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Action planning and position sense in children with Developmental Coordination Disorder

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ABSTRACT

The present study examined action planning and position sense in children with Developmental Coordination Disorder (DCD). Participants performed two action planning tasks, the sword task and the bar grasping task, and an active elbow matching task to examine position sense. Thirty children were included in the DCD group (aged 6–10 years) and age-matched to 90 controls. The DCD group had a MABC-2 total score ⩽5th percentile, the control group a total score ⩾25th percentile. Results from the sword-task showed that children with DCD planned less for end-state comfort. On the bar grasping task no significant differences in planning for end-state comfort between the DCD and control group were found. There was also no significant difference in the position sense error between the groups. The present study shows that children with DCD plan less for end-state comfort, but that this result is task-dependent and becomes apparent when more precision is needed at the end of the task. In that respect, the sword-task appeared to be a more sensitive task to assess action planning abilities, than the bar grasping task. The action planning deficit in children with DCD cannot be explained by an impaired position sense during active movements.

1. Introduction

Action planning is an important feature of daily life and involves behavior that depends on learned movement skills (Cohen & Rosenbaum, 2004; Rosenbaum, van Heugten, & Caldwell, 1996). Action planning with regard to grasping an object can be defined as the ability to take into account the task demands of the movement and its goal when first taking hold of the item (e.g., Johnson-Frey, McCarty, & Keen, 2004). Rosenbaum et al. (1990), Rosenbaum and Jorgensen (1992), Rosenbaum, Vaughan, Jorgensen, Barnes, and Stewart (1993) and Rosenbaum et al. (1996) have used several object manipulation tasks that evaluate the type of grip selected by participants (e.g. overhand vs. underhand) when asked to perform a two-stage task (e.g. grasp-and-turn). In these tasks, adults prefer to make a less comfortable initial grasp if this allows them to end in a comfortable posture; this is referred to as the end-state comfort effect (ESC). The ESC effect is the tendency to ensure a comfortable position at the end rather than at the beginning of simple object manipulation tasks. The advantage of ending

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in a comfortable posture is that it allows more precision to be exerted at the end of the task (Short & Cauraugh, 1999). As such, the grip types employed at the start and end of the task can be used to assess action planning (Craje, Aarts, Nijhuis-van der Sanden, & Steenbergen, 2010; Rosenbaum, Meulenbroek, Vaughan, & Jansen, 2001). Several studies have examined the ESC effect in adults (e.g. Cohen & Rosenbaum, 2004; Rosenbaum et al., 2001) and typically developing (TD) children (Jongbloed-Pereboom, Nijhuis-van der Sanden, Saraber-Schiphorst, Craje, & Steenbergen, 2013). The majority of studies showed an increased occurrence of the ESC effect with development (Janssen & Steenbergen, 2011; Stockel, Hughes, & Schack, 2012; Thibaut & Toussaint, 2010; van Swieten et al., 2010; Weigelt & Schack, 2010). Less efficient planning for ESC, might result from difficulties with the use of predictive motor control (Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013). In children with Developmental Coordination Disorder (DCD), some studies showed that these children are more likely to select an initial comfortable grip, instead of planning for ESC (van Swieten et al., 2010; Wilmut & Byrne, 2014).

Children with DCD show motor performance that is substantially below expected levels, given the child's chronologic age and previous opportunities for skill learning (American Psychiatric Association, 2013). A viable hypothesis to explain impaired motor control in children with DCD, is the internal modeling deficit (IMD) hypothesis (Adams, Lust, Wilson, & Steenbergen, 2014; Wilson & Butson, 2007). According to the IMD hypothesis, children with DCD have a reduced ability to use predictive motor control (Wilson et al., 2013). During action planning tasks, this predictive motor control (based on information from internal models) is needed to anticipate the end state of a movement. The present study examined action planning in children with DCD and a control group by using two grasping tasks. In addition, the position sense of children with DCD and a control group was compared, as this is one major component of proprioception on which an internal model about the limb position at the end of a movement and subsequent initial grip choice can be built (Capaday, Darling, Stanek, & van Vreeswijk, 2013).

Internal models of movements are constructed in order to provide predictions about the sensory feedback of a movement and to enhance the processing of sensory information. When a motor plan is initiated, the motor cortex generates a motor command that is relayed to the body via descending corticospinal tracts (Tresilian, 2012). An efference copy of this motor command is generated in parallel as a corollary discharge and relayed to parieto-cerebellar and parieto-frontal networks (Wolpert, 1997). This efference copy is used to compose an internal model of the movement, which is used for anticipatory action planning. During the planning and execution of actions, the left-lateralized network is chiefly activated in the brain, including parietal and frontal areas and areas of the ventral stream in addition to the primary sensorimotor areas (Brandi, Wohlschlager, Sorg, & Hermsdorfer, 2014; Gallivan, McLean, Valyear, & Culham, 2013; Hermsdorfer, Terlinden, Muhlau, Goldenberg, & Wohlschlager, 2007).

The ESC effect has been examined in children with DCD in four studies (Noten, Wilson, Ruddock, & Steenbergen, 2014; Smyth & Mason, 1997; van Swieten et al., 2010; Wilmut & Byrne, 2014) but showed conflicting results because some studies showed an impaired ability to plan for ESC in the DCD group only, while other studies found no differences between DCD and TD groups. Based on the IMD hypothesis, we expected that children with DCD would have difficulties with planning for ESC. They are more likely to select an initial comfortable grip compared to typically developing children, instead of planning to end in a comfortable position in which they then finish their goal directed action more accurately. Smyth and Mason (1997) showed no difference in grip selection between a DCD and control group, using a handle rotation task and a bar grasping task in children aged 4–8 years. Similar results were found in the study of Noten et al. (2014) in which a bar grasping task was used to assess planning for ESC. Both groups of children (DCD and control), aged 7–12 years demonstrated an ability to plan their actions according to the ESC effect. In contrast, van Swieten et al. (2010), found a difference in grip selection between children with DCD, aged 6–13 years and an age-matched control group. In this study, a handle rotation task was used and children with DCD were biased toward selecting the simplest initial movement (minimal rotation) instead of planning for ESC. Wilmut and Byrne (2014) showed that both children and adults with DCD are able to plan some movements for ESC. In that study subjects had to rotate a disc so that an arrow pointed toward a specific target. Task complexity was increased by increasing the number of targets to be pointed to from 1 to 3. However, in more complex movements, neither adults with DCD nor children with DCD were able to plan for ESC as efficiently as their TD peers. It can be assumed that the level of task difficulty is an important factor when examining the ESC effect. The precision hypothesis states that ESC effect should be small or even absent when precision requirements in the end-state are low (Rosenbaum et al., 1996) and it is probable that differences in action planning between DCD and control are then not elicited. This might explain the differences in findings among studies. Two often-used action planning tasks in children are the bar grasping task (Craje, van der Kamp, & Steenbergen, 2009; Noten et al., 2014) and the sword task (Craje et al., 2010; Jongbloed-Pereboom et al., 2013). Although both tasks appear similar, several important differences are evident. The first difference relates to the target movement in the sword task, which has to be more precise than in the bar grasping task, because in the sword task, the fit of the thin blade in the wooden box is tighter than the fit of the bar in the cylinder in the bar grasping task. Second, the grip is different because to be able to pick up the sword and subsequently reach a comfortable end position the wrist has to be moved in an ulnar abduction (Parsons, 1987), whereas in the bar grasping task, a fist grip can be used and only pronation and supination of the forearm are needed while executing the task. Performance on these two action planning task by a DCD and a control group was compared in the present study in order to examine which task is most sensitive to group differences. We expected that the higher precision demands in the sword task would elicit more pronounced group differences between the DCD and control group than in the bar grasping task.

Poor sense of body movement and position has been reported as one of the possible perceptual factors related to poor motor coordination in children with DCD (Bairstow & Laszlo, 1981; Coleman, Piek, & Livesey, 2001; Smyth & Mason,