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Postural Dual Task Performance during Anti-Saccades in Healthy Children

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Abstract

Purpose: It is known from literature that postural stability in children is affected by a secondary task. In the present study we explored the effect of anti-saccades on postural sway in healthy children.

Methods: 43 healthy children from 8 to 15 years old participated to the study. Postural stability was measured by Techno Concept platform and simultaneously eye movements were recorded by an eye tracker (Mobile T2). Children performed anti-saccades task (saccades away from the target), pro-saccades task (saccades toward the target) and a fixation task.

Results: The surface area, the length and the mean velocity of the center of pressure were significantly reduced in similar way by anti-saccades and pro-saccades task in comparison with a simple fixation task. The performance of anti-saccades influenced postural control given that the increase of the error rate was correlated with the increase of all postural parameters measured.

Conclusion: These results suggested an interaction between oculomotor and postural control during dual task. Most likely, in order to perform a correct anti-saccade, child could shift attention to inhibitory processes and working memory away from postural control leading to a better automatic postural performance.

Keywords

Anti-saccade, Pro-saccades, Fixation, Inhibitory process, Dual task, Posture, Children

Introduction

Belen'kiĭ et al. (1967) were the first to report that postural control is not an automatic system, and that several processes are responsible to control postural stability. In everyday life, attentional resources used to control posture are frequently shared so as to perform other tasks simultaneously; thus postural stability is naturally part of a dual-task [1,2]. In laboratory, dual-task paradigm is used to investigate the attentional demand to postural task and to examine the effects of concurrent tasks on postural performance. Kerr et al. (1985) were the first to show that postural control of young adults is attention-dependent and that postural stability is affected differently by different cognitive tasks [3]. Fraizer and Mitra (2008) suggested that attention is used in postural stability; more in detail they suggested that attention has to integrate sensory information, to select the appropriate information in case of sensory conflict and, eventually, to compensate for a perturbation of postural control [4].

Several studies have been done in order to explore the effects of eye movement task on postural control in adult population. Some authors (Uchida et al. 1979; Stoffregen et al. 2006; Rougier and Garin, 2007) reported a decrease of the surface area of the center of pressure (CoP) while saccadic eye movements were performed [5-7]. In contrast, others studies (White et al. 1980; Straube et al. 1989; Glasauer et al. 2005) showed that eye movements did not modify or decrease the surface area of the CoP [8-10]. The various experimental conditions used in such different studies could explain these contradicting results.

Studies exploring the effect of saccadic eye movements on posture in children are rare. Our group reported an improvement of postural control in children while performing saccadic eye movements; such improvement has been reported in dyslexic and non dyslexic children (Legrand et al. 2012) as well as in children with strabismus (Lions et al. 2013) suggesting that while performing an additional task, e.g. a task involving eye movements postural control became more automatic [11,12]. A study of our group (Ajrezo et al. 2013) on a population of 95 children from 6 to 18 years old, coupling for the first time eye movements and posture recordings, confirmed our previous results reinforcing the idea that a saccadic secondary task can shift the attentional focus away from postural control, leading to a better automatic postural performance [13]. In a recent study of our group (Bucci et al. 2015) we reported that in children saccades toward a target as well as during reading task reduced significantly the CoP displacement and its velocity, while during pursuit eye movement's children increased postural parameters [14]. This study suggested that visual attention to perform saccades (to stationary targets or to words) influences postural stability more than the frequency of saccade triggering does.

Based on these findings a question arises on whether anti-saccades task could improve postural stability, given that this paradigm required several cognitive factors including the disengagement of attention from the peripheral target and working

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memory in order to prepare and trigger the reflexive saccade of the similar amplitude in the opposite direction [15]. Recall that the anti-saccade paradigm, introduced for the first time by Hallet (1978), is frequently used to explore the capacity of voluntary response suppression because subject had to inhibit an automatic response and to generate a voluntary response [16,17]. Neuropsychological studies have shown an important role of the frontal cortex when performing anti-saccades and Everling and Munoz (2000), and Funahashi et al. (1993) reported that several frontal structures (frontal eye field, dorsolateral cortex and supplementary eye field) are activated during anti-saccade tasks [18,19].

In the present study we explored in children how anti-saccadic task could affect postural control recording simultaneously eye movements and postural sway. It is well known that attentional mechanisms are involved in eye movements' execution [20-22], and also that several cortical and sub-cortical areas are involved in both postural and eye movements control [23,24]. We made the hypothesis that we would find interference between oculomotor and postural control while eye movements and postural stability are executed in a dual-task, however we wanted to explore further whether the performance of anti-saccades task could be in relationship with postural stability.

Materials and Methods

Subjects

43 children (aged from 8.08 to 15.83 years) participated to the study. All children underwent a neurological, vestibular and ophthalmologic/orthoptic examination. The investigation adhered to the principles of the Declaration of Helsinki and was approved by our institutional Human Experimentation Committee (Comité de Protection des Personnes CPP Ile de France V, Hôpital Saint-Antoine). Informed written consent was obtained for each subject and from the children's parents after careful review of the experimentation with the participants.

Inclusion criteria

Children have to be between 8 and 15 years. Children have not to have any neuro-visual, anatomical or orthopaedic abnormalities. The children have not to suffer from any cognitive disorder even if any test to explore cognitive impairments was used; for all children tested the scores for French (reading, comprehension and spelling), mathematics and foreign languages were all beyond the mean scores for their respective classes. The results of the clinical assessments (ophthalmologic, orthoptic and vestibular) must be normal.

Ophthalmologic and orthoptic evaluation

All children had normal corrected visual acuity (≥ 20/20) and normal binocular vision (mean value 58.43 ± 2.96 s of arc), evaluated by using the TNO random dot test. All children had also normal value of the near point of convergence (NPC, mean value 2.13 ± 0.11 cm) and normal heterophoria (measured by using the cover-uncover test at near distance, mean value -3.29 ± 0.78 pD). Fusional amplitudes of convergence and divergence measured at near distance by using a base-in and a base-out prism bar were also in normal range (mean value 37.00 ± 1.02 pD and 16.98 ± 0.23 pD, respectively).

Neurological, hearing and Vestibular evaluation

Neurological examination, a hearing test (tonal and speech audiometric techniques), Hamalgyi's test and vestibulo ocular responses recording with rotatory chair (to evaluate clinically the function of the semicircular canals) were normal for all children tested.

Visual tasks

The stimuli were presented on a flat black PC screen of 22", its resolution was 1920 × 1080 and the refresh rate was 60 Hz. The target was a white filled circle subtending a visual angle of 0.5°.

Anti-saccades: The trial consisted of a target positioned at the centre of the screen for a variable delay comprised between 2000 and 3500 ms, followed by its disappearance during a gap interval of 200 ms. Then, a lateral target appeared randomly to the left or to the right of the centre, and stayed on for 1000 ms. The central fixation target then reappeared, signalling the beginning of the next trial. Child was instructed to look at the central fixation point, then to trigger a saccade as soon as possible in the opposite direction and symmetrically to the lateral target. Thus, when the target appeared on the right, the child had to look to the left, at a distance equivalent to the central point-target distance. When the target returned to the centre, the child was instructed to visually follow it back to the centre. An initial training block of trials was given to ensure that the instructions were well understood.

Pro-saccades: Horizontal, visually-guided saccades were elicited using a simultaneous paradigm.Child had to fixate a central target on a period randomly ranging between 2000 and 3500 ms, then the central target disappeared and a target on the left or on the right side of the screen was switched on for 1000 ms. The central fixation target then reappeared, signalling the beginning of the next trial.

The saccade amplitude in the anti- and pro-saccades paradigm was of 15°.

Fixation: child had to fixate the target appearing in the centre of the screen and switched on during 25.6 sec. Note that even if this visual task is quite a difficult task, requiring precise active stabilization of the eyes and attention, it is usually used as a control task for postural measures (see articles cited in the Introduction).

While performing the visual tasks, child was standing on a platform and both eye movements and posture were recorded simultaneously.

Postural recording

Postural stability was measured during 25.6 sec by using a platform (principle of strain gauge) consisting of two dynamometric clogs (standards by Association Française de Posturologie, produced by TechnoConcept®, Céreste, France). Two postural recordings were done for each visual task that was presented randomly to children. The recording sessions were in a dark room to avoid that children could fixate other stimuli. Viewing distance was 60 cm and visual tasks were presented at eye level. The position of the feet was as follows: heels 4 cm apart and the feet spread out symmetrically at an angle of 30° with respect to the child's sagittal axis. Arms were vertical along the body.

Eye movement recording

Eye movements were recorded by Mobile EyeBrain Tracker (Mobile T2®, e(ye)BRAIN) a CE-marked medical eye-tracking device. The Mobile EBT® is equipped with a camera that captures the movements of each eye independently. Recording frequency was set up to 300 Hz. The precision of this system is typically 0.25°. There is no obstruction of the visual field with this recording system. During the calibration procedure, children were asked to fixate a grid of 13 points (diameter 0.5 deg) mapping the screen. Point positions in degree in horizontal/vertical plan were: −20.9°/12.2°; 0°/12.2°; 20.9°/12.2°; −10.8°/6.2°; 10.8°/6.2°; −20.9°/0°; 0°/0°; 20.9°/0°; −10.8°/−6.2°; 10.8/−6.2°; −20.9°/−12.2°; 0°/−12.2°; 20.9°/−12.2°.

Each calibration point required a fixation of 250 ms to be validated. A polynomial function with five parameters was used to fit the calibration data and to determine the visual angles. After the calibration procedure, ocular motor task was presented to the child [25].

A calibration was done before starting the experiment test was explained to each child, but no training trails were done before recording.

Data processing

Eye movements from the dominant eye of each child were analysed. In the anti-saccade task, the mean error rate was examined

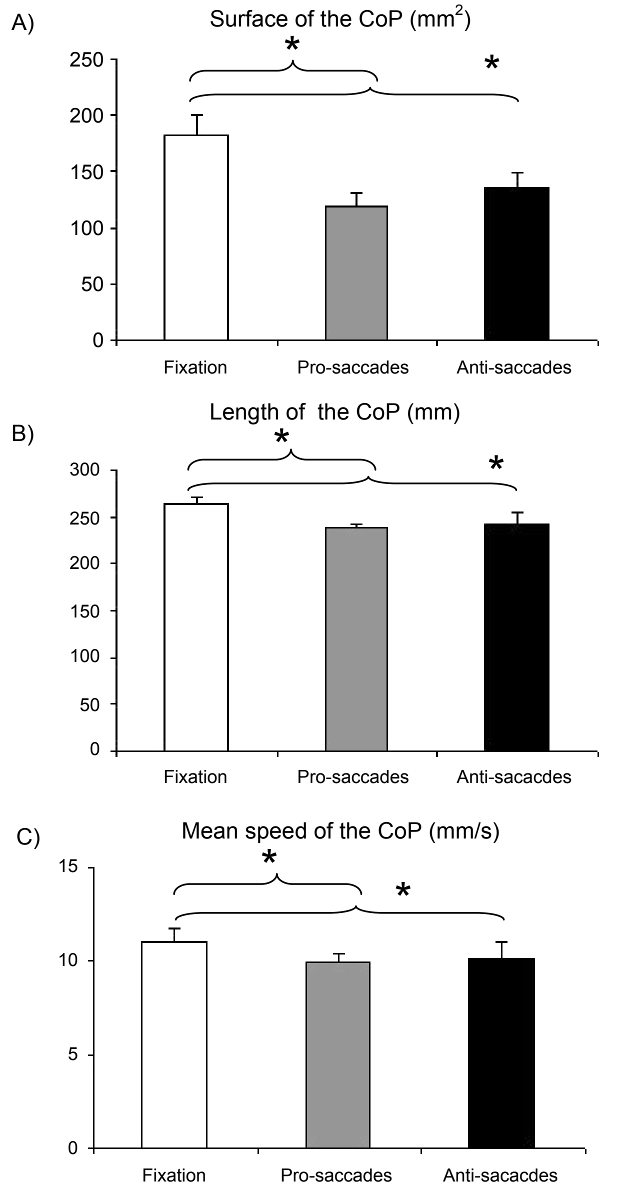

Figure 1: Mean values of the surface area (A), of the length (B) and of the mean speed of the CoP (C) during fixation pro- and anti-saccades task. Vertical bars indicate the standard error. Asterisks indicate that the value is significantly different (p < 0.05)

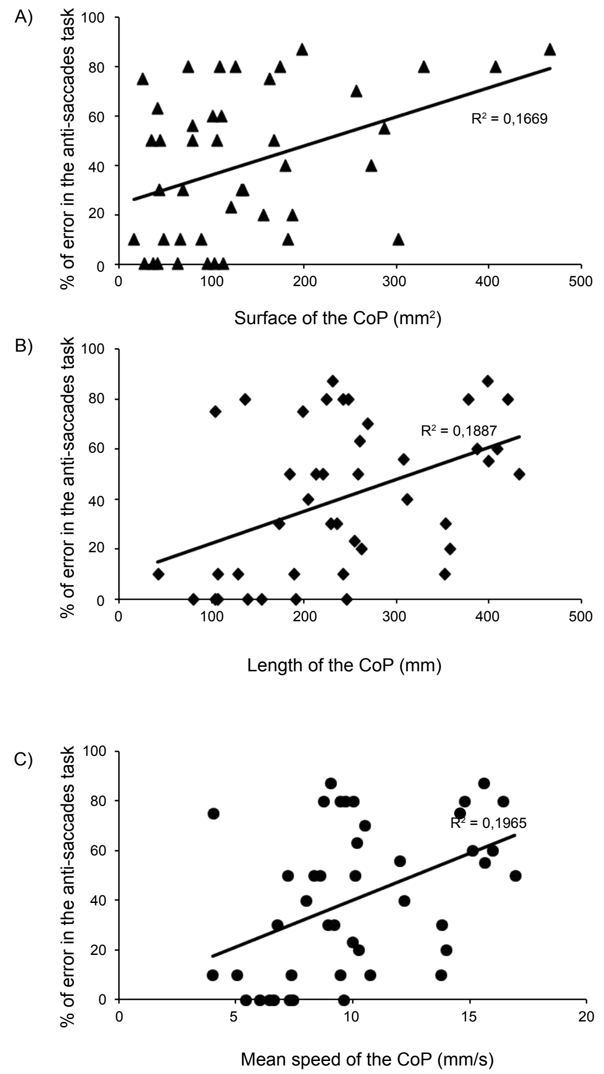

Figure 2: Relationship between the percentage of error rate in anti-saccades task and the mean value of the surface area (A), of the length (B) and of the mean speed of the CoP (C). Line represents the corresponding regression

(i.e. the number of saccades made in the target direction). For evaluation of postural control, the surface area, the length and the mean speed of the centre of pressure (CoP) were analysed.

Statistical analysis

For all children, we compared with ANOVA postural parameters (surface, length and mean speed of the CoP) during pro-, anti-saccades task and the baseline condition (fixation task). Post hoc comparisons were made with the Fischer's least significant differences (LSD). Error rate of anti-saccades was analysed using multiple linear regression models with the surface, length and mean speed of the CoP as outcome parameters. The effect of a factor was considered as significant when the p-value was below 0.05.

Results

Figure 1 shows respectively the mean surface area (A), the mean length (B) and the mean speed (C) of the CoP during pro-, anti-saccades and fixation task. For all these postural parameters a significant effect of the visual task occurred (ANOVA test results were $F_{(2,84)} = 12.44$, $p < 0.0001$, $F_{(2,84)} = 4.72$, $p < 0.01$ and $F_{(2,84)} = 4.83$, $p < 0.01$, respectively for the surface, the length and the mean speed of the CoP). Post hoc comparison showed that all values of the three postural parameters measured were significantly larger during fixation than during making pro- and anti-saccades (both $p < 0.01$ for the surface area, the length and the mean speed of the CoP, respectively).

In order to explore whether a relationship exists between the anti-saccades performance and the postural control we looked the correlation between the percentage of error in the anti-saccades task and postural parameters. Figure 2 shows the percentage of error in the anti-saccades task as function of the values of the surface area, of the length and of the mean speed of the CoP for each child tested and the regression line. The R^2 value reached significance ($R^2 = 0.1669$, $p < 0.006$, $R^2 = 0.1887$, $p < 0.004$ and $R^2 = 0.1965$, $p < 0.003$ respectively for the surface, the length and the mean speed of the CoP).

Discussion

The main findings of this study are as follows: (i) Performing saccadic tasks (pro- and anti-saccades) decreased postural values with respect to simple fixation task; (ii) The percentage of errors in anti-saccades task is correlated with postural parameters measured. These findings are discussed individually below.

Performing pro- and anti-saccades task decreased postural values with respect to simple fixation task

Our results show that performing pro- and anti-saccades improved postural stability with respect to a simple fixation task. This finding is in line with previous reports on children with neurodevelopmental disorders as hyperactivity or dyslexia [26,27]. Recall that in order to perform saccades (pro- or anti-) several cortical areas needed to be activated and that for performing anti-saccades task such cortical network is even larger [24,28,29]. Based on these knowledges, our results are in agreement with the U-shaped non-linear interaction model for which body balance can be either improved or diminished depending on whether the cognitive demand of the secondary task is low or high [30]. Our present results showed that performing a secondary task during a postural task could prevent attention from being focused on postural stability, leading to a reduction of postural sway (automatic attentional system). In other words, such decrease might be due to the fact that postural control could become more automatic. This hypothesis is also in line with other studies leading with dual task in elderly subjects [31].

Finally, our study also showed an interaction between the oculomotor and the postural systems, insofar as the similar structures of the central nervous system play an important role in postural control as well as in programming saccadic eye movements; however as discussed below, anti-saccades task gives more information on such type of interaction.

The percentage of errors in anti-saccades task is correlated with postural parameters measured

The important new finding of the present study is that more correctly is performed the anti-saccade task more child reaches good postural stability. This finding reinforces our hypothesis that attention is focus away from posture leading to its improvement via an automatic postural control. Furthermore we observed that when the child is not able to perform correctly the anti-saccade task, postural instability increased significantly. Recall that inhibitory processes and working memory are activated to perform correctly anti-saccades task, consequently we suggest that such cortical network could be shared also during controlling postural stability. Indeed, different structures of central system are involved in the control of posture, namely the spinal cord and brainstem, basal ganglia, cerebellum, somatosensory, premotor and motor cortices [32]. On the other side, we showed that when child is not able to focus correctly attention on anti-saccades task he/she is not able either to obtain postural stability suggesting that when the secondary task is high cognitive demanding some child cannot assure correctly both stability as well as oculomotor task.

Conclusion

By recording simultaneously eye movements and postural sway, we showed that saccades (pro- and anti-tasks) affect postural parameters leading to automatic control of postural stability. Given that the performance of anti-saccades is in relationship with postural stability we could advance the hypothesis that child drives attention on anti-saccadic performance leading to more automatic postural control. Further studies exploring different tasks to test attentional capabilities during postural control will be useful to better understand the relationship between attention, motor and visual performance in children.

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Author Contributions

Conceived and designed the experiments: MPB, SWV; Performed the experiments: LA, MPB; Analyzed the data: LA; Contributed reagents/materials/analysis tools: SW, LA, MPB; Wrote the paper: LA, SW, MPB.

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