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Discriminant validity of spatial and temporal postural index in children with neurodevelopmental disorders

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ABSTRACT

Autism, learning disabilities and attention deficit/hyperactive disorder are often comorbid disorders. In order to try and find some markers that might be transnosographic, we hypothesized that abnormal postural sway profiles may discriminate children with neurodevelopmental disorders (NDDs) from typically developing children. The aim of our study was thus to compare spatial and temporal measures of the Center of Pressure in three distinct groups of children with NDDs (high functioning autism spectrum disorders, learning disabilities (dyslexia) and attention deficit/hyperactive disorders) and in typically developing children. Postural performances were thus evaluated in 92 children (23 per group, sex-, age- and IQ-matched groups) by using the Multitest Equilibre platform (Framiral®). Two viewing conditions (eyes open and eyes closed) were tested on a stable and unstable platform.

Results reported similar poor postural instability for the three groups of children with NDDs with respect to the typically developing children, and this was observed for both spatial as well as temporal analysis of displacement of the center of pressure.

Such postural instability observed in children with NDDs could be due to impairment in using sensorial inputs to eliminate body sway, probably due to poor cerebellar integration.

1. Introduction

Postural stability is a complex process, which allows obtaining a coordinated relation of the various physical segments of the body. Muscle effectors involved in postural control are connected to various structures in the central nervous system, such as the basal ganglia, the brainstem, the cerebellum, and several cortical areas (Mergner and Rosemeier, 1998). Different inputs are also responsible for good postural control, including those transmitted through the proprioceptive, vestibular, and visual afferents (Brandt, 2003). The correct relationship between all of this information is necessary to reach an appropriate posture during everyday life in the natural environment. Thus, a deficit in one of these inputs may lead to an imbalance in other sensory inputs and consequently may lead to postural instability.

Several studies explored postural control in children with neurodevelopmental disorders as autism, dyslexia and hyperactivity; however, to our knowledge no study has compared at the same time these pathologies with respect to typically developing (TD) children.

Kohen-Raz et al. (1992) were the first, to record body stability of children with autism using a computerized posturographic procedure, and they showed that autistic children exhibited fewer age-related changes in postural performance and were significantly more unstable than control children. A synthesis and meta-analysis of deficits in motor control in autistic children was done by Downey and Rapport (2012). All studies exploring postural control in autistic children are in favor of the hypothesis that their poor postural stability could be due to a deficit in multimodal sensory integration, in other words to poor ability of autistic children at reweighting sensory inputs.

Similarly, dyslexic children have poor postural control. Frank and Levinson (1973) were the first to show poor postural capabilities in dyslexic children subjectively with the Romberg test. Afterwards, several studies were done by our group (Bucci et al., 2013a,b, 2014;

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Goulème et al., 2015a,b) and other researchers (Barela et al., 2011; Quercia et al., 2011; Vieira et al., 2013) during simple and/or dual postural tasks in dyslexic population, measuring body sway objectively with postural platforms. All these studies confirm the hypothesis that automaticity, via the cerebellum activity, is responsible for co-ordinating sensory and motor information, and that it could be impaired in dyslexic children, leading to poor postural stability.

Attention deficit hyperactivity disorder (ADHD) is associated with poor gross and fine motor control tasks (Piek et al., 1999; Wang et al., 2011; Papadopoulos et al., 2014). Several studies also reported postural instability in ADHD children compared to TD children (Zang et al., 2002; Wang et al., 2003; Buderath et al., 2009; Bucci et al., 2014, 2016). Interestingly, a study by Hove et al. (2015) reported for the first time a positive correlation between postural sway and cerebellar gray matter volume in adults with ADHD, providing additional support for cerebellar involvement in ADHD. Furthermore, as reported by Stoodley (2016) in a recent review, cerebellar deficiencies have been found in several developmental disorders (autism, dyslexia, ADHD); she suggested that deficits in different cerebellar subregions related to poor specific cerebro-cerebellar circuits could lead to the behavioral symptoms at both motor and cognitive levels observed in these children.

Based on these findings, we aim to compare postural capabilities in children with autism, dyslexia and ADHD and in a group of typically developing children. We used the Multitest Equilibre from Framiral® (www.framiral.fr), which permits to analyze the Center of Pressure (CoP) both in the spatial and temporal domains. In particular, important information on the dynamic of the CoP may be reached by applying nonlinear analysis methods such as the wavelet transformation method. Indeed, a study by Ghulyan et al. (2005) demonstrated that a dynamic analysis of posture allows a better discrimination of the pathological effects on postural control.

2. Materials and methods

2.1. Subjects

Postural capabilities were explored in four different groups of twenty-three children sex-, IQ-and age-matched (Table 1): *Group 1*, children with high functioning Autism Spectrum Disorder (ASD); *Group 2*, dyslexic children; *Group 3*, children with ADHD and *Group 4*, typically developing children (TD).

Patients from *Groups 1, 2 and 3* were enrolled in the study at the Child and Adolescent Psychiatry Department, Robert Debré Hospital (Paris, France); they had a neurological exam in the normal range and were naïve of psychotropic treatment.

Children with ASD had been evaluated by the Expert Centre for High Functioning and diagnosis of ASD was based upon evaluation data from the ADI-R (Autism Diagnostic Interview-Revised, by Lord et al., 1994), the ADOS (Autism Diagnostic Observation Schedule, by Lord et al., 2000) and expert clinical judgment based on DSM-5 criteria.

Dyslexic children were recruited from the Center for Language Disorders and Learning, to which they had been referred for a complete evaluation of their dyslexia, including an extensive examination of their phonological capabilities. For each child, the time required to read a text passage, text comprehension and the ability to read words and pseudo-words using the L2MA battery (oral Language, written Language, Memory, Attention, Chevrie-Muller et al., 1997) were measured. Inclusion criteria (more than two standard deviations from the mean) were scored on the L2MA.

The diagnosis of ADHD children was done according to DSM-5 criteria (APA, 2013) and it was carried out using the Kiddie-SADS semi-structured interview (Kiddie Schedule for Affective Disorders and Schizophrenia, Goldman et al., 1998). ADHD symptom severity was assessed using the ADHD Rating Scale-parental report (ADHD-RS). This scale is based on a large collection of normative data and has demonstrated reliability and discriminant validity in children and adolescents (DuPaul et al., 1998; Collett et al., 2003).

Patients with comorbid diagnosis such as developmental coordination disorder, ASD and ADHD (or ADHD and dyslexia) were not included in our study.

For each ASD, dyslexic and ADHD child the mean intelligence quotient (IQ) was evaluated using the WISC-IV (Wechsler Intelligence Scale for Children, fourth edition); for all subjects the WISC-IV was in the normal range (between 85 and 115). The WISC-IV is composed of four indexes: (1) Verbal Comprehension Index (VCI). This index is calculated from the performance to tests measuring verbal concept formation (including similarities, vocabulary, and comprehension). (2) Perceptual Reasoning Index (PRI). This index is calculated from the performance to tests measuring non-verbal and fluid reasoning (including block design, picture concepts, and matrix reasoning). This index may also be influenced by visual-spatial perception and visual perception-fine motor coordination, as well as planning ability. (3) Working Memory Index (WMI). This index is calculated from the performance to tests measuring working memory (including digit span and letter-number sequencing). (4) Processing Speed Index (PSI). This index is calculated from the performance to tests measuring speed of information processing (including coding and symbol search).

The IQ in typically developing children was estimated in two

Table 1
Clinical characteristics of the four groups of children tested (TD, typically developing children; ASD, children with autism spectrum disorders, DYS, Dyslexic children and ADHD, children with hyperactivity).

	TD (N = 23)	ASD (N = 23)	DYS (N = 23)	ADHD (N = 23)
Age (years)	10.2 ± 0.3	10.3 ± 0.4	10.2 ± 0.2	10.3 ± 0.3
ADHD-RS total score	5 ± 1	6 ± 2	5.8 ± 1.8	39.9 ± 1.5
Autism Diagnostic Interview-Revised (ADI-R) scores				
Social Reciprocal Interaction		18.8 ± 0.9		
Communication		12.2 ± 0.8		
Stereotyped Patterns of Behaviors		5.0 ± 0.3		
Autism Diagnostic Observation Schedule (ADOS) scores				
Social Reciprocal Interaction		8.3 ± 0.7		
Communication		3.9 ± 0.3		
Wechsler scale (WISC-IV) scores				
Verbal Comprehension subscale		101 ± 6	100 ± 5	101 ± 2
Perceptual Reasoning subscale		99 ± 4	98 ± 3	97 ± 2
Working Memory subscale		92 ± 3	90 ± 4	85 ± 4
Processing Speed subscale		89 ± 3	90 ± 5	91 ± 3
Similarity test	12.5 ± 2	12 ± 1	10 ± 2	11 ± 1
Matrix reasoning test	10.7 ± 1	11 ± 1	10.8 ± 1	10 ± 2