Gait & Posture 32 (2010) 494–499

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Age-related differences in cognitive and postural dual-task performance

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ARTICLE INFO

Article history:
Received 6 March 2009
Received in revised form 4 March 2010
Accepted 12 July 2010

Keywords:
Children
Posture
Cognitive task
Dual-task
Interference

ABSTRACT

The present experiment assessed, in children aged 7–11 and in adults, whether postural control is affected by cognitive processes and vice versa. Using a dual-task, the level of difficulty of a Stroop task and bipedal quiet stance varied alternatively. We hypothesised that the interference between cognitive and postural tasks was non-linear during childhood with a so-called turning point around 8. Twenty-seven children 7- to 11-years-old and nine adults participated in the experiments. The postural task was executed in a semi-tandem Romberg position. Two cognitive conditions (congruent and non-congruent Stroop conditions) and two postural situations (with and without perturbed proprioceptive inputs) were presented simultaneously with the instruction to respond as correctly as possible while remaining as stable as possible. Results showed that, in the Vib condition, CoP mean velocity decreased with the increased cognitive complexity only in children aged 7. Moreover, the data showed a non-linear decrease in postural sway during childhood, whatever the level of complexity of the cognitive and/or postural tasks. CoP mean amplitude and mean velocity decreased between 7 and 8, and again between age 11 and adults. This study (1) confirmed that the interference between mental activity and postural control can be attributed mainly to attentional limitations, (2) showed the existence of a turning point around 8 in the development of this capacity, and (3) suggested that the mature level of attentional resources was not reached until age 11. Further research is needed to assess the development of attention implied in a cognitive/postural dual-task, including probably another so-called turning point during the adolescence.

1. Introduction

Cognition and postural control may require common mechanisms implying a conflicting relationship [1,2], thus contrasting the hypothesis of postural control as a mere spinal or subcortical process. The interaction between cognitive processes and balance control is typically investigated in dual-task paradigms [3] in which the two tasks can compete together [4–8]. Some authors showed that the postural task impacts the cognitive performance with the most difficult postural tasks having the greatest influence [4], whereas others showed an opposite pattern of results [7]. Studies in which the complexity of both cognitive and postural tasks was manipulated are scarce. Examining postural control when the concurrent task was the Stroop test [9], Dault et al. [5] reported a larger interference with the addition of a cognitive task to the more unusual and difficult postural task. Nevertheless, the Stroop conditions always induced the same degree of interference in postural sway. Barra et al. [10] showed that only the spatial (congruent or incongruent word left/right and laterality of the voice in the headphone) but not the verbal (congruent or incongruent gender of a name and male/female voice in a speaker) Stroop task increased the risk of falling but they did not find any influence of the difficulty of the postural task during any of the cognitive tasks.

Dual-task interference occurs when tasks requirements exceed the attentional capacity of the central nervous system (CNS) [11]. Yardley et al. [12] recently concluded that this interference can be attributed mainly to general capacity limitations, and is hence proportional to the attentional demand of both tasks. Woollacott and Shumway-Cook [1] highlighted that postural control may demand attentional resources that depend on the nature and complexity of the task, as well as on the individual's age and balance capacities.

Studies investigating children's balance only recently used the dual-task paradigm. Blanchard et al. [13] examined the effects of a concurrent cognitive task on standing at the age of 9.5 and concluded that performing concurrent cognitive tasks altered postural sway in children. Schmid et al. [14] confirmed that a mentally counting backwards task executed silently, i.e., with no articulation, strongly perturbed postural strategies in children aged 9. These results suggested that a concurrent cognitive task increased the intervention rate of the postural control system. In

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0966-6362/$ – see front matter
doi:10.1016/j.gaitpost.2010.07.008

children aged 7, when a modified Stroop task was executed while standing, postural stability decreased (i.e., CoP speed was higher) in comparison to a simple standing task [15]. All these results showed that when a cognitive task was added to a postural one, it modified the functional characteristics of postural control as soon as the age of 7.

Moreover, the Blanchard et al.'s results [13] suggested that children aged 9.5 adapt their postural strategy under conditions of increased complexity of the concurrent cognitive task by constraining the degrees of freedom. Olivier et al.'s study [15] also showed that the increased complexity of the Stroop task decreased CoP speed at 7. When both cognitive and postural difficulty increased, CoP speed decreased showing degradation of the postural criteria in children but not of the cognitive one when the postural task was more constraining. In children aged 5, the stance in a dual-task condition was also affected by an increasing postural complexity [16].

On the other hand, many studies reported a non-linear rate of improvement of balance control characterised by changes in the postural control strategy occurring around 8 years [17]. A shift in controlling inputs to posture from a visual dependence to a more adult-like dependence on a combination of ankle joint and visual inputs occurred between 4 and 6, and reached adult form between 7 and 10 [8]. Recently, authors [18] showed that when a proprioceptive perturbation was applied in children aged 7–11 and in adults postural control was less affected with age. Proprioceptive inputs were useful and integrated by the CNS to control posture from 7 to 20 with the presence of a non-monotonic pattern of postural control development characterised by a linear decrease of the use of proprioceptive inputs from 7 to 10.

Finally, studies investigating the development of selective attention, i.e., the ability to attend voluntarily to some attributes of the stimulus array while ignoring other attributes [19], have proposed two theoretical explanations for the processing of information requiring attention. Attentional resources may be considered as: (a) a single attentional mechanism [20]; or (b) a collection of independent attentional mechanisms such as overt search, filtering or priming [21]. In the single attentional mechanism model, whatever the nature of the dual-task to execute (complexity of the cognitive and/or postural tasks) the same attentional system is involved and its efficiency increases during childhood. In the multiple attentional mechanisms model, different and independent attentional mechanisms can be involved in different dual-tasks and can exhibit a different evolution rate during childhood.

The present work aimed to assess, in a year-by-year developmental study from 7 to 11 and in adults, to which extent the cognitive processes are affected by balance control and vice versa when manipulating the complexity of the cognitive and postural tasks. This will allow determining with a greater precision the turning point(s) in the development of postural control. Since there are less available attentional resources in children than in adults [20,21] and since the cognitive and postural dual-task performance does not seem to be monotonic during childhood [22], we hypothesised an age-related difference in the interference between cognitive and postural tasks. More precisely, we expected that the 8 years of age period was a time, the so-called turning point, in which behaviour changed markedly. Finally, we investigated the theoretical explanation underlying the cognitive/postural dual-task attentional demand in children.

2. Materials and methods

2.1. Participants

Forty six participants, divided into six age groups, participated to the experiment: eight 7-year-olds (4 girls and 4 boys, M = 7.3 years, SD = 2.3 months), eight 8-year-olds (3 girls and 5 boys, M = 8.2 years, SD = 2.4 months), seven 9-year-olds (3 girls and 4 boys, M = 9.2 years, SD = 4.6 months), six 10-year-olds (4 girls and 2 boys, M = 10.1 years, SD = 1.7 months), eight 11-year-olds (4 girls and 4 boys, M = 11.4 years, SD = 3.1 months) and nine adults (2 females and 7 males, M = 25.7 years, SD = 27 months). Participants were recruited on a voluntary basis from a social middle class, right-handed, and naive as to the purpose of the experiment. They had a normal scholastic level and did not show any known neurological or motor disorders or any colour blindness. This study was approved by the local ethics committee and in conformity with the Helsinki Convention informed consent was obtained from all participants.

2.2. Experimental set-up

Participants, arms close to the trunk, stood barefoot in a bipedal stance position (Fig. 1) on the force platform (AMTI®, model OR6-5-1), their feet placed slightly apart (4 cm) in a semi-tandem position with the right foot in front of the left one. Signals from the force platform were recorded with a 100 Hz frequency (12 bit A/D converter). To increase postural complexity by disturbing the proprioceptive signals from the feet, two vibrators (280 g, 4 cm × 8 cm, 80 Hz vibration frequency) were strapped on each foot just above the middle of the ankle joint, over the Achilles tendon and the insertion of the tibialis anterior [18].

A computer screen was placed 150 cm in front of the participants with the centre of the screen aligned on the middle of the body, at the eye level. Because the younger children were beginning readers, a modified Stroop test was used in which the words were replaced by fruits. Forty-eight pictures of strawberries, bananas, apples or oranges drawn in orange, yellow, green or red were presented to the participants in two series. The first series (congruent colour condition: C-C) was composed of fruits drawn in their natural mature colour. The second series (non-congruent colour condition: NC-C) was composed of fruits which were drawn in three abnormal colours. In each series, presentation of the four fruits was equiprobable. Participants responded verbally which is known to affect postural sway [23] and respiratory activity [24]. Nevertheless, these two factors had presumably similar effects in all cognitive conditions and groups.

2.3. Procedure and independent variables

Four blocks of four trials (30 s each) were randomised among participants. In two control blocks, participants were instructed to stare at a fruit picture presented on the TV and to remain as stable as possible with or without vibration (Vib or non-Vib). In the other two dual-task blocks, participants had to respond to the colour of the fruit as fast as possible without making errors and to remain as stable as possible in the Vib or non-Vib condition. The two cognitive tasks (two trials per cognitive task) were randomly presented. Once participants had responded, the following picture was immediately presented. In the Vib condition, the experimenter started the vibrators 5 s before the beginning of the first trial and stopped them after the last trial.

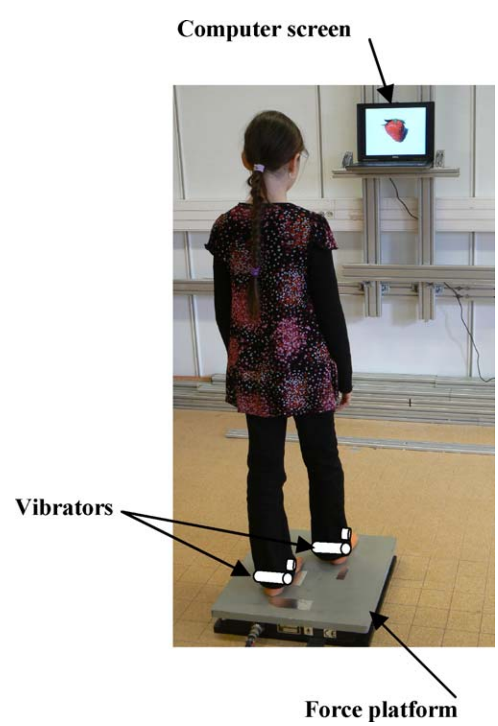

Fig. 1. Experimental set-up.