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Full Length Article

Motor learning and movement automatization in typically developing children: The role of instructions with an external or internal focus of attention

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ABSTRACT

The aim of the current study was to examine the effects of an external focus of attention (i.e., on the movement outcome) versus an internal focus of attention (i.e., on the movement itself) on motor learning in typically developing children. We examined both immediate motor performance (i.e., *practice effect*, when focus instructions are given) as well as motor performance after one week (i.e., *learning effect*). In addition, we examined if an external and an internal focus of attention differently affected movement automatization, as measured using a dual-task paradigm. Finally, we explored whether the effect of attentional focus instructions on motor learning was influenced by children's working memory capacity. Participants were 8–12 year old ($N = 162$) typically developing children. Participants practiced a new motor task (i.e., 'Slingerball throwing task'). Results showed that an external focus of attention led to higher throwing accuracy during practice, but this beneficial effect did not extent to the retention test one week later. Furthermore, movement automatization did not differ after external or internal focus of attention instructions, and working memory capacity did not predict motor learning in children in either of the instruction conditions. This is the first study to show that the beneficial effects of an external focus of attention on discrete motor tasks found in previous studies with a child population seem to be short lived and decline after a one-week interval.

1. Introduction

The use of instructions is one of the most important variables in the process of motor skill learning (Schmidt & Lee, 2005). With regards to the content of the instructions, minor differences in wording of instructions can already influence the performer's focus of attention. This, in turn, has a significant impact on motor performance and learning (Wulf, Hoss, & Prinz, 1998). In this respect, an external focus of attention (i.e., focus on the outcome of a movement) was shown to result in enhanced motor performance and learning compared to an internal focus of attention (i.e., focus on movements of the body; for a review, Wulf, 2013). Instructions promoting an external focus of attention facilitate both immediate changes in motor performance (i.e., during practice when focus instructions are given) and later motor learning (i.e., after a certain interval) across a wide variety of tasks (e.g., Chiviacowsky, Wulf, & Wally, 2010; Ong, Bowcock, & Hodges, 2010; Totsika & Wulf, 2003). Wulf, McNevin, and Shea (2001) formulated the constrained

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action hypothesis to explain the differential effects of attentional focus on motor skill performance and learning. According to this hypothesis, an external focus of attention allows automatic control processes to naturally self-organize. In contrast, an internal focus of attention induces a conscious type of control. The theory implies that this type of control involves working memory and interferes with automatic control mechanisms. This may lead to less effective and less efficient motor performance and motor learning.

To test the constrained action hypothesis, studies have used a dual-task paradigm to assess to what extent the level of movement automatization differs as a function of attentional focus (Kal, van der Kamp, & Houdijk, 2013; Poolton, Maxwell, Masters, & Raab, 2006; Wulf et al., 2001). In the dual-task paradigm, a secondary cognitively demanding task has to be performed in parallel with the primary motor task. The rationale behind this paradigm is that the attentional resources needed to perform the primary motor task are higher for consciously controlled movements as compared to automatized movements. As such, the performance of a cognitive task is expected to interfere with performance on a consciously controlled motor task, but should not, or to a lesser extent, affect performance on an automatized motor task (Abernethy, 1988). Wulf et al. (2001), using a dual-task paradigm, showed that adopting an external focus of attention as compared to an internal focus of attention, led to better performance on the primary balancing task, and also to shorter reaction times in response to auditory stimuli during balancing. The finding that an external focus of attention yields superior dual-task performance as compared to a an internal focus of attention has been replicated twice with different motor tasks and using varying dual-task manipulations (Kal et al., 2013; Poolton et al., 2006). Thus, movements performed and learned under an external focus of attention demand less attention than movements performed and learned under an internal focus of attention. This implies that cognitive resources, like working memory, are less involved in motor performance and motor learning with an external focus of attention as compared to an internal focus of attention.

Research examining the effects of attentional focus instructions is predominantly performed in the adult population. Surprisingly however, only a few studies have examined attentional focus effects in children, despite the fact that childhood represents an important motor learning period. The handful of studies that were performed in typically developing children have led to equivocal results. Chow, Koh, Davids, Button, and Rein (2014), Emanuel, Jarus, and Bart (2008), Perreault and French (2016), and van Abswoude, Nuijen, van der Kamp, and Steenbergen (2018) did not find significant differences between performance after external or internal focus of attention instructions measured both during practice (Emanuel et al., 2008; van Abswoude et al., 2018) and during retention test assessed 24–48 h after the last practice session (Chow et al., 2014; Emanuel et al., 2008; Perreault & French, 2016; van Abswoude et al., 2018). On the other hand, many studies replicated the beneficial effects of adopting an external focus of attention as measured during practice (Abdollahipour, Wulf, Psotta, & Nieto, 2015) or following retention test 24–48 h after practice (Brocken, Kal, & van der Kamp, 2016; Flores, Schild, & Chiviacowsky, 2015; Hadler, Chiviacowsky, Wulf, & Schild, 2014; Thorn, 2006). Notably, all studies examined the effects of attentional focus instruction either immediately, during practice, or following a short-term retention test 24–48 h after practice. Changes in motor performance that are generally reported during practice are promising, however, they may only be temporary and do not necessarily reflect learning (Emanuel et al., 2008).

Given these equivocal results, it is crucial to examine the underlying mechanisms of attentional focus instructions in children, which may differ from those in adults. Yet, only two of these studies did address the possible mechanisms underlying attentional focus effects in children (Brocken et al., 2016; van Abswoude et al., 2018). Both studies examined the effects of external focus instructions (i.e., “to move the golf club like a pendulum”) and internal focus instructions (i.e., “to move the arms like a pendulum”) on motor learning of a golf-putting task in children. Additionally, they included a measure of working memory to explore the relationship between motor learning and working memory capacity. Contrary to their expectations, however, both studies found that working memory capacity did not affect motor learning in a different way for the internal focus group compared to the external focus group. That is, working memory capacity of the children could not explain the differential effect of attentional focus instructions on motor learning.

The first aim of the present study is to examine the effects of attentional focus instructions in typically developing children. To this end, we examined the effect of instructions with an external versus instructions with an internal focus of attention on both immediate motor performance (i.e., *practice effect*, when focus instructions are given) and motor performance after one week (i.e., *learning effect*) of a novel movement task. In line with the constrained action hypothesis and previous research, we expected that adopting an external focus of attention as compared to an internal focus of attention is more beneficial for both *practice and learning effects* in children. Second, we examined the effect of external versus internal focus of attention on movement automatization. We used a dual-task paradigm to assess movement automatization. We expected that performing a dual-task interferes less with performance on the primary motor task after external focus instructions as compared to internal focus instructions. Third, and finally, we explored the role of verbal and spatial working memory capacity with regard to motor learning after both focus of attention instructions.

2. Methods

2.1. Participants

A total of 169 children participated. Seven participants who were diagnosed with ADHD (2), ADD (3), Autism (1) or ADHD and PDD-NOS (1) were excluded from further statistical analyses. The remaining sample consisted of 86 boys and 76 girls with ages varying from 8.27 to 12.80 ($M = 10.64$, $SD = 1.19$). Written informed consent was obtained from the parents/guardians, the schools, and the participants themselves if they were twelve years old. The study was approved by the university’s ethics committee (EC2013-1811-147a1). The participants were unaware of the purpose of the experiment and the experimental task was novel to all of them and, hence, devoid of pre-established automaticity.