misclassified as DCD. These groups appear to differ in the severity of deficits in expressive language, social cognition, and fine motor coordination; misclassified children obtain intermediate scores.

Discussion

Results confirm previous research showing pervasive ability deficits in children with RELD or DCD and substantial overlap in deficits across groups (7 13 27). Despite this overlap, distinctive patterns of normal or superior performance in some ability domain distinguish AD or DCD children (high response inhibition) from RELD children (high fine motor coordination). Where the pattern of normal performance is less distinctive (higher theory of mind and emotion recognition in DCD) and where groups have similar patterns of superior and inferior performance (high response inhibition and low fine motor coordination in AD and DCD), classifying children is more difficult. These results have implications for how we define and understand developmental disorders.

Specific versus Pervasive Developmental Disorders

DSM definitions of learning, communication and motor skills disorders require that a child underachieve in a specific ability domain compared to the child's age and mental age. These definitions imply that 'disorders' differentially affect performance in circumscribed domains. If a child underachieves in more than one area, the child's performance is affected by more than one disorder. Our results add to evidence indicating that children who underachieve in any domain are likely also to underachieve in other domains. Just as Hill (27) concluded that specific language impairments are not specific, RELD may be a 'pervasive' disorder marked by deficits in language and verbal comprehension, social cognition, executive functions, and even perceptual organization and gross motor coordination. We had questioned whether children with a language or coordination disorder had their most severe deficits in these ability domains: in

general, they do. But even though an RELD child has relatively lower receptive language ability, this will be but one of many areas in which the child underachieves relative to age peers. Similarly, DCD children may especially lack motor coordination, but they also lag in most domains. The deficits of RELD or DCD children approach the pervasiveness of AD, and describing these children's problems only in terms of language or coordination problems is misleading.

Is the pervasive underachievement in our RELD and DCD groups due to 'comorbid' disorders rather than the defined disorder? This question cannot be answered because the causes of underachievement by these children are not known. Diagnoses define putative syndromes rather than disorders. Our results show that defined syndromes do not correspond with observed syndromes. Although the criteria that define RELD and DCD do not provide a complete picture of these children's underachievement, children with RELD or DCD are discriminable, partly based on lower scores in the defining ability domains. This result suggests that patterns of achievement within groups are relatively consistent, that is, most individuals within groups share syndromes. It may mean that children within groups also share disorders, i.e., the pervasiveness of underachievement is not due to different combinations of comorbid conditions which cause children to underachieve on different subsets of abilities. In that case, variability within groups on most measures (other than language in RELD, etc.) would have been high. Except for response inhibition and working memory in the RELD group, variability is not much greater than in typical children.

DCD and the Autism Spectrum

Although AD and DCD were discriminable from RELD, they were less so from each other. The problem is that each group attains its lowest scores on the motor coordination scales (with AD lower), its highest scores on the response inhibition measure, and differ only on emotion understanding and theory of mind. Because the groups so closely resemble each other, we need to question whether they differ in severity or in kind.

We don't have the data to answer this question: autism symptoms were not assessed in the DCD group, so we cannot establish whether sub-threshold impairments in communication, etc., were present in the DCD group. However, Ahsgren et al. (1) assessed the prevalence of autism and other symptoms in persons with congenital ataxia and observed three or more disabling features of autism in 50% of cases. Green et al. (21) assessed autism symptoms and motor skills in children with Asperger's Disorder or DCD. Their data show a moderate relationship between the severity of motor impairments and impairments in social reciprocity skills and restricted behavior/interests. In our data, among children with AD, we can assess how children with higher and lower levels of ability differ, and whether these groups can be discriminated. Assuming that children with missing data were less able, we sorted AD children into two groups based on whether we had response inhibition data (group performance was strongest). Data were missing from 14 children. They were compared with the remaining 16 children on the other 10 variables and were found to obtain lower scores on fine and gross motor coordination, emotion understanding, theory of mind, and verbal comprehension. Discriminant function analysis did not yield a significant function and 6 children were misclassified. Less able AD children differed from more able ones as children with AD differ from those with DCD. When the more able AD group is compared with the DCD group, they do not differ on any measure (differences on emotion understanding and theory of mind approach significance).

Children with DCD or RELD have ability deficits nearly as pervasive as children with AD. When a child has a deficit in one domain, the child's other abilities need to be assessed to gain an accurate picture of her/his capacities. Despite overlap in the deficits of children with RELD or AD, these children can be accurately classified based on the superior response inhibition of the AD group and the superior fine motor coordination of the RELD group. This result suggests that where differential diagnosis of AD/RELD is difficult, assessment of response inhibition/motor coordination may prove decisive. In contrast, DCD children differ less

clearly from those with AD, and mainly in the severity of motor coordination and social cognition deficits. Research needs to determine whether DCD is a part of the autism spectrum.

The idea that DCD may be part of the autism spectrum implies that processes underlying motor skills deficits play a key role in all autism spectrum disorders. Research consistently indicates cerebellar impairments in AD (60), but given that coordination problems are a distinguishing characteristic of individuals with cerebellar lesions (28 58), it is surprising that cerebellar functioning has not been systematically studied in children with DCD.

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Table 1

Means and standard deviations for each ability measure, by clinical group

	AD		RELD		DCD	
	M	sd	M	Sd	M	sd
Receptive Language	81.02	28.18	67.78	18.60	82.07	21.07
Expressive Language	85.51	27.85	72.54^a	14.78	90.06^a	20.59
Perceptual Organisation	77.55	30.41	85.18	15.45	87.24	18.20
Verbal Comprehension	77.97	25.43	79.89	12.31	85.15	19.12
Emotion Recognition	79.57	21.90	85.45	13.67	86.89	14.60
Emotion Understanding	75.66^a	19.79	78.13^b	10.53	93.33^{ab}	17.44
Theory of Mind	68.66^a	29.32	75.87^b	22.84	92.69^{ab}	21.38
Fine Motor Coordination	59.25^a	30.84	97.78^a	16.12	81.64^a	20.79
Gross Motor Coordination	51.46^a	23.95	86.99^a	20.08	70.02^a	24.79
Response Inhibition	111.81^a	11.05	81.16^{ab}	36.45	106.84^b	18.51
Working Memory	79.01	28.50	72.36	25.32	79.27	16.84

Note: groups sharing a superscript differ significantly in *post hoc* tests at $p < .05$.

Table 2

Discriminant function analyses: Analysis 1 = AD, RELD, and DCD Groups; Analysis 2 = AD and RELD Groups; Analysis 3 = RELD and DCD Groups; Analysis 4 = AD and DCD Groups

Standardized Discriminant Function Coefficients

	Analysis 1		Analysis 2	Analysis 3	Analysis 4
	Function 1	Function 2	Function 1	Function 1	Function 1
Emotion Recognition	.056	-.521	-.040	-.101	-.584
Emotion Understanding	.011	.862	.233	.187	.926
Theory of Mind	-.291	.746	-.448	.112	1.270
Response Inhibition	.278	-.083	.208	.347	-.393
Working Memory	.710	.102	1.085	.562	.050
Perceptual Organisation	.055	-.606	.329	-.300	-.805
Verbal Comprehension	-.738	-.346	-.970	-.547	.280
Expressive Language	1.496	-.133	1.692	1.294	-1.188
Receptive Language	-.197	.164	-.506	-.163	.003
Fine Motor	-.521	.659	-.669	-.387	.913
Gross Motor	-.668	-.204	-.680	-.519	.018

Function at Group Centroid

	Analysis 1		Analysis 2	Analysis 3	Analysis 4
Group	Function 1	Function 2	Function 1	Function 1	Function 1
AD	1.16	-.72	1.74		-.97
RELD	-1.67	-.13	-1.52	-1.22	
DCD	.65	.77		1.22	.85

Classification Results

			Predicted	
Analysis 1	Observed	Autism	RELD	DCD
	Autism	22	2	6
	RELD	3	23	4
	DCD	8	4	10
Analysis 2				
	Autism	27	3	
	RELD	4	26	
Analysis 3				
	RELD		26	4
	DCD		1	21
Analysis 4				
	Autism	26		4
	DCD	8		14