Importance of multidimensional developmental assessments to define subtypes and specific impairments of Developmental Coordination Disorder

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Objectives

Developmental Coordination Disorder (DCD) involve a marked impairment in the development of motor coordination although visuo-spatial, digital and visuo-motor perception, qualitative and quantitative developmental measures of neuromuscular tone, gross and fine motor coordination-related impairments might be used to isolate three main subtypes of DCD/dyspraxia: ideomotor, visuo-spatial and constructional, and a mixed group (MX) sharing common impairments with additional comorbidities. The MX group appears as an umbrella of motor disorders, found in clusters studies. This study focus on isolating specific diagnosis markers with high predictive discriminatory power of MX vs. pure form of DCD/dyspraxia.

Methods

Data collection. Data were collected on 63 children with DCD aged 5-15 years (median 8.1), enrolled on DSM-5 criteria with a strict inclusion (full term, free of remediation and of medical abnormalities). Each subject underwent a neuropsychological, neuro-psychomotor (NP-MOT developmental battery), and neurovisual testing battery totalling 49 milestones assessment scored as pass/fail variables (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 mixt (MX) DCD.

Statistical methodology. A classification tree incorporating bagging was used to rank those variables, either alone or in interaction with other variables, by their relative importance in classification accuracy of clinical subgroups. Model calibration (number of leaves and number of trees) was done on a training sample through nested repeated 5-fold cross-validation while predictive performance was assessed on a held-out validation sample, using a split ratio of 0.7/0.3.

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).

The frequency of impairments for MX and PURE (VSC + IM) clinical groups is summarized in **Figure 1**. On the training sample, univariate group comparisons with Perason's X2 tests, controlling for False Discovery Rate of 5% (Benjamin and Hochberg's procedure) indicate that four items show significant difference in terms of frequency of failure: IMOG (76.2% of difference), DIPR (71.1%), MAND (62.8%), and DIPE (53.6%)

Table 1. Sample characteristics

	N	Training N=45	Validation N=18	Combined N=63
Type: MX	63	40% (18)	39% (7)	40% (25)
Gender: Male	63	87% (39)	72% (13)	83% (52)
Age	63	7.1 8.6 10.1	6.3 8.0 11.0	6.8 8.1 10.4
FIQ	62	86 100 117	88 97 108	86 100 115
PIQ	62	75 93 105	73 86 108	74 90 105
VIQ	62	92 114 124	94 103 118	92 110 124

Three-number summaries are lower quartile, median, and upper quartile.

N is the number of non--missing values.

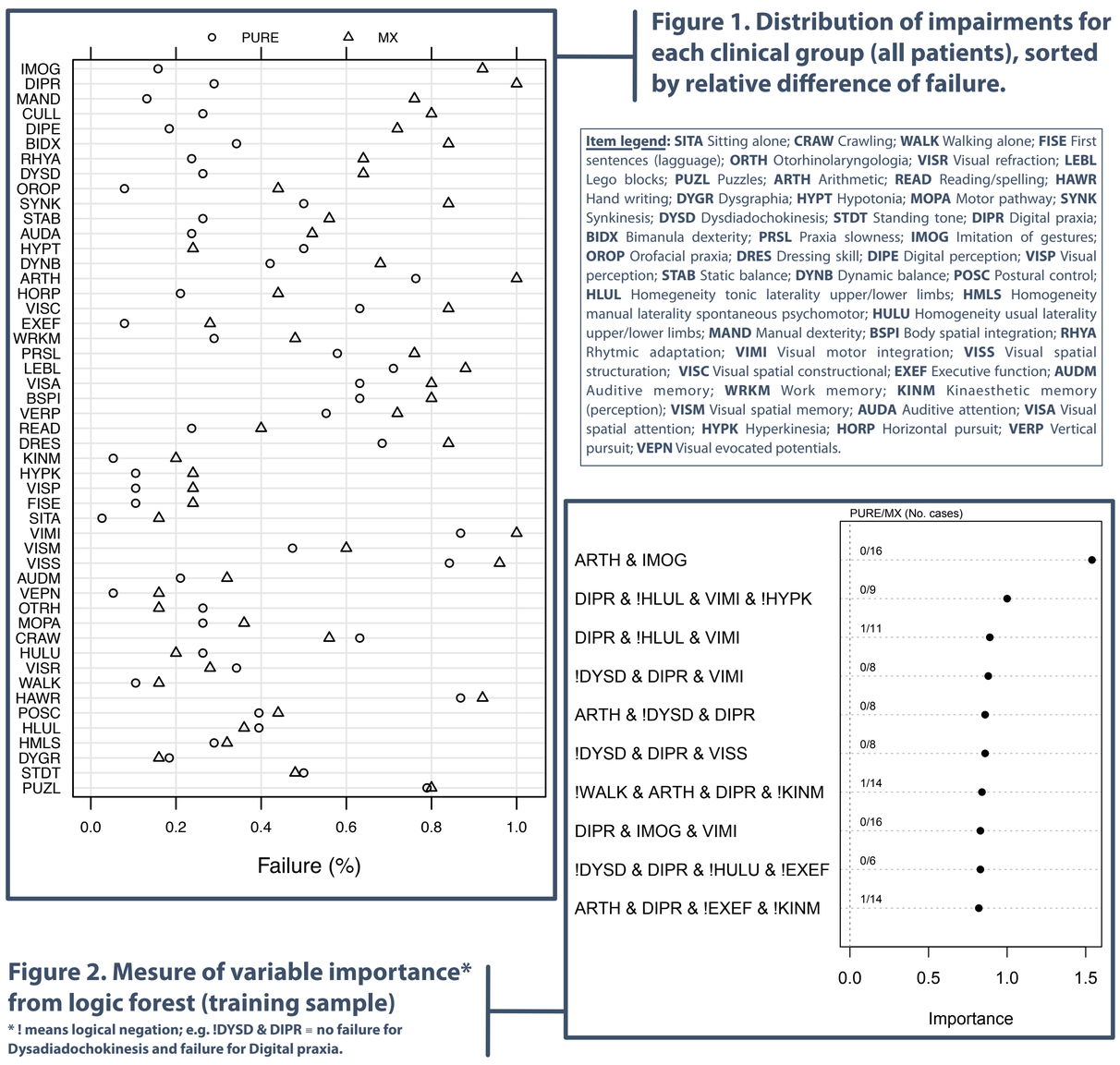

Figure 1. Distribution of impairments for each clinical group (all patients), sorted by relative difference of failure.

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** Dysdiadochokinesis; **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. Mesure of variable importance* from logic forest (training sample)

*** ! means logical negation; e.g. !DYSD & DIPR = no failure for Dysadiadochokinesis and failure for Digital praxia.**

According to the Logic Forest algorithm (built upon 100 trees, **Figure 2**), the five most important predictors appeared to be (with normalized predictor importance): Imitation of gestures (1), Digital praxia (0.64), Arithmetic (0.18), Visual motor integration (0.03), and Digital perception (0.02). This is in agreement with our previous study where Random Forests and sparse PLS regression were used to isolate the most contributing predictors to three clinical subgroups. Among the ten most important interactions we found items such as arithmetic, digital praxia, visuo-motor related abilities, dysadiadochokinesis, or executive function.

Table 2. Mesure of predictive accuracy(test sample only)

	Accuracy (95% CI)	Sensitivity	Specificity
`logforest`	0.889 (0.653, 0.986)	0.818	1.000
`logbag`	0.889 (0.653, 0.986)	0.818	1.000
`rf`	0.833 (0.586, 0.964)	0.727	1.000

`logforest`: ensemble classifier of logic regression models;

`logbag`: bagged version of logic regression; `rf` Random Forests.

Predictive accuracy on the validation sample (**Table 2**) was good for both methods, with out-of-bag (OOB) error rate below 9% in each case. Compared to Random Forests (6.7% OOB error), they showed higher accuracy and better sensitivity, with only two PURE DCD patients classified as MX.

The two misclassified patients suffered from visual and constructional dyspraxia, confirming earlier results. These two methods further demonstrate that comorbidities help to distinguish between the two clinical groups.

Conclusion

Taylored follow-up of patients presenting with DCD should consider the specificity of neuro-sensory-motor, visuo-spatial, and neuropsychological impairments of which co-occurrence allows to define different subtypes of DCD. Less than 15 milestone tests might be required to provide a sensitive and specific diagnostic of DCD subtypes, and isolated markers allow a better understanding of DCD. The five most important predictors appeared to be Imitation gestures, Digital praxia, Arithmetic, Visuo-motor integration and Digital perception. Indeed, the choice of appropriate measures has an impact on understanding of the nature and etiology of disorders. Investigations involving standardized neuro-developmental assessments with qualitative and quantitative measures are necessary.

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