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Upper-limb motor control in patients after stroke: Attentional demands and the potential beneficial effects of arm support

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ABSTRACT

The goal of this study was to investigate the attentional load of using the upper limb in moderately and mildly affected patients after stroke, with and without arm support. Ten patients with stroke (4 mild and 6 moderate paresis) and ten healthy, gender- and age-matched control subjects performed a dual-task experiment that consisted of a circle drawing task and an auditive Stroop task. Complexity of the motor task was manipulated by supporting the arm against gravity. Individual motor (area × speed) and cognitive (accuracy/reaction time) scores during the dual-task conditions were converted into percentage scores relative to the respective single-task scores and then combined in a single measure of net dual-task performance. Without arm support, only moderately affected patients showed significantly greater side differences in dual-task performance to the detriment of the affected upper limb. With arm support, no side differences were found for any of the three groups. Thus, the hypothesis that patients with moderate upper-limb paresis suffer from a lack of automaticity of motor control was substantiated by the dual-task condition. Furthermore, supporting the arm reduced the attentional load of using the affected side.

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1. Introduction

Approximately 70% of patients in the acute phase of stroke suffer from some degree of paresis of the upper limb (Nakayama, Jorgensen, Raaschou, & Olsen, 1994). Regaining optimal use of the affected upper limb after stroke is a formidable challenge. Although new training interventions (e.g., robot-assisted training, virtual reality training, constraint-induced movement therapy) (Krakauer, 2006) often show beneficial effects on the motor capacities of the affected upper limb, the transfer of functional gains into daily-life activities is not as apparent (Hakkennes & Keating, 2005; Kwakkel, Kollen, & Krebs, 2008; Mehrholz, Platz, Kugler, & Pohl, 2008; van Peppen et al., 2004). The discrepancy between what patients are able to do with their paretic upper limb (i.e., capacity) and the actual use of this limb in daily life (i.e., performance) has been addressed in detail by Michielsen, de Niet, Ribbers, Stam, and Bussmann (2009). They found that upper-limb capacity in patients after stroke needed to reach a certain level before spontaneous daily use of the paretic limb really improved. This observation raises the question what underlying processes determine spontaneous upper-limb use, besides a certain level of sensorimotor capacity. In this study, we relate motor learning to attentional processes as a possible explanation for the often observed discrepancy between capacity and actual use of the upper limb in patients after stroke.

Motor learning is often divided in distinct phases, leading to skilled behavior requiring minimal attentional resources. Doyon and Benali (2005) described a fast and slow learning stage, followed by a retention stage. In the fast (or early) stage, considerable improvements in performance may occur in a single training session. In the slow (or later) stage, improvements occur over several sessions of practice, usually at a slower pace than in the fast stage. In the final retention stage, motor skills can be performed effortlessly even after long periods without additional practice. At this stage, the skills are believed to be automated, requiring only minimal attentional resources. In patients after stroke, attentional demands have previously been investigated for gait and postural control using dual-task experiments (Bensoussan et al., 2007; Brown, Sleik, & Winder, 2002; Woollacott & Shumway-Cook, 2002). These studies have shown that gait and postural control in these patients are not as fully automated as in healthy controls. Interestingly, up to date only one study investigated automaticity of upper-limb motor control after stroke by means of a dual-task experiment (Platz, Bock, & Prass, 2001). Because this study used a *motor* (and not a *cognitive*) secondary task, the observed effects cannot unambiguously be attributed to generalized attention capacity interference. Indeed, two motor tasks are likely to cause structural interference, since they may use the same sensory and motor processing systems (Wickens, 2008).

In the present study, we hypothesize that the attentional demands of using the affected upper limb after stroke are disproportionately high because of a lack of automaticity. Obviously, upper-limb motor control is more cognitively driven than gross motor activities such as walking. Nevertheless, even complex unimanual or bimanual actions, such as writing or tying shoelaces, can normally be performed almost without significant attention. This allows other attention-demanding tasks to be continued, such as listening or maintaining a conversation. In fact, paying too much attention to a highly-learned (manual) skill can even be detrimental as the focused attention implies a step-by-step monitoring of the skill leading to worse performance than when the action is executed more automatically (Beilock, Carr, MacMahon, & Starkes, 2002). For many patients with upper-limb paresis due to stroke, we presume that the motor control of the affected limb has not reached a level of automaticity that is sufficient to allow its effortless use during daily-life activities, perhaps even for those patients that appear relatively mildly affected. As a consequence of this lack of automaticity, the affected limb may be used less than one would expect based on the individual's motor capacity, leading to compensatory overuse of the non-affected limb.

Automaticity of motor control can effectively be examined using a dual-task paradigm. In such a paradigm, a motor task must compete with a cognitive task for the same attentional resources (Huang & Mercer, 2001). If the motor task requires a disproportional amount of attention, dual-task interference is observed. Dual-task interference results in decreased performance of either the motor task, the