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Learning of writing letter-like sequences in children with physical and multiple disabilities

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ABSTRACT

This study compared implicit and explicit learning instructions in hand writing. Implicit learning is the ability to acquire a new skill without a corresponding increase in knowledge about the skill. In contrast, explicit learning uses declarative knowledge to build up a set of performance rules that guide motor performance or skills. Explicit learning is dependent on working memory, implicit learning is not. Therefore, implicit learning was expected to be easier than explicit learning in children in special education, given their expected compromised working memory. Two groups of children (5–12 years) participated, children in special education with physical or multiple disabilities (study group, $n = 22$), and typically developing controls ($n = 32$). Children learned to write letter-like patterns on a digitizer by tracking a moving target (implicitly) and verbal instruction (explicitly). We further tested visual working memory, visual-motor integration, and gross manual dexterity. Learning curves were similar for both groups in both conditions; children in the study group did learn both implicitly and explicitly. Motor performance was related to the writing task. In contrast to our hypothesis, visual working memory was not an important factor in the explicit condition. These results shed new light on the conceptual difference between implicit and explicit learning, and the role of working memory therein.

1. Introduction

Motor skills can be learned in an explicit or an implicit manner (Masters, 1992). Explicit learning requires cognitive processes that generate declarative knowledge. Declarative knowledge is knowledge which we can describe, and which we consciously remember (Maxwell, Masters, & Eves, 2003). Implicit learning, on the other hand, is the process by which we do not show any awareness of learning the rules underlying the learning process (Berry & Dienes, 1993). Implicit learning builds up procedural knowledge, which is difficult or even impossible to access consciously and/or report verbally. Importantly, in

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contrast to explicit learning, research has found minimal associations between implicit learning and intelligence or (mental) age (Meulemans, van der Linden & Perruchet, 1998; Reber, Walkenfield & Hernstadt, 1991; Vinter & Detable, 2003; Vinter & Perruchet, 2000), indicating that it could be easier for children with intellectual disabilities (ID) to learn in an implicit manner than in an explicit manner. Furthermore, studies on motor skill learning in healthy adults have shown that intact working memory is a necessary prerequisite for the explicit learning of motor skills, while this is no prerequisite for implicit learning (Maxwell et al., 2003).

Working memory is an active processing system that keeps different types of information available for current use, for example for activities such as problem solving, reasoning, and comprehension (Baddeley, 2001). Poor memory function has consequences for different aspects of learning and cognitive ability (Cowan & Alloway, 2009). Several studies have shown that working memory deficits are related to learning disabilities and the severity of intellectual disabilities (Henry, 2001; Henry & MacLean, 2002; Maehler & Schuchardt, 2009). Working memory deficits are also related to disorders of the development of movement, posture and coordination, such as cerebral palsy (CP) (Bax, Goldstein, Rosenbaum, Leviton & Paneth, 2005; Jenks, Moor de & Lieshout van, 2009; Straub & Obrzut, 2009) and developmental coordination disorder (DCD) (Wilson, Ruddock, Smits-Engelsman, Polatajko & Blank, 2013). It is therefore likely that working memory capacities have important consequences for a child's ability to acquire knowledge and to learn new complex skills in an educational context. Students frequently have to rely on working memory to perform a range of activities. Students with working memory impairments may struggle in classroom because they are unable to hold in mind sufficient information to allow them to complete a task (Engle, Carullo & Collins, 1991). This could lead to failures in simple task performance such as remembering classroom instructions (Engle et al., 1991), but also to problems in more complex activities involving storage and processing of information and keeping track of progress in difficult tasks (Gathercole & Alloway, 2008). Up to date, in (special) education, acquisition of cognitive skills is predominantly guided by explicit instructions, either from the teacher or from textbooks (Graham et al., 2008). Obviously, such explicit instructions place a high demand on working memory functioning and may potentially hinder proper learning of cognitive skills, given the impaired nature of working memory (Steenbergen, van der Kamp, Verneau, Jongbloed-Pereboom, & Masters, 2010). Since implicit learning is less dependent on working memory functioning (Maxwell et al., 2003), this type of learning may be useful for applications in educational contexts for children with working memory impairments.

Handwriting is a complex perceptual-motor skill that requires a multitude of abilities and skills, such as visual-motor integration, motor planning, cognitive and perceptual skills, kinesthetic and tactile sensitivities (Feder & Majnemer, 2007), and linguistic awareness (Berninger, Abbott, Nagy, & Carlisle, 2010). The prevalence of handwriting problems in school-age children varies between 12% and 33% (Karlsdottir & Stefansson, 2002; Rubin & Henderson, 1982; Smits-Engelsman, Niemeijer, & Van Galen, 2001). Moreover, most children with learning disabilities experience fine motor difficulties or handwriting problems (Clements, 1966; Rourke, Ahmad, Collins, Hayman-Abello, & Warriner, 2002; Tamopol & Tamopol, 1977). Handwriting problems are among the most common reasons for referring school-age children to physiotherapy or occupational therapy services (Bosga-Stork et al., 2009; Hammerschmidt & Sudsawad, 2004). Furthermore, handwriting difficulties do not only influence a child's success in school performance, but can also affect his/her self-esteem (Dunford, Missiuna, Street, & Sibert, 2005). At present, no consensus exists as to the most effective method for teaching handwriting in classroom. The majority of teachers use a variety of instructional practices for teaching handwriting, which are predominantly explicit procedures, such as copying, tracing, verbal description and modeling (Graham et al., 2008). In physiotherapy, especially the amount of handwriting practice is important for improving handwriting skills. It is not yet clear in what way these handwriting skills should be provided, in a more cognitive or sensorimotor focused training (Hoy, Egan, & Feder, 2011).

This study attempted to gain more insight into the relation between children's disabilities and two methods of learning abstract letter-like patterns, implicit and explicit learning. Children with physical or multiple disabilities (special education) and typically developing controls (mainstream education) learned to write unfamiliar, abstract patterns on a digitizing tablet. The patterns included all aspects of letter-like patterns. In the implicit condition (moving target) children used a stylus to track a target that moved along an invisible trajectory. The explicit condition focused on simple verbal instructions.

We hypothesized that children in the control group learned new handwriting skills better than the children with physical and multiple disabilities in both conditions. Furthermore, given their compromised working memory, the study group would benefit from the implicit learning procedure compared to the explicit condition. This beneficial effect was not expected for the control group. Next to these main research questions and hypotheses, we also examined the possible effects of gross manual dexterity and visual motor integration in learning these letter-like patterns in both conditions.

2. Method

2.1. Participants

Children in the study group were recruited from and tested in two schools for special education for physical and/or multiple disabilities. Children in the study group had the following inclusion criteria: age between 5 and 11 years and IQ score $\geq$55 (based on personal file). Furthermore, to fulfill the test they had to be able to respond to the instructions, to be able to grasp a pencil, to respond verbally, and to discriminate colors. Twenty-nine children were eligible for participation in the