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How do children complete a seated combined cognitive and motor multi-tasking paradigm?

Dorelle C. Hinton, Lori Ann Vallis *

Department of Human Health and Nutritional Sciences, University of Guelph, 50 Stone Road E, Guelph, ON N1G 2W1, Canada

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Healthy children ($n = 12$, age 7 years) and young adults ($n = 11$, age 21 years) were asked to perform a bimanual balance and reaching protocol in a seated posture. Subjects balanced a ball on a Frisbee on the non-dominant palm of the hand while reaching with the dominant hand to pick up a toy off the ground. During half of the trials, an auditory Stroop task was administered simultaneous to onset of the participants' reach. All children (CH) and adults (AD) successfully completed both motor and cognitive tasks when combined: the ball and Frisbee were not dropped and cognitive accuracy rate for both groups was 77%. Angular range of motion (ROM) measures indicated that the trunk, upper arm (UA) and forearm (FA) segments were moving as articulated individual segments in both adults and children (ROM for trunk $\neq$ UA $\neq$ FA; $p < .001$). However, differences between CH and AD upper body segmental control were evident: greater variability existed between trials and between subjects for segmental ROM in CH compared to AD ($p < .001$), suggesting that adult-like control is still developing in this age group. Results indicate children aged 7 years can successfully perform a simultaneous upper body motor and cognitive task in a seated posture, however motor performance control is not yet at the same level as adults.

* Corresponding author. Tel.: +1 519 824 4120x54589.
E-mail addresses: dhinton@uoguelph.ca (D.C. Hinton), lvallis@uoguelph.ca (L.A. Vallis).

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1. Introduction

The ability to multitask, whether performing multiple motor tasks, cognitive tasks or a combination of the two, is crucial for the execution of activities of daily living. The ability to integrate complex motor tasks is a learned behavior, developed throughout childhood (Assaiante, 1998; Assaiante, Thomachot, Aurenty, & Amblard, 1998). The dynamic systems theory provides a basic model for infant and child skill acquisition. Coordination and performance of a skilled task requires the interaction between the skill, the task requirements and the environment (Corbetta & Thelen, 1996) For example, in order to maintain balance while learning to stand and eventually walk, infants must learn to negotiate between overall balance control and the destabilizing movements of their body segments.

Development of postural control is thought to originate from a trunk based reference frame (Assaiante, 1998; Assaiante et al., 1998). Classic motor developmental literature has reported that seated infants are able to perform articulated head-trunk movements, by first controlling their head and trunk position and then learning to integrate muscle synergies required for their reach (Assaiante, 1998; Assaiante & Amblard, 1995; Bertenthal & Von Hofsten, 1998). Posture and reaching are highly intertwined as head and trunk stability is critical to reaching performance (Sveistrup, Schneiberg, McKinley, McFadyen, & Levin, 2008). This is also apparent during dual motor tasks while seated: young children under the age of 6 years performing bimanual tasks requiring changes in trunk lean, couple movements of their upper arm and forearm to their trunk. This adapted strategy, termed '*en bloc*' or egocentric control in developmental literature, reduces the degrees of freedom required to maintain balance during the task (Roncesvalles, Schmitz, Zedka, Assaiante, & Woollacott, 2005). Infants first use co-activation muscle synergies to stiffen the trunk and arm to counteract forces moving the arm and hand in the wrong direction (Thelen & Spencer, 1998). By the age of 6–7 years, children are able to reorient the position of their upper arm and forearm to the support surface rather than couple movement of their upper extremity to the orientation of their trunk however their performance continues to show high inter-subject variability (Roncesvalles et al., 2005). Measures of variability (standard deviation) can provide insight into how robust segmental control strategies were from trial to trial for each subject. As motor development matures, variability of performance trial to trial decreases indicating a tighter overall control of movement.

In addition to their motor development stage and age, the difficulty of the task to be performed also plays a role in the selection of control strategies used by a child. For example, postural control studies revealed that children age 7–8 years show independent control of the head, pelvis and shoulder while walking on a flat surface, a relatively easy motor task at this stage of development. However, as the difficulty of the motor task increases, the child's temporal organization regresses to previous stages of balance control. They no longer use an ascending organization but rather switch erroneously between ascending and descending control (Assaiante, Mallau, Viel, Jover, & Schmitz, 2005). Assaiante and colleagues (2005) concluded that at certain transitional periods, the control and coordination of segmental onset and timing seems to be the most challenging to the developing central nervous system (CNS).

Simultaneous to motor development, children are in the process of cognitive development, both in terms of attentional resources and dual tasking capabilities. In a dual-task scenario, each task's demands compete for attentional processing capacities. The decrease in performance of each single task during a dual task performance, expressed as the percentage difference in performance (positive or negative), is known as dual-task cost (DTC). With age, children decrease DTC with simultaneous tasks. In other words, as children age, performance of single tasks does not decrease as considerably when performed at the same time as another task (Guttentag, 1989).

Irwin-Chase and Burns (2000) used a novel approach in their experimental paradigm in order to control for this change in DTC with age, by first controlling for the subject's performance during the single task. The researchers increased the difficulty of the single task (a visual detection task) in a stepwise approach until an 80% accuracy rate was performed and any more increases in difficulty produced a lower accuracy rate. Since there was a significant difference between the difficulty levels reached for the criterion accuracy by the two age groups (8 and 11 years old), using the level at which 80% accuracy was reached allowed for control over the difficulty of the single task before the addition