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Motor imagery for walking: A comparison between cerebral palsy adolescents with hemiplegia and diplegia

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ABSTRACT

The goal of the study was to investigate whether motor imagery (MI) could be observed in cerebral palsy (CP) participants presenting a bilateral affected body side (diplegia) as it has been previously revealed in participants presenting a unilateral body affected sided (hemiplegia). MI capacity for walking was investigated in CP adolescents diagnosed with hemiplegia ($n = 10$) or diplegia ($n = 10$) and in adolescents with typical motor development ($n = 10$). Participants were explicitly asked to imagine walking before and after actually walking toward a target located at 4 m and 8 m. Movement durations for executed and imagined trials were recorded. ANOVA and Pearson's correlation analyses revealed the existence of time invariance between executed and imagined movement durations for the control group and both groups of CP participants. However, results revealed that MI capacity in CP participants was observed for the short distance (4 m) but not for the long distance (8 m). Moreover, even for short distance, CP participants performed worse than typical adolescents. These results are discussed inline of recent researches suggesting that MI in CP participants may not depend on the side of the lesion.

1. Introduction

Motor disorders in individuals with cerebral palsy (CP) are kwown to induce deficit in motor anticipatory planning (Crajé et al., 2010; Mutsaarts, Steenbergen, & Meulenbroek, 2004; Mutsaarts, Steenbergen, & Bekkering, 2005, 2006) which, in turn, has been be related to impaired ability to use motor imagery (i.e. Mutsaarts et al., 2006). Motor imagery (MI) is the mental simulation of a motor act, without any overt motor execution and thus refers to the capacity to produce kinesthetic representations of motor actions (Decety, Jeannerod, & Prablanc, 1989). MI would be used to predict the proprioceptive consequences of an action and then contribute to movement planning (Grush, 2004; Papaxanthis, Pozzo, Skoura, & Schieppati, 2002).

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Various studies conducted in adult participants without brain damaged (Schluter, Krams, Rushworth, & Passingham, 2001) and with left hemispheric stroke (Rushworth, Nixon, Wade, Renowden, & Passingham, 1998) have corroborated a left cerebral dominance for movement planning. In line with these studies, MI capacity in CP participants has been mainly investigated in hemiplegic cerebral palsy (HCP) with the idea that right HCP with left brain damage would be impaired in MI (Mutsaarts, Steenbergen, & Bekkering, 2007). Most of these studies have used a hand laterality task that addresses implicit MI: a judgment on the laterality of a displayed hand stimulus has to be made as quickly as possible. In this kind of tasks, participants are not explicitly instructed to imagine the rotation of their own hand to judge the laterality of the hand stimulus presented. MI is deduced from the recorded reaction times profiles: reaction times are expected to vary according to the rotation angle and to biomechanical constraints of the hand stimuli (Horst, Van Lier, & Steenbergen, 2010). Studies have led to non-converging conclusions concerning the capacity of individuals with hemiplegia on the left or the right body side to perform MI implicit tasks. For instance, Mustaarts et al. (2007) reported a linear increase in reaction time as a function of angle rotation of the hand in left hemiparetic individuals (right brain-damaged) but not in right hemiparetic individuals (left brain-damaged). In contrast, Steenbergen, van Nimwegen, and Crajé (2007) failed to find differences in reaction times in individuals with hemiplegia on the left body side or on the right body side. Increasing biomechanical constraints modify reaction time in CP children with both left- and right-side affected (Williams, Anderson, et al., 2011; Williams, Reid, Reddihough, & Anderson, 2011) but yet another study indicated that reaction time was not affected in CP adolescents with right-sided hemiplegia (Crajé et al., 2010).

Studies using explicit MI tasks have led to more convergent results. Explicit MI tasks are supposed to increase body awareness, and consequently help participants to use MI (Spruijt et al., 2013). These tasks are based on the mental chronometry paradigm: participants are asked to move and to imagine moving themselves (or a body part), from a first person perspective, toward targets located at different distances. The durations of both, the actual and imagined movements are then compared. When participants use MI, they preserve the temporal unfolding of displacement when asked to imagine acting: a temporal invariance between executed and imagined movement durations is consequently observed. The results obtained with typical participants commonly revealed the existence of a temporal invariance between overt and covert movement whatever the distance to be performed. The mental chronometry paradigm has also been used in a finger-pointing task to targets varying in size with typically developing children (Caeyenberghs, Wilson, van Roon, Swinnen, & Smits-Engelsman, 2009) and in children with hemiplegic cerebral palsy (Williams, Anderson, Reid, & Reddihough, 2012). These studies have revealed that the duration of performed and imagined movements is congruent with Fitts' law (Fitts, 1954): The time required to rapidly move or imagine moving to a target area is a function of the distance to the target and the size of the target both, in typically developing children (Caeyenberghs et al., 2009) and in right-sided HCP children, but not in HCP children with left-sided hemiplegia (Williams et al., 2012). According to Williams et al. (2012), this last result which is in sharp contrast with implicit hand task studies reporting compromised MI ability in right-sided but not in left-sided hemiplegic participants (Mustaarts et al., 2007), reveals that the side of hemiplegia alone is not an indicator of MI performance. This important conclusion has received some additional support from a recent study conducted by Spruijt et al. (2013), in which walking was used as the experimental motor task. Left and right hemiplegic adolescents were explicitly required to walk or to imagine walking on paths varying in length and width that defines various indexes of difficulty according to Fitts' law (1954). Results revealed that task difficulty had similar effects on movement duration for both actual walking and imagined walking revealing MI capacity in CP adolescents with left and right hemiplegia. These results are thus inline with Williams et al. (2012), who stated that MI performance in the HCP may not be related to the affected side of hemiplegia.

A direct implication of the conclusion of Williams et al. (2012) is that MI in a walking task should be also observed in other clinical subtypes of cerebral palsy. The main goal of the present research was to evaluate MI in a walking task in two clinical subtypes of CP: diplegia and hemiplegia. Contrary to hemiplegia, which most frequently involves a unilateral lesion, diplegia involves in most cases bilateral injury (Okumura, Kato, Kuno, Hayakawa, & Watanabe, 1997). CP subtypes differ according to the topography of the motor impairment with both lower limbs more affected than upper limbs in participants with diplegia and one side of the body affected in HCP participants (Dabney, Lipton, & Miller, 1997). We hypothesized that, inline with the conclusion of Williams et al. (2012), according to which MI is not related to the affected body side in CP children, MI would be observed as well in CP adolescents with diplegia as with hemiplegia. A second goal was to assess the general impairment in MI for motor task in both groups of CP participants. In order to reach this goal, MI performance of each group of participants was compared to MI performance of adolescents with a typical motor development.

2. Methods

2.1. Participants

The CP participants were recruited at two schools for special education in France. Participants contributed on a voluntary basis. In accordance with the Helsinki Declaration and approved by the Regional Ethical Committee, participants took part in the study after their own written consent was obtained. Consent was also obtained from parents and/or caregivers. Inclusion criteria described participants with CP, related to identified-brain damage that occurred during the first six months of life. Information about the diagnoses and additional disabilities was obtained from participant's medical records.