



## Implicit and explicit motor sequence learning in children born very preterm



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### ABSTRACT

**Background:** Motor skills can be learned explicitly (dependent on working memory (WM)) or implicitly (relatively independent of WM). Children born very preterm (VPT) often have working memory deficits. Explicit learning may be compromised in these children.

**Aims:** This study investigated implicit and explicit motor learning and the role of working memory in VPT children and controls.

**Methods:** Three groups (6–9 years) participated: 20 VPT children with motor problems, 20 VPT children without motor problems, and 20 controls. A nine button sequence was learned implicitly (pressing the lighted button as quickly as possible) and explicitly (discovering the sequence via trial-and-error).

**Results:** Children learned implicitly and explicitly, evidenced by decreased movement duration of the sequence over time. In the explicit condition, children also reduced the number of errors over time. Controls made more errors than VPT children without motor problems. Visual WM had positive effects on both explicit and implicit performance.

**Conclusion:** VPT birth and low motor proficiency did not negatively affect implicit or explicit learning. Visual WM was positively related to both implicit and explicit performance, but did not influence learning curves. These findings question the theoretical difference between implicit and explicit learning and the proposed role of visual WM therein.

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### What this paper adds

This study examined both implicit and explicit learning of a serial reaction time task in children, both in typically developing children (controls) and children born very preterm with- and without motor problems. The influence of visual working memory on implicit and explicit learning was also assessed. To our knowledge this is the first study where both implicit and

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explicit learning are compared in a counterbalanced within subjects design. Moreover, although in theory working memory is an important factor in explicit learning, a test of working memory is often not included in motor learning studies. The results show that very preterm birth does not affect learning of such a basic serial reaction time task, nor do motor difficulties. Working memory affected both implicit and explicit performance, but it did not influence the learning curves. This paper adds to the existing literature on implicit and explicit learning, and it questions the role of working memory in explicit learning.

## 1. Introduction

Children born preterm, especially children born very preterm (VPT; gestational age <32 weeks), have an increased risk for developmental problems in the motor, cognitive, and behavioral domains (Allen, 2008; Bhutta, Cleves, Casey, Craddock, & Anand, 2002; de Kieviet, Piek, Aarnoudse-Moens, & Oosterlaan, 2009), including working memory deficits and learning disabilities (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Jongbloed-Pereboom, Janssen, Steenbergen, & Nijhuis-van der Sanden, 2012). These problems may occur in the absence of diagnosed major neurological disorders, and tend to persist during childhood and early adolescence. More subtle cognitive, motor and behavioral problems may emerge or first become measurable as children grow older (Foulder-Hughes & Cooke, 2003; de Kieviet et al., 2009). Although developmental problems have been extensively described for VPT children, and poorer motor outcome has been related to poorer school outcomes (Marlow, Roberts, & Cooke, 1993; Verkerk, Jeukens-Visser, van Wassenaeer-Leemhuis, Kok, & Nollet, 2014), there is only limited information on motor learning capacities in children born very preterm.

Motor skills can be learned implicitly and explicitly (Destrebecqz & Cleeremans, 2001; Nissen & Bullemer, 1987). In implicit learning a new skill is acquired by doing it without a corresponding increase in knowledge about the skill itself. Therefore, the procedural knowledge gained via implicit learning is difficult or even impossible to access consciously and/or report verbally. Implicit learning is relatively independent of age, IQ, and working memory (Maxwell, Masters, & Eves, 2003; Meulemans, van der Linden, & Perruchet, 1998; Reber, Walkenfeldt, & Hernstadt, 1991). 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 age, IQ, and working memory (Maxwell et al., 2003; Meulemans et al., 1998; Reber et al., 1991).

Studies on motor learning in VPT children are limited to the conjugate reinforce mobile paradigm in young infants (3–4 months of age). Overall, infants born preterm had a slower rate of learning compared to controls or did not learn at all (Jongbloed-Pereboom et al., 2012; Lobo & Galloway, 2013). Information gained from studying motor learning problems in VPT children can be used to guide the development of adequate interventions, therapies, and educational methods.

The serial reaction time (SRT) task is a well-established paradigm to study implicit and explicit learning in adults and adult patient groups (e.g. people with dementia). In the implicit condition participants learn a sequence by performing it, mostly guided by visual or auditory cues. In the explicit condition, participants get information about the sequence to be learned based on explicit instructions and feedback. This way, participants will focus on learning the sequence and make use of working memory (Thomas & Nelson, 2001). In this study we examined both implicit and explicit motor sequence learning in VPT children, and the possible mediating roles of motor proficiency and visual working memory. We expected that explicit motor sequence learning was affected in VPT children compared to controls, given their compromised working memory. We did not expect differences between groups in implicit learning. Three groups of children participated to disentangle the effects of very preterm birth and additional effects of motor proficiency: VPT children with motor problems, VPT children without motor problems, and full term controls. For both the implicit and explicit condition a nine button press sequence was learned. In the implicit condition children learned the sequence by pressing lighted buttons as quickly as possible and in the explicit condition they discovered the sequence via trial-and-error.

## 2. Method

### 2.1. Participants

Three groups of children aged 6–9 years were included in this study: 20 VPT children with motor problems (VPTmp), 20 VPT children without motor problems (VPTnmp), 20 healthy controls without motor problems. All VPT children (gestational age <32 weeks) had been treated in the neonatal intensive care unit (NICU) of the Radboud university medical center (Radboudumc). Control children were recruited and tested at three primary schools. The presence or absence of motor problems was assessed with the Movement Assessment Battery for Children, second edition (MABC2-NL; Henderson, Sugden, Barnett, & Smits-Engelsman, 2010). Children were diagnosed as having motor problems with a score lower than  $-1$  SD on the MABC2-NL. Groups were matched for gender, age and IQ. Children were included if their IQ was  $\geq 85$  and if they had no major neurological problems (e.g. intraventricular hemorrhage Grade III or IV) and/or handicaps. Group characteristics are shown in Table 1. The study was approved by the Medical Ethical Committee of the Radboud University Medical Center (NL17984.091.07). Participants' parents gave informed consent and filled in a questionnaire about their child's health to assess whether there were any medical or psychological conditions that could influence performance on the learning task.

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