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The influence of errors during practice on motor learning in young individuals with cerebral palsy

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ABSTRACT

The aim of this study was to investigate the effect of errors during practice on motor skill learning in young individuals with cerebral palsy (CP). Minimizing errors has been validated in typically developing children and children with intellectual disabilities as a method for implicit learning, because it reduces working memory involvement during learning. The present study assessed whether a practice protocol that aims at minimizing errors can induce implicit learning in young individuals with CP as well. Accordingly, we hypothesized that reducing errors during practice would lead to enhanced learning and a decrease in the dependency of performance on working memory. Young individuals with CP practiced an aiming task following either an error-minimizing ($N = 20$) or an error-strewn ($N = 18$) practice protocol. Aiming accuracy was assessed in pre-, post- and retention test. Dual task performance was assessed to establish dependency on working memory. The two practice protocols did not invoke different amounts or types of learning in the participants with CP. Yet, participants improved aiming accuracy and showed stable motor performance after learning, irrespective of the protocol they followed. Across groups the number of errors made during practice was related to the amount of learning, and the degree of conscious monitoring of the movement. Only participants with relatively good working memory capacity and a poor initial performance showed a rudimentary form of (most likely, explicit) learning. These new findings on the effect of the amount of practice errors on motor learning in children of CP are important for designing interventions for children and adolescents with CP.

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What this paper adds?

The findings of this paper contribute to a growing body of knowledge concerning implicit and explicit motor learning. In particular, it showed how the concepts can be incorporated into motor learning protocols for children and adolescents with cerebral palsy. It is the first study to test the applicability of error reducing and error strewn practice protocols in this population. The results showed beneficial effects of reducing errors for improving motor performance. At the same time, more individualized protocols need to be developed to tailor the difficulty of the task to the abilities of the learner. Advancing knowledge on the effectiveness of the different motor learning protocols can benefit both rehabilitation and educational protocols to improve the abilities of children and adolescents with CP.

1. Introduction

Cerebral palsy (CP) is a non-progressive disorder that is caused by disturbances during the maturation of the fetal or infant brain, and that affects movement and posture control. CP is the most common childhood disorder with a prevalence of 2–2.5/1000 births (Stanley, Blair, & Alberman, 2000). Except for the problems in motor control, there is high comorbidity with disorders in perception, cognition and social interaction (Bax et al., 2005). Many children with CP are more dependent on others and participate less in physical activities than their typically developing peers. This decreased participation remains as the children reach adolescence and adulthood (Bjornson et al., 2008; Engel-Yeger, Jarus, Anaby, & Law, 2009). Participation in society in general and in physical activities in particular depends considerably on proficiency in motor skills (WHO, 2007). Alleviating this skill barrier is therefore crucial for individuals with CP.

There is a dearth of studies on motor skill learning in individuals with CP. Instead, most studies have investigated either specific therapy forms, learning in cognitive tasks, or sequence learning tasks. The latter studies have shown that one cause for learning difficulties in individuals with CP is poor working memory functioning (Jenks et al., 2007; Jenks, De Moor, & Van Lieshout, 2009; van Rooijen et al., 2012, 2014). Poor working memory functioning can result in difficulties to comply with verbal instructions and rules, even to the point of forgetting them (Gathercole, Lamont, & Alloway, 2006). That is not to say, however, that all learning is necessarily compromised. Learning paradigms that are less dependent on working memory functioning, such as implicit or incidental learning, may still be effective. For instance, Gagliardi, Tavano, Turconi, and Borgatti (2013) and Gagliardi, Tavano, Turconi, Pozzoli, and Borgatti (2011) have recently shown that more than half of the children with spastic CP were able to successfully improve performance on a sequential task. After practice, children were able to correctly reproduce ordered sequences that exceeded their memory span. Children were not consciously aware of the order of these sequences. This suggests that learning was implicit without the children consciously processing rules to improve task performance. In the present study we address the question as to what degree implicit learning can also be invoked in the learning of more complex motor skills in young individuals with CP. Answering this research question will help to provide important guidelines for structuring intervention programs in these children (Steenbergen, van der Kamp, Verneau, Jongbloed-Pereboom, & Masters, 2010).

Traditionally, motor skill learning has been described as a succession of stages, in which the first stage is directed toward increasing awareness and gaining explicit knowledge of how the motor skill needs to be performed (Anderson, 1983; Fitts & Posner, 1967). This verbal-cognitive stage relies critically on the manipulation and storage of explicit information (actively searched for, or passively obtained through instructions and feedback) in working memory (Masters, 1992). With further practice, motor performance becomes more autonomous and less dependent on working memory. It has been argued, however, that motor skill learning does not necessarily require an initial verbal-cognitive stage. In this case, motor skill learning proceeds in a largely unconscious manner, with less dependence on working memory and with the accumulation of explicit knowledge being minimized (Masters, 1992). For example, novice golf players can improve putting performance by merely practicing putting and concurrently performing a cognitive task that loads working memory. That is, they improve the skill without conscious processing of instructions or augmented feedback (Masters, 1992). Implicit motor learning is not only shown to be equally or even more effective, but performance is also more stable following an implicit learning protocol. For example, there is ample evidence that after implicit learning less interference of motor performance occurs when working memory is loaded with a concurrent secondary task, both in adults (Lam, Maxwell, & Masters, 2009b; Maxwell, Masters, Kerr, & Weedon, 2001) and in children (Capio, Poolton, Sit, Eguia, & Masters, 2013; Capio, Poolton, Sit, Holmstrom, & Masters, 2013). This indicates that motor performance after implicit learning is less dependent on working memory involvement (Maxwell, Masters, & Eves, 2003). In addition, evidence for the increased stability of performance after implicit learning has also been shown in conditions of stress and anxiety (Hardy, Mullen, & Jones, 1996; Koedijker, Oudejans, & Beek, 2007; Lam, Maxwell, & Masters, 2009a; Mullen, Hardy, & Oldham, 2007) and physiological fatigue (Masters, Poolton, & Maxwell, 2008; Poolton, Masters, & Maxwell, 2007). The reduced reliance on working memory may make implicit motor learning particularly suitable for individuals with poor working memory functioning compared to the more traditional explicit learning (Capio, Poolton, Sit, Eguia, et al., 2013; Jongbloed-Pereboom, Janssen, Steenbergen, & Nijhuis-van der Sanden, 2012; Steenbergen et al., 2010).