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Development of motor planning for dexterity tasks in trisomy 21

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ABSTRACT

We examined the macroscopic aspects of motor planning in two manual dexterity tasks, comparing children, adolescents, and young adults with trisomy 21 (T21) with typically developing controls from a developmental perspective. We analyzed the order in which objects were picked up from a table during two manual tasks of the Movement Assessment Battery for Children (M-ABC). Participants with T21 were always slower than controls. Task completion times depended on the strategy used by participants to gather up the pegs or coins. A structured strategy, in which the participants picked the items up moving methodically along each row/column, contributed to rapid task completion by younger children and participants with T21. This study highlights the ability of children with T21 to select and maintain an efficient strategy that takes account of their motor difficulties. Developmental trajectories help to explain T21 functioning in these dexterity tasks.

1. Introduction

Full trisomy 21 (T21), often referred to as *Down syndrome*, remains the major genetic cause of intellectual disability (Carlier & Roubertoux, 2014; Roubertoux & Kerdelhue, 2006; Sherman, Allen, Bean, & Freeman, 2007). The great majority of people with T21 exhibit mild to severe levels of intellectual impairment and a wide range of associated physical, medical, and cognitive deficits (Davis & Escobar, 2011).

The development of gross and fine motor skills in children with T21 has been shown to be both slower and defective as compared to typically developing (TD) children (Mazzone, Mugno, & Mazzone, 2004; Palisano et al., 2001; Spano et al., 1999; Volman, Visser, & Lensvelt-Mulders, 2007; Weeks, Chua, & Elliott, 2000). Specific body and brain characteristics, as well as hypotonia or impaired manual laterality, probably all contribute to this atypical development (Carlier et al., 2011; Lauteslager, Vermeer, & Helder, 1998; Savelsbergh, van der Kamp, & Davis, 2001). Furthermore, because this chromosomal disorder affects not just physical but also cognitive development, intellectual disability may also impair goal representation, decision making, response selection, action planning, and ultimately contribute to poorer motor performances. The development of motor coordination is known to result from adaptation, and therefore depends on the characteristics of the individual child with T21 (e.g. morphology, muscle tone, intellectual disability; Latash, 2000; Virji-Babul & Latash, 2008), just as it does in TD children.

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Many studies have investigated fine motor development in T21, focusing on the movements' microscopic or macroscopic features. Using 3D motion analysis, some studies have yielded knowledge on motor programming, that is, the microscopic aspects of movement. For instance, children with T21 have been shown to exhibit atypical movement kinematics when reaching for an object. In 5- to 7-month-old children with T21, Cadoret and Beuter (1994) observed less straightness in hand trajectory during reaching than in TD children. de Campos, Rocha, and Savelsbergh (2010) and de Campos, Francisco, Savelsbergh, and Rocha (2011) confirmed this result in a longitudinal protocol with 4- to 6-month-old children. Kearney and Gentile (2003) also observed variable and awkward reaching movements in 3-year-old children with T21. In older groups (8–10 years), Charlton, Ihsen, and Oxley (1996), Charlton, Ihsen, and Lavelle (2000) reported that reaching movements were slower, more jerky, and more variable in children with T21 than in TD children, the former spending more time on deceleration than the latter. Taken together, these results suggest that children with T21 have a deficit in the feedforward control of reaching.

In our everyday actions, we also make large-scale plans about behavior. *Motor planning* and *action sequencing* are the terms that are usually used to address these macroscopic aspects of motor control (Rosenbaum & Jorgensen, 1992). These plans involve the ability to organize movement units into a coordinated motor response in order to meet a specific goal in a specific context, such as adjusting a handgrip to a particular task or avoiding an uncomfortable body posture in the final part of a movement (e.g. end state comfort, Haggard, 1998; Rosenbaum & Jorgensen, 1992). The end-state comfort effect refers to the fact that, when manipulating objects, adults, but also children around five years (Weigelt & Schack, 2010), tend to adjust the orientation of their grip, i.e., the orientation of the hand relative to the object to be displaced, to future manipulations. Many studies looking at grasping development in individuals with T21 have drawn attention to the fact that children with T21 sometimes exhibit grasps that do not belong to the typical repertoire (e.g. thumb – middle finger grasp), and their grasping follows an atypical developmental trend (Hogg & Moss, 1983; Jover, Ayoun, Berton, & Carlier, 2010; Thombs & Sugden, 1991). However, when object properties and task goals are changed, children with T21 are able to adapt their handgrip, that is, to plan a movement according to the nature of the object/task. This observation is true, whether the children are aged 3–6 months (de Campos et al., 2011), 3–11 years (Savelsbergh et al., 2001), or 8–10 years (Charlton et al., 1996, 2000), albeit with considerable interindividual differences.

Furthermore, these large-scale motor plans involve the linking of movement units, that is, the combination of the various subunits of a given skill in order to make it smoother and more rapid when, say, fitting pegs into holes (Connolly, 1970; Elliott & Connolly, 1974). In this modular approach, once a skill has been mastered, subroutines can be inserted into new action plans (Elliott & Connolly, 1974). Little is known about these aspects of motor planning in individuals with T21. Moss and Hogg (1987) specifically explored this question by getting children to perform a task where they had to turn or move a rod to which a shape had been attached, in order to insert it into the corresponding hole. Children with T21 with a mental age of 22–60 months displayed a reduced ability to develop an integrated sequence of movements as part of a motor plan. More recently, Mellier and Eloy (1998) explored the early development of action sequencing in children aged 7–33 months who were asked to take a spoon, fill it with fish food, and bring it to a goldfish in an aquarium. The authors showed that the children with T21 mastered the task (time needed to take the spoon and fill it, hand orientation during food transfer, etc.) and planned it as a whole later than chronological age-matched children, but not later than developmental age-matched children. It is thus not clear whether children with T21 are slow in completing multiple-step tasks because of difficulty integrating different motor programs.

We examined the macroscopic aspects of motor planning in a manual dexterity task in children, adolescents, and young adults with T21. In an extension of a previous study of motor planning (Jover et al., 2010), we explored the gathering strategies implemented during two manual tasks of the Movement Assessment Battery for Children (M-ABC): Posting coins and Placing pegs (Henderson & Sugden, 1992). We expected task completion times to depend on whether the participants used a step-by-step strategy to pick up the pegs or coins, or whether they gathered them all in one go. We further expected the former strategy, reflecting poorer motor planning and leading to longer task completion times, to be more often implemented by the children, adolescents, and young adults with T21. Finally, we used developmental trajectories to explain T21 functioning in these dexterity tasks (Thomas et al., 2009).

2. Methods

2.1. Participants

Twenty-eight children, adolescents, and adults with full T21, aged 61–233 months (5–19.4 years), took part in the study. They were contacted through the Trisomie 21 France association, which supports the study. The participants' cognitive level was estimated using nonverbal tests: the Triangles subtest of the Kaufman Assessment Battery for Children (K-ABC, Kaufman & Kaufman, 1993), the Practical Adaptation subtest of the Differential Scales of Intellectual Efficiency (EDEI-R; Perron-Borelli, 1996), and Raven's Colored Progressive Matrices (CPM; Raven, Court, & Raven, 1998). They were screened either by their family special needs worker or by the authors of the paper. Their mental ages ranged from below 24 months to 96 months (Table 1). Twenty-eight age-matched TD participants aged 58–225 months (4.8–18.7 years) were included in the comparison group. They were all enrolled in a regular curriculum and were assessed in their own homes. Participants were matched on their chronological age, on a case-by-case basis, with a difference of no more than six months up to 10 years, and a difference of no more than ten months after 10 years. Prior to the experiment, all legal guardians gave their written informed consent