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Motor imagery difficulties in children with Cerebral Palsy: A specific or general deficit?

Jessica M. Lust[a,*], Peter H. Wilson[b], Bert Steenbergen[a,b]

[a] Radboud University Nijmegen, Behavioural Science Institute, P.O. Box 9104, 6500 HE Nijmegen, The Netherlands
[b] Australian Catholic University, School of Psychology, Melbourne 3065, VIC, Australia

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ABSTRACT

Aim: The aim of this study was to examine the specificity of motor imagery (MI) difficulties in children with CP.
Method: Performance of 22 children with CP was compared to a gender and age matched control group. MI ability was measured with the Hand Laterality Judgment (HLJ) task, examining specifically the direction of rotation (DOR) effect, and the Praxis Imagery Questionnaire (PIQ).
Results: In the back view condition of the HLJ task both groups used MI, as evidenced by longer response times for lateral compared with medial rotational angles. In the palm view condition children with CP did not show an effect of DOR, unlike controls. Error scores did not differ between groups. Both groups performed well on the PIQ, with no significant difference between them in response pattern.
Conclusion and implication: The present study suggests that children with CP show deficits on tasks that trigger implicit use of MI, whereas explicit MI ability was relatively preserved, as assessed using the PIQ. These results suggest that employing more explicit methods of MI training may well be more suitable for children with CP in rehabilitation of motor function.

What this paper adds

1. This paper presents the first study to compare explicit and implicit MI ability in the same group of children with CP.
2. Deficits in MI that are specific to the implicit mode of control are highlighted in children with CP.
3. Results suggest that children with CP may benefit from rehabilitation techniques that utilize the explicit forms of MI.

1. Introduction

Cerebral Palsy (CP) is the most common cause of childhood disability (Cans, 2000) with a prevalence of approximately 2/1000 live births (e.g. Blair & Watson, 2006; Johnson, 2002; Stanley, Blair, & Alberman, 2000). The underlying disorder of movement and posture is attributed to non-progressive disturbances in the development of the neuromotor system during the foetal or infant period (Rosenbaum et al., 2007). The impact of CP on activities of daily living is profound, with much debate still on the nature of the motor control and cognitive deficits that contribute to impaired function. In the present paper

* Corresponding author.
E-mail address: j.lust@pwo.ru.nl (J.M. Lust).

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we examined the issue of motor imagery (MI) in CP, reflecting the ability to represent movement parameters internally. To advance our knowledge of those aspects of MI that are impaired in children with CP, we used both a hand laterality judgment task enlisting implicit MI and a subjective MI questionnaire enlisting explicit MI.

To address the movement problems of CP, children regularly participate in rehabilitative activities aimed at improving the execution of motor actions (Koman, Smith, & Shilt, 2004; Sakzewski, Ziviani, & Boyd, 2014). There is moderate to strong evidence for the effectiveness of several intensive physical therapy interventions in CP (reviewed in Anttila, Autti-Rämö, Suoranta, Mäkelä, & Malmivaara, 2008; Sakzewski et al., 2014). However, there is converging evidence that the motor deficits in these children are not related solely to problems in the (overt) motor execution of movement but may also derive from problems in cognitive processes that precede action, e.g., MI, a core aspect of motor simulation (Steenbergen, Jongbloed-Pereboom, Spruijt, & Gordon, 2013). MI is regarded as an internal (multimodal) representation of a prospective action, performed under varying levels of conscious control (Vogt, Di Rienzo, Collet, Collins, & Guillot, 2013). MI is experienced as an embodied phenomenon, with visuospatial, somatic, timing and force parameters that are normally associated with overt movement also preserved (Vogt et al., 2013). MI can be generated purely in an imaginary context or with reference to the immediate environment; as such, it serves both motor planning and decision making over various timescales. In neurocomputational terms, MI is thought to be a function of internal modelling (e.g. Jeannerod & Decety, 1995; Steenbergen, Crajé, Nilsen, & Gordon, 2009; Steenbergen & Gordon, 2006; Van Elk et al., 2010).

Internal forward models of movement are necessary for skilled actions. This is particularly true of those movements performed under tight temporal and spatial constraints as neural transmission times through sensory feedback loops are inherently slow (Flanagan, Vetter, Johansson, & Wolpert, 2003; Kawato, 1999). Forward models are a core part of the motor system, generated as a corollary of motor commands emanating from premotor regions. More precisely, efference copy signals are used as an input for (forward) model estimation. Forward models are processed along fast visuomotor channels and act as a template against which real-time feedback can be compared and limb adjustments can be made should unexpected perturbations occur, whether they be visual, kinaesthetic or other (Flanagan et al., 2003; Kawato, 1999). Structures underpinning this intricate system of control have been confirmed in neuroimaging, neurophysiological and neuropsychological investigations, and involve reciprocal connections between prefrontal, posterior parietal and cerebellar cortices (Shadmehr & Krakauer, 2008).

A deficit of internal modelling may interfere with the ability to adequately prepare and control a movement and is hypothesized to underlie motor execution problems in children with other neurodevelopmental disorders like Developmental Coordination Disorder (DCD; see the internal modelling deficit (IMD) hypothesis, Adams, Lust, Wilson, & Steenbergen, 2014; Wilson & Butson, 2007; Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013). Like DCD, evidence for an internal modelling deficit in CP comes from studies of MI, specifically those on anticipatory planning and mental rotation (reviewed in Steenbergen & Gordon, 2006; Steenbergen et al., 2013). MI is an embodied process that involves the ability to mentally simulate movements from a first person perspective (Jeannerod, 1994, 1995). MI is both pervasive and important, used when watching somebody else's actions with the intention to imitate, mentally rehearsing a to-be-performed skill, anticipating the effect of a motor action or preparing a movement (Jeannerod, 1995; Toussaint, Tahej, Thibaut, Possamai, & Badets, 2013; Fuelscher, Williams, Enitcott, & Hyde, 2015; Noten, Wilson, Ruddock, & Steenbergen, 2014). Studies on anticipatory planning in CP (Steenbergen & Gordon, 2006; Steenbergen et al., 2013) have been particularly instructive. Prospective judgment tasks, for example, show that when executing a grasp-to-turn movement, children with CP do not always adjust their initial grip type prospectively in order to prevent an uncomfortable posture at the end of the movement, i.e. these children do not generally show the end-state comfort effect as described by Rosenbaum and Jorgenson (Rosenbaum & Jorgensen, 1992). Prospective judgment tasks are a strong marker of forward modelling – they enlist a process of action simulation before response initiation (Adams et al., 2014).

Impaired MI in CP is also shown in mental rotation tasks (Crajé et al., 2010). In these tasks, the ability to accurately represent movement internally is inferred by the ability to imagine movements or postures that conform to the biomechanical constraints of an action performed overtly (Jeannerod, 1995). An often used paradigm to measure (implicit) MI ability is Parson's Hand Laterality Judgment task (HLJ task, e.g. Parsons, 2001). Here subjects are asked to judge the laterality of pictures of rotated hands displayed on a computer screen; judgments can be made *without* explicit reference to the use of imagery. For typically developing children differences in response time are observed between stimuli that require biomechanically efficient/"easy" (medial) hand rotations and those requiring more awkward (lateral) rotations (e.g. De Lange, Hagoort, & Toni, 2005; Parsons & Fox, 1998; Parsons, 1987, 1994; Ter Horst, Van Lier, & Steenbergen, 2010). Absence of this difference (or direction of rotation, i.e. DOR) effect in CP indicates that participants do not use an MI strategy to solve the hand laterality task (Steenbergen et al., 2013; Williams et al., 2011).

Whereas there is good evidence of impaired MI in CP, we know little about the specificity of this deficit—i.e., is it a general deficit or is it confined to actions generated implicitly by limb-related stimuli? This is an important question as MI training has been reported as a tool for rehabilitation of movement in adults (Munzert, Lorey, & Zentgraf, 2009; Schuster et al., 2011) and for children with motor execution problems (Steenbergen et al., 2009; Wilson et al., 2013; Wilson, Thomas, & Maruff, 2002). Knowledge of those aspects of MI most affected in CP could inform both theoretical models of (atypical) motor control and how imagery training might be optimized in this population.

In the study presented here we addressed three questions about the nature and specificity of the imagery deficit in CP: First, we examined the DOR effect to test for difficulties in the implicit use of MI in the present sample of children with CP. Second, we examined whether implicit MI difficulties in CP extend to explicit forms of MI. The latter requires that