Specific impairments of developmental coordination disorder subtyping: a multivariate investigation

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Background

The DSM IV-R criteria for Developemental Coordination Disorder (DCD) involve a marked impairment in the development of motor coordination although visual-spatial, digital and visuo-motor perception, neuromuscular tone, qualitative and quantitative measures impairments related to of gross and fine motor coordination might be used to isolate three main subtypes of DCD/dyspraxia: ideomotor, visual-spatial and constructional, and a mix group sharing common impairments with additional comorbidities. This study focus on isolating specific markers with high predictive discriminatory power from a wide range testing battery in a sample of children enrolled in two French hospitals (Necker and Cochin).

Methods

Data collection. Data were collected on N=63 children with DCD (83% of males), aged between 5 and 15 years (median 8.1 years), enrolled on DSM IV-R criteria. IQs were in the expected range. Children were free of previous assessment, medication, and therapy followup-up. Each subject underwent a neuropsychological testing battery comprised of 49 milestone assessment covering tone, praxia, perception, as well as visual, motor, perceptuo-motor, and general performance. Subjects' responses were treated as binary indicators of failure/success, based on percentile or SD reference for each test. Following clinical examination detailed in Vaivre-Douret et al. (2011), patients were classified as suffering from either ideomotor (IM), visual-spatial and constructional (VSC), or mist (MX) dyspraxia.

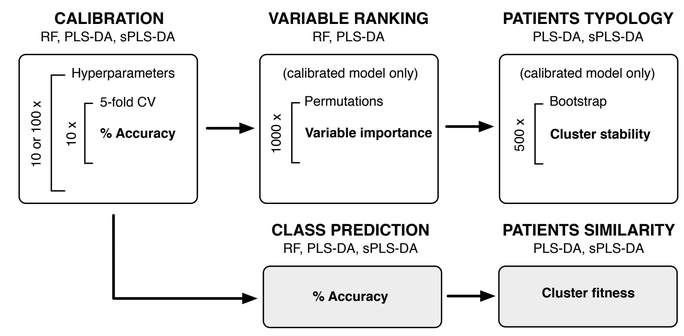

Figure 1. Overview of model validation

Statistical methodology. Random Forest™ (RF) and Partial least-squares Discriminant Analysis (PLS-DA)–with and without L1-norm penalty (*lasso*)–were used to isolate most informative markers given clinical classes (feature extraction). The sample was divided using a 0.7:0.3 split ratio (training/validation sample). A nested cross-validation scheme was used, consisting in stratified and repeated 10x5-fold resampling combined to a search grid to tune hyperparameters of those models (number of variables used to build trees with RF, L1 penalty for PLS-DA), with average classification accuracy as the main criteria on the training sample. Measures of variable importance were computed for each model (mean decrease in accuracy for RF, variable loadings for PLS-DA), and statistical significance was assessed using 1000 permutations. Classification accuracy and measures of patients proximity (using PAM algorithm, where clustering stability was assessed using 500 bootstrap samples) was analyzed on the validation sample (**Figure 1**).

Results

Patients' characteristics are summarized in **Table 1**, for the training and validation sample, and for the whole sample. Interitem Pearson correlations are in the range [-0.411;0.831], and marginal frequencies of item failure were between 7.9% (Sitting alone) and 92.1% (Visual motor integration). The average level of failure did not differ between the training and validation sample on any of the studied variables (all p > 0.05, with p-values computed from Monte Carlo chi-square tests).

Item failure frequencies are summarized in **Figure 2** with item ordered according to variables-based hierarchical clustering using 1 minus correlation as dissimilarity measure. This basically shows how some variables tend to hang together with respect to class-specific frequency of failure.

	N	Training $N = 46$	Validation $N = 17$	Combined $N = 63$
Diagnosis: IM	63	9% (4)	6% (1)	8% (5)
VSC		52% (24)	53% (9)	52% (33)
MX		39% (18)	41% (7)	40% (25)
Gender: Male	63	78% (36)	94% (16)	83% (52)
Age (years)	63	6.8 8.0 9.7	6.6 8.7 12.3	6.8 8.1 10.4
Term: Yes	63	96% (44)	88% (15)	94% (59)
FIQ	62	85 98 114	92 108 121	86 100 115
PIQ	62	73 87 102	75 93 107	74 90 105
VIQ	62	92 107 122	100 119 130	92 110 124

Three-number summaries are lower quartile, median, and upper quartile.
N is the number of non–missing values.

Table 1. Sample characteristics

Item legend: **SITA** Sitting alone; **CRAW** Crawling; **WALK** Walking alone; **FISE** First sentences (lagguage); **ORTH** Otorhinolaryngologia; **VISR** Visual refraction; **LEBL** Lego blocks; **PUZL** Puzzles; **ARTH** Arithmetic; **READ** Reading/spelling; **HAWR** Hand writing; **DYGR** Dysgraphia; **HYPT** Hypotonia; **MOPA** Motor pathway; **SYNK** Synkinesis; **DYSD** Dysadiadochokinesis; **STDT** Standing tone; **DIPR** Digital praxia; **BIDX** Bimanula dexterity; **PRSL** Praxia slowness; **IMOG** Imitation of gestures; **OROP** Orofacial praxia; **DRES** Dressing skill; **DIPE** Digital perception; **VISP** Visual perception; **STAB** Static balance; **DYNB** Dynamic balance; **POSC** Postural control; **HLUL** Homegeneity tonic laterality upper/lower limbs; **HMLS** Homogeneity manual laterality spontaneous psychomotor; **HULU** Homogeneity usual laterality upper/lower limbs; **MAND** Manual dexterity; **BSPI** Body spatial integration; **RHYA** Rhytmic adaptation; **VIMI** Visual motor integration; **VISS** Visual spatial structuration; **VISC** Visual spatial constructional; **EXEF** Executive function; **AUDM** Auditive memory; **WRKM** Work memory; **KINM** Kinaesthetic memory (perception); **VISM** Visual spatial memory; **AUDA** Auditive attention; **VISA** Visual spatial attention; **HYPK** Hyperkinesia; **HORP** Horizontal pursuit; **VERP** Vertical pursuit; **VEPN** Visual evocated potentials.

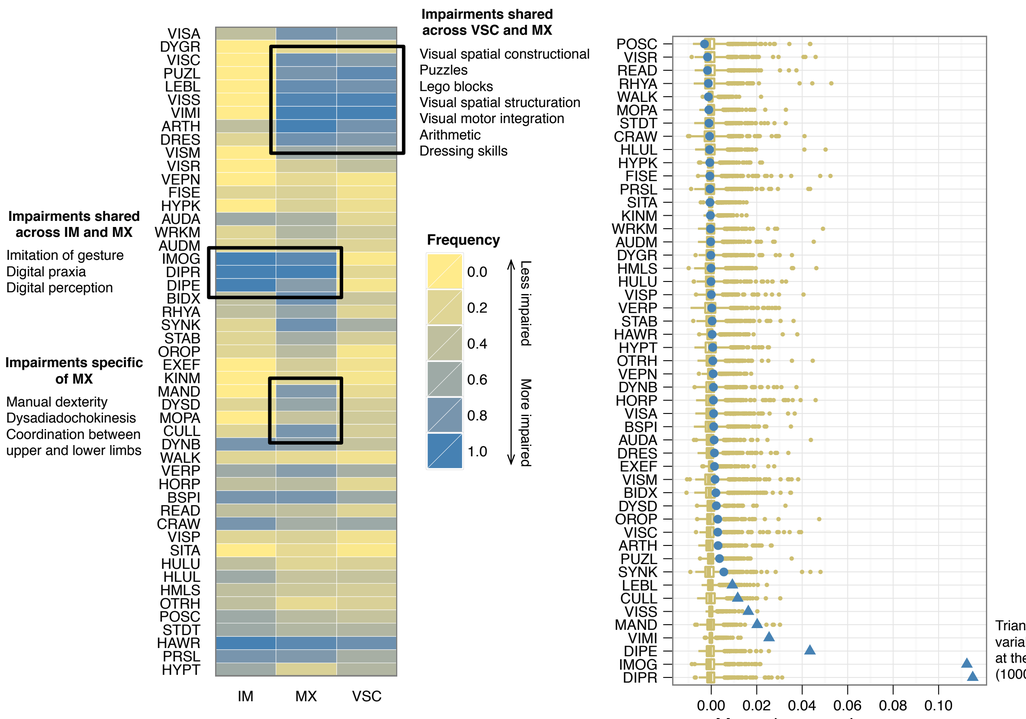

Figure 2. Frequency of item failure

Figure 3. RF variable importance

Variable ranking based on re-rerandomized measures of variable importance in RF (**Figure 3**) showed eight significant items: digital praxia (DIPR), imitation of gestures (IMOG), digital perception (DIPE), visual motor integration (VIMI), manual dexterity (MAND), visual spatial structuration (VISS), coordination between upper and lower limbs (CULL) , and lego blocks (LEBL). Comparable results were obtained when using variable importance from sparse PLS-DA.

Classification accuracy on the validation sample was perfect in the case of RF and identical for PLS and sparse PLS-DA (91.4%, [71.3–99.9]). Clustering based on individual sparse PLS component scores highlighted three clusters (average silhouette width, 0.625), and cluster wise Jaccard similarity values were found in the acceptable range (**Table 2**).

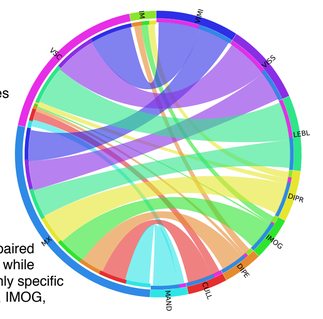

Figure 4. Associations between subtypes and most salient markers

As depicted in **Figure 4**, conditional and marginal distributions of failure highlights three main characteristics of class-specific impairments: IM patients are equally impaired on DIPE, IMOG and DIPR; some impairments are shared across VSC and MX patients (LEBL, VSS, VIMI); some impairments are specific of MX patients (DIPR, IMOG, CULL, DIPE).

Classifier	Class	Sensitivity	Specificity	Jaccard	C1	C2	C3
PLS-DA	IM	1.00	1.00	0.462	**1.587**	2.784	1.206
	VSC	0.89	1.00	0.665	3.106	**0.838**	2.315
	MX	1.00	0.90	0.605	2.811	2.416	**0.587**
sPLS-DA	IM	1.00	1.00	0.792	**0.129**	0.437	0.386
	VSC	0.89	1.00	0.928	0.468	**0.103**	0.282
	MX	1.00	0.90	0.854	0.487	0.330	**0.073**

C1, C2, C3 indicate 'clustering fitness' for each cluster found in the dataset with the PAM algorithm. Fitness is defined as euclidean distance between patients from the validation sample and medoids identified in the training sample.

Table 2. Classification and Clustering results

Conclusions

The most salient markers with respect to the three subtypes of dyspraxia studied in this sample are digital praxia, imitation of gestures, digital perception, visual-motor integration, manual dexterity, visual spatial structuration, coordination between upper and lower limbs, and lego blocks. This study confirms the importance of some aspects of visual processing of spatial information, and motor control in DCD. Ideomotor patients are impaired on fewer tasks overall, and clustering results suggest they define a homogeneous group of patients. The MX group shared some of the disorders expressed in the IM or VSC subtypes, with additional comorbidites , typically difficulties in coordinating lower and upper limbs or poor manual dexterity which are not part of actual DSM IV criteria in diagnosing DCD.

Less than 15 neuro-visual, neuro-psychomotor and neuro-psychological milestone tests might be required to provide a sensitive and specific diagnostic of DCD, and isolated markers could be used to refine our understanding of DCD in future studies.

Vaivre-Douret, L., Lalanne, C., Ingster-Moati, I., Boddaert, N., Cabrol, D., Dufier, J.L., Golse, B., and Falissard, B. (2011). Subtypes of developmental coordination disorder: Research on their nature and etiology. *Developmental Neuropsychology*, *36(5)*, 614–643.