Research in Developmental Disabilities 34 (2013) 4154–4160

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Assessment of motor imagery in cerebral palsy via mental chronometry: The case of walking

Steffie Spruijt [a,*], Francois Jouen [b], Michèle Molina [c], Cyril Kudlinski [c], Jessica Guilbert [c], Bert Steenbergen [a]

[a] Radboud University Nijmegen, Behavioural Science Institute, PO Box 9104, 6500 HE Nijmegen, The Netherlands
[b] Laboratoire Cognitions Humaine et Artificielle, Ecole Pratique des Hautes Etudes, 75005 Paris, France
[c] Laboratoire Psychologie des Actions Langagières et Motrices, Université de Caen, 14032 Caen, France

ARTICLE INFO

Article history:
Received 5 July 2013
Received in revised form 29 August 2013
Accepted 30 August 2013
Available online 26 September 2013

Keywords:
Motor imagery
Mental chronometry
Cerebral palsy
Walking

ABSTRACT

Recent studies show varying results on whether motor imagery capacity is compromised in individuals with cerebral palsy (CP). Motor imagery studies in children predominantly used the implicit hand laterality task. In this task participants judge the laterality of displayed hand stimuli. A more explicit way of studying motor imagery is mental chronometry. This paradigm is based on the comparison between the movement durations of actually performing a task and imagining the same task. The current study explored motor imagery capacity in CP by means of mental chronometry of a whole body task. Movement durations of 20 individuals with CP (mean age = 13 years, SD = 3.6) were recorded in two conditions: actual walking and imagined walking. Six unique trajectories were used that varied in difficulty via manipulation of walking distance and path width. We found no main effect of condition (actual walking versus imagining) on movement durations. Difficulty of the walking trajectory did affect movement durations. In general, this was expressed by an increase in movement durations with increasing difficulty of the task. No interaction between task difficulty and movement condition was found. Our results show that task difficulty has similar effects on movement durations for both actual walking and imagined walking. These results exemplify that the tested individuals were able to use motor imagery in an explicit task involving walking. Previous studies using the implicit hand laterality task showed varying results on motor imagery capacity in CP. We therefore conclude that motor imagery capacity is task dependent and that an explicit paradigm as the one used in this study may reveal the true motor imagery capacity. The implications of these findings for the use of motor imagery training are discussed.

1. Introduction

Individuals with cerebral palsy (CP) have compromised motor behavior, due to congenital disturbances in the brain (Bax, Goldstein, Rosenbaum, Leviton, & Paneth, 2005). One facet of this compromised motor behavior is an impaired motor planning ability which is proposed to be related to an impaired ability to use motor imagery (i.e. Mutsaarts, Steenbergen, & Bekkering, 2006). Motor imagery is the mental simulation of a motor act, without any overt motor execution (Decety, 1996). Motor imagery is related to motor representations that are involved in planning and controlling movements. According to

* Corresponding author. Tel.: +31 243612148.
E-mail address: s.spruijt@pwo.ru.nl (S. Spruijt).

0891-4222/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ridd.2013.08.044

Jeannerod (1994), these motor representations may be regarded as the conscious experience of internal models of intended motor actions. As such, they have a distinctive role in the feed-forward planning and control of movements.

In addition to studies reporting that motor planning is affected in individuals with CP (Crajé, Aarts, Nijhuis-van der Sanden, & Steenbergen, 2010), lines of empirical evidence suggest that the capacity to use motor imagery may be impaired in CP (Crajé, van Elk et al., 2010). Thus far, motor imagery capacity in adolescents with CP was generally studied by means of a hand laterality task. In this task, a judgment on the laterality of a displayed hand stimulus has to be made as quickly as possible via a button press. The task was designed to elicit implicit motor imagery. That is, in order to judge the laterality of the hand stimulus, participants have to imagine rotating their own hands. In the hand laterality task, the reaction time profiles are the main outcome measures to reflect motor imagery capacity. The use of motor imagery is indicated when characteristics that affect actual movements, similarly affect the imagined task. For instance, in studies with adults and typically developing children it was shown that the reaction times increased with an increasing rotation angle away from the canonical orientation of the presented hand stimulus (i.e. Funk, Brugger, & Wilkening, 2005; Parsons, 1994). In addition, reaction times to hand stimuli in orientations that are biomechanically more demanding were longer, compared to those in less demanding orientations. To exemplify, medially oriented hand stimuli are biomechanically easier to perform and judgment of these hands resulted in shorter reaction times, compared to judging laterally oriented hand stimuli (i.e. Caeyenberghs, Tsoupas, Wilson, & Smits-Engelsman, 2009). The combined behavioral effects of rotation angle and biomechanical constraints of the hand stimuli on the reaction time profiles are crucial to draw conclusions on motor imagery ability (ter Horst, van Lier, & Steenbergen, 2010).

The results on the hand laterality task to study motor imagery capabilities in individuals with CP are equivocal. In two studies, the effect of rotation angle on reaction times was considered (Mutsaarts, Steenbergen, & Bekkering, 2007; Steenbergen, van Nimwegen, & Crajé, 2007). In the study of Mutsaarts et al. (2007) it was shown that the group of individuals with hemiplegia on the left body side displayed the expected effect of longer reaction times for hand stimuli with larger rotation angles, but this effect was not found for the group with right-sided hemiplegia. In contrast, Steenbergen et al. (2007) reported an overall effect of rotation angle on reaction times for both left- and right-side affected CP. Next to the effect of rotation angle on the reaction time profile, other studies also examined the effect of biomechanical constraints on reaction times in CP. These studies also showed equivocal results. In one study, adolescents with right-sided hemiplegic CP did not show an effect of medially versus laterally oriented hand stimuli (Crajé, van Elk et al., 2010), while other studies did observe an effect of biomechanically constraining orientations on reaction times in children with both left- and right-side affected CP (Williams, Anderson et al., 2011; Williams, Reid, Reddihough, & Anderson, 2011). Collectively, these studies do not allow a definite conclusion as to whether motor imagery capacity is compromised in CP.

An essential feature of the hand laterality task is that it, in principle, implicitly elicits motor imagery. We argue that this task may therefore not be most suitable to assess motor imagery capacity in individuals with CP. It is known that these individuals have impaired sensorimotor integration (Gordon, Charles, & Steenbergen, 2006), which may lead to a decreased body awareness. In motor imagery, however, body awareness is critical as the individual produces a kinesthetic image of the motor action. It may be suggested that an explicit way of assessing motor imagery capacity, as is the case in mental chronometry tasks, may facilitate body awareness and consequently motor imagery. Indirect evidence for this suggestion stems from research using the hand laterality task (Sirigu & Duhamel, 2001). Sirigu and Duhamel (2001) showed that explicit instruction facilitates the use of motor imagery in this task. Specifically, participants were instructed to rotate the hand from a ‘first-person’ perspective (motor imagery), or from a ‘third-person’ perspective (alternative imagery strategy). During the task, participants placed their hand on the lap or behind the back. Sirigu and Duhamel found that posture had an effect on response times only when participants were instructed to rotate the hand from a ‘first-person’ perspective. Importantly, these results suggest that participants were able to use motor imagery, but this capacity was ‘hidden’ when no explicit motor imagery instructions were provided in the hand laterality task.

In the mental chronometry task, the instruction to perform the movement from a first person perspective forms an essential element of the experimental paradigm. Therefore, this task may be better suited to assess true motor imagery capacity in individuals with CP (see Williams, Anderson, Reid, & Reddihough, 2012). In a study using this paradigm in typically developing children, Caeyenberghs, Wilson, van Roon, Swinnen, and Smits-Engelsman (2009) considered temporal congruence between an actual motor task and imagining this motor task and the effect of task difficulty (as manipulated via Fitts’ law, 1954) on movement durations. Movement durations for both conditions were congruent. Furthermore, task difficulty not only affected movement durations of the actual performance, but similarly influenced imagined movement durations. As the combination of these results indicated that imagery of the motor task was similarly affected by task constraints as the actual motor task, this led to the conclusion that the children in this study were able to use a motor imagery strategy to perform the task.

Thus far, the mental chronometry paradigm was used only once to study motor imagery capacity in CP. Williams et al. (2012) reported that the movement durations of performed and imagined finger pointing movements were in line with Fitts’ law in both a control group and in a group of children with right-sided hemiplegic CP. For children with an affected left body side however, only actual performance was in line with Fitts’ Law. No lawful relationship between movement durations and task difficulty was found in the imagery condition. This indicates that these children did not use a motor imagery strategy to perform the imagery task. Note that Williams et al. (2012) reported an affected motor imagery capacity in left-sided hemiplegics (i.e. primarily right hemisphere damage), which is in contrast with earlier reported findings on the hand laterality task that motor imagery capacity is compromised in right-sided hemiplegics (Mutsaarts et al., 2007). According to