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Emergence and stability of interlimb coordination patterns in children with developmental coordination disorder

Marcela de Castro Ferracioli *, Cynthia Yukiko Hiraga, Ana Maria Pellegrini

Department of Physical Education, Bioscience Institute, Sao Paulo State University, Rio Claro, SP, Brazil

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ABSTRACT

The purpose of this study was to investigate the emergence and stability of coordination patterns in children with developmental coordination disorder (DCD) when performing a rhythmic interlimb coordination task on rigid (floor) and elastic (mini-trampoline) surfaces. Twelve typically developing (TD) children and 12 children with DCD were required to clap while jumping under different conditions: in a chosen pattern – *Free*; when the feet touched the surface – *Clapping-surface*; when the body reached the maximum jumping height – *Clapping-jump*; and when the feet touched the surface and the body reached the maximum jumping height – *Clapping-both*. The results showed that the coordination pattern of children with DCD was more variable in the *Free*, *Clapping-surface*, and *Clapping-jumping* conditions and more variable on the mini-trampoline than on the floor under the *Free* condition when compared with the TD children. *Clapping-jumping* was more difficult to perform than *Clapping-surface* for both groups. These findings suggest that the children with DCD were less capable of rhythmically coordinating the jumping-clapping task because they used a type of exploratory strategy regarding the physical properties of the surfaces, whereas the TD children used a type of adaptive strategy displaying behavior that was more consistent across the tasks/environmental demands.

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1. Introduction

The acquisition of motor skills is a continuous challenge for children (Geuze, 2007), particularly for those whose coordination is not developing in a typical fashion. A basic motor action might represent a burdensome task rather than play and fun for these children, who gradually tend to withdraw from tasks that include motor coordination demands. The constraints inherited by the constantly changing organism, combined with the constraints specified by the task and the constraints imposed by the environment, define a space of interactions that modulate motor performance (Newell, 1986). A relevant question regarding the performance of these children, who are identified by the *Diagnostic and Statistical Manual of Mental Disorders IV* (APA, 1994) as having developmental coordination disorder (DCD), is how they address the interaction of such constraints to overcome their motor difficulties. Regardless of the motor action and its measure, the performance of children with DCD is consistently described as slower, less accurate and more variable than that of typically developing (TD) children, i.e., those without such disorders (Geuze, 2003, 2007; Huh, Williams, & Burke, 1998; Law, Lo, Chow, & Cheing, 2011).

* Corresponding author at: Rua 5, 1600, Rio Claro 13500-181, SP, Brazil. Tel.: +55 19 3526 4369.
E-mail addresses: marcelaferracioli@gmail.com, mcf@rc.unesp.br (M. de Castro Ferracioli).

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Motor coordination may be characterized by the relationship among body segments that meet task requirements (Haken, Kelso, & Bunz, 1985; Kelso, 1995; Mayville et al., 2001; Volman, Laroy, & Jongmans, 2006). Motor performance in a given task is also greatly influenced by the information available in the environment, particularly the information that the individual captures and considers essential for accomplishing the task goal (Engström, Kelso, & Holroyd, 1996; Mackenzie et al., 2008; Post, Peper, & Beek, 2000; Schoner & Kelso, 1988; Volman & Geuze, 1998; Whitall et al., 2008, 2006). According to the dynamical system approach (Kelso, 1995), the emergence and stability of coordinated patterns with a rhythmic structure reflects the dynamics of the system interacting with the environment (Kudo, Park, Kay, & Turvey, 2006), that is, the coupling between the perception of environmental information and motor action. Little is known about the nature of this coupling in atypical motor behavior, such as in children with DCD.

In studies involving rhythmic coordination patterns, the tempo of oscillator systems (e.g., limbs and fingers) during an action is often constrained by an environmental stimulus (Kudo et al., 2006), such as an auditory metronome pulse (Schoner & Kelso, 1988) or specific starting and ending points of a motor action (Kelso, Fink, DeLaplain, & Carson, 2001). Coordination patterns are identified and classified according to this rhythmical constraint in complex systems (Engström et al., 1996; Kelso, 1981; Von Holst, 1973; Whitall et al., 2006). According to the literature about the stability of rhythmic coordination, children with DCD have difficulty producing bimanual and interlimb coordination patterns compared with TD children (Roche, Wilms-Floet, Clark, & Whitall, 2011; Volman & Geuze, 1998; Volman et al., 2006; Whitall et al., 2008, 2006). In bimanual coordination tasks, children with DCD were more unstable when oscillating their fingers in the *anti-phase* pattern (see Kelso, 1981) than TD children were (Volman & Geuze, 1998). Furthermore, children with DCD were not able to synchronize finger-tapping with the lowest auditory signal frequency (Whitall et al., 2008), and they were less accurate and more variable than their peers at self-selected tapping frequencies (Roche et al., 2011).

In terms of interlimb coordination, Volman et al. (2006) showed that children with DCD were more variable when performing a tapping task with three limb combinations (hand-hand, hand-foot on the same side, and hand-foot on opposite sides) in the *in-phase* and *anti-phase* pattern conditions than TD children were. In addition, Whitall et al. (2006) investigated how adults, children with DCD and TD children synchronize walking and clapping with a metronome pulse at four different frequencies. Their results indicated that the coordination patterns of adults were different than those of both groups of children. The children with DCD showed increased variability in the coupling between limbs compared with TD children and adults, especially when the frequency increased. Similar results were shown by Mackenzie et al. (2008), who analyzed the walking/clapping task under four different information conditions: with vision and hearing; without vision; without hearing; and without vision and hearing. They found no significant differences among the conditions.

The motor behavior of children with DCD may be viewed as lacking the necessary adjustments in the coupling between information perception and motor response, with increased variability of rhythmic coordination patterns, for instance. Taking into account that in exploratory behavior, variability provides great adaptive benefits by allowing the organism to gather information from himself/herself and from the environment (Deutsch & Newell, 2002), the coordination patterns of children with DCD may also benefit from such behavior (Savelsbergh, Van der Kamp, & Rosengren, 2006). It is possible that the variability in interlimb coordination patterns, which require temporal and spatial organization among body segments, will increase as the environment and task constraints are manipulated. It could be predicted that children with DCD would show unstable coordination patterns as a result of the exploratory behavior they engage in while attempting to capture relevant information to achieve their task goal. In addition, it is possible to suggest that motor intervention for these children should consider this type of exploitation, allowing them varying possibilities of action before restricting them to constant practices of the same task. The present study examines the interlimb coordination patterns of children with DCD and these children's ability to respond to different environmental and task characteristics. Specifically, this study focused on the child's ability to maintain a steady relationship between jumping and clapping sequences in different coordination patterns on rigid and elastic surfaces without any imposed frequency.

2. Method

2.1. Participants

Children aged 9–10 years participated in the present study. Twelve children (female $n = 7$, male $n = 5$; 120.3 ± 6.7 months) scoring below to or at the 5th percentile for total impairment on the Movement Assessment Battery for Children (M-ABC) (Henderson & Sugden, 1992) formed the DCD group. Another 12 children matched by age and gender (female $n = 7$, male $n = 5$; 120.3 ± 7.2 months) who scored at or above the 45th percentile for total impairment on the M-ABC constituted the TD group. The parents of the participants gave informed consent for the children's participation as required by the study protocol, which was approved by an Ethics Committee of the University.

2.2. Procedures

The participants were required to perform a sequence of vertical jumps combined with claps for 15 s under four different conditions: (i) *Free*, jumping and clapping freely; (ii) *Clapping-surface*, one clap when both feet landed on the surface after one vertical jump; (iii) *Clapping-jumping*, one clap at the maximum height of the vertical jump; and (iv) *Clapping-both*, one clap when both feet landed on the surface and one clap at the maximum height of the vertical jump. The four conditions were

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