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Effect of visual attention on postural control in children with attention-deficit/hyperactivity disorder

Maria Pia Bucci [a,*], Magali Seassau [b], Sandrine Larger [c], Emmanuel Bui-Quoc [d], Christophe-Loic Gerard [c]

[a] UMR1141, INSERM – Université Paris Diderot, Hôpital Robert Debré, 48 Boulevard Sérurier, 75019 Paris, France
[b] e(ye)BRAIN, 1 bis rue Jean le Galleu, 94200 Ivry-sur-Seine, France[1]
[c] Service de Psychopathologie de l'enfant et de l'adolescent, Hôpital Robert Debré, 48 Boulevard Sérurier 75019 Paris, France
[d] Service d'Ophtalmologie, Hôpital Robert Debré, 48 Boulevard Sérurier, 75019 Paris, France

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ABSTRACT

We compared the effect of oculomotor tasks on postural sway in two groups of ADHD children with and without methylphenidate (MPH) treatment against a group of control age-matched children. Fourteen MPH-untreated ADHD children, fourteen MPH-treated ADHD children and a group of control children participated to the study. Eye movements were recorded using a video-oculography system and postural sway measured with a force platform simultaneously. Children performed fixation, pursuits, pro- and anti-saccades. We analyzed the number of saccades during fixation, the number of catch-up saccades during pursuits, the latency of pro- and anti-saccades; the occurrence of errors in the anti-saccade task and the surface and mean velocity of the center of pressure (CoP). During the postural task, the quality of fixation was significantly worse in both groups of ADHD children with respect to control children; in contrast, the number of catch-up saccades during pursuits, the latency of pro-/anti-saccades and the rate of errors in the anti-saccade task did not differ in the three groups of children. The surface of the CoP in MPH-treated children was similar to that of control children, while MPH-untreated children showed larger postural sway. When performing any saccades, the surface of the CoP improved with respect to fixation or pursuits tasks. This study provides evidence of poor postural control in ADHD children, probably due to cerebellar deficiencies. Our study is also the first to show an improvement on postural sway in ADHD children performing saccadic eye movements.

1. Introduction

Children with attention-deficit hyperactivity disorder (ADHD) are characterized by the symptoms of impulsiveness, hyperactivity and inattention. ADHD is a prevalent neurobehavioral disorder estimated to affect 5% of children for some of whom these symptoms could persist into adulthood (Barkley, 1997).

Children with ADHD have shown deficiencies in sensorimotor processing (Parush, Sohmer, Steinberg, & Kaitz, 1997; Parush, Sohmer, Steinberg, & Kaitz, 2007). Neuroimaging studies of ADHD patients have also reported abnormalities in the

* Corresponding author at: UMR1141, INSERM – Université Paris Diderot, Hôpital Robert Debré, 48 Boulevard Sérurier, 75019 Paris, France. Tel.: +33 0140035362.
E-mail address: mariapia.bucci@gmail.com (M.P. Bucci).

[1] www.eye-brain.com.

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brain regions such as the prefrontal cortex, which are important for executive function (Amen, Paldi, & Thisted, 1993; Zametkin et al., 1990; Vaidya et al., 1998) as well as in the cerebellum and basal ganglia, areas involved in the sensorimotor control (Filipek et al., 1997; Diamond, 2000; Gustafsson, Thernlund, Ryding, Rosen, & Cederblad, 2000; Kim, Lee, Shin, Cho, & Lee, 2002). All these findings are in line with studies reporting poor motor performances in children with ADHD. Zang, Gu, Qian, & Wang (2002) and Wang, Wang, & Ren (2003) have examined sensory contributions to postural abilities in children with ADHD. Both studies have found that the sway velocity of the center of pressure (COP) was significantly higher in the ADHD children group than in the control group under various testing conditions (e.g., standing with the eyes closed, standing on a foam pad). They suggested that balance control is an important sensorimotor function that could be compromised in the ADHD children because it requires the capability to integrate inputs from various sensory systems (i.e., somatosensory, visual, vestibular) in order to maintain body equilibrium. Furthermore it should be noted that postural control is not a simple reflex task, but that it demands attentional resources (Woollacott & Shumway-Cook, 2002). Over the last decade, several studies have examined the postural control of children as they are asked to accomplish a secondary task requiring the focus of attentional resources. Olivier, Cuisinier, Vaugoyeau, Nougier, & Assaiante (2010) have suggested that two independent attentional mechanisms could exist, one for controlling posture and the other one responsible for the secondary cognitive task. These two mechanisms could interfere with each other depending on the difficulty of the dual task – cognitive and postural. Recent work from Shorer, Becker, Jacobi-Polishook, Oddsson, & Melzer (2012) has examined postural performance during simple and dual tasks (listening and memorizing children's songs) conditions in ADHD children. They found that ADHD children showed poor postural stability with respect to control children under both conditions (simple as well as dual-task), suggesting that postural control is affected by attention deficit disorders. Interestingly, postural sway was reduced in dual task compared to simple task condition in both ADHD and control children, suggesting improved control of balance during dual task. This result is in line with the hypothesis that a secondary task can shift the attentional focus away from postural control leading to a better automatic postural performance.

Several studies have also investigated eye movements in children with ADHD. Most of them have explored executive functions in these patients in order to test the hypothesis that the prefrontal areas, which are responsible for intentional motor performances, are affected in children with ADHD (for a review see Rommelse, Van der Stigchel, & Sergeant, 2008). For instance, more intrusive saccades are reported during fixation tasks (Gould, Bastain, Israel, Hommer, & Castellanos, 2001). The latency of pro-saccades has been also reported to be longer and more variable compared to controls (Munoz, Armstrong, Hampton, & Moore, 2003; Klein, Fischer, Fischer, & Hartnegg, 2002). On the other hand, other studies have failed to show any differences between children with ADHD and controls (Hanisch, Radach, Holtkamp, Herpertz-Dahlmann, & Konrad, 2006; Karatekin & Asarnow, 1998; O'Driscoll et al., 2005). Similarly, the results on anti-saccades performance in children with ADHD are inconsistent although a large number of studies report an elevated number of errors in the anti-saccade task for these patients (see Table 1 of the review from Rommelse et al., 2008). Finally, pursuit eye movements have also been investigated in children with ADHD and the findings are again in contrast with each other: Castellanos et al. (2000) do not report pursuit deficiencies in these patients while Gargouri-Berrechid et al. (2012) show lower pursuit gain for ADHD children. Taken together, all these reports however are in agreement with the idea of an increased variability of oculomotor performance in children with ADHD compared to the literature on controls (Kuntsi, McLoughlin, & Asherson, 2006; Leth-Steensen, Elbaz, & Douglas, 2000).

Methylphenidate (MPH) is frequently used as medication to treat ADHD patients (Wilens, Spencer, & Biederman, 2002) but little is known about its effect on postural and oculomotor performances. Leitner et al. (2007) have reported that children with ADHD under methylphenidate treatment show slight alteration/changes in walking with increased stride-to-stride variability that is not significantly different with respect to control children; Buderath et al. (2009) have also observed minor balance and stepping disorders in children with ADHD treated with methylphenidate at the time of testing, such impairment was similar to those reported in children with mild cerebellar dysfunction. Using the Movement Assessment Battery, Flapper, Houwen, & Schoemaker (2006) also found an improvement in the motor performances of children with ADHD after methylphenidate treatment. Jacobi-Polishook, Shorer, & Melzer (2009) have explored the effect of methylphenidate on postural stability in children with ADHD in single and dual-task conditions (while performing a memory attention demanding task such as memorizing children's songs while listening to music). These authors reported that postural performance improved significantly with methylphenidate only in the two dual-task conditions, suggesting that such a drug could enhance attention capabilities, leading to better postural stability when performing tasks that require attention.

The effect of methylphenidate was also investigated on eye movement performances but the results are quite discordant. For instance, Aman et al. (1998) reported no difference in performing anti-saccades before and after treatment. Mostofsky,

Table 1
Clinical characteristics of children examined.

Participants (years)	TNO (s of arc)	PPC (cm)	Phoria (pD)	Convergence (pD)	Divergence (pD)
ADHD off MPH (9.5 ± 0.5)	62 ± 8	3 ± 0.4	-0.7 ± 0.5	34 ± 2	$9.8 \pm 0.9^{*}$
ADHD on MPH (9.8 ± 0.6)	65 ± 9	4 ± 0.7	-1.8 ± 0.9	30 ± 3	$10 \pm 0.5^{*}$
Control (9.7 ± 0.8)	58 ± 8	3 ± 0.6	-1.8 ± 1	36 ± 4	18 ± 0.4

Clinical characteristic of ADHD children off and on methylphenidate and age-matched control children. Mean values of: binocular vision (stereoacuity test, TNO measured in seconds of arc); near point of convergence, NPC measured in cm; heterophoria at near distances measured in prism diopters; negative values indicate exophoria and positive values indicate esophoria; vergence fusional amplitudes (convergence and divergence) at near distances measured in prism diopters. Asterisks indicate that value is significantly different with respect to the group of control children ($p < 0.05$).