Human Movement Science 32 (2013) 527–539

Contents lists available at SciVerse ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

External attentional focus enhances movement automatization: A comprehensive test of the constrained action hypothesis

E.C. Kal [a,b,*], J. van der Kamp [b,c], H. Houdijk [a,b]

[a] Heliomare Rehabilitation Centre, Research & Development, Wijk aan Zee, The Netherlands
[b] Research Institute Move, Faculty of Human Movement Sciences, VU University Amsterdam, The Netherlands
[c] Institute of Human Performance, University of Hong Kong, Hong Kong

ARTICLE INFO

Article history:

PsycINFO Classification:
2330
2343
234

Keywords:
Focus of attention
Motor control
Human performance
Kinematic analysis

ABSTRACT

An external focus of attention has been shown to result in superior motor performance compared to an internal focus of attention. This study investigated whether this is due to enhanced levels of movement automatization, as predicted by the constrained action hypothesis (McNevin, Shea, & Wulf, 2003). Thirty healthy participants performed a cyclic one-leg extension-flexion task with both the dominant and non-dominant leg. Focus of attention was manipulated via instructions. The degree of automatization of movement was assessed by measuring dual task costs as well as movement execution parameters (i.e., EMG activity, movement fluency, and movement regularity). Results revealed that an external focus of attention led to significantly better motor performance (i.e., shorter movement duration) than an internal focus. Although dual task costs of the motor task did not differ as a function of attentional focus, cognitive dual task costs were significantly higher when attention was directed internally. An external focus of attention resulted in more fluent and more regular movement execution than an internal focus, whereas no differences were found concerning muscular activity. These results indicate that an external focus of attention results in more automatized movements than an internal focus and, therefore, provide support for the constrained action hypothesis.

* Corresponding author. Address: Research & Development, Rehabilitation Centre Heliomare, Relweg 51, 1949 EC Wijk aan Zee, The Netherlands. Tel.: +31 88 920 801.
E-mail address: e.kal@heliomare.nl (E.C. Kal).

0167-9457/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.humov.2013.04.001

1. Introduction

An increasing body of evidence shows that motor performance can be directly influenced by the performer's focus of attention. More specifically, focusing on the effects of movement (i.e., an external focus of attention) has been found to result in superior motor performance compared to focusing on the movement pattern itself (i.e., an internal focus of attention; for comprehensive overviews see Wulf and Prinz (2001) and Wulf (2007)). McNevin, Shea, and Wulf (2003; see also Wulf, 2007) posited the 'constrained action hypothesis' to explain the differential effects of attentional focus on performance. The hypothesis holds that an external focus facilitates motor performance because it promotes automatic control of movement. By contrast, adopting an internal focus of attention induces more deliberate and conscious control of movement, thereby constraining or disrupting 'normal' automatic control processes. The constrained action hypothesis has proven useful in explaining the effects of focus of attention on performance and learning in a wide variety of tasks, such as basketball shooting (Zachry, Wulf, Mercer, & Bezodis, 2005), balancing (Shea & Wulf, 1999), tennis strokes (Maddox, Wulf, & Wright, 1999), and jumping (Wulf, Dufek, Lozano, & Pettigrew, 2010). However, most of these studies merely described the effects of attentional focus using relatively simple outcome measures (e.g., accuracy or number of successful attempts). Outcome measures, however, do not easily allow inferences about *how* the two distinct attentional foci effectuate differences in performance. To address this issue, it is necessary to investigate the assumptions of the constrained action hypothesis by assessing to what extent automatization of movement differs as a function of attentional focus. To this end, we aim to measure the effects of attentional focus on automatization of movement in two ways: by assessing dual task interference and through the analysis of movement execution parameters associated with automaticity.

A common method to assess automaticity of movement is investigating the effects of secondary task loading on primary motor task performance (Abernethy, 1988). The conjecture is that consciously controlled movements place a substantially higher demand on working memory than automatized movements. Therefore, the execution of a secondary task is expected to interfere with performance on a consciously controlled motor task (i.e., movements performed with an internal focus of attention) but should not – or to a lesser extent – affect performance on an automatized task (i.e., movements performed with an external focus of attention). To date, only a few studies have investigated the effects of attentional focus on dual task performance. In a study by Wulf, McNevin, and Shea (2001) adopting an external focus of attention was not only associated with better balancing performance, but also with swifter reactions to auditory stimuli during balancing compared to an internal focus. Similar findings were reported by Poolton, Maxwell, Masters, and Raab (2006). The authors found golf putting performance to be robust to secondary task loading (e.g., a tone counting task) when attention was focused externally, but not when attention was focused internally. Notwithstanding these promising results (cf. Canning, 2005), a limitation of these studies is that they did not control for differences in task prioritization in dual task conditions. That is, dual task performance was not corrected for differences in baseline (single task) performance. By contrast, this study assessed dual task costs (DTCs; McCulloch, 2007) of both the primary motor and secondary cognitive task.

An alternative approach to assess movement automatization is the analysis of movement execution related parameters that indicate to what extent movements are under automatic or conscious control. One such parameter is electromyographic (EMG) activity. The rationale is that if task execution is consciously controlled this results in more EMG activity than when the task is performed automatically, since the latter constitutes a more efficient mode of motor control (e.g., Wulf et al., 2010). Indeed, a few studies reported that an internal focus led to significantly higher EMG activity than an external one (e.g., Lohse, Sherwood, & Healy, 2010; Wulf et al., 2010; Zachry et al., 2005). Two additional parameters that have been frequently discussed in motor control literature with respect to movement automatization – but have not yet been applied in the context of the constrained action hypothesis – are *fluency of movement* (e.g., Shemmell, Tresilian, Riek, Barry, & Carson, 2005) and *movement regularity* (e.g., Roerdink, Hlavackova, & Vuillerme, 2011). With regards to fluency of movement, the rationale is that in the course of acquiring a motor skill, the fluency with which a movement