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The effect of a cognitive task on the postural control of dyslexic children

Maria Pia Bucci [a,*], Christophe Loic Gerard [b], Emmanuel Bui-Quoc [c]

[a] *UMR 676 INSERM-Université Paris Diderot, Hôpital Robert Debré, 48 Boulevard Sérurier, 75019 Paris, France*
[b] *Service de Psychopathologie de l'enfant et de l'adolescent, Hôpital Robert Debré, 48 Boulevard Sérurier, 75019 Paris, France*
[c] *Service d'Ophtalmologie, Hôpital Robert Debré, 48 Boulevard Sérurier, 75019 Paris, France*

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ABSTRACT

We explore the influence of a secondary cognitive task on concurrent postural control in dyslexic children. Seventeen children with dyslexia (DYS) were compared with thirteen non-dyslexic children (NDYS). Postural control was recorded in Standard Romberg (SR) and Tandem Romberg (TR) conditions while children, in separate sessions, have to fixate on a target and name simple objects appearing consecutively on a computer screen. The surface, the length and the mean speed of the center of pressure were analyzed; the percentage of correct responses to the cognitive task was also measured. DYS are significantly more unstable than NDYS. The secondary cognitive task significantly decreases the postural stability in DYS only. For both children postural performances in the TR condition is significantly worse than in the SR condition. The percentage of wrong responses to the cognitive task is significantly higher in DYS. Postural instability observed in DYS supports the hypothesis that there is a deficit of automatic integration of visual information and postural control in these children. This result is in line with the U-shaped non linear model showing that a secondary task performed during a postural task leads to an impaired postural stability probably due to focus attention on the cognitive task.

1. Introduction

Dyslexia is a neurobiological disorder characterized by a difficulty in reading acquisition despite adequate intelligence, conventional education and motivation (American Psychiatric Association, 1994). Frank and Levinson in 1973 were the first to suggest a cerebellar-vestibular impairment in dyslexia population. These authors examined 115 children with dyslexia and they found that 97% of them showed neurological signs of cerebellar-vestibular deficiency as positive Romberg test, difficulty in tandem walking, articulatory speech disorders, hypotonia, and several dysmetric deficits (finger-to-nose, heel-to-toe, writing and drawing). Nicolson and Fawcett (1999) also observed balance and motor coordination impairment in children with dyslexia and they hypothesized that dyslexia is characterized by a cerebellar deficit. Several subsequent studies examining postural performances in dyslexia population. For instance, Poblano et al. (2002) and Ramus (2003) reported impaired postural control in dyslexia but only in some cases, suggesting that the impairment was not strictly correlated with dyslexia but that it could co-occur with other types of developmental disorders in line with the finding from Rochelle and Talcott (2006). Stoodley, Fawcett, Nicolson, and Stein (2005) examined in children with dyslexia the balancing ability (with the right and the left foot) and they found that many dyslexics were significantly less stable than the control

* Corresponding author at: UMR 676 Inserm - Université Paris Diderot, Hôpital Robert Debré, 48 Bl Sérurier, 75019 Paris, France. Tel.: +33 0140035362.
E-mail address: mariapia.bucci@gmail.com (M.P. Bucci).

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children. They suggested that several factors, including cerebellum deficiency and the magnocellular immaturity could be at the origin of such impaired balancing in dyslexia.

In everyday life postural control is naturally part of dual or multiple tasks and several studies examined in children with dyslexia the quality of postural control when child is asked to accomplish a secondary task needing focus of attentional resources. Nicolson and Fawcett (1990) reported that postural stability in children with dyslexia was affected by a secondary task which shifts attention from the primary postural one. These authors suggested that dyslexic subjects need to invest more attentional resources than non-dyslexic subjects to control their balance when two tasks are performed simultaneously. Recent studies from Quercia's group (Quercia, Demougeot, Dos Santos, & Bonnetblanc, 2011; Vieira, Quercia, Michel, Pozzo, & Bonnetblanc, 2009) have suggested that children with dyslexia have a postural deficiency syndrome constituting an impairment of postural control accompanied by a deficit affecting proprioceptive and visual information. Interestingly, a vibration of the ankle muscles impaired stability more strongly in dyslexic than in non-dyslexic children, independently of the attentional task; in the condition without vibration, the attentional performance of dyslexics was significantly impaired with respect to the non-dyslexic group of children. Furthermore, these authors have shown that a cognitive task, such as reading single words, impairs postural stability in children with dyslexia and that the attentional performance of such a population was significantly impaired when compared to the non-dyslexic group of children. Our group (Legrand, Bui-Quoc, Doré-Mazars, Lemoine, Gerard, & Bucci 2012) reported also that when reading text silently children with dyslexia were significantly more unstable than non-dyslexic children. In line with the U-shaped non-linear interaction model of Lacour, Bernard-Demanze and Dumitrescu (2008) these results suggest that the attention used for the cognitive task could be responsible for the loss of postural control in children with dyslexia and that such children could have a lack of integration of multiple sensorimotor inputs.

The goal of this study is to further explore the effect of a cognitive task (naming a simple object, similar to the task previously used by Laufer, Ashkenazi, & Josman, 2008) on the postural control in children with dyslexia in 2 different postural conditions (Standard Romberg and Tandem Romberg), the latter being more challenging than the former.

Our driven hypothesis, based on previously cited works regarding the dyslexic population, is that in comparison to control children, children with dyslexia would show poor postural control during a baseline condition, in particular in the more complex postural condition (being the Tandem Romberg condition). Furthermore, a dual-task condition, in which the attention is engaged for correctly accomplishing the cognitive task (see Olivier, Cuisinier, Vaugoyeau, Nougier, & Assaiante, 2007; Olivier, Cuisinier, Vaugoyeau, Nougier, & Assaiante, 2010), could lead to a worst postural control at least in dyslexic children.

2. Materials and methods

2.1. Subjects

Seventeen children with dyslexia participated in the study. Children with dyslexia were recruited from a pediatric hospital where they had been referred for a complete evaluation of their dyslexia with an extensive examination, including neurological/psychological and phonological capabilities. For each child, the time required to read a passage of text, text comprehension, and the ability to read words and pseudowords were evaluated using the L2MA battery (Chevrie-Muller, Simon, & Fournier, 1997). This is the standard test developed by the Applied Psychology Centre of Paris (Centre de Psychologie Appliquée de Paris), and is used throughout France. Inclusion criteria were scores on the L2MA which were more than two standard deviations from the mean, and a normal mean intelligence quotient (IQ, evaluated using the WISC-IV), namely between 80 and 115. The mean age of the children with dyslexia was 10.8 ± 0.4 years, the mean IQ was 105 ± 9, and the mean reading age was 8.5 ± 0.5 years. Children with dyslexia had no sign of hyperactivity or developmental coordination disorder (DCD). Diagnostic and Statistical Manual of Mental Disorders Fourth Edition (DSM-IV) was used to exclude hyperactive children (American Psychiatric Association, 1994). A selected age-matched control group (mean age: 10.7 ± 0.6 years) of thirteen non-dyslexic children was chosen. These children had to satisfy the following criteria: no known neurological or psychiatric abnormalities, no history of reading difficulty, and no visual stress or difficulties with near vision. IQ and reading measurements were not available for these children, but their scores for French (reading, comprehension and spelling), mathematics and foreign languages were all beyond the mean scores for their respective classes. Recruitment of controls based on school performance alone has been used by other researchers.

All children tested underwent an ophthalmological examination accompanied by orthoptic evaluation of their visual functions (mean values shown in Table 1).

Visual acuity was normal ($\geq$20/20) for all children in both groups. All children had normal binocular vision (60 s of arc or better), as evaluated with the TNO (Netherlands Organisation of Applied Scientific Research Test of stereoacuity), see Table 1 for details. The near point of convergence was normal for both groups of children tested ($\leq$5 cm). In addition, an orthoptic evaluation of vergence fusion capability using prisms was carried out at near distances. The phoria that is defined as deviation kept latent by the fusion mechanism (Von Noorden & Campos, 2002) is measured by the cover-uncover test. It was within the normal range for all children tested (-4 pD and -2 pD in non-dyslexic and dyslexic children, respectively). The divergence and convergence amplitudes were significantly smaller in the dyslexic group than in the non-dyslexic children. An ANOVA showed a significant main effect of group ($F_{(1,28)} = 22.38$, $p < 0.0001$ and $F_{(1,28)} = 5.16$, $p < 0.03$, for divergence and convergence amplitude, respectively).

Table 1
Clinical characteristics of dyslexic and non-dyslexic children.

	TNO	NPC	Heterophoria	Divergence	Convergence
Non-Dyslexic children	60 ± 5	2 ± 0.4	-4 ± 1.2	17 ± 0.8	38 ± 2
Dyslexic children	60 ± 6	3 ± 0.4	-2 ± 1.5	$11 \pm 1^{*}$	$31 \pm 2^{*}$

Clinical characteristics of all children tested. Mean and standard deviation values for binocular vision (stereoacuity test, TNO measured in seconds of arc); near point of convergence (NPC measured in cm); heterophoria at near distance, measured in prism diopters; vergence fusional amplitudes (divergence and convergence) at near distance, measured in prism diopters.
* Value is significantly different for the group of dyslexic children ($p < 0.01$).

In sum, the orthoptic evaluation showed poor vergence fusional capabilities in dyslexic children in line with other studies (Bucci, Nassibi, Gerard, Bui-Quoc, & Sessau, 2012a; Bucci, Nassibi, Gerard, Bui-Quoc, & Sessau, 2012b; Buzzelli, 1991; Yung, 1989).

The investigation adhered to the principles of the Declaration of Helsinki and was approved by our Institutional Human Experimentation Committee (CPP Ile de France I, Hôpital Hotel-Dieu). Written consent was obtained from the children's parents after an explanation of the experimental procedure.

2.2. Platform

A platform (principle of strain gauge) consisting of two dynamometric clogs (standards by Association Française de Posturologie, produced by TechnoConcept, Céreste, France) was used to measure postural stability. In the Standard Romberg condition the heels were placed four centimeters apart and feet positioned symmetrically with respect to the child's sagittal axis at a 30° angle. In the Tandem Romberg position, the feet were placed slightly apart (four centimeters) in a semi-tandem position with the dominant foot in front of the non-dominant one. The excursions of the center of pressure (CoP) were measured for 26 s and the surface of the CoP was calculated following the standards proposed by Gagey et al. (1993): signals from the force platform were recorded at a frequency of 40 Hz (16-bit analog-digital resolution). The sampling frequency of the CoP was.

2.3. Stimuli

Visual stimuli were presented on a flat screen (1280 × 768 pixels), placed 40 cm from the children. The elevation of the screen was adjusted as a function of the height of each child so that its center was exactly facing the eyes. The fixation target was a black cross (0.50°) and it was displayed at the center of the white screen. The cognitive task required that the child named thirteen simple objects (e.g., ball, table, hat) appearing consecutively for 2 s on the white screen. Prior to data collection, pictures used for this task were presented to each child in order to ensure that the child could identify and name the objects correctly.

2.4. Postural recording procedure

Postural measurements were performed in 2 different postural conditions: Standard Romberg and Tandem Romberg. The duration for each postural recording was 26 s. For each condition (two tasks × two postural positions) 2 trials were run, and a total of 8 postural measures were recorded for each child. The order of the tasks and of the postural conditions varied randomly across children. Children were asked to stay as stable as possible, with the arms along the body.

2.5. Data processing

To quantify the effect of tasks and the postural performance from data obtained from the platform, we analyzed the surface area, the length and the mean speed of the center of pressure (CoP). Fig. 1 shows an example of sway path of the center of pressure during postural recording from a non dyslexic child. The surface area and the length allow the efficient measurement of CoP spatial variability (Chiari, Rocchi, & Capello, 2009). The surface of CoP corresponds to an ellipse with 90% of CoP excursions. The length of CoP is the path of the center of pressure. These 2 postural parameters are uncorrelated; indeed the inner surface of the same length may be different (Gagey & Weber, 1999). It represents a good index of the amount of neuromuscular activity required to regulate postural control (Geurts, Nienhuis, & Mulder, 1993; Maki, Holliday, & Fernie, 1990). For each child, we also calculated the percentage of correct responses to the cognitive task.

2.6. Statistical analysis

Analysis of variance (using the ANOVA test) was performed to compare data between the different tasks (fixation and object naming) with the different type of postural conditions (Standard and Tandem Romberg). Post hoc comparisons were

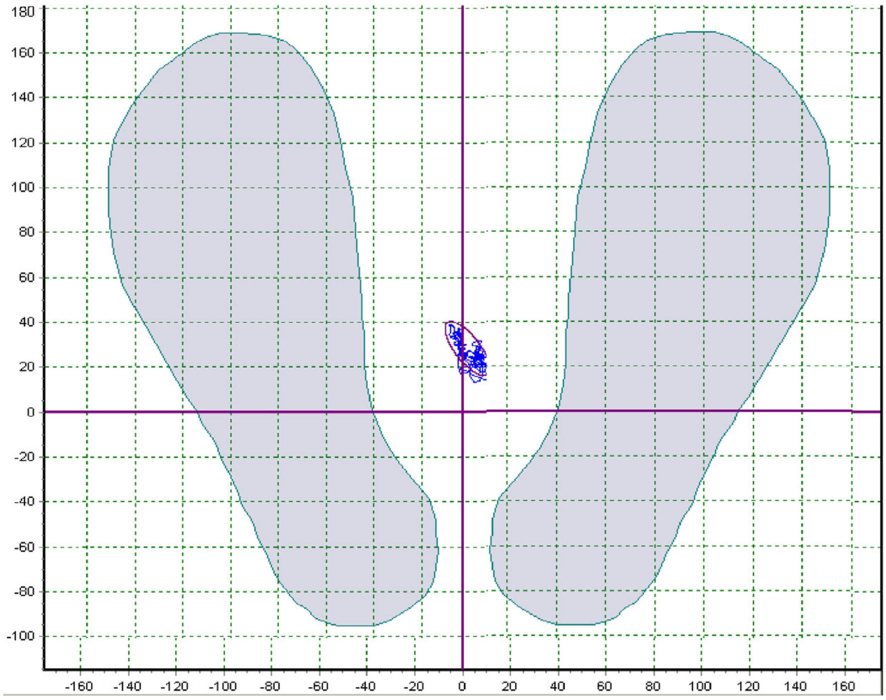

Fig. 1. **S**way path of the center of pressure during postural recording from a non dyslexic child in the Standard Romberg condition.

made with the least significant differences (LSD) test. The effect of a factor was considered as significant when the p-value was below 0.05.

3. Results

Fig. 2A shows the mean of the surface area of the CoP measured during the 2 experimental conditions for non-dyslexic and dyslexic children. ANOVA showed a significant effect of group ($F_{(1,28)} = 4.31$, $p < 0.04$): non-dyslexic children were more stable than dyslexic children. The ANOVA also showed a significant effect of the postural condition ($F_{(1,28)} = 44.61$, $p < 0.001$), meaning that the surface area of the CoP was greater in the Tandem than in the Standard Romberg condition. There was also a significant effect in relation to the task ($F_{(1,28)} = 5.65$, $p < 0.02$); the surface area of CoP in the fixation task was significantly smaller than those measured during the object naming task. Interestingly, Fig. 2B shows there was a significant interaction between groups of children and tasks ($F_{(1,28)} = 4.20$, $p < 0.05$); post hoc comparisons showed that for dyslexics the surface area of the CoP increased significantly during object naming, while for non-dyslexic children the surface area of the CoP was similar for the 2 tasks.

Analysis of the length of CoP (Fig. 3A) showed a significant effect of group ($F_{(1,28)} = 8.11$, $p < 0.008$), of the postural condition ($F_{(1,28)} = 122.43$, $p < 0.001$) and of the task ($F_{(1,28)} = 19.15$, $p < 0.001$). Furthermore, there was a significant interaction between groups and postural conditions ($F_{(1,28)} = 4.35$, $p < 0.04$) showed in Fig. 3B. Post hoc comparisons reported that in the Tandem Romberg condition the length of the CoP was significantly longer than that recorded for the Standard Romberg condition for both dyslexic and non-dyslexic children. Finally, Fig. 3C showed the interaction between groups and tasks ($F_{(1,28)} = 5.42$, $p < 0.02$) indicating that the length of the CoP was significantly longer in dyslexic children during object naming while for non-dyslexic children this parameter was not significantly different for the two tasks (fixation or object naming).

Fig. 4A shows the data obtained concerning the mean speed of the CoP. The ANOVA showed a significant effect of group ($F_{(1,28)} = 8.69$, $p < 0.006$), of the postural condition ($F_{(1,28)} = 143.85$, $p < 0.001$) and of the task ($F_{(1,28)} = 5.59$, $p < 0.02$). There was also a significant interaction between the group of children and the postural condition ($F_{(1,28} = 6.63$, $p < 0.01$) showed in Fig. 4B; post hoc comparisons showed that the mean speed of the CoP was significantly greater in both groups of children in the Standard Romberg condition.

The correct response to the cognitive task for both groups of children was also evaluated. The ANOVA showed a significant difference between the 2 groups of children ($F_{(1,28)} = 13.07$, $p < 0.001$); dyslexic children made more errors in naming objects compared to non-dyslexic children who performed this task without any error (100% correct response). The percentage of correct responses for dyslexic children was 68% and 70% in the Standard Romberg and Tandem Romberg conditions, respectively.

4. Discussion

The aim of the study was to explore the effect of a secondary cognitive task in children with dyslexia on the surface, length and mean speed of CoP when using two types of postural conditions (Standard Romberg and Tandem Romberg). Our results highlight several main points, as set out below.

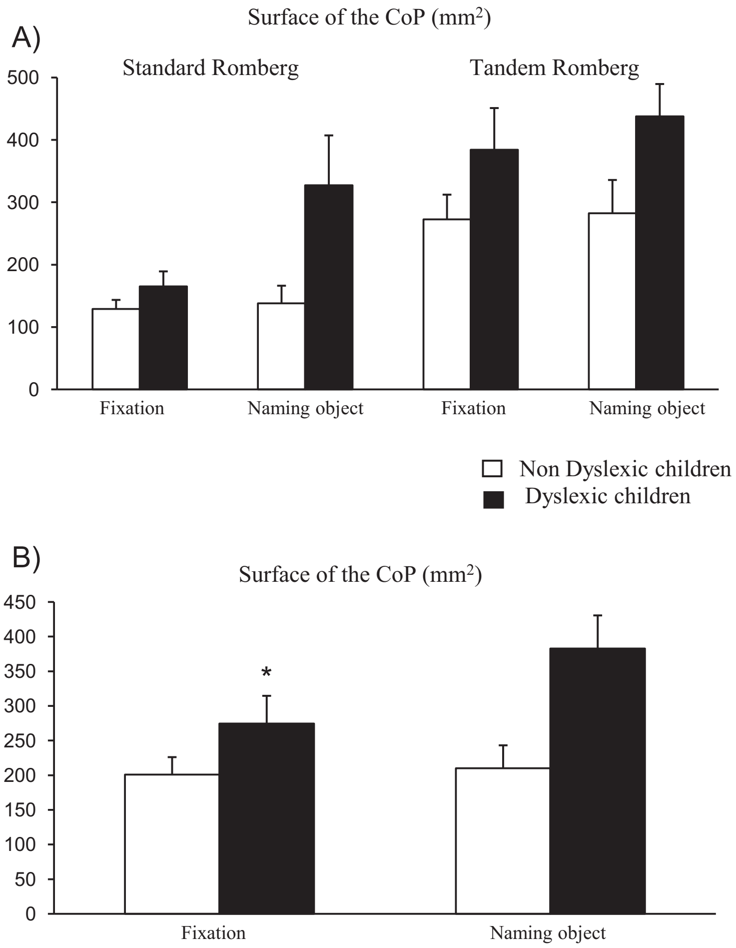

Fig. 2. (A) Means and standard deviations of surface area of CoP in Standard Romberg (SR) and Tandem Romberg (TR) conditions in the two tasks (fixation and object naming) for the two groups of children (dyslexic and non-dyslexic). (B) Means and standard deviations of surface area of CoP showing the interaction between GxT; * significance.

4.1. Children with dyslexia are more instable than non dyslexic children

This study shows significant differences in postural control between dyslexic and non-dyslexic 11-year old children. Children with dyslexia reported a larger surface area of CoP, a longer length of CoP and a greater mean speed of CoP in comparison to non-dyslexic children. We also note that for all postural parameters measured such instability was greater in the object naming task and in the Tandem Romberg condition, suggesting that the difficulty of the task, calling for greater postural or cognitive effort, leads to worse postural control in children with dyslexia. These data confirm and expand previous findings reported in the dyslexic population (as cited in Section 1) suggesting cerebellar impairment in such children. Indeed, according to the cerebellar hypothesis (Fawcett & Nicolson, 2004; Frank & Levinson, 1973) the ability to learn how to perform tasks with automaticity could be deficient in children with dyslexia, leading to poor ability in reading, writing, and the performance of other tasks such as postural control. The vestibular system, the proprioceptors, and the cerebellum are responsible of muscle tone, posture, balance, binocular coordination, and spatial orientation; as previously showed by Frank and Levinson's studies these systems seem also to be largely involved in school learning processes and deficient in dyslexia population. Narciso et al. (2004) looked at vestibular variations in children and they observed that 47% of them had complaints related to performance at school. They found that vestibular disorders may be associated with learning and motor impairment. More recently Franco and Pahoca showed that there was a greater prevalence of vestibular problems (67%) in children underperforming in school than in a normal children population (26%).

Note also that it is well known that postural control involves a complex relationship between sensory information and motor activity, meaning that children need to learn how to automatically adapt their body in order to achieve good postural control (see Barela, Jeka, & Clark, 2003). According to a recent study by Barela, Dias, Godoi, Viana, and de Freitas (2011), such automaticity could be impaired in dyslexic subjects given that they showed difficulties in coupling visual/sensory information and motor response. This raises the possibility of training children with dyslexia to override this deficit and improve their automaticity capabilities. Given the well known involvement of the cerebellum in motor adaptation (see Leigh & Zee, 2006), postural tasks coupled with cognitive tasks could be a useful tool for children with

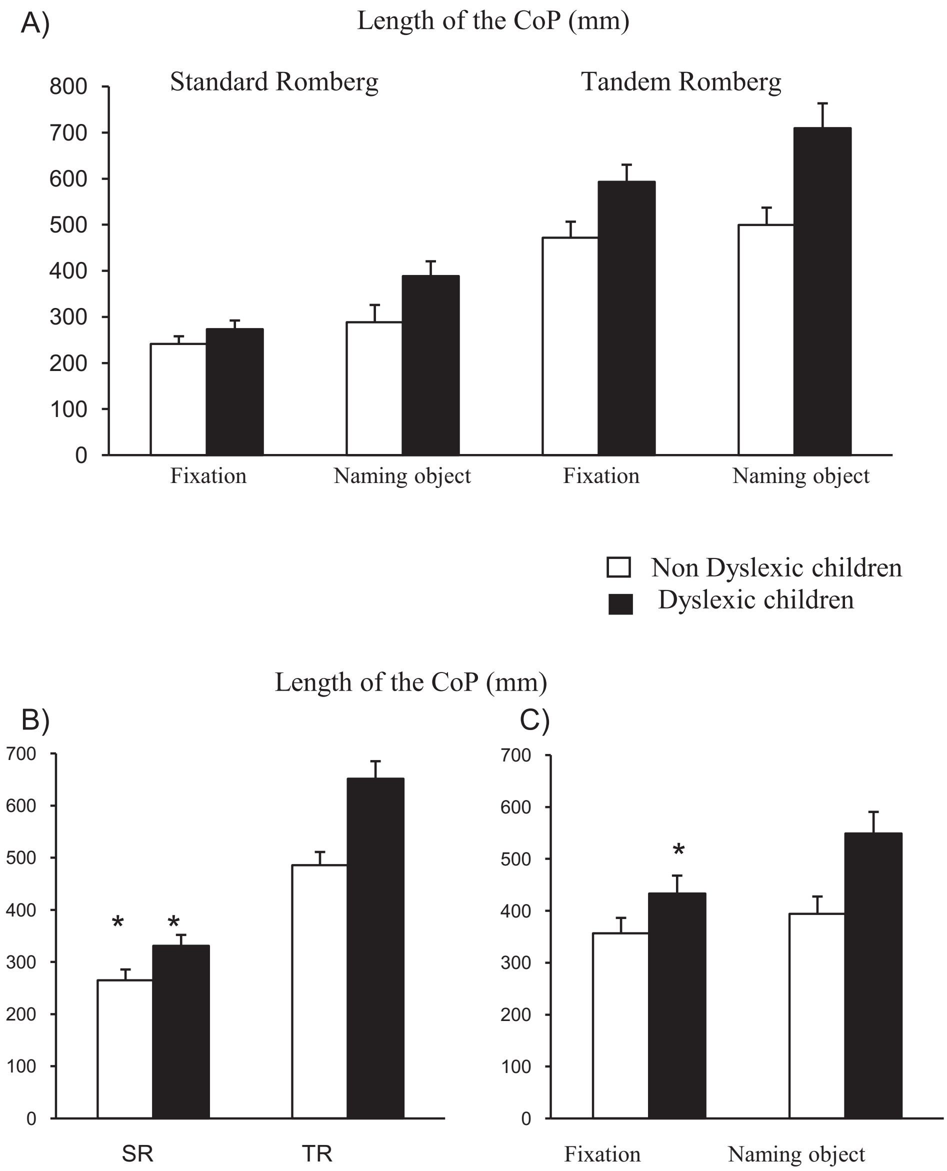

Fig. 3. (A) Means and standard deviations of length of CoP in Standard Romberg (SR) and Tandem Romberg (TR) conditions in the two tasks (fixation and object naming) for the two groups of children (dyslexic and non-dyslexic). (B) Means and standard deviations of length of CoP showing the interaction between GxP; * significance. (C) Means and standard deviations of length of CoP showing the interaction between GxT; * significance.

dyslexia for learning and improving automaticity performances (Thach & Bastian, 2004). Studies dealing with postural control in the dyslexic population before and after dual-task training are needed to explore these ideas further. In our previous study showing poor binocular control in dyslexia (Bucci et al., 2012a, 2012b) we suggested that vergence training in order to improve fusional vergence capabilities could improve vergence-saccade interaction, therefore binocular control in these children. Maybe a combined visual, attentional and motor training could improve in children with dyslexia reading as well as motor performances. Our ongoing studies are dealing with such issue.

4.2. Dyslexic and non-dyslexic children perform differently at dual-tasks

Our findings show a different effect of the cognitive task on posture in the dyslexic population only; indeed, performing a cognitive task leads to impaired postural control in children with dyslexia, but this does not occur in non-dyslexic children. In other words the postural control of non-dyslexic children is good independent of the cognitive task (fixating or object naming). For dyslexics this result could be due to their difficulty in allocating attention correctly; their performance in cognitive tasks as well as in postural control is poor. Attentional deficits in children with dyslexia have been already reported (Ruffino et al., 2010) and their difficulties in dual-task prioritization have also been well documented (see Section 1). Furthermore, it is well known that rapid automatized naming is a difficult task for dyslexic population (see recent works from Jones Ashby, & Branigan, 2012; Zoccolotti et al., 2012) and even if our task was simpler (to name single picture) children with dyslexia reported difficulties most likely due to deficits in fucus their

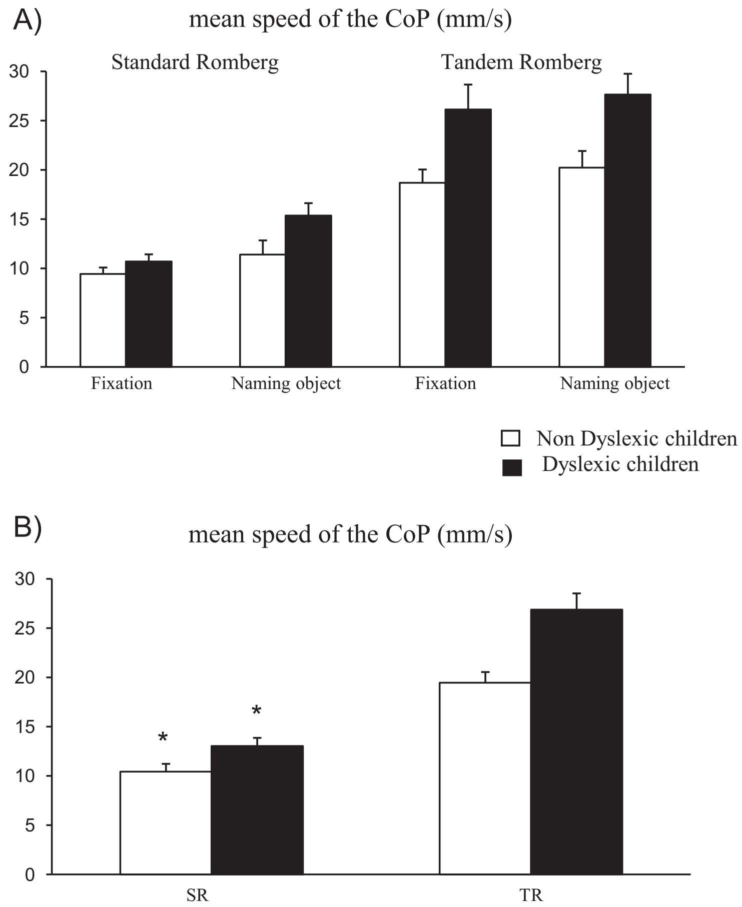

Fig. 4. (A) Means and standard deviations of mean speed of CoP in Standard Romberg (SR) and Tandem Romberg (TR) conditions in the two tasks (fixation and object naming) for the two groups of children (dyslexic and non-dyslexic). (B) Means and standard deviations of the mean speed of CoP showing the interaction between GxP; * significance.

attention. In contrast, non-dyslexic children under both simple (Standard Romberg) and more difficult (Tandem Romberg) postural conditions do not prioritize the cognitive task, presumably because they do not have to do so: for them fixating a target is as simple as naming an object. Most likely non-dyslexic children were able to focus attention on the cognitive task leading to an automated postural control.

Finally, it must be pointed out that we employed the same stimulation used by Laufer et al. (2008), and that the results which we observed in non-dyslexic 11 year old children are similar to those reported by these authors in five year old control children even if the postural parameters examined were not exactly the same (mean, path length, velocity and sway variability in Laufer's research, and surface, length and mean speed of the CoP in the present research) and the platform used in the two studies was different.

4.3. Effect of a dual-task on posture

In accordance with the SOC (selection, optimization and compensation) model proposed by Baltes and Baltes (1990), we expected a lower performance of the cognitive task in children tested in a dual task situation (dyslexic as well as non-dyslexic). This was not the case, indeed, only children with dyslexia showed poor postural control during object naming. The results relating to children with dyslexia are in line with the U-shaped non-linear interaction model described by Lacour et al. (2008) which explored the effect of a secondary task on postural stability; the secondary task could decrease postural stability depending on the attentional cost of such a task. For instance, the absence of a cognitive task (the simple fixation of a target) directs childrens' attention to postural control thereby increasing the attentional resources needed to control posture; in contrast a more complex cognitive task (i.e. object naming) could be responsible for shifting the attention away from postural control, decreasing postural performance.

Finally, it should be noted that postural task difficulty (i.e. Tandem Romberg condition) did systematically decrease postural performance; such a task could require more resources, leading to more pronounced control decrements when these resources have to be shared between two tasks (Schaefer, Krampe, Lindenberger, & Baltes 2008). It should also be noted that even if the Standard Romberg condition is a rather simple postural task requiring cognitive resources (Lajoie, Teasdale, Bard, & Fleury, 1993), the Tandem Romberg activates a larger cortical network involving pre-motor cortex and parietal areas (Rushworth, Johansen-Berg, Göbel, & Devlin, 2003), leading to less postural stability independent of the secondary task used.

5. Conclusion

Our results highlight that the complexity of the task leads to a U-shaped postural performance. Additional studies in which eye movements and postural performance are simultaneously recorded are needed to further explore these issues.

Conflict of interest statement

The authors have no financial or personal relationships with other people or organizations that could inappropriately influence or bias their work in this study.

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