1. Thesis summary

The ability to perform dual-tasks while moving is often impaired in people with stroke. The aim of this thesis was to investigate the potential of implicit motor learning interventions to target this problem. The rationale was that implicit motor learning should result in relatively automatic movements and thereby enhance dual-task performance in stroke patients. To ensure a comprehensive assessment, the thesis comprised three main parts: reviews of the current evidence, observational studies of current rehabilitation practice, and experimental studies to determine the immediate and longer-term effects of an implicit- versus explicit learning intervention on motor skill, automaticity, and dual-task performance.

In the first part, which is covered by **Chapters 2 and 3**, I systematically reviewed the current evidence regarding implicit motor learning in healthy adults and people with stroke. Specifically, the results of **Chapter 2** suggest that implicit motor learning interventions have a small benefit for dual-task performance compared to explicit motor learning interventions in healthy adults. In addition, the results in **Chapter 3** indicate that the ability for implicit motor learning seems largely preserved after stroke. Importantly, however, in both chapters the strength of the evidence is weak, due to a significant lack of reporting on group selection, randomization, and blinding procedures. Other important limitations of the current literature are the short intervention periods and small samples involved. Also, the results of **Chapter 3** reveal a clear lack of studies that assess implicit motor learning in clinically relevant, dynamically complex motor tasks in people with stroke (e.g., gait or balance tasks); all but one study investigated implicit learning by means of the serial reaction time paradigm.

The second part of this thesis focused on how implicit and explicit motor learning strategies are currently applied within rehabilitation practice, both by patients and physical therapists themselves. First, the results of **Chapter 4** show that it is possible to use a self-report questionnaire – the Movement-Specific Reinvestment Scale – to validly and reliably measure a stroke patient's general inclination to use conscious (explicit) motor control in daily life. Results further confirm the idea that stroke patients are more strongly inclined to do so than their healthy peers. In **Chapter 5** this scale was used in a different sample of rehabilitating stroke patients. Results show that patients with stronger inclinations for conscious control experience greater reductions in gait speed when they concurrently need to perform a tone-counting dual-task. This provides indirect evidence for the hypothesis that conscious control impairs dual-tasking after stroke. In **Chapter 6**, I show that physical therapists use a balanced mix of more implicit (external focus) instructions and more explicit (internal focus) feedback during inpatient rehabilitation. Interestingly, therapists adapt their use of instructions to the individual patient, using more externally focused statements for patients with a longer length of stay and with a stronger conscious control inclination. Also, therapist-interviews reveal that they tried to rely more on implicit, external focus strategies for patients with cognitive

impairments and relatively intact sensory functioning. As such, the results of **Chapter 6** nuance the findings of **Chapter 5**, as they suggest that – rather than being negative per se – explicit, conscious motor control could be beneficial to performance and learning in particular subgroups of patients.

The third part of this thesis focused on the actual effects of one particular implicit learning intervention – external focus instructions – on movement automaticity and dual-tasking in stroke. First, the results of **Chapter 7** show that external focus instructions can be used to induce implicit motor learning. Specifically, healthy adults show significantly faster leg-stepping performance and increased automaticity with external focus instructions compared to with internal focus instructions. Most importantly, results show that external focus instructions also enhance dual-task performance compared to internal focus instructions. In **Chapter 8**, however, these results cannot be replicated in chronic stroke patients – even though the exact same paradigm is used. Thus, external focus instructions do not benefit patients' leg-stepping performance, automaticity, or dual-task performance. The absence of group level effects seems due to the fact that patients do not uniformly respond to the focus instructions; in this study, patients with weaker conscious control inclinations and better motor skill performed better with external- compared to internal focus instructions (and vice versa). Finally, in **Chapter 9** a randomized controlled trial is described to compare the effectiveness of external and internal focus instructions on *learning* of a more clinically relevant balance board task in rehabilitating stroke patients. Results show a small benefit of external instructions for single-task motor performance after one week of practice. However, after 3 weeks of practice both the external- and internal focus group show similar improvements in balance skill and dual-task performance. Most importantly – similar to **Chapter 8** – the effects of attentional focus seem to depend on certain patient characteristics. In particular, external focus instructions result in more effective learning for patients with better baseline motor skill and sensory functioning, and with worse attention capacity.

Overall, the results of this thesis do not support the hypothesis that implicit motor learning uniformly benefits motor skill, automaticity of movement, and dual-task performance in people with stroke. Rather, the findings in **Chapters 6, 8, and 9** suggest that implicit and explicit motor learning interventions need to be tailored to the individual patient. A patient's motor skill, sensory functioning, attention capacity, and conscious control inclination all seem to influence whether an implicit- or explicit intervention is most effective. In the remainder of this discussion section I will discuss these results in more detail. The aim is to provide leads for future research on this topic, but also to give some (preliminary) guidance for clinical application.