Perspectives on THEORY and APPLICATION of implicit and explicit motor learning in neurological rehabilitation

Melanie Kleynen | 2018

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Contents

Chapter 1	General introduction	7
Chapter 2	Terminology, taxonomy, and facilitation of motor learning in clinical practice: protocol of a Delphi study *Journal of Medical Internet Research, Research Protocols 2013;2(1):e18*	21
Chapter 3	Using a Delphi technique to seek consensus regarding definitions, descriptions and classification of terms related to implicit and explicit forms of motor learning ***PloS One 2014;9(6):e100227***	37
Chapter 4	Multidisciplinary views on applying explicit and implicit motor learning in practice: an international survey ***PloS One 2015;10(8):e0135522***	59
Chapter 5	Physiotherapists use a great variety of motor learning options in neurological rehabilitation from which they choose through an iterative process: a retrospective think-aloud study ***Disability and Rehabilitation 2017;39(17):1729-1737***	79
Chapter 6	Application of motor learning in neurorehabilitation: a framework for healthcare professionals *Submitted*	99
Chapter 7	Exploring the utility of analogies in motor learning after stroke: a feasibility study ***International Journal of Rehabilitation Research 2014;37(3):277-80***	131
Chapter 8	The potential influence of implicit motor learning strategies on spatiotemporal gait characteristics in stroke patients: an exploratory study *Submitted*	141
Chapter 9	General discussion	165
	Summary	195
	Samenvatting	203
	Valorisation	211
	Dankwoord / Acknowledgements	221
	Curriculum vitae	231
	List of publications	235

CHAPTER 1

General introduction

1

GENERAL INTRODUCTION

Movement is an essential part of our lives. Voluntary movements enable us to perform basic motor skills like walking, reaching, grasping and manipulating objects. These motor skills are essential for performing motor tasks related to general needs (e.g., feeding ourselves), ADL (Activities of Daily Living, e.g., dressing) and mobility (e.g., walking, riding a bike or a car). Throughout our life, we acquire many different motor skills. Initially, we learn how to walk, cycle or swim as a child. Later, we might learn more specific skills related to our hobbies (e.g., hitting a ball with an implement or dancing in a particular way) or our work (e.g., typing or using specific equipment).

Athletes, especially professional athletes, are dependent on optimal motor performance in order to succeed (e.g., win competitively). Therefore, optimal motor control and the improvement of motor skills have traditionally been key topics in the study of sport. In the field of rehabilitation, motor learning also plays an important role. As a consequence of aging, trauma or chronic disease, motor skills may deteriorate or become “lost”. Learning, relearning, and improving motor skills may then be essential to maintain or regain independence. Using a walking aid, transferring from a wheelchair to a bed, or walking are complex motor tasks, which are often conditional for independent living.

There are many different ways in which the process of learning a motor skill can be shaped. Children often learn by trying and discovering. In other contexts, we learn by imitating others or we receive verbal rules and explanations about how to perform a motor skill. Athletes and patients are particularly dependent on an efficient and effective way of motor learning. Although research into efficiency and effectiveness of motor learning is commonplace in sports,[1,2] such research has increased exponentially in recent years in the field of rehabilitation.[3] Consequently, it would be efficient for knowledge and insights to be translated from one field to another. The problem is that the terminology used within research articles and more general literature has been insufficiently uniform. This has hampered exchange of knowledge within and between fundamental domains of research and target groups. For clinical practice and education, clear terminology is important and allows therapists and coaches to speak a common language with colleagues (e.g., to set up treatment plans) or when instructing students.

This thesis, entitled *Perspectives on theory and application of implicit and explicit motor learning in neurological rehabilitation*, focuses on the theory and application of motor learning during rehabilitation of patients with neurological disorders. This introductory chapter first defines ‘motor learning’ in general and establishes its meaning for rehabilitation. Subsequently, the chapter explains why motor learning has become a central topic within neurological rehabilitation. Afterwards, implicit and explicit motor learning are discussed, as the distinction between these two forms of learning provides a conceptual departure point for the thesis. Next, challenges and problems in the application of motor learning in neurological rehabilitation are outlined. The introduction ends with a description of the aims and structure of the thesis.

Motor control and motor learning in neurological rehabilitation

In the literature, two different terms are frequently used in relation to improving motor skills: motor control and motor learning. Motor or movement control refers to the planning and execution of movements[4] and in textbooks chapter on motor control often focuses on understanding the control of a movement already acquired is studied.[4] For example, understanding why a person walks using a certain gait pattern is about motor control. Motor learning, on the other hand, *focuses on understanding the acquisition and/or modification of a movement.*[5] For example, understanding how a person learns to walk and improve his/her gait pattern is about motor learning. Motor learning has been described as *a set of processes associated with practice or experience leading to a relatively permanent change in the capabilities for skilled movemen*t.[6] Although understanding why a person moves the way he/she moves (motor control) clearly is an important topic in the context of rehabilitation, the focus of this thesis is on the process of motor learning in the specific context of neurological rehabilitation.

Motor learning in neurological rehabilitation

Within rehabilitation, physiotherapists and occupational therapists are specialized to provide therapy that is tailored to facilitate motor skill learning of patients with a wide range of pathologies. During the last century, treatment of patients with neurological disorders was mainly driven by specific treatment concepts and approaches, such as Bobath,[7,8] proprioceptive neuromuscular facilitation (PNF)[9] and the Brunnstrom concept.[10] However, in recent years research has shown that therapists should no longer strictly follow these concepts and approaches, because the underlying evidence base is questionable. Further, these concepts and approaches often leave limited room to tailor therapy to the individual abilities of a patient.[11-13] Such concepts and approaches feature less prominently in modern guidelines and textbooks and are referred to less frequently, because the evidence for their use is now perceived to be unconvincing, especially if they are applied in a strict manner.[12,13] As a consequence, these concepts and approaches, which previously provided clear structure and support for clinical decision-making and application of therapy, are less and less used in education and daily care by therapists.

In the 1980's, the potential importance of motor learning in neurological rehabilitation was highlighted[14] and, over recent years, an enormous increase in motor learning literature has been observed.[3] Especially in the field of neurological rehabilitation, attention has turned to the potential added value of motor learning principles that have evolved in other fields especially in the context of sport.[15-17]

More recently, the importance of motor learning principles for neurological rehabilitation has been reinforced by new scientific insights into recovery mechanisms and neuroplasticity after neurological disorders.[18,19] Based on these insights, more general therapy principles have been recommended. For example, therapy should be intensive and task-specific.[20] Despite the simplicity of these principles, there is significant variability in their application,[21] which might be explained by the fact that principles of intensity and task-specificity mainly guide *how* therapy should be organized and not *what* should be applied with respect to instructions, feedback and variation of the practice, for example. To improve cardiovascular fitness and strength, clear guidelines exist (e.g.,[22]). However, when it comes to more complex motor skills (e.g., dressing, eating, walking) it remains unclear from the current evidence and guidelines how intensive and task-specific training should be shaped in daily practice in order to optimally facilitate motor learning or how motor learning interventions should be tailored to the specific capabilities of the patient. Nevertheless, on a daily basis, therapists are required to make justified decisions about how to apply motor learning in the individual patient.

In addition to motor impairments, up to 60% and more of patients suffering from neurological diseases experience cognitive problems.[23-25] Examples of cognitive problems that patients have to cope with are impairments of memory function, information processing and/or attention. These cognitive problems will most likely hinder the process of motor learning at a didactic level. Therapists in rehabilitation often use a high amount of verbal instructions.[26,27] Processing and remembering these instructions is especially challenging for patients with cognitive impairments. Therefore, there is a need to tailor motor learning strategies to a broad variety of possible impairments of a patient, which makes applying motor learning in this target population especially complex and challenging.

To treat these patients efficiently and effectively, therapists should be able to combine the growing evidence and elements of different (motor learning) approaches.[13] In order to do so, they first need insight into their application, feasibility and effectiveness. Further, they need skills and support to incorporate these insights into their daily routine.

Implicit and explicit forms of motor learning

In the literature, a departure point for explanatory models of motor learning, in a variety of healthy and rehabilitation target groups, is the broad distinction between conscious and non-conscious attributes of the motor learning process. The distinction is often delimited by an implicit-explicit conceptualization first made within the field of cognitive psychology.[28] This distinction proposes that implicit motor learning relies on more non-conscious attributes, whereas explicit motor learning relies on more conscious attributes of the motor learning process.[2,29] Neuro-anatomically, the (dorsolateral) prefrontal cortex and the medial temporal lobe seem to be involved in explicit motor learning whereas the brain structures involved in implicit motor learning are probably subdivided across the cerebellum, the basal ganglia and the sensormotor cortex, especially the primary motor cortex and the supplementary motor cortex.[30]

An example of implicit motor learning is learning to ride a bike as a young child. Children are not aware of the underlying rules and processes for cycling (e.g., steering, balance, the way their legs should move) when they first step onto a bike. Although they are aware of the fact that they are learning to ride a bike, they normally do not discover how the process of riding a bike works in more detail. Contrary to riding a bike, most people have learned how to drive a car in a more explicit way. The complex process of driving a car is usually first split into smaller tasks (e.g., steering) and learners are provided with an extensive number of instructions and rules about the riding process by the instructor. While learning how to drive, they are aware of what they are doing and how they are performing tasks, like shifting gear, looking into the rear-view mirror etc. With practice, however, conscious control of driving a car diminishes and more and more of the driving task is performed automatically.

As illustrated by the latter example, motor learning has traditionally been considered to evolve via a cognitive stage, in which the learner is reliant on conscious processing of his/her movement.[31-33] More recent insights, however, show that this cognitive, conscious stage of motor learning is not per se necessary for successful skill acquisition and automation.[2,29,34,35]

Numerous studies using the distinction between implicit and explicit forms of learning have been performed in the world of sports. It seems that implicit learning in general gives better results in sport-related skills than explicit learning.[29,36-39] Results of such studies suggest that implicitly learned skills can, for instance, withstand mental pressure better[29,37,38] and implicit learning results in more efficient motor control than explicit learning when people make complex decisions under time pressure.[39] Implicit motor skills also remain stable under aerobic fatigue, whereas explicitly learned skills are more likely to deteriorate.[36,39] Explicit learning on the other hand seems to be faster[37] in the earlier learning phases and is mainly used in therapist practice.[26,27]

It is unclear whether this knowledge can be transferred to rehabilitation, and neurological patients in particular; however, there are reasons that it might be expected that implicit learning is the better choice for the neurological target group. The brain structures probably involved in implicit motor learning are spread throughout the brain. Therefore, the neural basis for implicit motor learning seems less vulnerable to (a single) lesion or disease[40] and loss of one of these structures will probably not preclude implicit knowledge being stored.[30]

Further, reduced cognitive functioning, as is often the case in neurological disorders, makes it more difficult to understand, process and remember (extensive) verbal information often used in explicit motor learning. Implicit motor learning strategies are hypothesized to circumvent the processing of declarative, verbal (explicit) information related to the motor skill. Previous research has revealed that compared with learning through extensive verbal instructions (i.e., explicit motor learning), implicit motor learning requires fewer attentional resources and working memory capacity (e.g., [29,37,39,41-43]). Therefore, implicit learning seems to have potential for neurological rehabilitation, as it may make fewer demands on the patient’s cognitive skills.

Application of motor learning in practice

Another challenge arises when it comes to the application of motor learning in daily practice. The interpretation of evidence from research is difficult as implicit and explicit motor learning are applied in many different ways. Even if researchers define implicit and explicit motor learning for the context of their research, intervention paradigms to apply these learning forms often vary. For example, Masters (and colleagues) applied implicit motor learning by asking participants to carry out a concurrent random letter generation task while practicing a golf-putting task (dual-task) or by using a biomechanical metaphor (analogy) or by manipulating feedback.[29,42,44,45] Van Tilborg et al. used modelling (observation) to facilitate implicit motor learning of every day instrumental ADL (activities of daily living) tasks.[46] In other work, the environment has been manipulated during learning of tasks, such as dynamic balancing or throwing,[47,48] in order to promote or reduce errors, which is thought to facilitate explicit or implicit motor learning, respectively. Explicit learning has been operationalized by instructing learners to discover rules by themselves[48] but also by providing them with extensive verbal instructions or rules.[49,50] The diversity in the use of terminology, applications and options related to motor learning hampers the translation of knowledge and new insight into daily practice and makes the communication about motor learning with colleagues and within education difficult. Achieving consensus about the meaning of terms and ordering of terms (taxonomy) would support both translation of knowledge and communication about motor learning daily practice and education.

In summary, applying motor learning in neurological patients is complex. At the moment, there is insufficient knowledge to support therapists when making decisions within the application of motor learning in daily practice. Knowledge from other fields of research (e.g., sports) could in potential be used to support therapist; however, translation of knowledge is hindered by unclear terminology and taxonomy. As stated above, there are reasons to assume that implicit motor learning is in general a better choice for patients with neurological disorders. However, it is unclear how implicit learning can be applied in patients with neurological disorders, whether it is feasible and which effects might be expected.

AIM OF THE THESIS

The overall aim of this project is to provide therapists in neurological rehabilitation with knowledge and tools to support the justified and tailored use of motor learning in daily clinical practice. Both available knowledge from other fields (e.g., sports), as well as new insights from applied studies, were used to compile an overview of clinically feasible options to apply motor learning in daily practice within neurological rehabilitation.

To achieve this aim, the thesis is divided into two parts. The aim of the **first part** was to develop a theoretical basis to apply motor learning in clinical practice, using the implicit-explicit distinction as a conceptual basis. Afterwards, in the **second part**, strategies identified in first part were tested for feasibility and potential effects in people with stroke.

OUTLINE OF THE THESIS

The outline of the thesis is presented in Figure 1.1. In *Chapters 2 to 5* of the thesis, uniform definitions of implicit and explicit motor learning, together with descriptions and taxonomy of related interventions strategies, were developed using a survey with integrated Delphi technique in experts from different motor learning domains (i.e., therapists, coaches, researchers). In *Chapter 2,* the design of this Delphi technique a is described and *Chapters 3 and 4* describe the results this study. *Chapter 3* focuses on more theoretical aspects, including definitions, descriptions of terms related to implicit

and explicit motor learning and a first attempt to classify these terms. *Chapter 4* has a more practical focus and describes results related to the underlying application.
Therapists apply motor learning on a daily basis and experienced therapists seem to somehow 'know' what works in which patients. *Chapter 5* gives insights into how experienced therapists apply motor learning and on the basis of which factors they make choices regarding the motor learning process in daily practice.

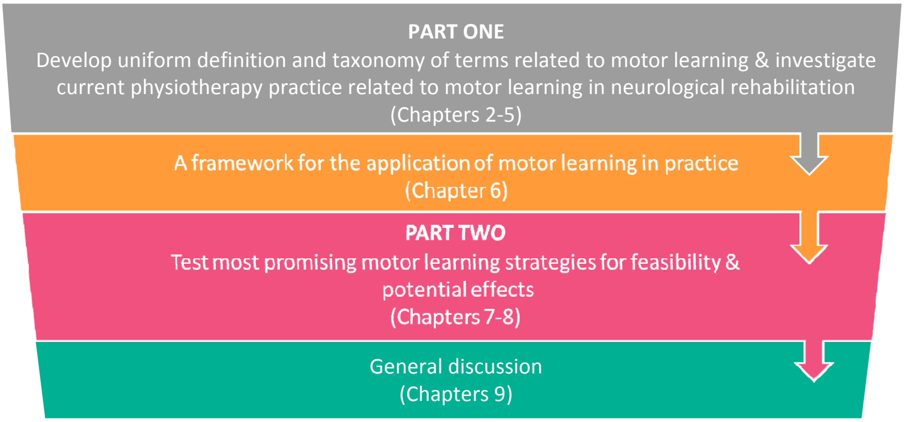

Figure 1.1 Outline of the thesis

A framework for the application of motor learning is presented in the *Chapter 6* from the perspective of clinical practice in neurological rehabilitation. The framework includes different forms of motor learning (implicit and explicit) and related motor learning strategies. It also shows options and elements, which can be used to apply and tailor the motor learning process in practice. Factors that should be taken into account when choosing motor learning content are discussed.

The second part of the thesis focuses on the target group 'stroke', because this is a large subpopulation within the group of patients with neurological disorders.[51] The focus of this part was further restricted to the improvement of gait pattern, because of the relevance of this motor skill. Gait problems often occur after stroke, including asymmetrical posture, slow walking narrow walking trail or lack of optimal weight distribution between both feet.[52] These deviations in the walking pattern often result in disrupted functioning in daily life.[53]
Within the context of research, different strategies have been used to operationalize motor learning. In patients with neurological conditions, promising results were reported when the implicit motor learning strategies analogy learning, errorless learning and observational learning were used.[46,48,54] It is, however, unclear whether

these implicit motor learning strategies are feasible and can in potential improve walking performance. Therefore, *Chapter 7* evaluated the feasibility of the use of analogy instructions in three stroke patients. *Chapter 8* describes the results of an exploratory study, which examines whether different applications of the implicit motor learning strategies can influence spatio-temporal parameters of the gait pattern. Finally, in *Chapter 9*, the results of the entire project are discussed.

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CHAPTER 2

Terminology, taxonomy, and facilitation of motor learning in clinical practice: protocol of a Delphi study

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JMIR Res Protoc 2013;2(1):e18

2

ABSTRACT

Background
Facilitating motor learning in patients during clinical practice is complex, especially in people with cognitive impairments. General principles of motor learning are available for therapists to use in their practice. However, the translation of evidence from the different fields of motor learning for use in clinical practice is problematic due to lack of uniformity in definition and taxonomy of terms related to motor learning.

Objective
The objective of this paper was to describe the design of a Delphi technique to reach consensus on definitions, descriptions, and taxonomy used within motor learning and to explore experts' opinions and experiences on the application of motor learning in practice.

Methods
A heterogeneous sample of at least 30 international experts on motor learning will be recruited. Their opinions regarding several central topics on motor learning using a Delphi technique will be collected in 3 sequential rounds. The questionnaires in the 3 rounds will be developed based on the literature and answers of experts from earlier rounds. Consensus will be reached when at least 70% of the experts agree on a certain topic. Free text comments and answers from open questions on opinions and experiences will be described and clustered into themes.

Results
This study is currently ongoing. It is financially supported by Stichting Alliantie Innovatie (Innovation Alliance Foundation), RAAK-international (Registration number: 2011-3-33int).

Conclusions
The results of this study will enable us to summarize and categorize expert knowledge and experiences in a format that should be more accessible for therapists to use in support of their clinical practice. Unresolved aspects will direct future research.

INTRODUCTION

Background

Motor learning has been a central topic in the sport domain, and has more recently received increased attention in the context of rehabilitation,[1] especially in people with neurological disorders.[2,3] In both populations, research into fundamental (e.g., underlying mechanisms)[4] as well as clinical (e.g., application to individuals) aspects[5,6] of motor learning is increasing. Although the target populations within sport and rehabilitation do not seem to be comparable, the processes, principles, and underlying assumptions of their learning process share considerable features. However, a clear structure for the translation of knowledge and evidence, not only from sports to rehabilitation, but also from laboratory research to the clinical situation, is currently absent.

Speaking the same language

Within the behavioral motor learning literature, usually in the context of skill acquisition in sports, several models and concepts exist where different terms, classifications, and/or taxonomies are used (e.g.,[7-13]). Often, the degree to which conscious knowledge is involved in the learning process is used as a starting point. Forms of learning that result in the accumulation of non-conscious, procedural knowledge are described as implicit, whereas forms of learning that result in the accumulation of conscious, declarative knowledge are generally described as explicit.[14,15] In recent years, there has been a significant increase in the number of studies evaluating the application of implicit and explicit forms of learning. Target populations are not only healthy people and athletes but also patients with neurological disorders.[16-26]

Unfortunately, there is a lack of clarity with regard to definitions across studies and consequently the forms of learning are applied differently within study paradigms.

If we want to link research from different fields, we need to enable comparison of evidence and expertise. In order to further translate results into practice, it is important that researchers, therapists, and others professionals involved in facilitating the motor learning process speak the same language and use uniform terminology. Therefore, the main aim of the described study protocol is to achieve consensus on the definitions, descriptions, and taxonomy of terms related to motor learning, using the distinction in implicit and explicit forms of motor learning as a conceptual basis.

Application of motor learning

Physiotherapists and occupational therapists are specialized in providing therapy that is tailored to facilitate motor skill learning of patients with a wide range of pathologies. A substantial proportion of the patients therapists treat are older people with pathologies of the central nervous system, related to conditions such as stroke, Parkinson's disease or dementia.[27] As well as motor problems, these patients often experience problems on a cognitive level, making motor learning more difficult.[28]

Some general principles of motor learning related to neural plasticity (e.g., intensive and task specific training, "use it or lose it") are available for therapists to use in their practice.[29,30] These principles generally direct clinical practice in terms of what to do and how often; however, the application of these theoretical principles during daily practice often remains unclear (e.g., When and how to vary between tasks? Which instructions should be given and when?).

Traditionally, therapists often use rational arguments and many verbal instructions to engage patients in motor learning[31] possibly promoting more explicit forms of motor learning. In patients with cognitive impairments, this approach is often not feasible. It remains unclear though to what extent cognitive impairments should influence the choice between more implicit and more explicit forms of learning.[32]

Achieving consensus on applying motor learning is probably not realistic and maybe even not desirable, as clinical practice is complex and choices made within the motor learning process are often multi-factorial. Following a "one-size-fits-all" approach to motor learning is not possible in such a dynamic process. However, especially for less experienced therapists, it is important to have a starting point, a framework, which can help guide their practice while leaving enough space for patient tailored decision-making. The second aim of the study is therefore to explore how motor learning can be facilitated in practice and how choices for motor learning strategies can be made, particularly in people with cognitive impairments. The experiences of the experts might provide indications of how theory can be translated into practice and provide a framework to support therapists' choices for designing treatment.

The objective of this paper was to describe the design of a Delphi technique: (1) to achieve consensus on the definitions, descriptions, and taxonomy of terms related to motor learning, and (2) to explore how motor learning can be facilitated in practice and how choices within motor learning can be made, using the distinction in implicit and explicit forms of motor learning as a conceptual basis.

METHODS

Delphi technique

The Delphi technique consists of a series of sequential questionnaires or "rounds" aiming to obtain the most reliable consensus of opinions from a group of experts.[33] The Delphi technique was chosen because it is useful for situations where individual opinions and knowledge are selected, compared, and combined in order to address a lack of agreement or an incomplete state of knowledge.[33,34] In this study, at least 30 experts will be invited to provide their opinion of different motor learning-related constructs. Two parallel processes will be initiated in the preparation of the actual Delphi rounds: (1) identification and invitation of experts, and (2) design of the structure and content of the questionnaires in the Delphi rounds.

Referee group

An international referee group, consisting of all authors of this paper, will identify and invite the experts. We will also prepare the content of the Delphi rounds and will supervise and monitor the process. We are a group of 7 researchers and 2 therapists with expertise in the field of motor learning and/or conducting the Delphi technique. Our backgrounds include epidemiology, physiotherapy, occupational therapy, movement sciences, and (sport) psychology. As members of the referee group, we will not participate in the survey.

Identification and invitation of experts

Heterogeneity within the expert panel is an important quality criterion.[33] We will therefore seek to include experts from different fields of motor learning. These experts should be researchers, lecturers, experienced therapists, or coaches working in the field of motor learning. Figure 2.1 provides an overview of how the experts will be identified and the expert panel will be composed. Experts in the field of research will be identified through a literature search (Figure 2.1, route A). The referee group will identify lecturers, experienced therapists, and coaches using their networks as these experts are more difficult to identify through literature (Figure 2.1, route B). Both routes together will be termed the *first layer of identification*. The aim of the extensive selection procedure is to create a heterogenic, international expert panel. However, it is not possible to predict to what extent we will succeed, as the expert group will be a purposive sample and not stratified on all characteristics that might be of influence.

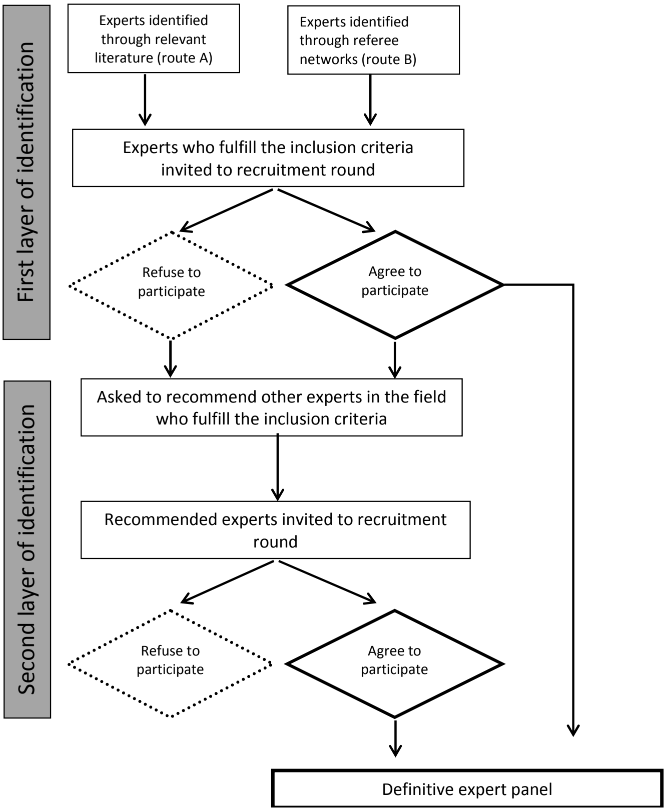

Figure 2.1 Identification and composition of the expert panel.

Experts identified from literature (Route A)

Researchers in the field of motor learning will be identified by an extensive literature search. This search will be conducted through PubMed/Medline and PsycINFO. Several search terms will be combined, depending on the search options of the digital database. The most important search terms will be motor learning, implicit, explicit, and skill acquisition. A researcher will be defined as an expert if he/she is the first, second, or last author of at least one empirical publication in the area of motor learning. Publications can be in the field of motor learning or skill acquisition in healthy populations, sports, and rehabilitation. Experts who have only published in the field of fundamental neuroscience related to motor learning will not be invited to participate, as the focus of the Delphi study is on facilitating motor learning in clinical practice. Fundamental research will be defined as studies using only outcome measures evaluating "body function and structures", according to the International Classification of Functioning, Disability, and Health.[35]

Experts identified from the referee members' network (Route B)

Parallel to the identification through the literature search, experts with practical expertise, such as therapists, lecturers, and coaches, will be recruited from the networks of the referee group. Though somewhat arbitrary, we defined an expert as a therapists, coach, or lecturer with at least 3 years of working experience in applying motor learning in practice and involvement in education or research.

Recruitment round

All eligible experts will be invited to participate in a recruitment round. Experts will receive an email comprising of a brief introduction of the aim and content of the survey, the amount of time to complete the questionnaires, and a personal link to open the online survey program. The aim of this recruitment round will be twofold. The first aim is to inform experts about the survey and to obtain consent for participation. Participating experts will be asked to provide detailed information on their age, background, years of experience, field of interest, working country, and current position to help to define the composition of the panel (see Multimedia Appendix 2.1). The second aim is to identify additional experts who were not identified through the literature and the network of the referee group members. All invited experts will be asked to recommend other experts (Figure 2.1, the so-called *second layer of identification*) irrespective of whether they have agreed to participate or not (i.e., snow-ball sampling). They will be explicitly asked to identify expert lecturers, coaches, or therapists who fulfil the inclusion criteria, as those experts are more difficult to identify through publications. This process hopes to limit the extent to which the sample of experts is biased by the network of the referee group.

Panel size and composition

There are no clear guidelines for an appropriate panel size for studies using the Delphi technique and there is only limited evidence on the effect of the panel size on the validity and reliability of any consensus that is reached.[34] Therefore, in accordance with another study,[36] we consider a panel size of at least 30 experts to be appropriate-approximately 10 researchers from motor learning in rehabilitation, 10 researchers from the field of motor learning in healthy individuals and sports, and 10 experts with experience in applying motor learning in practice. Although it is not possible to predict the number of experts who will be identified, agree to participate, and complete the survey, we used data from earlier studies for guidance. Based on data of a recent, Web-based Delphi study,[37] it is expected that 60% of the invited experts will agree to participate, that 70% of the participants will return the first questionnaire, and 50% of the participants will complete the entire survey. Therefore, we will initially invite at least 100 experts to participate (on a voluntary basis), however no upper limit will be imposed on the number of invited experts. Experts who do not respond to the invitation will be reminded twice to do so. If experts agree to participate, they will be considered part of the definitive expert panel. Experts who agree to participate but do not respond to one of the questionnaires will be sent two reminders. As long as experts do not explicitly withdraw from participation (via mail or using a link within the survey), they will be considered part of the panel and will receive an invitation for each round. An exception will be those experts who do not respond to round one and round two. They will not be invited to the third round and will be excluded from the panel.

Design and content of the survey

All rounds will be designed and distributed using an online survey program (SurveyMonkey, LLC, California, USA). Figure 2.2 provides an overview of the process and content of the 3 rounds. In the following section, the content of the 3 rounds and the expected results are described. The description of the first round is more detailed than the second and third rounds, as the content of these rounds will mainly be based on the findings from the earlier ones. In general, the second and third round will each consist of 2 parts. In the first part, answers from the former round will be further verified and the second part will focus on new aspects.

The first round

The first round will focus on the definitions, descriptions, and taxonomy of implicit and explicit forms of motor learning and a variety of motor learning strategies.
First, aspects of different definitions and descriptions for implicit and explicit motor learning that are provided in the literature will be presented. Experts will be asked to choose which of these aspects should be included in the definitions. Next, a list of strategies (e.g., analogy learning, discovery learning) that are often described in the literature will be presented together with a description of each strategy. Per strategy, experts will first be asked whether they know the strategy and whether they have used the strategy in research or in practice. Experts, who stated to know the strategy, will then be asked whether they agree with the description provided. If they do not agree, they will be asked to provide arguments in an open comment box. Third, experts will be asked whether they can classify the strategy as promoting a more implicit or explicit form of motor learning.

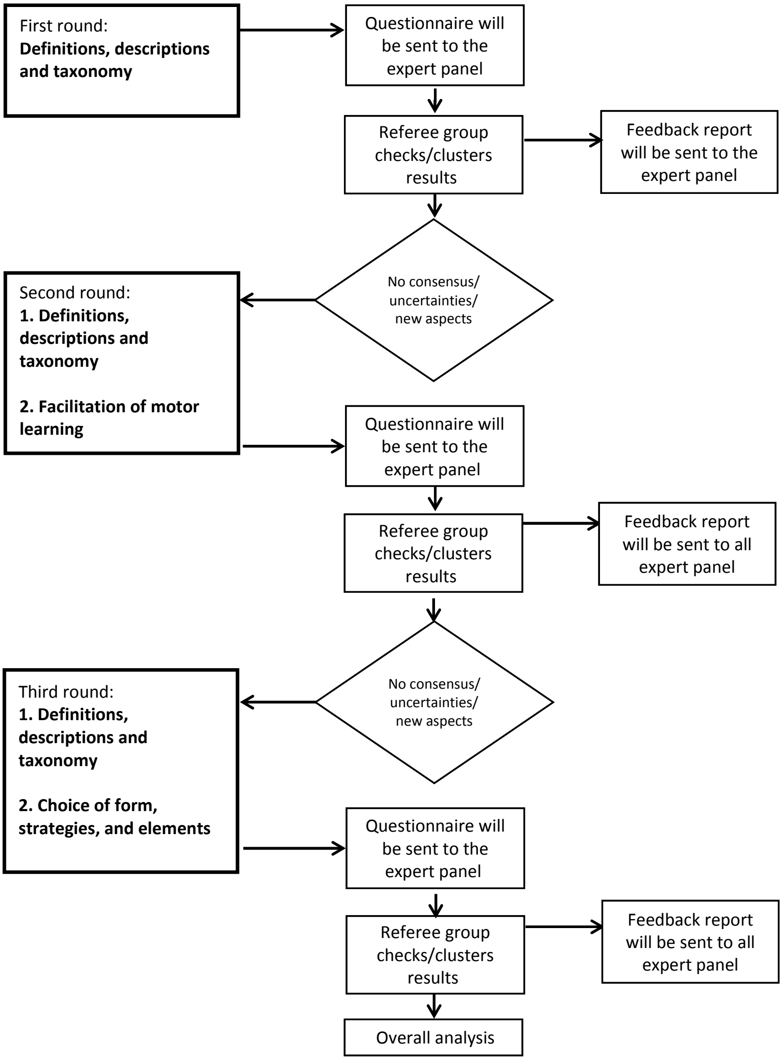

Figure 2.2 Overview of the procedure and content of the Delphi rounds (squares=process steps; rhomboids=decision steps).

Preliminary data analysis after first round

To prepare the second round, the referee group will perform a preliminary analysis of data. Definitions of implicit and explicit motor learning will be created based on consensus from the separate definitional aspects provided in the survey. Consensus will be defined when 70% or more of the experts agree on a certain aspect. If no consensus is achieved, then percentages of agreement will be presented, however, no definitions will be formulated. Only strategies that more than 70% of the experts state to know will be taken into account in the second round (termed best-known strategies). Descriptions of those strategies will be adapted and if necessary, reformulated based on the open text comments.

The second round

The aim of the second round will be twofold. First, a summary of the answers of the first round will be provided. The formulated definitions will be presented to the experts and they will be asked whether they agree with these definitions. The adapted description of the strategies will also be presented again.
The second part of the survey will focus on experts' opinions and experiences on how motor learning can be facilitated in a single therapy session. Experts will be asked to state how instructions, feedback, and organization of the environment (so-called "elements" of motor learning) can be used to facilitate implicit and explicit motor learning.
Experts will be presented with a list including elements that could be used to facilitate motor learning. They will be asked whether these elements would facilitate a more implicit or a more explicit form of learning. To make answers comparable, we will mainly use multiple choice questions, however, experts will have the opportunity to comment on every question (either by using the option "other" or "open comment box"). Furthermore, we will assess how these elements relate to the motor learning strategies identified by the experts as the best-known strategies from the first round.

The third round

If necessary, aspects for which no consensus in definitions, descriptions, and taxonomy was reached in rounds one and two will be presented again. Further, the second aim of the third round will be the identification of factors influencing and directing choices made within the motor learning process. The impact of cognitive impairments for these choices will be addressed specifically.

Data analysis

The referee group will be unaware of the identity of expert panel members with the exception of two members of the referee group who are responsible for correspondence (MK, SB). The analysis of the responses of the experts will be processed anonymously.
The questionnaires for the 3 rounds will consist of closed/multiple choice questions and some open questions. Closed/multiple choice questions will be used if there is some knowledge available with regard to the answers (e.g., from the literature or

earlier survey rounds). Each closed/multiple choice question will have the option “other” or “comment” to ensure that experts can also add answers that are not listed. If little or not enough knowledge is available to pre-structure the answer options, open questions will be used. Further, open questions will be used to inventory experiences of the expert panel.

The referee group will not decide for specific aspects where no consensus is reached. They will however, choose between two different options to proceed: (1) the aspect will be presented again to the expert panel in cases where consensus is likely to be achieved in the next survey round, or (2) the variety in answers will be reported in case of very diverse answers.

The answer to all explorative questions (facilitation of motor learning in the second round, and choice of form, strategies, and elements in the third round) will be analyzed using majorities and trends (e.g., ≥50%). Consensus is not expected for these questions as answers will be more influenced by the specific practical experience the expert has, and the target group he/she works with. Free text comments and answers from open questions will be described and if possible, clustered into themes. Quotes will be used to illustrate the main results.

Feedback reports

After every round, a summary of the results will be sent to each member of the expert panel. The results will be clustered, but not analyzed or interpreted in detail.

RESULTS

This study is currently ongoing. It is financially supported by Stichting Alliantie Innovatie (Innovation Alliance Foundation), RAAK-international (Registration number: 2011-3-33int).

DISCUSSION

This paper describes the design of a study using the Delphi technique in the broad area of motor learning. To our knowledge, it is the first time that the Delphi technique has been used for this topic area. The objective of this paper was to describe the design of the Delphi technique to reach consensus on definitions, descriptions, and taxonomy used within motor learning and to explore experts’ opinions and experiences on the application of motor learning in practice. However, as in any other study designs, the Delphi technique is subject to some points of consideration.

The most important advantage of using the Delphi technique is that it enables the synthesis of existing knowledge from experts with different backgrounds, including unpublished and practical expertise. In addition to gaining more insight into the definitions and taxonomy used within motor learning, the results of this study might also shed light on unresolved questions and controversial aspects within the field. A disadvantage of the Delphi technique is that the questions and answers are generally based on a theoretical, hypothetical basis. In addition, the referee group needs to have some conceptual structure in designing the survey. In this study, the distinction in implicit and explicit forms of motor learning is used, which will probably influence the line of reasoning and answers of the participants to some extent.

A well-composited expert panel is the linchpin of this study. As the scope of the Delphi topic is broad, it is important that the expert panel truly represents the available expertise on the subject. Experts from different fields of motor learning and with different backgrounds must participate in the Delphi study. As invited experts will be asked to recommend other experts, we will try to invite as broad a sample of experts as possible to prevent selection bias, however, only after the results are available can a judgment of the representativeness of the expert panel be made.

No new evidence will be generated by this study. The Delphi technique will merely be used to summarize existing knowledge and experiences regarding motor learning from experts with different backgrounds. It is therefore important that the results of this study will be considered as a starting point for future applied research. The aim of this research should be to confirm results and further explore unresolved aspects found in this study. At the same time, the available knowledge and experiences from the experts in this study can be accessed by therapists (and other users) who might find the information useful to directly support their clinical reasoning and practice.

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APPENDIX 2.1

Motor Learning

Delphi survey- PRELIMINARY ROUND

57%

In the following section, check only the box(es) that pertain(s) to you.

What is your background?
Please choose all applicable options.

- ☐ Rehabilitation Practitioner (PT, OT, ST)
- ☐ Psychologist
- ☐ Nurse
- ☐ Physician
- ☐ Movement Scientist
- ☐ Physician/medical doctor
- ☐ Coach
- ☐ Other (please specify)

In which area(s) of motor learning are you an expert?
Please choose no more than two options.

- ☐ Fundamental research (neuroscience)
- ☐ Sports
- ☐ Rehabilitation
- ☐ Elderly
- ☐ Children
- ☐ Education
- ☐ Other (please specify)

CHAPTER 3

Using a Delphi technique to seek consensus regarding definitions, descriptions and classification of terms related to implicit and explicit forms of motor learning

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ABSTRACT

Background

Motor learning is central to domains such as sports and rehabilitation; however, often terminologies are insufficiently uniform to allow effective sharing of experience or translation of knowledge. A study using a Delphi technique was conducted to ascertain level of agreement between experts from different motor learning domains (i.e., therapists, coaches, researchers) with respect to definitions and descriptions of a fundamental conceptual distinction within motor learning, namely implicit and explicit motor learning.

Methods

A Delphi technique was embedded in multiple rounds of a survey designed to collect and aggregate informed opinions of 49 international respondents with expertise related to motor learning. The survey was administered via an online survey program and accompanied by feedback after each round. Consensus was considered to be reached if >70% of the experts agreed on a topic.

Results

Consensus was reached with respect to definitions of implicit and explicit motor learning, and seven common primary intervention strategies were identified in the context of implicit and explicit motor learning. Consensus was not reached with respect to whether the strategies promote implicit or explicit forms of learning.

Discussion

The definitions and descriptions agreed upon may aid translation and transfer of knowledge between domains in the field of motor learning. Empirical and clinical research is required to confirm the accuracy of the definitions and to explore the feasibility of the strategies that were identified in research, everyday practice and education.

BACKGROUND

Motor learning is a central issue in sports, but has recently received increased attention in the context of rehabilitation.[1–6] A departure point for explanatory models of motor learning, in a variety of healthy and rehabilitation target groups, is the broad distinction between conscious and non-conscious attributes of the motor learning process. The distinction is often delimited by an implicit-explicit conceptualisation first made popular in cognitive psychology,[7] which proposes that implicit motor learning targets more non-conscious attributes of the motor learning process, whereas explicit motor learning targets more conscious attributes of the motor learning process.[8,9]

Although investigation of implicit and explicit forms of motor learning has become common-place in recent years, particularly in the sport-related motor literature,[9,10] for the most part, terminology has been insufficiently uniform. This has raised a barrier that hampers exchange of knowledge within and between fundamental domains of research and practical target groups.

For example, in describing or defining implicit and explicit (motor) learning, independent research groups have focused on the type of knowledge accrued during the learning process, e.g.,[8] the amount of attention or awareness needed to learn, e.g.,[11–13] or the way the results of the learning process are measured, e.g..[11,14] The terms implicit and explicit are sometimes also used to refer to the underlying memory systems that are involved, e.g.,[15] as synonyms associated with declarative and procedural knowledge, e.g.,[12] or to describe the actual application of learning in practice, e.g.,[16]. However, there is some overlap in underlying conceptualisations of implicit and explicit motor learning. For example, in many definitions and descriptions explicit motor learning is associated with conscious cognitive processes, whereas implicit learning is associated with nonconscious cognitive processes, e.g..[8,17] The lack of agreement sometimes results in different, or even conflicting, applications of implicit and explicit learning in study paradigms, clinical practice and education.

Intervention strategies, such as discovery learning, analogy learning and errorless learning, have been used to shape the motor learning process in clinical or non-clinical studies within different target groups.[18–20] In general, intervention strategies that lead to high conscious awareness of how the motor behavior is accomplished are applied to promote explicit motor learning, whereas intervention strategies resulting in low conscious awareness of how the motor behavior is accomplished are applied to promote implicit motor learning.[8,9] The theoretical underpinning for this implicit/explicit distinction proposes that motor learning is a process in which solutions to the motor problem are discovered either explicitly through a process of hypothesis testing made possible by the human ability to temporarily manipulate and store information consciously in working memory, or implicitly through a process of discovery that does not rely on conscious manipulation and storage of information by

working memory.[8,9,21] For example, reducing the amount of errors made during the motor learning process (errorless or error-reduced learning) is thought to moderate the need for hypothesis testing about possible motor solutions, which minimizes working memory involvement in movement and promotes implicit motor learning.[19,22]
Further, it has been argued that learning a motor task while performing a concurrent cognitive task (dual task learning) prevents working memory from temporarily storing conscious information related to motor solutions because working memory must engage in completing the cognitive task. Thus, the motor behaviour is learned more implicitly than if a cognitive secondary task was not performed concurrently.[8]
However, not all intervention strategies are used unambiguously with respect to the implicit/explicit distinction. For many motor learning strategies, it seems unclear whether they promote implicit or explicit motor learning or whether their ability to promote either form of learning is a function of the target population or the specific learning context in which they are applied. For example, discovery learning is regarded by some researchers as likely to result in predominantly implicit learning outcomes, whereas, other researchers argue that predominantly explicit outcomes result.[23] Yet, trial and error learning, which in practice seem little different from discovery learning, has been described to promote explicit motor learning.[19,24]
For therapists, coaches, researchers and teachers, uniform terminology is particularly important. Effective transfer of research results to clinical practice and education is promoted by clear terminology, and allows therapists and coaches to speak a common language among themselves (e.g., to set up treatment plans) or when instructing students.[25] The aim of this study was therefore to seek consensus regarding the definitions, descriptions and classification of terms related to the general distinction between implicit and explicit forms of motor learning.

METHOD

A survey consisting of a series of sequential rounds interspersed by controlled feedback[26] was performed to collect and aggregate informed judgments about motor learning from a group of experts. The survey consisted of three rounds, which were designed and distributed using an online survey programme (SurveyMonkey Inc, SurveyMonkey.com, California, USA). More detailed information about the method and rationale for the entire survey is presented elsewhere.[27]
A Delphi technique was embedded into the first two rounds of the survey to seek consensus regarding definitions, descriptions and classifications related to the explicit/implicit distinction in motor learning. Although there is minimal scientific evidence available to inform decisions about the number of survey rounds appropriate for a Delphi technique, two or three rounds have typically been employed.[28]

Information regarding the content and the results of the third round is not presented here as this round was not used as part of the Delphi technique.

The Central Ethics Committee Atrium-Orbis-Zuyd (Institutional Review Board) was contacted and formal written permission to perform the study described in the protocol[26] was obtained (13-N-144). The study was excluded from IRB review, because under the law, Medically Scientific Research with people (WMO), it does not submit people to actions or impose specific behaviors on them.

Procedure

A referee group consisting of seven researchers with backgrounds in epidemiology, physiotherapy, occupational therapy, movement sciences and psychology supervised and monitored the process. The group conducted the literature search, identified experts to be approached to complete the surveys, and prepared the questions for each survey round. Between each survey round, the group performed a preliminary analysis of data blinded to the identity of the experts. In addition, two members of the referee group (MK, SB) were responsible for distributing and monitoring the survey (e.g., sending reminders and feedback reports).
A panel of international experts was invited to contribute to the study. Panel members were initially selected on the basis of literature search or the networks of the referee group. Criteria for selection of an expert were based on either scientific publication(s) in the field of motor learning (researcher) or at least three years of working experience applying motor learning in practice plus involvement in education or research (therapist, coach, lecturer).
In a preliminary recruitment round, eligible experts were invited by mail to participate in the study. They were given a comprehensive introduction to the aims and content of the survey rounds, informed of the expected amount of time necessary to complete each survey and provided with a personal link to the online survey program. After informed consent was obtained from the experts, they were asked to provide personal information (e.g., background, years of experience, special interests). Those experts who were invited to participate were asked to recommend other experts in the field (so-called snowball sampling method), who were subsequently contacted in the same manner.
No clear guidelines regarding the optimal panel size for a Delphi study exist.[29] Consistent with another study using a Delphi technique,[30] a minimum panel size of 30 experts was targeted, comprising approximately ten motor learning researchers in rehabilitation, ten in healthy individuals and sports and ten with experience applying motor learning in daily practice.

Content of the survey rounds and analysis

Within the survey rounds, we distinguished between definitions and descriptions. The term "definition" was used when referring to forms of learning (e.g., implicit, explicit), whereas the term "description" was used when referring to motor learning strategies (e.g., errorless learning, trial and error learning). We made this distinction because the term 'definition' implies theoretical attributes/features of learning, while the term 'description' implies elements of how a strategy is applied.
Additionally, implicit and explicit motor learning have been described as representing a dichotomy in learning and also as representing tail ends of a learning continuum, so for the categorisation of intervention strategies we used answering categories that left room for both perspectives.

Table 3.1 presents the content of the survey rounds. Each survey round was divided into two parts. The first part of Round 1 focussed on creating a basic definition of implicit and explicit motor learning. The second part focussed on identifying, describing and classifying learning strategies. Questions in part one of Round 2 and 3 were used to verify responses in Round 1 and Round 2 respectively and to elaborate issues identified by the expert panel. Questions in part two of Round 2 and 3 addressed other predefined topics (results are not presented in this article).
In preparation of the study, the referee group performed a literature search in different fields of motor learning (sports, rehabilitation, fundamental research) using both scientific research articles and grey literature. The group identified several search terms, implicit, explicit, motor learning, skill acquisition, and used MeSH terms when possible. From these resources, e.g.,[1,8,11,17,31–35] statements which were related to implicit and explicit motor learning were extracted and compared. The referee group tried to improve readability of the statements by using comparable formulation.
Analysis of the data was conducted blind to the names and characteristics of the expert respondents. Open comments and additions made by the experts were clustered in themes and carefully considered by the referee group. Consistent with other studies, consensus was considered to have been reached when ≥70% of the experts agreed on a certain topic.[30,36,37] Differences in values and beliefs within the different professions represented by the experts might have influenced the results, so in cases where ≥70% of the experts agreed, the referee group checked for a profession-based imbalance in the responses, which was not the case.
If consensus was achieved, final definitions and descriptions were formulated. If no consensus was achieved, the topic and answers were presented to the expert panel in the following round.
After each round, panel members received a feedback report that summarised the response percentages for each question, as well as responses to open questions and additional comments. In these feedback reports, the results were clustered but not analysed or interpreted.

Table 3.1 Content and structure of the survey rounds

Round	Content	Questions	Answering options
1	Definition of implicit and explicit learning (part 1): Experts were provided with attributes used in the literature to define or describe implicit and explicit motor learning. The following questions were asked:	*The definition of implicit motor learning should in your opinion definitely contain the following attributes:*	multiple choice, more answers possible, see Results section for an overview of attributes provided
		The definition of explicit motor learning should in your opinion definitely contain the following attributes:	multiple choice, more answers possible, see Results section for an overview of attributes provided
		If you are aware of a definition of explicit/implicit motor learning from the literature, with which you can agree (best option), please give a citation of this definition in the box below. Please include the reference.	open comment box
	Identification and description of strategies promoting motor learning and their classification (part 2): A list of motor learning strategies was provided together with a description based on the literature. For each strategy the following questions were asked (see Results section for an overview of strategies provided):	*Do you know the strategy?*	dichotomous choice: yes/no, experts who agreed were referred to the next question, expert who did not agree were referred to the next strategy in the list
		Do you agree with the provided description?	dichotomous choice: yes/no and open box, see
		If not, please indicate what is missing or incorrect and/or provide your ideal description.	Results section for an overview the provided descriptions
		How would you classify the strategy?	multiple choice, only one answer possible, see Results section for the answering categories provided
		Have you used the strategy before (research or practice)?	dichotomous choice: yes/no
		Can you give an example of how you would apply this strategy in practice or research?	open comment box
2	Confirmation of results of part 1 from Round 1: Based on the results of part 1, the definitions of implicit and explicit motor learning were provided. Separately for the definitions of implicit and explicit motor learning the experts were asked:	*Do you, in general, agree with the definition?*	dichotomous choice: yes/no
		Please state any comments or additional information in the box.	open comment box
	Confirmation of results part 2 from Round 1: Only the best known-strategies were taken into account in this round. For each strategy the experts were asked:	*Do you, in general, agree with the modified description?*	dichotomous choice: yes/no

RESULTS

The recruitment process is shown in Figure 3.1. In total, 114 experts were invited to participate. Thirty-nine experts agreed to participate initially and recommended a further 49 experts. Fortynine experts completed the Round 1 survey and 44 completed the Round 2 survey. Characteristics of these experts are shown in Table 3.2. Experts were heterogeneous with regard to age, background and current working situation. Although the expert panel was internationally diverse, most were based in Europe. Of the 11 experts who did not respond to invitations or reminders, only two reported lack of time as the reason for non-response.

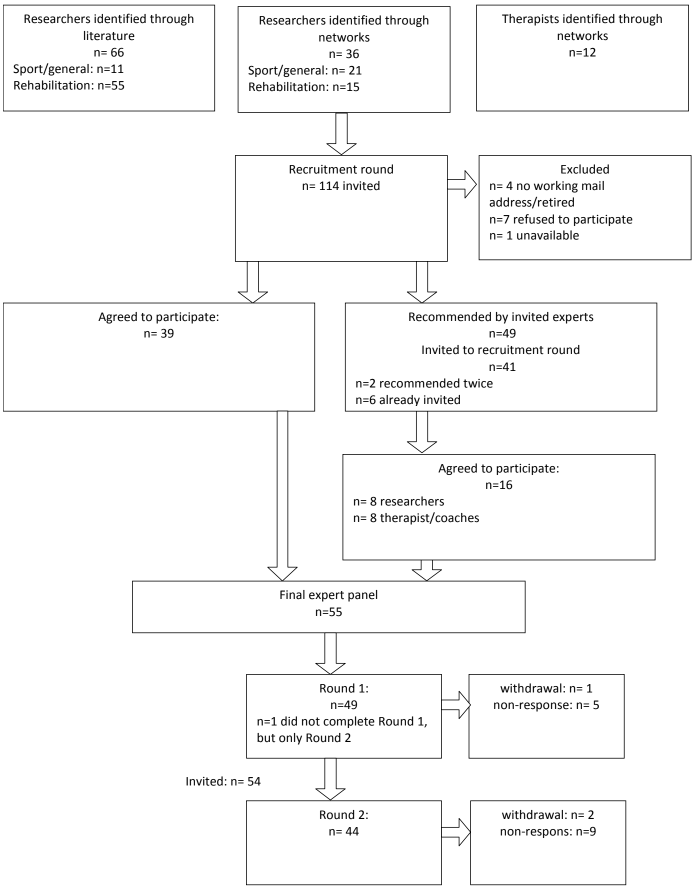

Figure 3.1 Recruitment and compilation of experts

Table 3.2 Characteristics of the expert panel

Category	Subcategory	Results (absolute numbers)
Gender	Male	23
	Female	27
Age category	20–30:	3
	31–40:	12
	41–50:	19
	51–60:	14
	61–70:	2
	>70:	2
	Not wanted to state/missing:	3
Working country	England/UK:	16
	The Netherlands:	8
	USA:	6
	Australia:	4
	Canada:	4
	France:	2
	Belgium:	2
	Germany:	2
	China/Hong Kong:	1/2
	New Zealand:	1
	Switzerland:	1
	Missing:	1
In last 5 years mainly worked as	Researcher:	22
	Lecturer/Educator:	8
	Therapist:	11
	Both researcher and lecturer equally:	2
	Other (e.g., consultant, psychologist):	6
	Missing:	1
Background*	Rehabilitation Practitioner (PT, OT, ST):	25
	Movement Scientist:	18
	Psychologist:	11
	Coach:	8
	Other (e.g., biomechanist, sport scientist):	5
Expert in which motor learning area*	Rehabilitation:	35
	Sports:	18
	Fundamental research (neuroscience):	13
	Elderly:	9
	Children:	4
	Education:	2
	Other (e.g., cognitive psychology, mental health):	4
Target population working with*	Neurological patients (adults):	23
	Elderly:	14
	Healthy population in general:	12
	Athletes:	11
	Neurological patients (children):	8
	Orthopaedic patients (adults):	1
	Healthy children:	1
	Other (e.g., therapists, patients with mental health problems):	5
Years of experiences	Research:	Mean: 14.1 (SD: 11.8)
	Not applicable:	7
	Practice:	Mean: 11.8 (SD: 10.0)
	Not applicable:	10

* more answer options were possible; Table is based on data of n=50 experts (n=49 experts completed Round 1 and 2; n=1 expert completed Round 2 only)

3

Definitions of implicit and explicit motor learning

The results with regard to the definitions of explicit and implicit motor learning are shown in Tables 3.3 and 3.4. Of the experts, 95.5% agreed in general with the following definition of explicit motor learning: *learning which generates verbal knowledge of movement performance (e.g., facts and rules), involves cognitive stages within the learning process and is dependent on working memory involvement.*

Table 3.3 Definition of explicit motor learning

Explicit Motor Learning	
Round 1 (n=49)	
Attributes provided in first round and percentages chosen	- **Involves cognitive stages*: 85.7%** - **Generates verbal knowledge of movement performance (e.g., facts and rules): 79.6%** - **Dependent on working memory involvement: 73.5%** - Facilitated by instructions abot how to perform the movement: 67.3% - With intention to learn: 63.3% - With purposeful hypothesis testing: 42.9% - Learning processes are faster (compared to implicit): 22.4% - Other: 12.2%
Round 2 (n=44)	
Definition provided in second round	Explicit motor learning can be defined as learning which generates verbal knowledge of movement performance (e.g., facts and rules), involves cognitive stages within the learning process and is dependent on working memory involvement
% agreement	95.5%
Comments after second round (n=agreed/disagreed)#	- <u>Aspect of an 'internal focus' should be involved (n=0/1)</u> - Three key attributes in definition are related and therefore redundant (n=1/0) - Disagreement about the involvement of cognitive stages (n=2/0)/working memory (n=2/0) - Disagreement about the distinction between implicit and explicit learning in general (n=1/0) - Disagreement about the verbal/explicit instructions (n=2/0)

* Attributes in bold were taken into account for the definition in Round 2; # Comments of experts who did not agree are underlined. Numbers in brackets signify amount of times that this comment was provided by experts who agreed/disagreed with definition

Six experts (12.2%) proposed additional attributes of the definition of explicit learning that were not provided initially (category ''other''). The additions included practical attributes (e.g., *"using an internal focus of attention", "using feedback"*) and attributes related to the result of explicit learning (e.g., *"responsible for rapid early improvement"*), but they were not incorporated into the definition as each was only suggested by one or two experts.

Table 3.4 Definition of implicit motor learning

Implicit Motor Learning	
Round 1 (n=49)	
Attributes provided in first round and percentages chosen	- **No or minimal increase in verbal knowledge*: 81.6%** - **Skills are (unconsciously) retrieved from implicit memory: 81.6%** - **Skills are learned without awareness: 69.4%** - Without exposure to verbal instructions about how to perform: 53.1% - Robust to disruption: 42.9% - Learning process takes longer (compared to explicit): 42.9% - Without an initial cognitive stage: 36.7% - No purposeful hypothesis testing: 30.6% - Other: 16.3%
Round 2 (n=44)	
Definition provided in second round	Implicit motor learning can be defined as learning which progresses with no or minimal increase in verbal knowledge of movement performance (e.g., facts and rules) and without awareness. Implicitly learned skills are (unconsciously) retrieved from implicit memory.
% agreement	88.6%
Comments after second round (n=agreed/disagreed)#	- <u>Disagreement about the fact that skills are learned without awareness (n=7/2)</u> - <u>Disagreement about use of the term ‘‘implicit memory’’ (n=5/1)</u> - Same attributes should be used in definition of implicit and explicit (n=1/0) - <u>Definition contains assumptions that should be tested first (n=0/1)</u> - Definitions should take the complexity of cognitive involvement more into account (n=1/0) - <u>External focus should be involved (n=1/1)</u>

* Attributes in bold were taken into account for the definition in Round 2. # Comments of experts who did not agree are underlined. Numbers in brackets signify amount of times that this comment was provided by experts who agreed/disagreed with definition

Of the experts, 88.6% agreed in general with the following definition of implicit motor learning: learning which progresses with no or minimal increase in verbal knowledge of movement performance (e.g., facts and rules) and without awareness. Implicitly learned skills are (unconsciously) retrieved from implicit memory.

Eight experts (16.3%) proposed additional attributes of the definition of implicit motor learning, which were eventually not incorporated into the definition, despite their importance for discussion (e.g., an *"external focus of attention"* is used; the learning is *"goal orientated"*; relies on *"functional practice in a meaningful environment"*). One expert pointed out that implicit learning is *"not non-cognitive"* and *"not unconscious"* but rather *"non-verbal"*. This expert further pointed out that implicit learning *"often does involve awareness of trying to accomplish something"*.

Thirteen existing definitions or extractions from literature were preferred or deemed to be as good as the new definitions, but none were mentioned more than once.

3

Descriptions of strategies

Table 3.5 provides an overview of 10 motor learning intervention strategies that were identified from the literature and gives the percentage of experts who indicated that they were aware of the strategies and/or used the strategies. Seven strategies were known by more than 70% of the experts and were therefore included in Round 2. After modification of the strategy descriptions, based on the comments in Round 1, consensus was achieved for six of the seven descriptions (see Table 3.6). Only for *observational learning* did percentage agreement decrease slightly after the description was reformulated (from 69.4% to 68.2%).

Table 3.5 Percentage of experts who knew/used the provided strategies

Strategy*	Percentage of experts who knew the strategy	Percentages of experts who have used the strategy before in research or practice
Trial and error	**91.8%**	**73.5%**
Observational	**89.8%**	**67.3%**
Errorless	**89.8%**	**63.3%**
Movement imagery	**85.7%**	**40.8%**
Discovery	**77.6%**	**36.7%**
Dual task	**77.6%**	**57.1%**
Analogy	**73.9%**	**55.1%**
Incidental	65.3%	
Self-regulatory	49.0%	
Constraints-led approach	46.7%	

*Strategies in bold were taken into account in Round 2

Classification of strategies

Responses regarding classification of whether the strategies are likely to result in (more) implicit or (more) explicit forms of motor learning were diverse (see Table 3.7).
Round 1 suggested that none of the strategies can be categorized as promoting just one form of motor learning. For the errorless, dual-task and analogy learning strategies, there was however a slight trend for the experts to consider these strategies as likely to result in a more implicit form of learning. Depending on the strategy, between 1 and 5 experts did not classify the separate strategies into one of the provided categories, but chose the option ‘other’ (between 4.5–16.7% of the sample).
A common argument in the open comment box was that the strategy could promote both implicit and explicit motor learning. Factors, such as, instructions, constraints in the environment, type of task/skill and the abilities of the learner were all deemed to have an influence on the outcomes of the learning strategy. According to the experts, manipulation of these factors has a profound influence over the degree to which a strategy results in implicit or explicit motor learning.

Table 3.6 Description of the best known strategies

Round 1 (n=49)	Description provided in first round	% agreement	Comments*	Round 2 (n=43/44)[#] Adapted description in second round	% agreement
Trial and error learning	*Learning by repeatedly attempting to perform a task during which errors are detected and corrected.*	71.4%	**The learner must (be able) to detect the error (n=6);** Learning is an iterative process (n=1); Correction of errors should not be emphasised (n=1)	*Learning by repeatedly attempting to perform a task during which the learner detects errors and corrects them.*	84.1% agreed; 9.1% preferred description from Round 1
Observational learning	*Learning by observing a movement. The observer determines the key spatial and/or temporal features of the task through observation, thereby creating a cognitive representation of the action pattern.*	69.4%	**Unsure about/delete ''cognitive representation'' (n=7); The demonstrator/ therapist can also direct the learner to the key features (n=1)**	*Learning by observing a movement. The observer determines the key spatial and/or temporal features of the task through observation, and/or is directed to these features by the demonstrator/ therapist.*	68.2% agreed; 20.5% preferred description from Round 1
Errorless learning	*Learning facilitated by constraining the learning environment so that very few errors occur.*	67.3%	**Learning environment and the instructions and skill difficulty can be constrained as part of the learning environment (n=3);** Should be applied particularly in early phase of learning (n=1); Replace ''very few errors'' with ''no errors'' (n=1)	*Learning facilitated by constraining the learning environment (e.g., instructions, skill difficulty) so that very few errors occur.*	77.3% agreed;13.6% preferred description from Round 1
Movement Imagery	*Learning by imagining oneself undertaking the skilled movement without actually doing the movement.*	71.4%	**Imagery should be from the first person perspective (n = 2); Exchange ''undertaking'' with ''performing'' (n=1);** Suggestions for terming the strategy (mental rehearsal, motor imagery) (n=2)	*Learning by imagining oneself performing the skilled movement (in the first or third person perspective) without actually physically performing the movement.*	81.8% agreed; 13.6% preferred description from Round 1

Table 3.6 Description of the best known strategies (continued)

Round 1 (n=49)	Description provided in first round	% agreement	Comments*	Round 2 (n=43/44)[#] Adapted description in second round	% agreement
Discovery learning	*Learning without guidance, instructions or feedback from another person.*	57.1%	**Without information from other sources (book, website) (n=2);** It is necessary to give instructions or feedback (n=2); Learning is facilitated by (constrained) context (n=3); Use (pure) discovery learning as a synonym for Trial and error (use this description) (n=1)	*Learning without guidance or feedback from another person <u>or information source.</u>*	75.0% agreed; 18.2% preferred description from Round 1
Dual-task learning	*Learning of a skill during simultaneous performance of another skill. The secondary task can be a motor or cognitive task.*	61.2%	**The (second) task must be of equal importance/difficulty and attention demanding (n=5);** Doubts about whether dual task is a form of learning (n=3)[+]	*Learning of a skill while simultaneously performing another <u>task</u>. The <u>second</u> task can be a motor or cognitive task but <u>must be attention demanding</u>*	81.8% agreed; 9.1% preferred description from round one
Analogy learning	*Learning facilitated by metaphors. The complex structure of the to-be-learned skill is integrated in a simple biomechanical metaphor that the learner is provided with*	51.0%	Did not agree with term 'biomechanical' (n=6)	*Learning facilitated by metaphors. The complex structure of the to-be-learned skill is integrated into a simple metaphor that the learner is provided with.*	95.5% agreed; 2.3% preferred description from round one

* Comments in bold were taken into account for the adapted description; [#] One expert did not complete all questions; [+] This remark was taken into account in separate questions in Round 2 (results not presented)

Table 3.7 Classification of the learning strategies

Classification	Trial and error learning (n=44)	Observational learning (n=44)	Errorless learning (n=44)	Movement imagery (n=42)	Discovery learning (n=38)	Dual task learning (n=38)	Analogy learning (n=36)
Implicit	2.3%	6.8%	18.2%	7.1%	18.4%	26.3%	11.1%
More implicit than explicit	9.1%	20.5%	45.5%	19%	26.3%	47.4%	58.3%
Both implicit and explicit	25%	34.1%	15.9%	21.4%	23.7%	7.9%	5.6%
More explicit than implicit	25%	25%	4.5%	23.8%	18.4%	10.5%	5.6%
Explicit	29.5%	9.1%	4.5%	11.9%	5.2%	0%	11.1%
Other	9.1%	4.5%	11.4%	16.7%	7.9%	7.9%	8.3%

Additional strategies

Twenty-two alternative motor learning strategies were suggested, which were not included in the initial list presented to the experts (e.g., win shift lose stay, verbal overshadowing, blocked practice, applied behaviour analysis). None of these strategies were mentioned by more than one expert and were therefore not incorporated in the following surveys rounds. Other suggestions were related more generally to the focus of attention during learning, the provision of feedback, the repetition and variability of practice and manual facilitation.

As a result of the diversity in answers and additional statements made by the experts, the referee group decided not to strive to seek consensus with regard to the classification but rather to explore the reasons for diversity. This was done in the third survey round and resulted in an overview of practical experiences, opinions and verifications of statements (results not presented).

Examples of the application of the strategies in clinical practice

The number of examples of the application of different strategies in clinical practice ranged from 30 (discovery learning) to 41 (errorless learning). For each strategy, the referee group chose two examples to present in this article (Table 3.8).

DISCUSSION

The aim of this study was to seek consensus on the definitions and descriptions of terms related to the conceptual distinction between implicit and explicit motor learning. Within a heterogeneous international group of experts, consensus regarding definitions of implicit and explicit motor learning, and descriptions of the best-known strategies used in the context of implicit and explicit motor learning, was reached. Both definitions incorporate central aspects of motor learning (e.g., form of memory and type of knowledge). Incorporation of more than one central aspect of motor learning is preferable to outlining a single aspect, as sometimes occurs in definitions, and suggests that there was at least some degree of consensus by the experts.

Consensus suggests that experts from the different fields represented within the study may think about and describe motor learning and the underlying processes in a comparable way, at least at a more theoretical level.

Table 3.8 Examples of the best known strategies provided by the experts

Strategy	Two random selected examples provided by experts
Trial and error learning	''Structure the learning environment so that errors will be made, but a positive outcome is achievable. Inform the learner that following the practice session they will be asked to describe the different techniques they tried and list what worked and what didn't.'' Putting on a jumper: ''Prompt when needed to avoid frustration but encourage patient to do without help. Positive reinforcement. Requires good attention levels.''
Observational learning	''Demonstration is probably used quite frequently by therapists who wish to demonstrate what they want a patient to do, or how they want them to do it. In my experience, this is generally accompanied by verbal instructions, making it more explicit. Patients may observe each other in a group setting, which could be formally set up (working in pairs) to create an observational learning environment –for example, for performing balance tasks.'' ''This technique is frequently used in dance classes where one dancer acts as a model and the other observe and then imitate.''
Errorless learning	''In aikido, novices may learn new techniques with a more experienced partner that would help novices to succeed every time they perform it.'' ''Learning to walk after a stroke with body weight support and a treadmill, and gradually increasing the body weight the person is taking as well as the treadmill speed.''
Movement Imagery	''With patients who are physically unable to perform such a movement at the beginning of rehabilitation, or if they fatigue quickly during physical practice.'' ''Imaging oneself climbing a wall and then climbing it.''
Discovery learning	''Children in a playful setting discover biomechanics of building with blocks.'' ''For teaching previously unknown skill – e.g., making piece of toast one handed. Explain what is needed and leave patient to work out how. Would need high level problem solving including attention and memory. Avoid distraction. Would require positive reinforcement.''
Dual task learning	''Having a child count backwards by 2's (depending on age and cognitive level) while walking on the balance beam.'' ''Clinicians working on more complex or real-world environments where motor tasks are combined with other motor tasks or cognitive tasks (such as talking). Instructions can be used to prioritize a task or it can be left to the discretion of the performer. Feedback and measures of performance should be provided on both tasks.''
Analogy learning	Jumping pattern: ''reach for an apple up in the tree'' Basketball shot: ''putting your hand into the cookie jar." Dance tango (in particular how to provide a good abrazo): ''like maintaining a newspaper always opened.''

According to the responses of the experts in this study analogy learning, errorless learning and dual task learning seem to promote more implicit learning in general. However, no consensus was reached within the expert panel on the classification of motor learning strategies for promoting a (more) implicit or (more) explicit form of motor learning. Based on the results of this study, it seems that most intervention strategies do not naturally promote implicit or explicit motor learning. They can promote either form of learning depending on their use in a specific learning situation and/or target population. It is probably impossible, and perhaps not even desirable, to achieve consensus. This result might be a consequence of the complexity of applying motor learning strategies in everyday practice. For example, athletes or patients usually need a tailored approach and the application of learning strategies is determined by multiple factors. Consequently, for research and education it is even more important that the application of an intervention strategy in a specific context is always described in detail.

Critical reflection on the study and the study results

To our knowledge, this is the first study that uses a Delphi technique in the field of motor learning. The results generated and summarized within the study are based on knowledge, opinions and practical experiences of an international expert panel. Consequently, the results should be interpreted tentatively; an expert group's opinion rather than empirical evidence.

Importantly, although consensus was obtained regarding the definitions, this does not mean that all of the experts, or indeed the authors (referee group), agree with the final definitions and descriptions. For instance, the final definition of implicit motor learning suggests that learning progresses "without awareness", but there are clearly occasions (e.g., sport, rehabilitation) when a person has intention to learn and is aware of learning, especially when outcome feedback is readily available.[21,38] It also seems unlikely that learning ever progresses with 'no' increase in verbal knowledge.

Although the Delphi technique is a well-accepted method for investigating opinions, there is currently no agreement on the meaning of *consensus*.[28] In our study, consensus was regarded as agreement within a selected group of leading experts on a certain topic, based on a criterion of 70% agreement or greater. However, lack of consensus (i.e., less than 70% agreement) does not directly imply that a statement was invalid, but may suggest that more plausible possibilities exist or that no alternatives exist yet. Numerous comments and statements were made by individual experts in response to the open questions. Although all were distributed in the feedback report, most were not carried back into the survey. As the aim of the study was to achieve consensus (a quantitative approach), we unfortunately were not able to take all single statements into account (a more qualitative approach). Consequently, comments/ statements which other experts may have agreed upon might have been overlooked.

The quality of the findings from a Delphi study is strongly related to the heterogeneity and representativeness of the expert panel. Although the response rate in the current study was low, the experts who participated can be described as heterogeneous with regard to their backgrounds, special interest and working experience. Further, the different practical areas of motor learning are represented by the expert panel. We tried to overcome selection bias within the sample by using snow-ball sampling; nevertheless, some selection bias may have occurred, as most of the experts who participated were based in Europe. This might be explained by the fact that six of the seven referee group members, whose networks were used to identify experts, were also based in Europe. We do not know to what extent the origin and background of the experts influenced the results, so we acknowledge that cultural values may account for some of our findings (especially, lack of consensus).

Contribution to scientific literature and implications for research

Despite the limitations already discussed, we believe that it is important to use uniform terminology when describing the content of motor learning studies and practical sessions, and within education. The study is a first important step towards helping therapists, researchers and other professionals to communicate about motor learning in general and to distinguish fundamentally between implicit and explicit motor learning more specifically. The added value of the study is that the definitions and descriptions that emerged are based on the opinions of an expert panel from different fields of motor learning, which might help to promote a common language across different fields.

Future applied research is needed to confirm the findings. Underlying neurophysiological and behavioural aspects of the definitions should be investigated by fundamental research. Clinical research investigating clearly defined and described techniques is needed to investigate whether the definitions of implicit and explicit motor learning, as well as the descriptions of the strategies, are feasible and applicable within clinical practice.

Acknowledgments

The authors are grateful to all the panel members who have participated in the study.

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(Two experts did not agree to be identified and the remaining experts did not respond).

3

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CHAPTER 4

Multidisciplinary views on applying explicit and iImplicit motor learning in practice: an international survey

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ABSTRACT

Background
A variety of options and techniques for causing implicit and explicit motor learning have been described in the literature. The aim of the current paper was to provide clearer guidance for practitioners on how to apply motor learning in practice by exploring experts' opinions and experiences, using the distinction between implicit and explicit motor learning as a conceptual departure point.

Methods
A survey was designed to collect and aggregate informed opinions and experiences from 40 international respondents who had demonstrable expertise related to motor learning in practice and/or research. The survey was administered through an online survey tool and addressed potential options and learning strategies for applying implicit and explicit motor learning. Responses were analysed in terms of consensus (≥70%) and trends (≥50%). A summary figure was developed to illustrate a taxonomy of the different learning strategies and options indicated by the experts in the survey.

Results
Answers of experts were widely distributed. No consensus was found regarding the application of implicit and explicit motor learning. Some trends were identified: Explicit motor learning can be promoted by using instructions and various types of feedback, but when promoting implicit motor learning, instructions and feedback should be restricted. Further, for implicit motor learning, an external focus of attention should be considered, as well as practicing the entire skill. Experts agreed on three factors that influence motor learning choices: the learner's abilities, the type of task, and the stage of motor learning (94.5%; n=34/36). Most experts agreed with the summary figure (64.7%; n=22/34).

Conclusion
The results provide an overview of possible ways to cause implicit or explicit motor learning, signposting examples from practice and factors that influence day-to-day motor learning decisions.

INTRODUCTION

The acquisition and improvement of motor skills is important to a range of people in different target populations, including athletes and patients in rehabilitation. Although these populations may not at first seem to be comparable, both seek to develop motor performance that is beyond their current capabilities in terms of temporal, spatial and environmental demands of the task.[1,2] Both coaches and therapists must decide how to shape motor performance by selecting from a variety of possible motor learning solutions.

There is a growing body of scientific evidence that reports on approaches designed to influence motor learning.[3] However, the circumstances in which motor learning approaches are applied during practice and research are often different. Researchers mainly apply motor learning interventions in controlled circumstances according to a protocol, often within a highly selected population. Practitioners (e.g., physical therapists), on the other hand, mainly apply motor learning in circumstances that are less controllable and more variable. To aggregate and compare knowledge and opinions from different fields, an international survey of researchers and professionals with different backgrounds and demonstrable experience of motor learning in sports, rehabilitation and research was performed.[4] The distinction between implicit and explicit motor learning was used as a conceptual departure point. The distinction between these two forms of motor learning has often been used in laboratory (e.g.,[5–7]) and clinical research (e.g.,[8–10]), as well as in overview papers,[11–15] in a variety of fields and for different skills.

We have previously reported our results from earlier rounds of the survey, which focused on definition and classification issues related to implicit and explicit motor learning.[16] Consensus was reached on the definitions of both explicit and implicit motor learning. Explicit motor learning was defined by experts as "learning which generates verbal knowledge of movement performance (e.g., facts and rules), involves cognitive stages within the learning process and is dependent on working memory involvement", whereas implicit learning was defined as "learning which progresses with no or minimal increase in verbal knowledge of movement performance (e.g., facts and rules) and without awareness". The experts further identified seven common motor learning intervention strategies (in this article referred to as best-known strategies): discovery learning, analogy learning, errorless learning, observational learning, dual task learning, trial and error learning, and movement imagery.[16]

Although there seems to be agreement on the definitions of terms related to motor learning, there are lot of examples of different methods and techniques used to apply implicit or explicit motor learning. For example, Masters "caused" implicit motor learning by asking participants to carry out a concurrent random letter generation task while practicing a golf-putting task (dual-task) or by using a biomechanical metaphor (analogy).[17,18] More recently, McCombe Waller and Prettyman probably caused implicit

4

learning of a balancing task by asking participants to focus on a different task (i.e., grasp, release and reach) during upright standing[19] and Van Tilborg et al. used modeling (observation) to facilitate implicit motor learning of every day instrumental ADL (activities of daily living) tasks.[8] In other work, the environment has been manipulated during learning of tasks, such as dynamic balancing or throwing,[9,20] in order to promote or reduce errors, which is thought to facilitate explicit or implicit motor learning respectively. Typically, explicit learning has been operationalized by instructing learners to discover rules by themselves[20] or by providing them with verbal instructions or rules.[8,10]

The aim of the current paper was to provide clearer guidance for practitioners on how to influence motor learning in practice. This was achieved by exploring experts' opinions and experiences of how motor learning can be applied in practice, using the distinction between implicit and explicit motor learning as a conceptual departure point.

METHOD

Design

This study was part of a larger Delphi technique.[4] Three sequential survey rounds, interspersed by controlled feedback, were used to collect and aggregate informed judgements from a group of experts on different aspects of motor learning. The study was designed and distributed using an online survey programme (SurveyMonkey, SurveyMonkey.com, LLC, California, USA).

In this article, we present results of the second and the third round, which addressed the application of motor learning approaches in practice. More detailed information about the method and rationale for the entire survey is presented elsewhere.[4] The Central Ethics Committee Atrium-Orbis-Zuyd (Institutional Review Board, IRB) was contacted and formal written permission to perform the study described in the protocol[4] was obtained (13-N-144). According to the IRB, this study was exempt from IRB review, based on the law Medically Scientific Research with people, because there is no way of submitting people to actions or to impose upon them certain behaviors.

A referee group (all authors of the paper) consisting of seven researchers with backgrounds in epidemiology, physiotherapy, occupational therapy, movement sciences and psychology, all with experience of working with different target groups (e.g., sports, general population, rehabilitation, geriatric care), supervised and monitored the process. Two members of the referee group (MK, SB) were responsible for distributing and monitoring the survey (e.g., sending reminders and feedback reports).

Study population

A panel of international experts was invited to participate in the survey. Members of the panel were initially identified via a literature search and/or the networks of the referee group (Figure 4.1.) Criteria for selection of an expert were based on either scientific publication(s) in the field of motor learning (researcher) or at least three years of working experience applying motor learning in practice plus involvement in education or research (therapist, coach, lecturer).[4] Experts gave informed consent to participate in the study within the online survey programme.

Content of the survey

First, experts were asked to state 1) how they would apply implicit and explicit motor learning and 2) how they would apply the seven best-known motor learning strategies.[16] A list of options (in this paper called "elements") that could be used to operationalize motor learning in practice was provided. Elements included the use of instructions, focus of attention, manual guidance, environmental constraints, variation and feedback and were based on the results of a general literature review, which was conducted when preparing the survey.[4] Experts were asked how they would cause a more implicit or explicit form of learning by using these elements (Round 2). To make answers comparable, primarily predefined categories of response options were used; however, experts had the opportunity to comment on each question (either by using the option "I cannot state as it depends on. "or by using an 'open text box') (Table 4.1).

During interim analysis, it was decided that it would be appropriate to try to synthesise the large amount of information provided by the experts into a more comprehensible overview using a summary figure (Figure 4.2). The aim of this summary figure was to present the different strategies and elements suggested in the survey together with a possible taxonomy. The elements were therefore clustered into three categories: instructions (instructions on task, instruction on focus of attention, and manual guidance), feedback (content and timing of the feedback) and organisation (environmental constraints, amount of variation, and division of the skill).

In the subsequent round (Round 3), the experts were asked to state whether they 1) agreed with the figure, 2) agreed with the figure subject to modifications (an open comment box was provided for suggested modifications) or 3) did not agree with the figure.

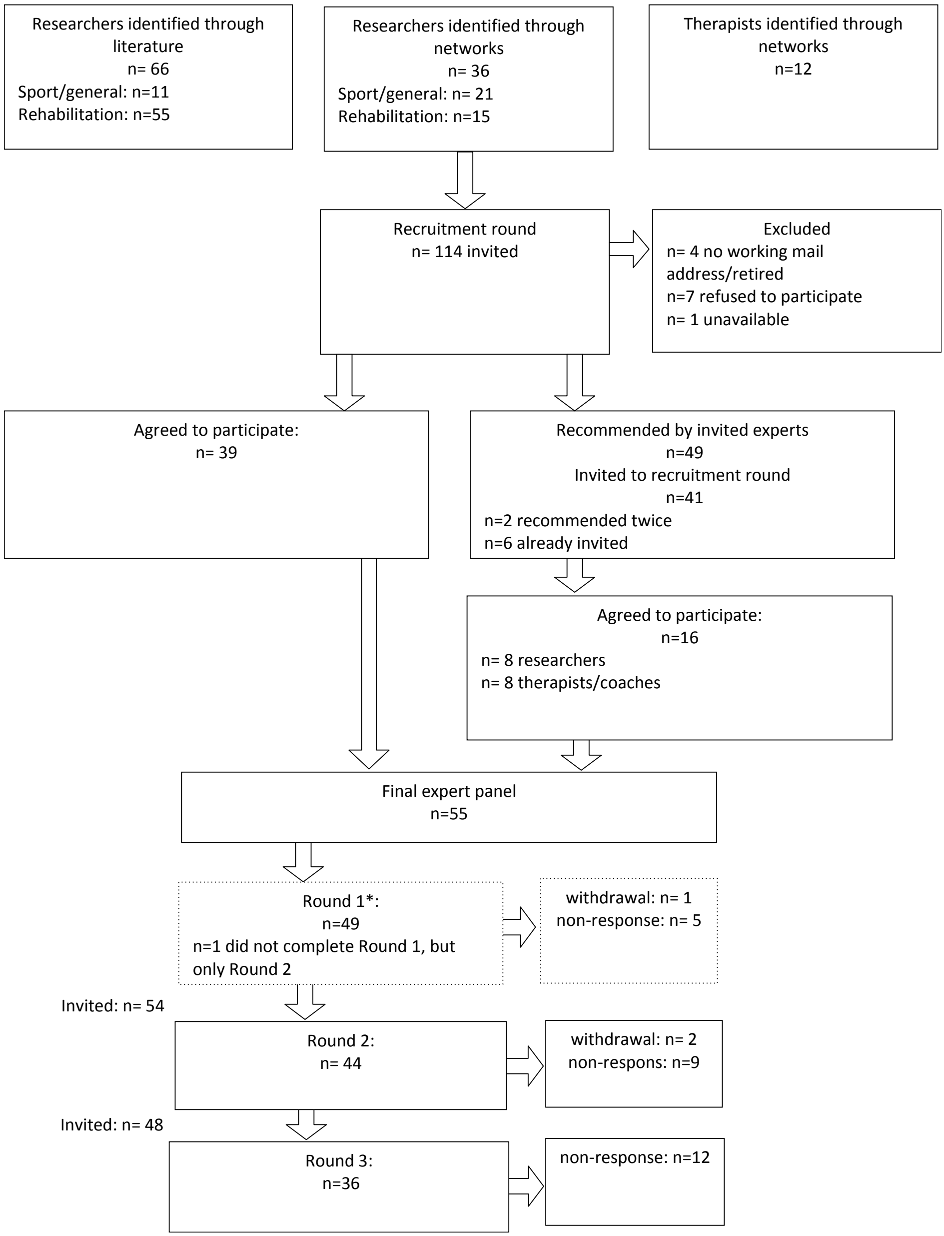

Figure 4.1 Recruitment and compilation of experts
*Boxes of Round 1 are dashed as results of this round are not taken into account in this article

Table 4.1 Questions asked within the survey

Element	Question	Answering method	Answering options
Instructions	Should any specific instructions be given to the learner about the task?	Open comment box	-
Focus of attention	Should the learner be instructed to focus on:	Multiple choice; one option	Internal cues (internal focus of attention) External cues (external focus of attention) Not applicable I cannot state as it depends on (open comment possible)
Manual guidance	Should manual guidance be used?	Multiple choice; one option	No Little Some Much Not applicable I cannot state as it depends on (open comment possible)
Feedback (content)	Which forms of feedback should the learner receive?	Multiple choice; more options	Feedback on the performance Feedback on the results Addressing the aspects of the performed skill which are good; Addressing the aspects of the performed skill which should be improved Not applicable I cannot state as it depends on (open comment possible)
Feedback (timing)	When should the feedback be given?	Multiple choice; more options	During the movement After the movement Immediately after the relevant action Delayed after the relevant action

Note: Questions were asked separately for implicit and explicit motor learning

Data analysis

Data analysis was conducted blind to the names and characteristics of the expert respondents. Responses to multiple-choice questions were presented as percentages or absolute numbers. Additionally, the level of agreement with regard to operationalization of motor learning was explored. According to earlier rounds of the survey, consensus on a topic was reached if ≥70% of the experts agreed on one option of a multiple-choice question.[4,21–23] As the study had an exploratory character, consensus was not expected for all questions. Therefore, answers were also analysed using trends (≥50%).

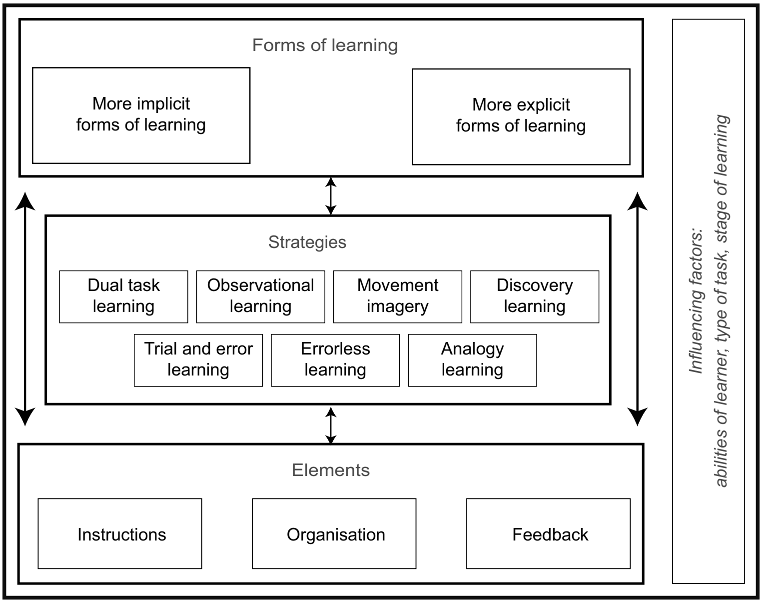

Figure 4.2 First version summary figure

Ninety-five percent confidence intervals for proportions are presented if possible using the Clopper-Pearson exact method.[24] Answers to questions for which experts could choose multiple answers are presented using absolute numbers, together with the percentages (and 95% CI's) of experts who chose identical combinations of multiple answer options. Subgroup analysis was performed to check whether there was a difference between the answers of experts with a more theoretical/scientist/management role and of experts with a more practical role (e.g., therapists and lecturers). This categorisation was based on the answer to the question "within the past 5 years I mainly worked as" (Table 4.2). Fisher's exact test was used and significance criteria was set at $\alpha = .05$. Free text comments and answers from open questions were described and, if possible, categorised. For example, experts were asked to state whether they would provide instructions when applying implicit or explicit learning in an open comment box and their responses were categorised into: "Yes (no further explanation)", "Yes with further explanation", "No (no further explanation)","No further explanation" and "other". These answers were presented in a figure together with additional subcategories.

RESULTS

Forty-four experts agreed to participate in the portion of the survey that is presented here. Four experts were excluded from analysis as they skipped all questions in this part of the survey. Two of these experts had mainly worked as researchers during the last five years, one mainly as lecturer and one as a therapist. One of the excluded experts indicated in earlier parts of the survey that he/she did not agree with the design and content of the overall survey. Characteristics of the remaining 40 experts are shown in Table 4.2. The population of experts was heterogeneous with regard to age, background and current working situation. Not all experts responded to every question. In the text below the number of experts reflects the actual number of participants who answered a certain question.

Facilitation of implicit and explicit motor learning

Most experts stated that, to promote explicit learning, instructions should be provided (n=29/34) and should either include 'the goal of the task', 'the steps or rules that need to be followed', or a combination of both. Most experts stated that, to promote implicit learning, instructions should be limited or avoided (n=25/35). The detailed answers to the open-ended questions regarding the use of instructions in explicit and implicit motor learning are illustrated in Figure 4.3.

The responses with regard to focus of attention, manual guidance, environmental constraints, variation and division of the skill were widely distributed (Table 4.2). Two trends were found: when applying implicit motor learning, 50% of the experts (n=20/40) stated that they would choose an external focus of attention and 52.5% of the experts mentioned that the entire skill should be practiced (n=21/40). Subgroup analysis was performed and revealed no significant difference between the two groups for either of the elements presented in Table 4.3 (all p-values>.05).

Experts could choose four options regarding the content and the timing of feedback when promoting implicit or explicit motor learning. For explicit learning, 60% (n=24/40; 95%CI: 43.3%-75.1%) of the experts chose all four feedback content options (performance, results, good and improvable aspects), whereas for implicit motor learning, 42.5% (n=17/40; 95%CI: 27.0%-59.1%) of the experts only chose feedback of results and 25% (n=10/40; 95%CI: 13.3%-41.2%) chose none of the content options, selecting only options "not applicable" or "depends on". With regard to the timing of feedback in explicit learning, answers by the experts group were broadly distributed. A similar trend was evident for the timing of feedback when promoting implicit learning, with 40% (n=16/40; 95%CI: 24.7%-56.7%) of the experts choosing "not applicable" or "depends on", rather than one of the available timing options. Again, subgroup analysis revealed no significant difference between the two groups for choices regarding the content and timing of feedback (all p-values>.05).

Table 4.2 Characteristics of the participating experts

Category	Subcategory	Results†
Gender (n=40)	Male	19
	Female	21
Age category (n=39)	20-30	1
	31-40	11
	41-50	16
	51-60	8
	61-70	-
	>71	2
	Not wanted to state/missing	2
Working country (n=39)	England/UK	14
	The Netherlands	7
	USA	4
	Australia	2
	Canada	3
	France	2
	Belgium	-
	Germany	2
	China/Hong Kong	3
	New Zeeland	1
	Switzerland	1
	Missing	1
In last 5 years mainly worked as (n=39)	Researcher	21
	Lecturer/Educator	5
	Therapist	8
	Other (e.g., consultant, psychologist	5
	Missing	1
Background	Rehabilitation Practitioner (PT, OT, ST)	19
	Movement scientist	14
	Psychologist	9
	Coach	6
	Other (e.g., sport scientist, podiatrist)	4
Expert in which motor learning area* (n=40)	Rehabilitation	28
	Sport	15
	Fundamental research (neuroscience)	13
	Elderly	7
	Children	2
	Education	1
	Other (e.g., cognitive psychology, mental health)	3
Target population working with* (n=40)	Neurological patients (adults)	19
	Elderly	12
	Healthy population in general	12
	Athletes	8
	Neurological patients (children)	4
	Orthopaedic patients (adults)	1
	Healthy children	1
	Not a practitioner	3
Years of experiences (n=40)	Research	Mean: 12.4 (SD:11.9)
	Practice	Mean: 10.9 (SD:9.5)

* multiple answer options were possible; † absolute numbers; PT: Physiotherapist;, OT: Occupational Therapist; ST: Speech and Language Therapist

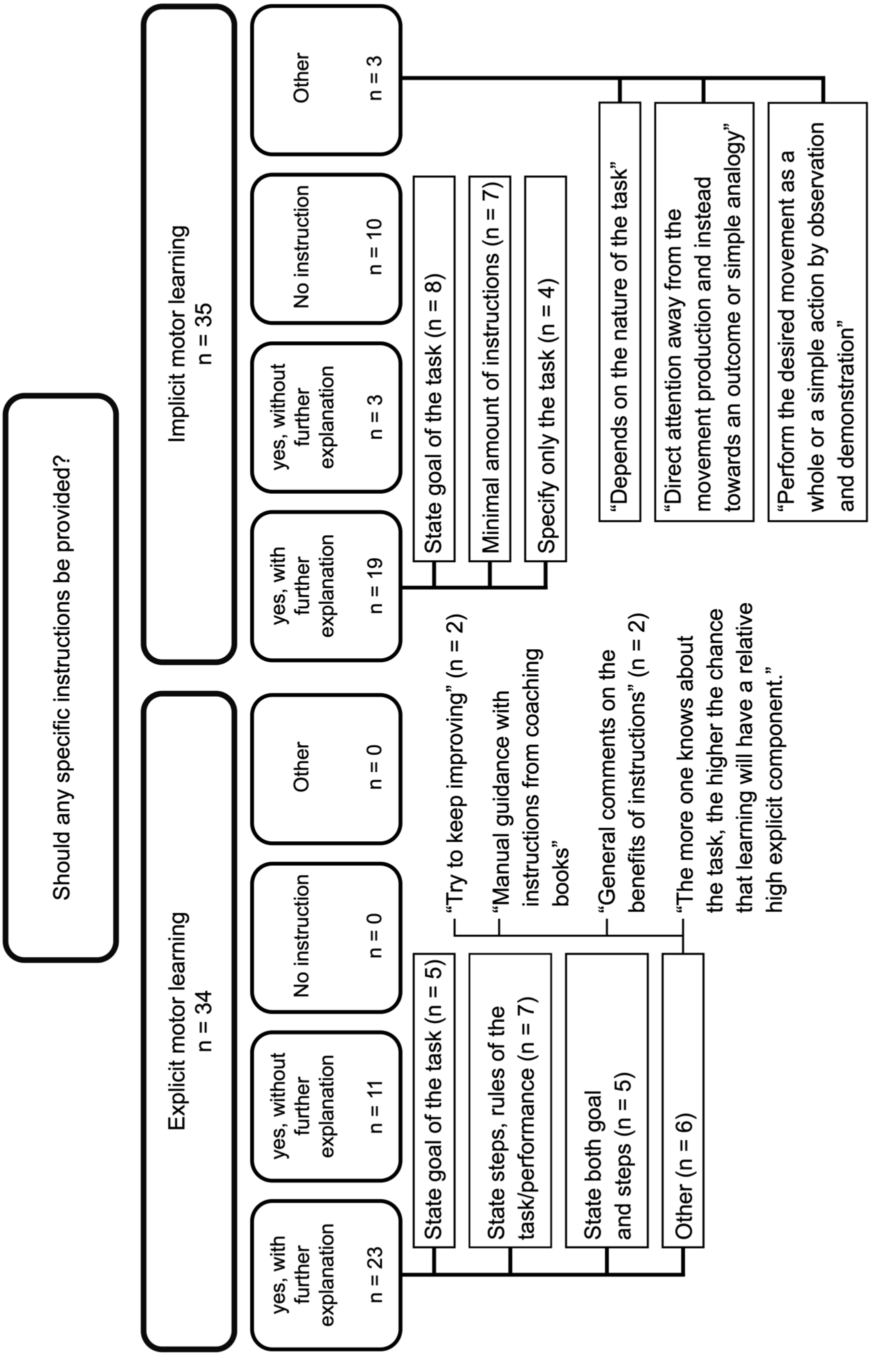

Figure 4.3 Overview of answers regarding instructions to promote implicit or explicit motor learning.

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Table 4.3 Overview answers regarding the use of focus of attention, manual guidance, environmental constraints, variation and the division of the skill into parts in implicit and explicit motor learning

Elements	Answer options	Implicit	95%CI	Explicit	95%CI
Focus of attention (n = 40)	Internal:	10%	2.8%-23.7%	32.5%	18.6%-49.1%
	External:	50%	33.8%-66.2%	32.5%	18.6%-49.1%
	Not applicable:	22.5%	10.8%-38.5%	2.5%	0.0%-13.2%
	Depends on:	17.5%	7.3%-32.8%	32.5%	18.6%-49.1%
Manual guidance (n =40)	Much:	2.5%	0.0%-13.2%	10%	2.8%-23.7%
	Some:	10%	2.8%-23.7%	30%	16.6%-46.5%
	Little:	17.5%	7.3%-32.8%	12.5%	4.2%-26.8%
	No:	17.5%	7.3%-32.8%	2.5%	0.0%-13.2%
	Not applicable:	12.5%	4.2%-26.8%	10%	2.8%-23.7%
	Depends on:	40%	24.9%-56.7%	35%	20.6%-51.7%
Environmental constraints (n =40)	Highly constrained:	15%	5.7%-29.8%	7.5%	0.2%-20.4%
	Somewhat constrained:	25%	12.7%-31.2%	35%	20.6%-51.7%
	Few constraints:	25%	12.7%-31.2%	17.5%	7.3%-32.8%
	No constraints:	7.5%	0.2%-20.4%	10%	2.8%-23.7%
	Not applicable:	-	-	5%	0.6%-16.9%
	Depends on:	27.5%	14.6%-43.9%	25%	12.7%-31.2%
Variation (n = 40)	Much:	22.5%	10.8%-38.5%	32.5%	18.6%-49.1%
	Some:	22.5%	10.8%-38.5%	17.5%	7.3%-32.8%
	Little:	17.5%	7.3%-32.8%	22.5%	10.8%-38.5%
	No:	2.5%	0.0%-13.2%	-	-
	Not applicable:	-	-	-	-
Division of skill into parts (n = 40)	Depends on:	35%	20.6%-51.7%	27.5%	14.6%-43.9%
	Divide into parts:	5%	0.6%-16.9%	45%	29.3%-61.5%
	Practice entire skill:	52.5%	36.1%-68.5%	12.5%	4.2%-26.8%
	Not applicable:	12.5%	4.2%-26.8%	5%	0.6%-16.9%
	Depends on:	30%	16.6%-46.5%	37.5%	22.7%-54.2%

Cumulative responses by all experts regarding the use of feedback when promoting implicit or explicit motor learning are shown in Table 4.4.

Facilitation of the seven best-known motor learning strategies

Of the experts, 72.5% (n=29/40) agreed that the motor learning elements provided (e.g., instructions, focus of attention) were specific to the seven best-known learning strategies. Some trends could be identified; however, given that on average n=22 experts skipped questions in this part of the questionnaire (min: n=16, max: n=28), data were not representative and are therefore not presented. Experts did not provide reasons for skipping this part of the questionnaire.

Table 4.4 Frequency count of all selected options regarding content and timing of feedback

	Answer options	Implicit	Explicit
Feedback (content) (n=40)	Feedback about the performance:	8	36
	Feedback about the results:	26	32
	Addressing good aspects:	9	33
	Addressing aspects which should be improved:	5	32
	Not applicable:	5	-
	Depends on:	8	2
Feedback (timing) (n=40)	During movement:	2	19
	After movement:	10	17
	Immediately after action:	6	22
	Delayed:	13	12
	Not applicable:	10	2
	Depends on:	10	12

Factors influencing motor learning choices

Within the survey, for the multiple-choice questions, the option ‘I cannot state, since it depends on...’ was chosen frequently (on average 11 of the 40 experts chose that option (27.5%)) (see Table 4.3). Many experts used the opportunity to clarify their responses and consistently suggested three factors that influence the choice of a specific motor learning intervention: type of task/skill, the learner’s ability (physical, cognitive) and the stage of learning. Subsequently, these three factors were presented for verification in the next survey round.

Most of the experts, 94.5% (n=33/34; 95%CI: 84.7-99.9%) agreed that these are the most important factors upon which to base motor learning content. Just under half of the experts, 47.1% (n=16/34; 95% CI:29.8%-64.9%), reported that the learner’s ability is the most influential factor when selecting motor learning content, and 42.2% (n=14/34; 95% CI: 24.7%-59.3%) of the experts reported that the type of task or skill to be learned is the most influential factor (e.g., complexity of the task). Only 11.8% (n=4/34; 95% CI: 3.3%-27.5%) of the experts reported that the stage of motor learning is most influential (e.g., initial or late stage).

Eight experts (5 researchers, 1 lecturer, 1 therapist, 1 manager) failed to complete this part of the survey. Six experts did not provide a reason for dropping out. One researcher dropped out because he/she did not agree with the content and set-up of the survey and one manager stated that he/she could not respond due to lack of time. Two experts (both lecturers) only participated in this second part (Round 3) of the survey after they had failed to complete the earlier part (Round 2).

Summary figure

With respect to the summary figure designed to illustrate the relationship between forms, strategies and elements, 64.7% (n=22/34; 95%CI: 46.5%-80.2%) of the experts stated that in general they agreed with the figure and 17.7% (n=6/34; 95%CI: 6.8%-34.5%) stated that they would agree if minor modifications were made. Subgroup analysis revealed no significant differences (p=0.885) between groups. Suggestions that the experts made about the figure in the open text box could be clustered into four categories: 1) Implicit and explicit learning should be presented as a continuum and not as a dichotomy, 2) Arrows connecting implicit learning and instructions are misleading, as they suggest that implicit learning is related to instructions, 3) All three levels of the figure should be connected to each other, 4) Strategies should be arranged in a way that makes visible whether they promote more explicit or more implicit learning. Figure 4.4 displays the summary figure, including the following improvements: 1) Implicit and explicit learning are presented within one box to illustrate the continuum, 2) Arrows connecting implicit learning and instructions have been deleted and the position of the box 'instructions' was moved to the right side of the figure (side of explicit learning), 3) Arrows were adapted to connect all three levels to each other, the lines encircling the boxes were made less sharp and boxes separating the three levels were deleted to illustrate that all three levels are connected, 4) Strategies were arranged in order of whether they promote more explicit or more implicit learning. In an earlier part of the survey, the experts classified the motor learning strategies according to whether they promote more implicit or more explicit learning.[16] Arrangement of the strategies within the figure is based on this earlier classification. One of the experts who did not agree with the figure suggested that the influencing factors should be placed at the base of the figure. As the referee group agreed on that point, this suggestion was adopted.

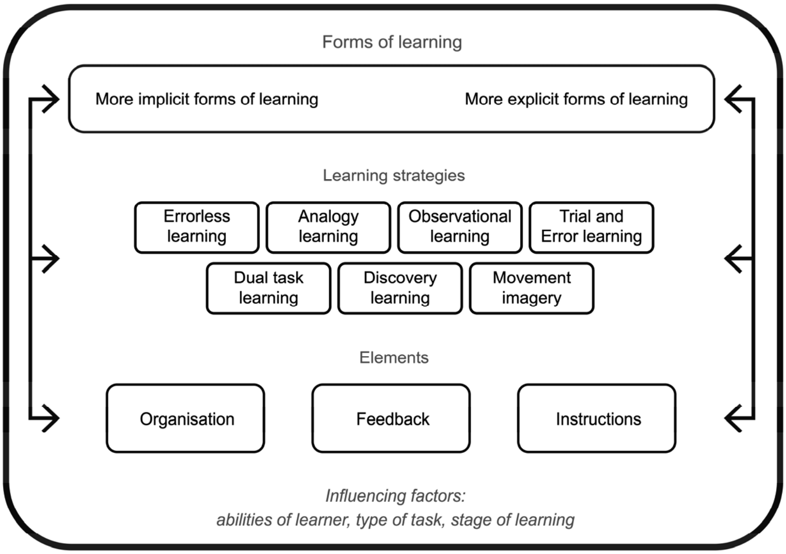

Figure 4.4 Modified figure based on suggestions of the experts

DISCUSSION

The aim of the current study was to explore experts' opinions and experiences of how motor learning can be applied in practice, using the distinction between implicit and explicit motor learning as a conceptual departure point. Answers of experts were broadly distributed. No consensus was found regarding the application of implicit and explicit motor learning. Cautious recommendations can be made on the basis of trends in the responses of the experts. Explicit motor learning can be facilitated with instructions about, for example, the goal of the task and steps and rules underlying performance. Various types of feedback (related to both performance and results of a movement) can also be used. In contrast, for implicit motor learning, instructions and feedback should be restricted. Additionally, when promoting implicit learning, an external focus of attention should be considered and the entire skill should be practiced. A reason for the variation in answers might be that, indeed, multiple options are valid depending on clinical situations. Further, answers may have been influenced by the specific practical experience of experts with respect to the target group that they worked with.

Subgroup analysis revealed no significant differences between experts from a research/theoretical field and experts from practical fields or education. This finding implies, comparable distribution of opinions between experts with a more practical role and experts with a more theoretical role.

Experts agreed that the learner's abilities, the type of task to be learned and the stage of motor learning are the most important factors upon which to base choices when seeking to promote motor learning. Experts also seemed to agree on a summary figure that illustrated forms, strategies and elements and their relationship (64.7% of the experts agreed). It seems likely that the modified figure (Figure 4.4) would have achieved consensus; however, it was not presented to the expert panel. The motor learning approaches in the figure are based on strategies identified as best-known in earlier parts of the survey and should be seen as examples rather than as reflecting a comprehensive overview of all possible motor learning strategies.

The arrangement of the strategies is based on the results of an earlier survey round in which strategies were classified as being more likely to promote implicit or explicit motor learning.[16] As the results of this classification were ambiguous, the arrangement of the strategies within the figure should not be interpreted as being definitive. As suggested by the experts, most learning strategies can promote both implicit and explicit motor learning, depending on how they are shaped in practice. In the current study, many experts skipped questions regarding the application of the motor learning strategies. A reason might be that the motor learning strategies can be applied in many different ways and, depending on the application, they can promote either implicit or explicit motor learning. Therefore, the questions might have been difficult to answer without a specific context or case. Another possible explanation might be that experts

knew the strategies in theory or within a research setting but did not have experiences regarding their application in practice. This finding emphasizes the importance of providing a detailed description of motor learning interventions in clinical studies, as it might not be self-evident how a motor learning strategy is applied.
Instructions, feedback and organisation are included in the figure to represent the various elements practitioners have at their disposal to shape motor learning. The list of elements used in this study is not comprehensive, but additional elements could be structured within the general terms “instructions”, “feedback” and “organisation”. For instance, “blocked practice” and “random practice”,[25] may be considered as part of the organisation of practice.
The general distinction in implicit and explicit motor learning was used as a conceptual basis because many motor learning strategies and other techniques can be positioned within this distinction. We, for instance, regarded internal and external focus, as well as feedback, as options that can be applied to promote implicit or explicit motor learning. We are aware that in other studies the distinctions between internal and external focus[26-28] or the comparison of different kinds of feedback (e.g., feedback about performance versus feedback about results)[29-32] are used as a legitimate conceptual basis for motor learning.

Strengths and limitations

The strength of the study is that its results synthesize knowledge from a multidisciplinary, international expert panel, with published scientific and practical expertise. As suggested by recent reviews within the field of rehabilitation,[33] research investigating complex interventions in practice is needed. Although this study does not evaluate the effectiveness of motor learning interventions, it may contribute to unravelling the complexity of motor learning by summarizing knowledge and experiences.
Although drawn from a variety of different backgrounds, fields and origins, the panel was not a random sample and the initial response rate with respect to participation in the survey was low, so we do not know whether their opinions are representative. Further, experts who dropped out of the study might have not have agreed with the conceptual basis, content and set-up of the study, which also might have biased the results. Therefore, all findings should be interpreted carefully and should be seen as a basis for further applied, empirical studies.
Although based on other studies and recommendations, the consensus cut-off of 70% is nevertheless arbitrary. In most Delphi studies that aim for consensus, Likert scales are used (e.g.,[21,22,34]). We decided not to use this kind of response option as it probably would have hindered the exploratory character of the study. When using Likert scales, sufficient support from literature (or other sources) is needed for the statements to be rated. However, in the case of motor learning, the literature varies and sometimes

even is contradictory. Therefore, response options that allowed participants to signal different views were used.

The purpose of the presented figure was to provide an overview of possible ways to apply motor learning, and their relationships, when using the implicit-explicit distinction as a conceptual basis. Therefore, the figure might support communication about motor learning. In recent years, numerous figures, models and programs based on different conceptual backgrounds have been developed to explain motor learning in different target groups (e.g.,[35-38]). The advantages of the current figure, however, are that it has been developed with input from international experts from different fields, and it signals both options for motor learning and factors that should be taken into account when choosing motor learning content.

Implications for practice and future research

Results of the current study may help practitioners (e.g., physiotherapists), especially those who are less experienced, by providing options and examples of theoretically underpinned methods of facilitating motor learning. Perhaps more importantly, students and neophyte professionals need to understand that there are factors worthy of consideration when preparing and conducting a motor learning session. Future research should focus on evaluation and comparison of the effects of different applications, taking into account the influencing factors identified in this study. It would also be of interest to investigate how practitioners currently make choices at a case level when promoting motor learning and to assess the value of the presented summary figure for decision-making in daily practice.

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(Two experts did not agree to be identified and the remaining experts did not respond).

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CHAPTER 5

Physiotherapists use a great variety of motor learning options in neurological rehabilitation, from which they choose through an iterative process: a retrospective think-aloud study

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ABSTRACT

Purpose
The goal of this study was to examine which motor learning options are applied by experienced physiotherapists in neurological rehabilitation, and how they choose between the different options.

Methods
A descriptive qualitative approach was used. A purposive sample of five expert physiotherapists from the neurological ward of a rehabilitation center participated. Data were collected using nine videotaped therapy situations. During retrospective think-aloud interviews, the physiotherapists were instructed to constantly ‘‘think aloud’’ while they were watching their own videos.

Results
Five ‘‘operators’’ were identified: ‘‘act’’, ‘‘know’’, ‘‘observe’’, ‘‘assess’’ and ‘‘argue’’. The ‘‘act’’ operator consisted of 34 motor learning options, which were clustered into ‘‘instruction’’, ‘‘feedback’’ and ‘‘organization’’. The ‘‘know’’, ‘‘observe’’, ‘‘assess’’ and ‘‘argue’’ operators explained how therapists chose one of these options. The four operators seem to be interrelated and together lead to a decision to apply a particular motor learning option.

Conclusions
Results show that the participating physiotherapists used a great variety of motor learning options in their treatment sessions. Further, the decision-making process with regard to these motor learning options was identified. Results may support future intervention studies that match the content and process of therapy in daily practice. The study should be repeated with other physiotherapists.

INTRODUCTION

An essential part of physiotherapy provided during neurological rehabilitation focuses on the learning of everyday motor skills. The use of motor learning within neurological rehabilitation is complex because, therapists need to take into account a great variety of impairments of their patients. In addition to physical impairments, cognitive and communicative impairments are common in this target population and can impede the learning of motor skills.[1–6] Evidence included in guidelines for physiotherapists is often based on research in selected samples of patients without or with minor cognitive or communicative impairments. As the majority of patients in rehabilitation do have these impairments,[1–6] the transfer of knowledge from guidelines to use in daily practice is not always self-evident.

Protocols and guidelines summarize scientific evidence in recommendations regarding the use of very specific treatment options (e.g., body-weight support treadmill training, electro-stimulation, constraint-induced movement therapy).[7,8] A lot of these specific treatment options are currently available, e.g., the current Dutch guidelines for physiotherapy after stroke summarizes evidence for more than 50 different treatment options,[9] and there is an increasing interest in research investigating how motor learning can be applied.[10] Another reason why motor learning is such a complex process, is that clinical guidelines often only provide little information on a limited amount of general principles of therapy (e.g., intensity and task specificity of practice) [e.g.,[11]].

Moreover, concrete recommendations on how the learning of complex motor skills (e.g., transferring from wheelchair to bed) should be applied are often lacking. It remains unclear how physiotherapist in daily practice cope with translating the limited amount of general recommendations into their patient care. There is little evidence for which motor learning is actually applied by therapists outside of research and in ‘‘real-life’’ practice.[12,13]

These studies provide some insights into the use of motor learning in daily practice, but they have been mainly restricted to the ‘‘attentional focus of instruction and feedback’’. Recently, however, it has been suggested that physiotherapists should use a combination of motor learning options and should not base their practice on one single concept.[14] In addition, little is known about the reasons why therapists apply certain motor learning options and how they combine them.

Research into the variety of motor learning options and decision-making between these options may help decide which factors are worth considering when therapists prepare and/or perform a motor learning session for patients with neurological disorders. Therefore, the goal of this study was to examine which motor learning options are applied by experienced physiotherapists in neurological rehabilitation, and how they choose between the many different motor learning options to create the optimal motor learning situation for the patient. This led to the following research question: Which motor learning options do physiotherapists apply in neurological rehabilitation and how do they choose between these options during a therapy session (decision-making process)?

METHOD

Design

The study involved a descriptive qualitative approach using retrospective think-aloud interviews with experienced physiotherapists while they watched and reflected on their own previously videotaped therapy sessions.[15] We opted for a retrospective rather than a concurrent approach, as it allowed the physiotherapists to complete the therapy session without interruption or distraction and with minimal additional burden for the patient. The therapy sessions were videotaped in a separate therapy room to ensure that only the participating therapist and patient were filmed. For each therapy session, two cameras were set up in a way that they covered the entire therapy room. The average duration of a treatment session and of the video recording was 30 min.

The interview was performed within two weeks after the video recording, by an interviewer who was not a member of the rehabilitation team. The interviewer was trained in qualitative research and had experience with conducting interviews in the context of health care. In a pilot interview with a nonparticipating therapist the interview guide was tested and fine-tuned. Participating physiotherapists were offered the opportunity to view the recordings before the interview. During the interview, the physiotherapists were instructed to constantly ‘‘think aloud’’ while they were watching their own video. The following prompting questions were repeatedly asked:[16] What are you doing? What are you thinking? Why are you doing this? The video could be stopped at any moment in order to ensure sufficient time for the physiotherapists to verbalize their thoughts. The duration of the interviews was about 45 min. The interviews were audiotaped and transcribed verbatim. The interviewer took field notes, which were later used to guide the data analysis.

Ethical considerations

Therapists and patients received an information letter and were orally informed about the study content. They had two days to consider whether to participate in the study and were able to pose questions about participation. They provided written informed consent if they agreed to participate. The study was approved by the ethics commission Atrium-Orbis-Zuyd (12-N-99) and the local ethics board of the rehabilitation center (MEC-10-12).

Setting and participants

The study was conducted at the brain injury unit of a local rehabilitation center, which provides rehabilitation for inpatients as well as outpatients. The brain injury unit specializes in the multidisciplinary treatment in the acute or subacute and chronic phases of the recovery of adults with acquired brain injury, such as stroke and traumatic brain injury. Purposive sampling was used to select participating therapists.[17]
Therapists with at least three years of experience working with the target population and who had access to eligible cases during the study period could participate. In selecting therapists we aimed at a broad variety in the number of years of experience, as well as a variety of included patients in terms of underlying diagnosis and severity. We aimed at including five therapists.

Participating physiotherapists were asked to identify two therapy situations in which different patients with a central neurological disorder (e.g., stroke or traumatic brain injury) were learning at least one of four predefined motor skills: (a) rolling over in bed from one side to the other, (b) moving from a lying to a sitting position, (c) transferring from wheelchair to bed and vice versa, or (d) getting up from a sitting position. Motor skills were predefined to generate more comparable treatment sessions. The main inclusion criterion was the motor skill deficit; no further exclusion criteria were defined, to allow inclusion of patients with a variety of cognitive and communicative impairments.

Data analysis

All interviews were analyzed according to the three-step protocol analysis provided by Fonteyn et al.[15]: Referring Phrase Analysis (RPA), Assertional Analysis (AA), and Script Analysis (SA). RPA was used to identify nouns and noun-phrases, while staying as close as possible to the transcripts. The vocabulary and concepts used by the physiotherapists were identified and subsequently coded (Table 5.1). AA was used to identify the relationships between the motor learning options used by the therapists and the process by which they chose between these options (clinical decision-making).

This step allowed us to understand how therapists were forming relationships between the concepts that were coded and defined using RPA. SA was used to perform an overall analysis of the reasoning processes, which resulted in the identification of the main ‘‘operators’’. Finally, results were translated into a figure to visualize the decision-making process.

The third author (AH) conducted all think-aloud sessions, checked the transcriptions and performed the primary analysis. Coding and identification of the main operators were discussed with the coauthors until agreement was reached. Additionally, the first authors analyzed a sample of the transcripts. To comply with credibility recommendations,[18] we used triangulation of sources (five therapists) and investigators (MK, SMB, AH and AM), as well as peer debriefing in the form of analytical sessions between the investigators. In addition, participating physiotherapists were asked to take part in a focus group to check the completeness of the identified motor learning options, and whether they could recognize their clinical decision-making (member check).

Table 5.1 Overview of the coding concepts from the Referring Phrase Analysis

Concepts	Definition of the concepts	Example
Plan	Information on the treatment plan in general	'Well, I'm practicing this specific skill because within the team we want the patient to be able to stay at home for weekends as soon as possible.'
Strategy	The motor learning options actually used within the treatment sessions.	'So I'm actually facilitating the patient's movement with my hands.'
Exercise	Patient actually practicing/repeating a specific movement, exercising.	'The patient is repeatedly getting up and sitting down.'
Knowledge	Knowledge from the medical charts, previous treatment sessions, clinical expertise, literature and experience.	'Her left side is the weaker side.'
Using senses	What therapists see, feel, hear, or generally find using their senses during the treatment session.	'Well, I see that she's using both hands at the moment.'
Patient's responses	All verbal and non-verbal responses noted by the therapist.	'She smiles about the situation.'
Assessment	All evaluations and judgements by the therapist regarding the patient's actions and reactions and responses.	'I can see that she's making a smooth movement and yes…, that's what I can really appreciate.'
Prognosis	A prediction of whether the patient will achieve something successfully within a specific situation.	'I don't think she's able to stand without support.'
Reason	Reasons for choosing a particular motor learning option.	'… because this is important for her at this moment.'
Aim	The specific aim a therapist wants to achieve by using a particular motor learning option.	'I'm testing whether she's aware of what's going well and what isn't.'

RESULTS

Participants

Sampling resulted in the inclusion of five physiotherapists working at the brain injury unit (Table 5.2).

Table 5.2 Overview of participating therapists

Code	Age in years	Number of years of experience in neurorehabilitation	Educational level (completed courses)
1	56	25	Bachelor in physiotherapy; Bobath course (basic and advanced); Vojta course (basic and advanced); Proprioceptive Neuromuscular Facilitation course (basic and advanced); General course in gait analysis and training; Specialized course for therapists working in neurorehabilitation/stroke (one year); Masterclass on balance rehabilitation
2	37	5	Bachelor in physiotherapy; Master of science in movement sciences; General course in gait analysis and training; Specialized course for therapists working in neurorehabilitation/stroke (one year)
3	37	6	Bachelor in physiotherapy; General course in gait analysis and training; Course in gait analysis after stroke; Specialized course for therapists working in neurorehabilitation/stroke (one year)
4	30	7	Bachelor in physiotherapy; General course in gait analysis and training; Specialized course for therapists working in neurorehabilitation/stroke (one year)
5	55	33	Bachelor in physiotherapy; Bobath course (basic and advanced); General course in gait analysis and training; Specialized course for therapists working in neurorehabilitation/stroke (one year); Lecturer for (international) courses on neurorehabilitation

Four therapists had two treatment sessions videotaped. One therapist was able to identify only one eligible treatment situation during the study period. Table 5.3 provides an overview of the demographic information of the participating patients.

Table 5.3 Demographics of patients being treated by the participating therapists

Code	Age	Gender	Diagnosis	Weeks elapsed between diagnosis and treatment session
A	24	Female	Traumatic brain injury	9
B	50	Female	Encephalitis	5
C	62	Female	Intracerebral hemorrhage right hemisphere	8
D	48	Male	Ischemic stroke right frontal hemisphere	2
E	60	Male	Ischemic stroke left hemisphere	9
F	64	Female	Encephalopathy after subarachnoid hemorrhage	8
G	24	Male	brain injury, with orbital fracture	16
H	54	Male	Ischemic stroke right hemisphere	10
I	48	Male	Hypoxic encephalopathy after cardiac arrest	8

The overall analysis process (RPA, AA and SA) led to ‘‘operators’’ relating to (1) which motor learning options were applied and (2) how the physiotherapists decided between different motor learning options within their decision-making process (Table 5.4). Five main ‘‘operators’’ were identified: ‘‘act’’, ‘‘know’’, ‘‘observe’’, ‘‘assess’’ and ‘‘argue’’. The ‘‘act’’ operator included the motor learning options used. The ‘‘know’’, ‘‘observe’’, ‘‘assess’’ and ‘‘argue’’ operators explained how therapists chose one of these options. Below, we first present an overview of the motor learning options that were applied, followed by a description of the process by which therapists selected one of these options.

Table 5.4 Overview of the operators, with definitions.

Operator	Definition of the operator
Act	Applying a motor learning option (action by the therapist)
Known	Studying and/or activating relevant patient data from chart, medical history related to the diagnosis or previous treatment sessions, clinical expertise, literature and experience
Observe	Observing and/or interpreting a patient’s action/reaction using visual, acoustic or tactile cues
Assess	Assessing or evaluating a patient’s action or reaction to a particular motor learning option
Argue	Explaining or giving a reason for the choice of a particular motor learning option

Which motor learning options were applied?

The ‘‘act’’ operator showed that the participating physiotherapists used a great variety of motor learning options (Table 5.5). These options were clustered into three main categories: Instruction, Feedback and Organization (Figure 5.1). Instruction was defined as any verbal of gestural information provided to the patients before the start of a task or exercise, to initiate a new action. This cluster includes options like providing verbal explanation about a task, using analogy, but also gestures made by the therapist (e.g. pointing in the right direction). Feedback includes positive and negative feedback and different forms of evaluations with the patients.

Organization was defined as the physical arrangement of the therapy room and the use of materials, as well as changing and varying the form of the task (e.g., practicing partial or complete tasks).

Depending on the specific way a motor learning option was applied, instruction and feedback were sometimes closely interrelated. For example, the use of rhythm or manual facilitation might be regarded as feedback, but also as an instruction.

In the focus group session, the physiotherapists reported that the motor learning options we had identified were not exhaustive. They provided examples of additional options (e.g., mirror therapy, using a greater variety of different environmental cues, learning from other patients by observing). They also stated that the motor learning options used might be specific to the tasks being practiced. They speculated that other tasks (e.g., walking, grasping) might need additional motor learning options.

Table 5.5 Overview of the information related to the 'Act' operator.

Category	Examples
Instruction	Set a task
	Give instructions
	Ask patient questions
	Provide an analogy
	Verbal explanation
	Warn the patient
	Challenge the patient
	Use a rhythm by counting or using a song
	Summarize
	Explain expectations
	Ask the patient to name the steps of the action
	Let the patient figure out how to do it by him/herself
	Instruct by pointing at something (with hands)
	Demonstrate action
	Manual facilitation
Feedback	Feedback (positive, compliment, negative)
	Evaluate with patient
	Encourage the patient
Organization	Not say or do anything (on purpose)
	Supply or take away support (by therapist or by walking aids)
	Structure or change the environment (furniture, wheelchair, bed)
	Change position of the therapist
	Use the situation which is accidentally created
	Stand by ready to intervene
	Position the patient (e.g. good position of the wheelchair or feet)
	End the exercise
	Switch to another exercise
	Repeat/practice
	Create variation
	Change tempo
	Use uniform mode of performance
	Try out
	Use a dual task
	Divide task into steps

How do physiotherapists choose between the motor learning options?

The remaining four operators, ''know'', ''observe'', ''assess'' and ''argue'', explain how physiotherapists chose between the motor learning options. These operators represent the clinical decision-making process that leads to the choice of applying a particular motor learning option. Below, we first describe these four operators, and then illustrate a possible relationship between the operators.

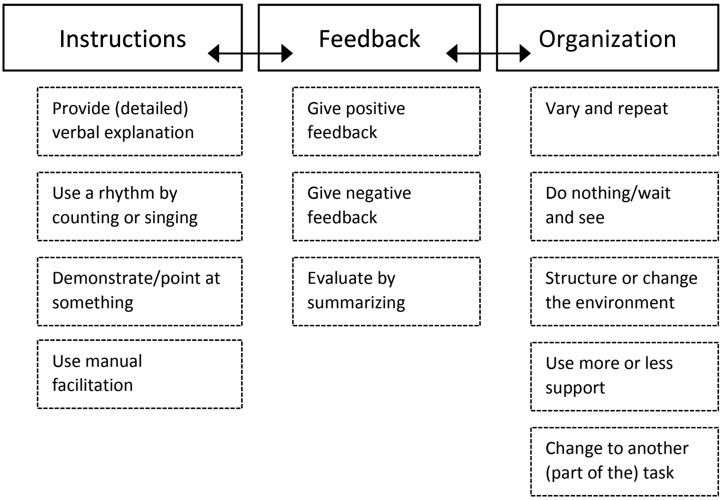

Figure 5.1 Clusters of motor learning options used by the therapists with examples (operator ''acts''). Note: The arrows indicate the close relationships between the three clusters.

5

Know

The ''know'' operator includes a combination of all available knowledge that the therapists considered and activated when deciding to apply a particular motor learning option (Table 5.6). Physiotherapists used more general information about the neurological disorder and more specific information about the individual patients. Sources of such information were: data on the prognosis and progress of the disorder, affected brain areas and movement disorders related to neurological impairment, such as stiffness and impaired selectivity. They also used general knowledge about motor control, healthy movement patterns, the difficulty and complexity of a particular movement pattern and requirements for efficient movement.

> ''...as she is now lying on her right side, I was wondering whether this was OK, as the fracture was in her right clavicle....'' (Th 1 pt A)

Other aspects taken into account included the knowledge and experiences gained during the patient's treatment so far and the specific characteristics of the patient regarding their cognitive, physical and communicative abilities.

> ''...normally she always uses the arm support, this is the first trial with a chair without arm support. And she was doing just fine.'' (Th 2 pt C)

(After having provided verbal explanation) ‘‘...he doesn’t understand everything...he needs some additional visual support.’’ (Th 3 pt E)

Physiotherapists also sought consensus within the multidisciplinary team on the treatment plan when making a choice.

Table 5.6 Overview of the information related to the ‘Know’ operator

Category	Examples
General knowledge of neurological disorders	Prognosis and progress of the disorder Brain areas involved Movement disorder related to neurological impairment (stiffness, impaired selectivity)
General knowledge about motor control	Normal, healthy movement patterns and positions of the body Difficulty/complexity of a particular movement pattern Requirements for efficient movement patterns or motor control
Knowledge about the patient	Possibilities with regard to movement pattern and motor control (strength, selectivity, range of motion, sensory impairments, balance) Character of the patient (critical, self-effective, capitulating easily, reflective) Patient’s preferences and affinities Stage of motor learning (was the movement/motor skill task already known or practiced earlier) Cognitive abilities (memory, attention, speed of information processing, ability to generalize learned skills) Premorbid movement pattern and movement experiences Communication (ability to process verbal information) Experiences from earlier treatment sessions in which approaches worked well Emotional aspects (patient being uncertain, agitated, anxious, emotional)
Comparison with previous sessions and the general process	What has the patient already learned? General progress until present session What has been practiced before, how often?
Agreements within the multi-disciplinary team	Agreement on specific approaches regarding e.g., patient’s behavior Aims Planning (e.g., discharge, weekends at home)

Observe

In all of the videotaped therapy sessions, physiotherapists’ observations were an essential part of the decision-making process. All senses were used during observation: seeing, touching, hearing and sensing the patient’s body. Therapists considered the actions and reactions of the patients that they saw, e.g., as regards posture, movement patterns and speed of the movements. They also used their hands to manually feel e.g., the muscle tone of a body part.

Feeling: ‘‘...and what I feel is, that when I push her trunk a bit forward, the first movement, [that] I feel there is some resistance, so I feel muscle tension which is keeping her from bending forward, and I don’t know what is causing this tension, and this tension fades quickly.’’ (Th 1 pt B)

> Seeing: ‘‘...you can see it a little bit, he is leaning a bit to one side, so he is putting a bit too much weight on his healthy leg.’’ (Th 2 pt D)

They also listened to the patient’s reactions as well as to the sounds and rhythm created by the patient’s movement.

> Hearing: ‘‘...and then he says: ‘Oh, I am sliding down the bed’’’. (Th 5pt I)

> ‘‘...and she herself says: ‘Bend over, chin on chest’’’. (Th 4 pt F)

But the participating physiotherapists also observed and interpreted what the patient might be thinking.

> ‘‘...and now he comes to the conclusion, that he is using his affected leg more, and he looks at me like he’s saying ‘you’ve tricked me into it’...’’ (Th 2 pt D)

Assess

The ‘‘assess’’ operator involved the physiotherapist evaluating or rating the patient’s action or reaction to a particular motor learning option. The ‘‘assess’’ operator was often closely linked to the ‘‘observe’’ operator. The criteria for the assessment could either be performing as best and efficiently as possible, or could be related to earlier sessions in which a certain type of motor performance was learned.

> ‘‘She is lying in a good position, she’s looking after her arm.’’ (Th 1 pt A)

> ‘‘...but he doesn’t fall, he has good balance, he can do this.’’ (Th 5 pt H)

The therapists also constantly assessed the difficulty of the motor performance, checking whether patients were performing the way they had learned earlier.

> ‘‘...but she has never done this before, and it was quite difficult with this chair...’’ (Th 2 pt D)

> ‘‘Now she’s getting up well, she is getting up the way she should.’’ (Th 2pt C)

Argue

This operator involves the physiotherapists providing a rationale for the motor learning options they used. The ‘‘act’’ operator describes which motor learning option the therapists actually chose (e.g., I varied the speed of the action), whereas the ‘‘argue’’ operator describes the intention (e.g., I changed the patient’s position [act] to increase the speed [argue]).

The arguments explained within this step were highly varied. They ranged from intentions related to aims from the level of motor performance (e.g., to stabilize body position or improve balance) to intentions related to more general aims at the level of patient behavior (e.g., to increase independence) (Table 5.7).

Table 5.7 Overview of the information related to the 'Argue' operator

Category	Examples
Aims at the level of motor performance	Let the patient perform the movement in his/her own manner Facilitate a specific movement pattern (e.g., raising leg higher, bending knee more) Improve balance. Provide an endpoint or aim for movement Facilitate relaxation or 'smoothness' of movement Activate premorbid movement pattern Stabilize body position Improve the quality of the movement Increase self-confidence Increase independence
Creating a specific situation/context/ learning environment	Add variation. Let the patient discover their own solution Create a familiar situation (e.g., similar to patient's home environment) Assess the patient's abilities (e.g., physical and cognitive) Show the patient what happens when they make a particular movement Changing difficulty level (e.g., easier or more difficult) Prevent patient from consciously thinking about movement control Stimulate patient
Support or safety	Change the situation because the movement/motor skill cannot be performed successfully otherwise Give patient more support if needed Prevent falls Ensure patient remains alert and pays attention

> ''...and it is even better if she can raise her leg even higher,... so I want her raise her leg way up.'' (Th 1 pt A)

> ''... this will probably give her more self-confidence.'' (Th 5 Pt I)

Therapists also argued that they used certain motor learning options to create situations in which they could assess the patients' reactions and motor performance or to see whether the patient was able to perform safely or to find their own solution.

> ''...I want to see whether she is able to relax in this specific situation.'' (Th 1 pt A)

Therapists further argued that motor learning options were also used to create a specific situation or context. In this case, the argumentation was closely linked to the ''act'' operator. Examples are creating variation or creating a therapy situation that is closely linked to the patient's home environment. Finally, therapists argued that some

5

motor learning options were intended to create more support or safety to prevent falls or other incidents.

Iterative process and relationships between the operators

The findings of the current study suggest that any motor learning option that is applied leads to new information relating to at least one of the operators, turning a single therapy session into an iterative process (Figure 5.2). In addition, the four operators (''know'', ''observe'', ''assess'' and ''argue'') seem to be interrelated and together lead to a decision to apply a particular motor learning option (''act'').

> ''Now she is doing very well, but she's positioned her hand completely wrong (assess), but I didn't say anything (act). She realized it herself and moves her hand up (observe). This is what I was aiming for (argue).'' (Th 2pt C)

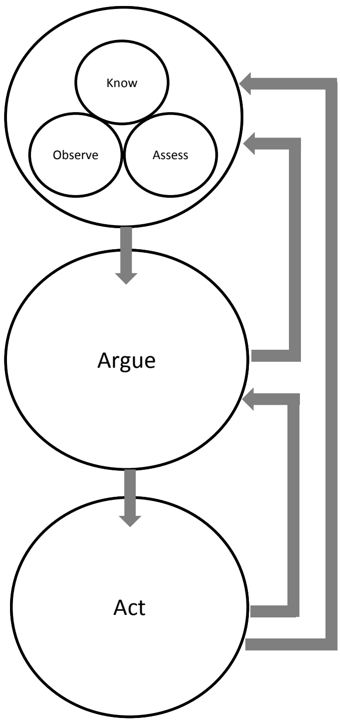

Figure 5.2 Relations between the five identified operators (iterative process).

Two different kinds of relationships (set of assertions) between the applied motor learning options (‘‘act’’) and the underlying reason for choices (‘‘know’’, ‘‘observe’’, ‘‘assess’’ and ‘‘argue’’) were identified. Their rationale could be intentional. In this case, the therapist acted based on certain predefined intentions or aims. Their rationale could also be situational. In this case, the therapist acted or changed/adapted her/his acting based on the observation within a certain situation. This could be an action or reaction by the patients but also opportunities, which were created (coincidentally) by the environment.

DISCUSSION

The aim of this study was to investigate which motor learning options physiotherapists use in neurological rehabilitation and how they choose a particular motor learning option during a therapy session (decision-making). With regard to the first part of the aim, results showed that the participating physiotherapists used a great variety of motor learning options in their treatment sessions. The member check showed that they agreed with the identified options for motor learning we distinguished, but they also emphasized that the list was not exhaustive. They argued that other options may not have been used because of the restrictions of the study situation (e.g., therapy room, the pre-defined task). We also noticed that the same motor learning option was sometimes used as part of instructions or feedback. It seems important, therefore, to check whether physiotherapists mean the same thing when they talk about and use a specific motor learning option.[19]

When choosing a particular motor learning option, physiotherapists used several operators (‘‘know’’, ‘‘observe’’, ‘‘assess’’, ‘‘argue’’) within an iterative process. The underlying information sources for each of these operators varied, ranging from neuroanatomical knowledge and the relation to motor control to the ability to observe any of the patients’ actions/reactions and assess them in terms of the therapy aim and progress. In agreement with what has been reported in the literature,[8,14] the physiotherapists used multiple motor learning options within one session, and they switched form one option to another almost continuously and with ease. These switches were context-specific and therapists often decided ‘‘on the spot’’ (situational) how to continue the therapy session. This reflects the complexity of motor learning for patients with neurological disorders. However, the participating therapists seemed not only to have a comprehensive view of this complexity, but also to anticipate the patients’ responses ad hoc. This finding is in line with the study by McGlinchey et al., who concluded that physiotherapists also need to consider the diversity of factors at multiple levels (patient, therapist and organizational level) when planning the delivery of therapy at a stroke unit.[20]

Contrary to the findings in the current study, two opposite motor learning options are often used in research, e.g., internal focus of attention versus external focus of attention, or implicit versus explicit motor learning.[21–24] This might be explained by the fact that for the purpose of research, it is useful to compare two options in a controlled situation, to create sufficient contrast between interventions. In practice, however, it seems that using only one motor learning option is not sufficient, especially if several tasks are practiced.
To our knowledge, this is the first study investigating the use of motor learning options within neurological rehabilitation using an open think-aloud approach. The study generated insight into how physiotherapists cope with the challenges of daily practice, like the heterogeneity of the target population. The participating therapists selected patients with a variety of problems at motor, cognitive and communicative level. Despite differences in patients' abilities, it seemed that therapists used the same underlying clinical reasoning process.
Within the Dutch guideline for physiotherapy after stroke, a few general recommendations regarding motor learning are made.[9] The data of the current study shows that the participating physiotherapist followed these recommendations. For example, the guideline states that the practiced task should be adapted to the abilities of the individual patients. This recommendation is clearly taken into account in the decision-making of the participating therapists as shown within the operator ''Know'' (Knowledge about the patient) and operator ''Argue'' (Assess the patient's abilities, e.g., physical and cognitive). Further, the guideline states that the motor task should be practiced in a meaningful environment. Therapists in the current study used motor learning options to create a familiar situation (e.g., similar to patient's home environment, operator ''Argue''). However, participating physiotherapists used more than the suggested motor learning options and considered more than the suggested factors, hence adding practice based options of motor learning to the recommended ones in the guidelines. This greater variety in options shown by the therapists might be explained by the fact that clinical practice is more complex than research situation regarding diversity of the tasks, patient characteristics and less controlled circumstances. In addition, therapists take not only evidence from research into account, but also the patient's preferences and their own experience when constructing a tailored therapy content, which may also explain the greater variety in observed motor learning options.

Methodological quality of the study

During the interviews, therapists sometimes found it challenging to verbalize their thoughts. The reason for this could be twofold. First, even though the interviews were facilitated by recordings of the therapy session, the time that elapsed between recording and interview might have led to recall bias. Second, the expertise of the participating physiotherapists consists not only of explicit, factual knowledge acquired through courses and education, but also of tacit (implicit) knowledge, which is hard to recollect and/or verbalize.[25]

To provide a rich and dense overview of the motor learning options, the 34 motor learning options we identified were clustered into three categories: feedback, instructions and organization. In a recently published study, international experts were able to allocate their actions to these three categories and agreed that such a general classification is possible. However, in this study the allocation of a specific motor learning option to one of the three clusters was not always unambiguous.[26]

As with qualitative methods, the think-aloud method seeks rich, in-depth data from small sample sizes. From think-aloud studies on other disciplines it appears that the number of interviews we included may have been sufficient to achieve saturation.[27] However, since physiotherapists from only one rehabilitation center were recruited, our results might be biased by this specific selection.

Implications for practice, education and research

The results of the current study provide some insight into 'therapy as usual' with regard to motor learning in neurological rehabilitation and may form a starting point in unraveling the complexity of factors which physiotherapists take into account when performing motor learning sessions. Within research, there is still a lot of obscurity regarding which motor learning option should be applied in which situation.[26] Descriptions of how these options should be applied in practice is often missing in research papers and guidelines. Therapists, however, need to choose therapy content and decide on how to apply it for every single patient and multiple times within every session. This study generated new scientific knowledge on how experienced therapist deal with this challenge.

The results of this study may contribute to patient care as they may aid less experienced therapists to make choices within the complexity of motor learning. The study provided insight into the way experienced therapist handle the great variety of possible motor learning options, including concrete ideas on how to operationalize these options in specific situations. This overview of possible motor learning options with examples of how to apply them, might inspire novice therapists to broaden their own repertoire of motor learning options by learning from the rich experience of expert therapists.

Our findings may contribute to better support for students and novice physiotherapists in acquiring the necessary competence to treat such a challenging target population. Our results may help them to understand that there are factors worthy of consideration when preparing and conducting a motor learning session. However, the complexity of the decision-making process and the great variety of knowledge sources physiotherapists have at their disposal may make it even more difficult for novice therapists and students to reach the level of their experienced colleagues or supervisors. With regard to the education of physiotherapy students, we might need to reconsider what is realistic to expect (e.g., during internships) or in which context the teaching program should be offered. If the iterative process of decision-making is necessary for an optimal motor learning context, it seems relevant that students learn in the context of daily practice as soon and as much as possible, preferably from experienced therapists.

Using the think-aloud approach has made the decision-making process and inter-individual differences more explicit and transparent for the participating physiotherapists and has led to discussions on new/other motor learning options in daily practice.[28] Participating therapists stated that contributing to this study has improved the communication with their colleagues. They were interested in repeating the methods of this study on a regular basis, especially when new, less experienced therapists join the team. Performing this kind of action research might therefore encourage research by practicing clinicians. We therefore recommend embedding this kind of think-aloud approach in peer-to-peer and student coaching, to enhance rich dialogs in which the options applied and the underlying choices are made transparent and can be further discussed.

Researchers might also benefit from knowledge about therapists' decision-making processes, in order to design and conduct studies that more closely match the content and process of therapy in daily practice.

In view of the existing differences in cultural background and patient characteristics, we recommend expanding the body of knowledge by repeating the current study with physiotherapists in other settings and countries.

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CHAPTER 6

Application of motor learning in neurorehabilitation: a framework for healthcare professionals

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Submitted

ABSTRACT

Learning motor skills is an essential part of most rehabilitation processes. Facilitating and supporting motor learning is particularly challenging in neurological rehabilitation: patients who suffer from neurological diseases experience both physical limitations and difficulties of cognition and communication which affect and/or complicate the motor learning process. Therapists (such as physiotherapists and occupational therapists) who work in neurorehabilitation are therefore continuously searching for the best way to facilitate patients during these intensive learning processes. To support therapist in the application of motor learning a framework was developed, integrating knowledge from the literature and the opinions and experiences of international experts. This article presents the framework, illustrated by cases from daily practice. The framework may assist therapists working in neurorehabilitation in making choices, implementing motor learning in routine practice, and support communication of knowledge and experiences about motor learning with colleagues and students. The article discusses the framework and offers suggestions and conditions given for its use in daily practice.

Case Patient A

Patient A has been admitted to a rehabilitation centre after an ischemic stroke in the left hemisphere two weeks ago. She is attending an intensive multidisciplinary programme. At this moment, her main goal is to function independently in her home environment.
At the moment, Patient A uses a wheelchair. She sometimes needs help using her wheelchair due to reduced perception of her left side.
She also needs a great deal of help from the nursing staff (2 persons) in transferring to the bed and the toilet. Together with her physiotherapist, the patient has set the following therapy goal: within 4 weeks, she wants to be able to transfer safely and independently from the wheelchair to the bed and the toilet (first in the rehabilitation centre and then later at home).
Already during the first therapy sessions, the physiotherapist notices that the patient is struggling to carry out the various steps of this motor skill in the correct order. Patient A is for instance skipping steps. As her balance is poor (Berg Balance Scale: 5/56) and she also easily gets distracted, her performance of the transfer is unsafe.
Patient A easily becomes emotional when her therapist points out that she is not performing it safely, or even when she notices this herself.
The therapist wants to find an approach that would fit the patient's capabilities, as soon as possible.

Case Patient B

Patient B was admitted to the same rehabilitation centre as Patient A, after suffering from a focal infarction in the left hemisphere six weeks ago. His main goal is to function independently in his home environment. He walks independently around the house with a cane. At this moment, the patient experiences severe shoulder pain. As a consequence, he has difficulty sleeping, washing himself and getting dressed. Controlling the shoulder pain is therefore important. The multidisciplinary team has agreed that the patient should wear a sling when he goes for a longer walk, in order to support and protect the shoulder. The occupational therapist provides him with a custom-made sling. However, the patient cannot put the sling on himself, so he always has to ask for help before he can go for a walk. He just cannot remember the right way to put on the sling and which steps he needs to follow. The patient decides, together with the occupational therapist, that the goal for the next sessions will be to learn how to put on the sling independently.

INTRODUCTION

Learning motor skills is an essential part of most rehabilitation trajectories. Motor learning has been described as a “set of the processes associated with practice or experience leading to a relatively permanent change in the capability for skilled behaviour”.[1] People in rehabilitation often need to learn new skills like using a wheelchair or a walking aid, as well as "old" skills they used to possess, such as getting up from a chair, walking or eating with a knife and fork. Therapists (e.g., physiotherapists and occupational therapists) who work in rehabilitation are therefore continuously searching for the best way to support patients during these intensive learning processes. The support for learning is particularly challenging in neurological rehabilitation as people suffering from neurological diseases often experience difficulties of cognition and communication, in addition to physical limitations.[2-4] These cognitive and communicative difficulties may affect and/or complicate the motor learning process.

During the 20th century, allied health treatment of motor problems of people who have a neurological disorder was mainly based on several treatment concepts such as Bobath,[5,6] Proprioceptive Neuromuscular Facilitation (PNF)[7] and the Brunnström concept.[8] In recent decades, however, evidence suggests that strictly treating patients according to only one of these concepts is not advisable.[9,10] This is why a more eclectic approach is currently recommended, in which task specificity, intensity and dose are important basic principles.[9,11] These principles may seem simple, but they have been interpreted and implemented in many different ways.[12] This could explain why experienced therapists use a large diversity of options when applying motor learning and also often switch between these options.[13] They base their choice to apply a particular form of motor learning on many factors, such as the patient's characteristics (e.g. physical, cognitive and emotional consequences of the disorder, location of the brain damage and age of the patient), the patient's expressed care needs and the agreements made within a multidisciplinary team.[13] The diversity of motor learning options and the large variety of underlying factors on which choices are based makes them complex, but this seems inevitable given the heterogeneity of the target group.[14] However, all these various options and factors make it difficult for less experienced therapists and students to achieve a comprehensive view regarding the use of motor learning in practice.

Furthermore, the number of scientific studies into the best way to apply motor learning has increased exponentially in recent years.[15] However, these studies are mostly based on laboratory research investigating constructed tasks under standardised circumstances.[16] Although the number of studies is increasing, there is still a lack of randomized controlled trials comparing motor learning interventions in clinically relevant tasks[16] and almost no evidence regarding which motor learning strategy works best for which patient and under which conditions.

In absence of evidence in the field of neurological rehabilitation, therapists might approach research in other target populations where, at least on certain aspects, more evidence can be found e.g., in sport (psychology), surgery, children and orthopaedics (e.g.,[17-19]). Often, these research fields use different terms to describe and compare interventions and different models to explain motor learning.[20] This lack of a uniform terminology impedes the efforts to translate the scientific knowledge into practice, as well as the exchange of knowledge between therapists and students.

In practice, therapists working in rehabilitation need to decide how to apply motor learning for every patient and diversity of different task, beside the uncertainty on effects and terminology. They also need to clearly communicate and document their decision and argumentations in treatment plans.
In order to gain more insight into the use of terminology and define and categorise the various terms (taxonomy), a study using a Delphi technique among international experts of motor learning was initiated.[21] In additional, participating experts who had practical experience were asked to describe the practical application of several motor learning strategies[a].[22] As part of this Delphi study a framework for the application of motor learning was proposed.

The framework provides an overview of options and an indication of how these options might be related (in theory) and used (in practice). We would like to emphasize that this framework is mainly based on theoretical, plausible assumptions, opinions and experiences of the Delphi expert group (researchers, therapist and lectures, n=49). It is therefore important, that potential users of this framework realize that it is a starting point and still under development. None of the options presented in the framework has yet proven to be in general superior. However, in this phase the framework can be used to provide an overview of possible options together with their (assumed) underlying working mechanism and therefore guide clinical reasoning and purposeful decisions-making.

The aim of this article is to describe the framework, illustrated by cases from practice.
The article first presents a brief description of the framework (a more detailed description of all parts of the framework is available in the appendices). It then discusses the framework and offers suggestions and conditions for its implementation

[a] The term "(motor) learning strategy" is used in this article with the following definition:
A learning strategy includes motor learning options that share a common background/theory and therefore also have comparable practical characteristics

in daily practice. Please refer to previously published articles for a description of the development and background of the framework.[20-22]

DESCRIPTION OF THE FRAMEWORK

The framework (Figure 6.1) consists of three different “layers”. The basis for the framework is the distinction between **implicit and explicit forms of motor learning**. This distinction is visualised in the upper layer of the outline. In the second layer, several **learning strategies** are presented. The bottom, most practical layer, consists of three **elements: organisation, feedback and instructions**. These elements are used in the practical application of the learning strategies, tailored to the individual patients. **Factors** that are important to consider regarding a specific use of motor learning are shown at the bottom of the framework: the patient's abilities, the type of motor task and the learning stage. The layers and components of the framework are discussed in more detail below.

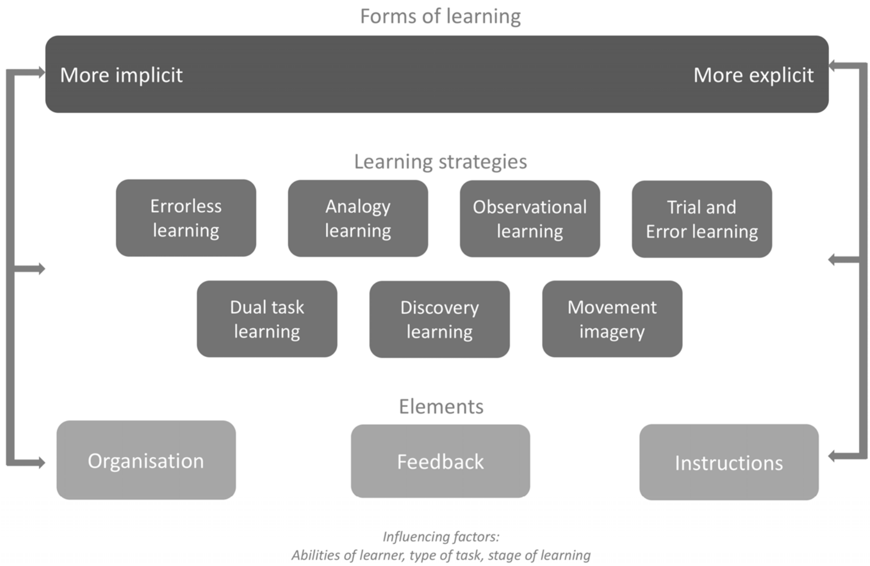

Figure 6.1 A framework for the application of motor learning (basis)

Forms of learning: implicit and explicit

Implicit and explicit forms of motor learning form the conceptual basis of the framework. This distinction is widely used in the literature about learning in general,[23] motor learning by people without health problems (e.g. athletes and children)[24] and rehabilitation.[25,26]

In explicit learning, also referred to as conscious learning, the patient acquires verbal knowledge (rules and facts) about a movement, and there is a cognitive stage in which the patient is aware of what he or she is learning. The learner has to collect, process, remember and translate the rules and facts which have been gathered during the learning process into a (motor) task.[24,27] The working memory is essential for explicit learning, as this is where rules and facts are processed.[28] The therapist can provide the patient with these rules. A patient can also discover rules and facts by, for example, making mistakes and analysing and correcting these mistakes ("trial and error" learning).

In implicit learning, patients might be aware that they are learning, but they should not be aware of (details of) the learning process itself. The learners receive little if any verbal information, so they have to process fewer rules and facts about the motor task. This implies that the working memory does (very likely) not have to process this information.[29] When implicit learning is put into practice, therapists can use sensitization, habituation, associations and automatisms to teach their learners.[30] An example is the (probably) unconscious adjustment of the gait pattern when walking on different surfaces. Changing the surroundings (different obstacles or surface) can influence the learners' motor behaviour, without any explanation being given. The learners are (subconsciously) "seduced" to adjust the movement.

The division of learning into explicit and implicit shows a kind of continuum, rather than a distinct dichotomy.[21,23] This means that learning processes can be more implicit or more explicit (e.g., depending on the numbers of rules and facts), and that these two modes of learning may also be combined.

Learning strategies

The second layer of the framework includes seven learning strategies, which have all been described in the general literature and in studies of the use of motor learning. This selection of strategies is based on the professional opinions of experts (i.e., represent the most commonly known/used ones).[22] Based on these professional opinions, the selected learning strategies have been classified into strategies which are likely to promote more implicit and those likely promoting more explicit forms of learning. A learning strategy includes motor learning options that share a common background/theory and therefore also have comparable practical characteristics. This does not mean there is no variation in the way each strategy is applied. For example, the common characteristic of the strategy of "observational learning" is that the patient first observes a movement and then tries to copy it. This strategy can be realised by observing a therapist, another patient or a video. Observational learning can become more explicit when the therapist gives verbal explanations before or during the observation. This learning strategy can also become more implicit when the explanation is limited to a minimum or when the therapist only asks the learner to just "copy" the movement. An overview and a description of the learning strategies is provided in Appendix 6.1.

Elements

A therapist needs several elements to put motor learning into practice. Within the framework these elements are clustered into three categories: instructions, feedback and the organisation of the learning environment and the task to be learned. These elements were chosen, based on the results of the Delphi technique and decision-making of expert physiotherapists.[13,22] The use of learning strategies or a specific form of learning involves a combination of these elements. For instance, the learning strategy of "analogy learning" requires the use of a specific instruction. The learning strategy of "errorless learning" can be applied by organizing the learning environment to ensure that errors are less likely to occur. The strategy of "trial and error learning" can be supported by giving feedback on errors that have been made. An overview of the three elements with an explanation and examples is included in Appendix 6.2.

Relation between forms of learning, strategy and elements

The framework visually distinguishes the three levels described above (forms of learning, strategy and elements). It is important to mention that the organization of the levels does not indicate a hierarchy between the levels. The levels are interrelated, which is indicated by the errors. In practice, this means, that a choice for a certain motor learning option can be on any level and does not need to contain all three levels. Therapist may choose to use a more explicit approach (form of learning) and apply this by using a combination of verbal instructions (elements) and feedback (elements), without particularly choosing a learning strategy. They may also choose to use analogy learning (learning strategy) which needs an analogy instructions (element) and will most likely promote implicit learning (form of learning).

Factors that may influence the choices within motor learning

Eventually, the therapist needs to decide along with the patient which (combination of) motor learning options will be used. A great number of factors might influence and direct this decision.[13] These factors can be clustered in three categories: the abilities of the learner, the characteristics of the task and the current learning stage.[22] The use of motor learning has to be tailored to the learner, which implies that the therapist needs to take the characteristics of the learner (in this case, the patient) into account, such as the pathophysiology of the condition, co-morbidities and their age. It is also important within the selection process to consider the characteristics of the task that has to be learned and the circumstances under which the task has to be carried out in daily life. For example: cyclic, open tasks (like walking) might ask for a different approach than tasks that can be divided into smaller steps (like making coffee). The patient’s current learning stage (e.g., beginning of the learning process or later phase in which movements will be more sophisticated) can also influence the choices. An explanation of the factors is presented in Appendix 6.3.

Based on the current state of literature it is not possible to describe specifically how the selected factors might influence the decision making. The information presented in Appendix 6.3 might help therapists to get an overview of factors that can be considered and probably measured/investigated in order to find an optimal motor learning approach.

THE USE OF THE FRAMEWORK IN REAL WORLD EXAMPLES (CASES)

Below authentic cases are presented to illustrate how a therapist can use the framework to support the choice of a specific form of motor learning.

A common basic assumption in these examples is, that the therapist has studied the patient's medical records and has carried out the usual physiotherapeutic assessment (according to professional guidelines). The interpretation of the measurement outcomes from the physiotherapeutic assessment and the observations made during the performance of these tests reveal first insights into the patient’s abilities regarding learning (e.g., can the patient follow the instructions?). The therapist thus gains information about the factors which may influence the choice of a specific form of motor learning (Appendix 6.3). The framework is then used to decide on which motor learning options are used and to develop a patient-tailored plan.

Patient A

Table 6.1 provides the details of the first case. This is followed by a description of a possible implementation of motor learning, together with the underlying argumentation.

Patient A has set herself the goal of transferring safely and independently from the wheelchair to the bed and the toilet (first at the rehabilitation centre and then later at home) within four weeks. The therapist chooses the learning strategy of errorless learning based on the details in Table 6.1, the observations made during the assessments and the first attempts to practice the transfer. These are his arguments: Errorless learning can be very motivating for the patient because it means she is not confronted with "errors". This approach can be favourable for a patient who easily becomes emotional. A structured learning environment can also be beneficial for a patient who has difficulties planning and organising. The therapist thinks that the order in which actions are carried out is especially important for this complex task. Given the patient's balance problems he expects that structuring the task will provide more safety. Characteristics of errorless learning include repetition and a gradual increase in the degree of difficulty. This can also be favourable for patients who act restlessly and impulsively. His decision to use errorless learning also fits in with the early stage of learning. The patient has just been admitted to rehabilitation and started to practice the motor skill, so she does not yet have a lot of experience, and has made few errors yet. This implies that she had probably not yet build op explicit knowledge about the motor skill. Based on these arguments, the therapist chooses for the following elements to specify the application of errorless learning in practice (Figure 6.2).

Table 6.1 An overview of the problems faced by patient A and relevant factors, based on the International Classification of Functioning, Disability and Health (ICF).

Disease	Ischemic stroke in the right hemisphere two weeks ago
Functions	-Poor balance (Trunk Control: 37/100; Berg Balance: 5/56) -Left arm: flaccid paresis, no selective motor control (Motricity Index: 0/100) -Left leg: Some strength in knee and hip (Motricity Index: 28/100) -Tone in left leg: increased (Modified Asworth Scale leg: flexion: 1 extension: 2) -Global sensory assessment: patient feels tactile stimuli on her left side when she concentrates. -Memory seems fine -Difficulty keeping up attention (patient easily gets distracted) -Reduced perception of her left side -Reduced awareness of illness. Patient is not well able to grasp that there is a higher risk of falling.
Activities	Patient is able to transfer from wheelchair to bed with physical help of two persons in her room at the rehabilitation centre.
Participation	Patient is not capable of taking care of her children or carrying out domestic tasks.
Personal factors	-49 years old, female -Acts quickly and impulsively -Restless -Emotional -Difficulty with planning and organising a complex (motor) task -Limited experience of making a transfer (initial stage of learning)
External factors	-Married, three children -Pets -Current situation: adjustable height bed in a single-occupant room at the rehabilitation centre -Home environment: double bed, not adjustable in height

Organisation

The therapist choses a calm learning environment with few distracting factors, using a bed with adjustable height. The therapist can structure the learning process according to the principle of forward/backward chaining. This means that the patient realises the first step of the motor task herself (e.g., parking the wheelchair correctly alongside bed). The therapist supports the patient during the subsequent steps (e.g., through manual assistance and demonstrations (more implicit)). Once the patient has mastered the first step independently and safely, she can try to carry out the second step. In this way, the patient is actively involved in the learning process and the therapist can still make sure that the number of errors is limited. In backward chaining, the procedure is followed inversely: the therapist assists in the realisation of the first steps and the patient carries out the last step independently. Chaining is a way to structure the learning process and to prevent errors. The principle of chaining is suitable for this type of task because transferring from wheelchair to bed can be clearly divided into sub-steps and has a specific final goal (closed and discrete task).

Feedback

The therapist limits the feedback to information regarding the result of the movement (knowledge of results, e.g. “This is the correct position, well done”). He argues that given the early stage of learning and the patient's goal, the training should focus on security and independence and not on efficiency and the optimisation of the motor performance (for which knowledge of performance could be used). The therapist only provides feedback after the patient has completed the motor task, in order to not unnecessarily distract her. He will only intervene if the patient puts herself in an unsafe situation. He will then interrupt the performance and ask her to start over (preventing errors).

Instruction

The therapist limits his verbal instructions because the patient is easily distracted. Instead he demonstrates the sub-steps and provides brief instructions with an external attention focus (e.g., "Watch closely what I'm doing and then try to copy me"). This approach is likely to promote a more implicit form of motor learning. He demonstrates only sub-steps of the movement (not the entire transfer) because the patient is easily distracted and has difficulty observing her performance of the task as a whole.

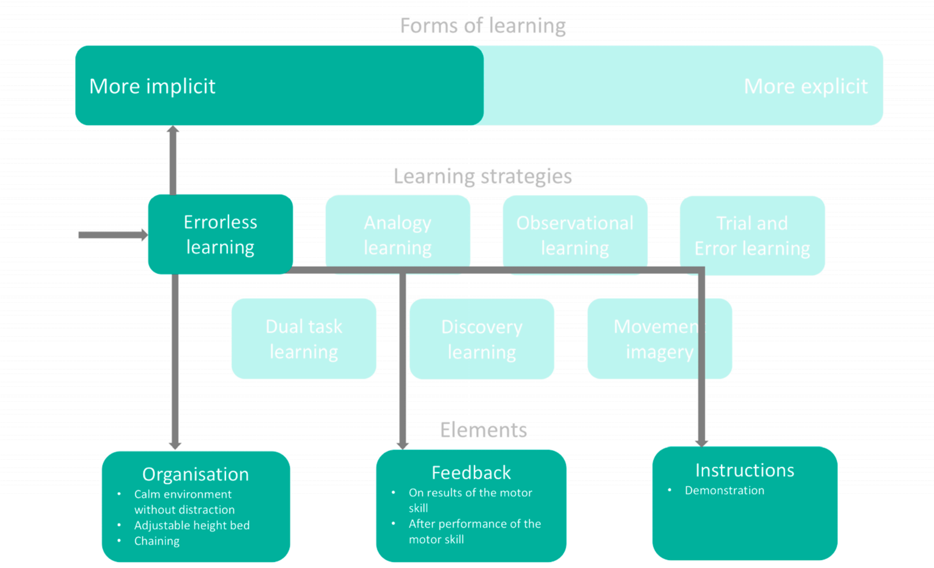

Figure 6.2 Choices within framework for patient A (start rehabilitation)

Patient A, after 6 weeks

Patient A has now been in rehabilitation for 6 weeks. She can now transfer independently in familiar and calm environments. Since the patient is almost ready to be discharged home, her goal has changed to being able to transfer independently and safely in her own home environment. The therapist and the patient have recently been to the patient's home environment to practise the transfers. The patient was able to safely transfer in different situations (bedroom and living room), except when she was distracted. The patient has a lively home environment. She has three children (11, 15 and 18 years old) and two cats who cause considerable distraction. As result of her stroke, she is also more easily distracted.

After talking with the psychologist, the therapist suspects that the patient will eventually learn to focus better, so that she will be able to continue to perform the primary task (in this case, the transfer) even when she gets distracted. Since the therapist cannot frequently practise with the patient in her home environment (which would have been preferable given the benefits of context specificity[11,31]) he chooses to continue therapy in a lively environment with a lot of distractions. He ensures there is a build-up in the level of liveliness of the environment. For example, he begins by practising the transfers in a busier practice room and then practises in the hallway where people are passing by. To make sure that the patient will also be able to perform the transfer safely in the future, the therapist could take this a step further and cause distractions by adding a second task (dual task learning). This can be done, for example, by asking the patient a question while she is performing the transfer. In this case, the therapist makes the deliberate decision only to choose a combination of elements. The use of these elements will most likely not lead to increase in verbal knowledge of the task and might therefore most promote a more implicit motor learning (Figure 6.3).

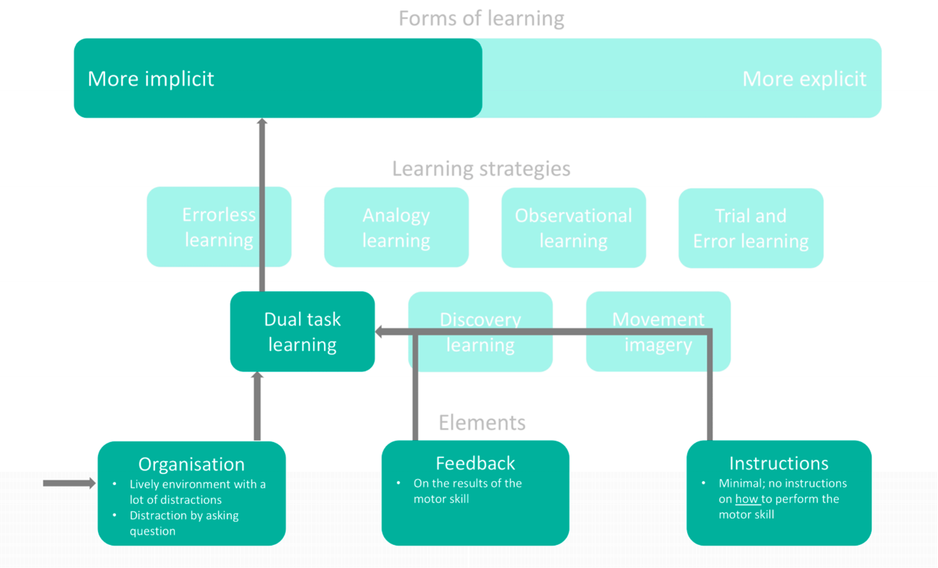

Figure 6.3 Choices within framework for patient A (after 6 weeks)

Patient B

Patient B has set himself the goal of putting on his sling independently. It is important that this goal is achieved soon, as not being able to put on the sling limits his independent mobility. Therefore, he strives to achieve this goal within the next week. An overview of the details of the Patient B is presented in Table 6.2.

The therapist chooses to use a more explicit approach. These are her arguments: It is important that the patient learns the new task quickly. Explicit motor learning generally seems to progress faster.[27] Further, from earlier sessions the therapist knows the patient can remember and carry out a limited number of verbal instructions. An advantage of implicit learning is, that implicit learned tasks seem more stable under dual task conditions and despite fatigue.[27] However, the patient is not expected to put on the sling under dual task condition or when fatigued.

The therapist does not choose for a specific learning strategy presented in the framework. She rather combines the elements of organisation, instructions and feedback in order to create an optimal, tailored approach (Figure 6.4).

Table 6.2 An overview of the problems faced by patient B and important factors based on the International Classification of Functioning, Disability and Health (ICF).

Disease	Focal infarction in the left hemisphere six weeks ago
Functions	– Patient has sufficient balance to walk independently (Berg Balance Scale: 52/56) – Flaccid paresis right arm, no motion possible in right arm (Motricity Index upper limb: 0/100) – Concentration, attention and memory seem fine. – Patient suffers from aphasia. He can follow verbal instructions well. – He can adequately indicate 'yes' and 'no'. – Severe shoulder pain
Activities	The patient walks independently around the house with a cane (FAC 4). Due to his upper limb paresis, he cannot fully look after himself yet, however, so he needs help and support.
Participation	The patient is currently not able to function in his home environment because he needs help and support with ADL and IADL tasks.
Personal factors	– 68 years old, male – single – Has never performed any sports – Appears clumsy sometimes – Patient is right-handed
External factors	– Sling to support shoulder

FAC: Functional Ambulation Category; ADL: Activity of Daily Living; IADL: Instrumental: Activity of Daily Living

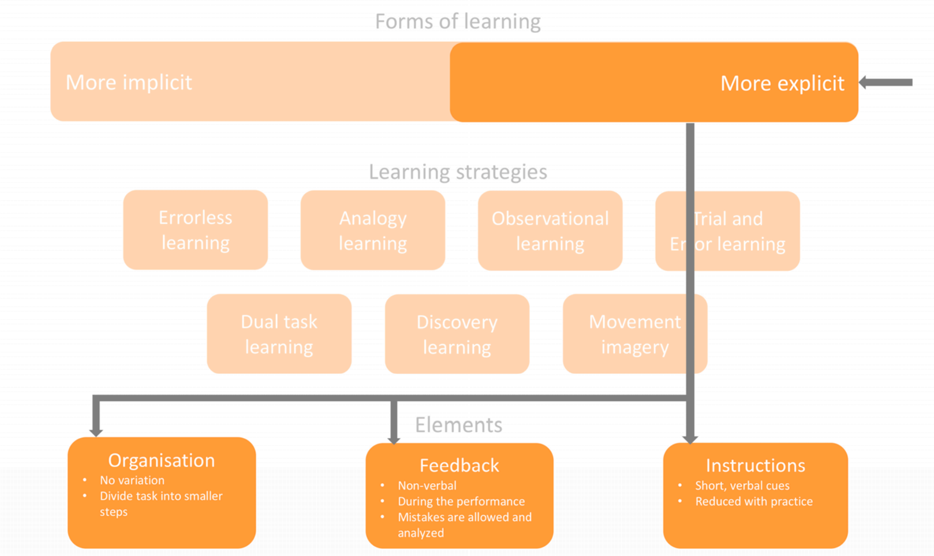

Figure 6.4 Choices within framework for patient B

Organisation

The patient will always be able to perform the task while sitting on his bed or in a chair in a calm environment with few distractions. The patient therefore practices the task in this environment and the therapist does not vary the (environmental) conditions (blocked practice).
During observation of the performance of the task, the therapist noticed that the patient encounters problems with three steps within performance: 1) organising the sling before starting (preparation), 2) choosing the correct loop to begin with and 3) putting his affected hand into the sling so that it is adequately supported. During practice, the task is therefore divided in these three steps.

Instructions

The therapist, along with the patient, devises a couple of short, verbal instructions and cues (e.g., “sling straight on lap”, “big loop first”, “check wrist”) and writes these down. In the beginning, the therapist repeats these cues before the start of the performance. Later, she asks the patient to repeat them himself. After a couple of successful repetitions, no instructions prior to the performance are provided any more. The patient acquired verbal knowledge (rules and facts) about the task in advantage of the performance.

Feedback

Since the therapist mostly gives verbal instructions about the steps in advance (feedforward), she limits the feedback to nonverbal cues by nodding when the patient performs the steps correctly. In case the patient makes a mistake she does not interrupt him but rather waits see whether he can manage himself. She helps by using prompting questions (e.g., what did go wrong?) and statements (“try it yourself, you can do this”). If the patient cannot solve the problem, she advices him to restart from the beginning.

Patient B, after 6 weeks

Meanwhile the patient has been discharged and follows an outpatient program. During evaluation of his current situation with the therapist, the patients states that he is able to put on the sling independently at home. He still is aware of the three steps and the cues and repeats them in his head when performing the task. He admits that he cannot put on the sling when he is interrupted of distracted, however, as this does not happen regularly, it is not a problem. As the pain diminishes, he thinks that he can try to reduce the use of the sling.

DISCUSSION

The framework presented in this article may help therapists working in neurorehabilitation to make choices about the application of motor learning in daily practice. In addition, the framework might support the exchange of knowledge and experiences among colleagues and to students.

If healthcare professionals wish to implement the framework, they should consider the following issues. First, the framework is a recommendation and not an intervention protocol that has to be strictly followed. It provides an overview of options for the application of motor learning in a patient-tailored way. Guidelines present more general advice on how to implement motor learning, for example, that therapy should be intensive, task-focused, motivating and patient-tailored (e.g., adjusting tasks to their limits), that the task to be practised should be meaningful, and that therapists should give feedback and include enough breaks.[32,33] In daily practice, however, these recommendations need to be further specified and individualised.[34] Therapists and other health care professionals are faced with the challenging task to make choices every day such as "Which instructions do I give?", "Which feedback should I provide and how should I time it?", "How do I present the task?" and "How do I organise therapy?" It is important to have an overview of the many options within motor learning to make a well-informed choice. The framework provides such an overview and can therefore support therapists during the process of clinical reasoning.

Second, therapists need to realise that neurorehabilitation research has not yet produced enough evidence on motor learning to give clear indications which form of learning is most suitable for which patient. However, some options within motor learning seem to be more effective and work better in specific situations (see appendices). For example, implicit learning appears to make fewer demands on the working memory, so there is more “free” capacity for the performance of a second task, such as walking and talking at the same time (dual task learning).[27,29] Therefore, it is hypothesized that people who have difficulties regarding working memory and speed of information processing due to neurological disorders seem to benefit more from implicit learning than explicit learning.[26] There is some evidence in stroke,[35] Parkinson's disease[36] and Alzheimer's[37,38] to support this hypothesis.

Third, the framework presents a classification of the seven learning strategies into more implicit and more explicit strategies. This classification is based on theories and opinions of experts and some strategies cannot clearly be classified as more implicit or explicit. In practice, the way a learning strategy is applied will finally determine whether it has a more implicit or explicit character. Each strategy will become more explicit when a therapist provides a larger number of verbal explanations about the details of the motor skill. Further, the framework is not a complete list of all learning strategies and elements.[22] Strategies such as incidental learning and differential learning [21,39] have not been included in it.

Finally, there is a great amount of literature about motor learning. Various models and theories to explain motor learning (motor control theories) have been published. These theories explain why someone moves in a particular way under particular circumstances. Well-known examples of these theories are the motor programme theory (e.g.,[40]) and dynamic systems theory (e.g.,[41]), but these are not direct components of the framework. They are obviously important because they could form the (theoretical) basis for a decision to apply a particular learning strategy. Sufficient insight into the way a patient is moving and why he/she is moving in this way is key to identifying the difficulties they face when moving, to search for a suitable approach to apply in the treatment plan and to evaluate and if necessary adjust the chosen approach.[42] In addition, the framework is based on a behavioural view of motor learning. When choosing a motor learning option, therapists should also consider neurophysiological recovery processes and expectations regarding prognosis (e.g., for stroke; see[43-45]). Within the framework and the current article, we focused on the options to apply motor learning in practice ("what is done to the patient"). More information about the underlying neurophysiological and psychological mechanism of learning in patient with neurological disorders, also in relation to recovery processes can be found in literature (e.g.,[32,46]).

Keeping the abovementioned issues in mind, physiotherapists, occupational therapists and other health care professional involved in motor learning of patients can use the framework to support their choice within all the different motor learning options. This overview can especially be useful for healthcare professionals with less experience or for novices. Experienced therapists can also refer to the framework when they want to test or evaluate their decisions or make them more explicit. For this purpose, the framework might be used in different ways. Researchers often choose between implicit or explicit learning (the top layer of the framework) and then find suitable strategies and elements. In daily practice, therapists more often seem to start at the bottom layer of the framework. They look at the characteristics of their patient, the tasks that need to be carried out and the learning stage, subsequently choose from among the elements (bottom layer).[13] After that, the therapists link their choice to a learning strategy and a form of learning.

The framework might also be used to support communication and alignment with colleagues in an interdisciplinary team. Motor learning represents a relatively permanent change in motor behaviour.[1] Changing a patient's motor behaviour requires a lot of practice and repetition, as well as varying the environment and the characteristics of the task. In daily practice, however, the number of therapy sessions is limited. It is therefore important for the patients to make the most of all the available possibilities (including outside regular therapy times) to practise and repeat movements. A patient's improvement depends on an interdisciplinary approach and the involvement of the patient's system.[11,47] When a therapist has found a suitable approach for a particular patient, it seems efficient to apply this approach as much and as consequent as possible. It is therefore important to make agreements with patients and colleagues about therapy goals, division of responsibilities and the approach to be used. In practice, however, alignment seems to be focussing mostly on goal setting ("*What* is being practised?") and less on the approach used to attain this goal (*How* is the therapy designed and which approach is being used?).[48] The framework could be supportive for the team communication by providing a common terminology and a collective overview. The framework and the motor learning options linked to it could also be used for more unambiguous description, to ensure alignment between colleagues regarding the therapeutic approach when transferring a patient to another setting.

Conclusion and future research

The presented framework provides a possible taxonomy and overview to assist well-informed decisions for motor learning which fit clinical reasoning. The exact implementation of the framework in the selection process and communication should be determined and tested in different settings. Research into user experience and evaluation of the implementation of the framework in different settings is a logical next step. Based on research and future insights, the framework could be adjusted, expanded and further substantiated.

6

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6

APPENDIX 6.1 OVERVIEW OF LEARNING STRATEGIES

Overview of learning strategies from the framework

Strategy	Description	Explanation	Classification and background	Implementation examples	Advantages and conditions	Tools and examples
Errorless learning	Learning facilitated by constraining the learning environment (e.g., instructions, difficulty of skill) so that very few errors occur.	• The learning process proceeds with as few errors as possible. • Mistakes can be prevented in several ways (see implementation examples).	Classification: Errorless learning is classified under the more implicit strategies. Background: If no mistakes are made, the learner needs to reflect less on the movement and requires less verbal knowledge.	Errors can be prevented, for example, by: • arranging the physical environment in such a way that the learner will make few or no errors; • adjusting the tasks (e.g., practising sub-tasks); • demonstrating (e.g., by the therapist or other patients); • using instructions (which however makes the strategy more explicit).	**Advantages** • Evidence increases • especially for patients with memory problems (46). • Errorless learning can be motivating. • If the environment can be used to prevent errors, EL can be designed so as to be very implicit (minimal explanation). **Conditions** • Need for clear team agreements with regard to the approach. • Consistent approach is essential.	**Tools** Targeted adjustments of the environment, preferably without the patient becoming aware of it. **Examples from literature**[17,36,47]

Analogy learning	Learning facilitated by metaphors. The complex structure of the skill to be learned is integrated into a simple metaphor that the learner is provided with.	The structure of the skill to be learned is integrated into a simple metaphor.	Classification:
			Analogy learning is classified under the more implicit strategies.
			Background:
			Analogy learning includes brief instructions without extensive facts and rules. This puts less strain on the working memory of the learner and he/she is probably less aware of the exact performance of the task.
				• Use of instructions like "pretend you are…"
				• Using a metaphor or suggesting a picture of the situation.
				  • Example: *"Walk as if you're following footprints in the sand."* to influence steps length, gait velocity and gait symmetry.[35]
				  • Note: The interpretation of the pictured analogy is something that should be determined for each individual patient.
					Advantages
					• Limited verbal instructions.
					• Patients are positive.[34,35]
					• Patients or family can be involved in finding the analogy.
					Conditions
					• The analogy should be meaningful to the patient.
					• Analogy should lead to the right change of the movement.
					• Not all tasks can be used for analogy (e.g., it is more difficult to find an appropriate analogy for ADL tasks).
						Tools
						The metaphor can be supported with a foto of a particular situation.
						
						Examples from literature[34,35,48]

6

Overview of learning strategies from the framework (continued)

Strategy	Description	Explanation	Classification and background	Implementation examples	Advantages and conditions	Tools and examples
Dual task learning	Learning a skill while simultaneously performing another task. The second task can be a motor or cognitive task but must be attention-demanding.	• During the learning process a second task is performed. • The choice of a second task is essential: it should be difficult enough to take up a large part of the storage memory, but not too difficult to make it impossible to perform the first motor task.	Classification: Dual task learning is classified under the more implicit strategies. Background: During dual task learning the working memory will be “blocked” by performing the second task. This way the learner can pay little or no attention to details of the performance of the primary motor task.	• Distracting conversations while patient is for instance walking on a treadmill. • Carrying objects and walking. • Doing calculations while performing a task. • Balance training during performance of grasp and reach tasks (e.g., fastening trousers while standing at the toilet). • Dual task learning is often used in practice as a test strategy (e.g., walking and talking at the same time) to test stability of the task learned.	**Advantages** • Dual tasks are common in daily life. • Dual task learning is especially useful for the later stages of the learning process, to achieve a more automatic performance. **Conditions** • Appropriate choice of dual task.	**Tools** Outline of dual task condition[49]. **Examples from literature**[50,51]
Discovery learning	Learning without guidance or feedback from another person or information source.	• By performing, the learner discovers independently (without explanation or feedback) how to carry out a motor task. • The therapist can provide guidance by adjusting the environment (guided discovery).	Classification: No unambiguous classification possible. Discovery learning is described in the literature as an implicit[52] or explicit strategy.[53] Background: How the process of discovery learning develops depends on the patient. Even without instructions, patients can search and discover more details and rules of the movement by themselves, which would make the learning process more explicit.	• Performance of a new task without specific instructions ("Give it a try"). • Performance of a familiar task in a new environment.	**Advantages** • Therapist can observe how the patient deals with a new situation without instructions or specific feedback. **Conditions** • In the end, the learner should receive a form of confirmation on how the therapy session went.	**Tools** Targeted adjustment to environmental factors (e.g., different chairs when learning how to get up, different surfaces when learning how to walk). **Examples from literature**[17]

Overview of learning strategies from the framework (continued)

Strategy	Description	Explanation	Classification and background	Implementation examples	Advantages and conditions	Tools and examples
Obser-vational learning	Learning by observing a movement. The observer determines the key spatial and/or temporal features of the task through observation, thereby creating a cognitive representation of the action pattern.	The movement is learned by imitating a task or movement. The literature also uses the terms "action observation" and "modelling".	Classification: No unambiguous classification possible. Background: How the process of observational learning develops depends on the way the therapist provides instructions. General instructions ("Look at me and imitate what I do") will probably lead to a more implicit form of learning, while specific instructions ("Look at how my elbow stretches when I reach for something") might lead to an explicit form of learning.	Demonstrations can be given by: • a therapist; • husband or wife; • other people (in public); • other patients in group therapy.	Advantages • Suitable for patients with communication difficulties as no explanation is needed. • Much evidence for neurophysiological mechanism of observational learning (mirror neurons).[54,55] Conditions • Patient needs sufficient attention to observe the demonstration. • Demonstration should suit the patient's level. A perfect performance (by healthy people walking) can be confronting for some patients and give them the feeling that they will never be able to imitate the movement.	Tools Video recordings of the performance of the task/movement. **Examples from literature**[18,56,57]
Trial and Error learning	Learning by repeatedly attempting to perform a task, during which the learner detects errors and corrects them.	Patient learns from making errors. He/she acknowledges the error and analyses why it went wrong and adjusts the performance.	Classification: More explicit strategy Background: Patient is assumed to analyse the movement/error and acquire knowledge of the details of the movement. Therefore, this strategy is classified as explicit learning.	• The therapist can make use of a more complex, busier environment to provoke errors and difficulties. • The therapist can ask the patient to describe what he/she does or has done, and what went well and what went wrong and why (analysis of the error).	Advantages • Therapist gains understanding of the patient's own solutions and his/her problem solving. Conditions • Patient should be able to recognize their own errors to learn from them. • "Unsuccessful" attempts should be alternated with successful performance to prevent that the patient becomes demotivated.	Tools - **Examples from literature**[47]

Overview of learning strategies from the framework (continued)

Strategy	Description	Explanation	Classification and background	Implementation examples	Advantages and conditions	Tools and examples
Movement Imagery	Learning by imagining oneself performing the skilled movement (in the first or third person perspective) without actually physically performing the movement.	Patient imagine him/herself performing the movement without physically performing it. Imagination alternates with actual performance. Imagining a movement is called "movement imagery". If it's applied systematically as a form of training, the term "mental practice" is used in literature.	<u>Classification:</u> No unambiguous classification possible. <u>Background:</u> See observational learning.	• The ratio of repetition (e.g., imagining twice, performing once) depends on the patient's cognitive and motor abilities. • Patients can imagine the movement from their own perspective (first person perspective) or by looking at themselves from a distance (third person perspective).	Advantages • After the teaching phase, the patient can use Movement Imagery to practise on their own. Since the movement does not necessarily have to be performed, movements which are not yet safe to perform can be practised as well. • Evidence for effects in stroke patients, especially training of upper extremities.[58] Conditions • It is important that the technique of imagining the performance is practised together with the patient. • The patient should preferably imagine the movement visually and kinaesthetically.	Tools -Use mental training in combination with relaxation.[59] -Audiotapes that stimulate the imagination. -Framework for motor learning by Braun et al. 2008.[59] -Questionnaires to find out if the patients can imagine the movements well (e.g., Kinaesthetic and Visual Imagery Questionnaire[60]). Examples from literature[61,62]

APPENDIX 6.2 OVERVIEW OF ELEMENTS

Examples of the element of "organisation"

	Explanation, examples and considerations
Organisation of the practice environment • Protective or open • Simple or complex • Quiet or busy • Limited (environmental constraints) or open (without constraints)	The organisation of the environment can be used to make the learning situation easier or more difficult. The ultimate choice of the structure depends on the objective (the situation in which the learner will finally perform the task) and of the learner's abilities (see Appendix 6.3). For example, in errorless learning, a structure can be used that changes from easy to difficult, so as few errors as possible will be made. In trial and error learning, the therapist can make the right choice by using a more complex and busier environment that provokes errors and difficulties.
Organisation of the task • Subdividing the task or practising the whole task • Blocked or random • Massed or distributed	The way the task is performed can also be organised in several ways. Subdividing the task is especially useful for complex movements that require multiple steps, like getting dressed or making coffee. Cyclical motor task (like walking, cycling) should preferably be practice a whole.[29] Repetition is important when teaching a task (blocked). However, variation is also important during the learning process ("random practice" or "contextual interference"). The natural variation that the task to be learned requires must be the starting point, i.e., in what situation and with what variations will the patient be performing the motor task. Blocked practice appears to work better during the early learning phase, whereas random practice can improve the performance of a task after a retention period.[63,64] The training can be organised at a given moment, followed by many repetitions (massed) or divided over a longer period (distributed). The therapist should take two considerations into account: (1) Rest periods between sessions/repetitions promote performance and learning of the task (distributed practice).[63,65] (2) Some tasks require a certain frequency of repetition in daily life (e.g., turning the pages while reading or leafing through a book). The patient's exercise tolerance level has to be considered before making a choice.

6

Examples of the element of “feedback”

	Explanation, examples and considerations
Shape/content of feedback • Verbal of nonverbal • Knowledge of performance of Knowledge of results[#]	Unlike instructions, feedback focuses on the preceding movement(66). Feedback can be given verbally or nonverbally (e.g., by nodding). Feedback is mostly given by the therapist, but patients can also provide themselves with feedback, thus adopting a more active role in the learning process.[67] Technologies that can provide patients with feedback even beyond regular therapy times are gaining increased interest (e.g.,[68,69]). Videos can also be used as a source of feedback.[70] It seems clear that feedback is useful to support the motor learning process [70,71] and that positive feedback (reward) can have an important influence on motivation.[32] However, there is a lot of uncertainty about the use and content of the feedback. The content of the feedback is often divided into knowledge of performance (KP) and knowledge of results (KR)*. KR focuses on the results of the feedback and the goal of the movement ("This went well."), while KP gives information about the quality of the performance of a movement ("Your arm was not stretched properly.").[67] Both forms of feedback have proved to be useful, also to enhance the quality of the movement.[70,71] If the therapist wants to implement a more implicit learning method, KR would be preferable, whereas KP seems more suitable for explicit learning.
Timing of the feedback • During or after the performance • Frequency	Therapists can give feedback during the performance (concurrent) or after the performance (terminal) of the movement. It is often necessary to give concurrent feedback in daily practice (e.g., when a patient puts himself in an unsafe situation). However, high-frequency concurrent feedback can complicate performance of the learning process.[72] It is advisable to deliberately reduce the frequency of the feedback in the course of the learning process to make the patient more independent (“faded feedback”/”reduced feedback frequency”).[73] Eventually, the frequency of the feedback needs to be adjusted to the patient's level and cognitive abilities.

*These examples focus on extrinsic, augmented feedback. The patient can also use intrinsic feedback, which is information based on sensory, visual and auditory experiences during the movements. #The terms “internal focus” and “external focus” are also used in the literature to describe feedback[24]

Examples of the element of "instructions"

	Explanation, examples and considerations
Focusing on the task (what) and/or the performance (how)	The therapist can only provide general instructions about the task. These general instructions can be combined with more details on how to peform the task. More detailed instructions about the movement or the progress of the movement will probably facilitate a more explicit way of learning.[21]
External of internal focus of attention	The literature distinguishes between internal and external focus of attention. During performance, a patient can direct his/her focus inwards/internal (on the body and the underlying processes for the movement itself) or outwards/external (on the goal and the effect of the movement) It has been described, that healthy persons benefit more from instructions with externally focussed attention to achieve a better motor learning result. The underlying idea is that a learner will complicate the automatic course of the movement if they pay attention to the movement itself (also known as "constrained action hypothesis").[71,74] Studies have also confirmed these findings in neurological patients (e.g., during balance tasks by patients who suffer from Parkinson's disease or have had a stroke).[75,76] In spite of this evidence, therapists seem to prefer to use an internal focus of attention.[77]
Other forms of instruction: • Auditory rhythm • Music • Manual help	Also non-verbal instructions can be used to guide the patient. Therapists can apply auditory rhythm and music to instruct the patient to move in a certain rhythm and to adjust the speed and symmetry of the patient's gait.[32] Therapists can apply manual assistance to make the patient feel how easy/efficient the movement can be, but also as a form of (concurrent) feedback.

APPENDIX 6.3 CHECKLIST OF FACTORS THAT CAN INFLUENCE THE DECISION

Checklist of factors that can influence the decision

Factor	Information available about:	Clarification and examples
Learner	Patient's learning style?	A patient's premorbid learning style can be considered when making a choice. The literature distinguishes between doers, observers, deciders and thinkers (Kolbs model (78)). This classification is also applied in research into persons with acquired brain injury. Unfortunately, there are no good questionnaires available within neurorehabilitation to ascertain the learning style.[79] However, therapists can use the observations gained during therapy and/or ask family members. There is evidence that stroke patients and patients with Parkinson's in general tend to control their movements more consciously.[80,81]There is a questionnaire available to assess the tendency to consciously control movements ("Movement Specific Reinvestment Scale").[82]
	Patient's background/experiences regarding movements (e.g., work, hobbies)?	The patient's movement experiences and background characteristics in terms of sports, work and hobbies could be a suitable input for using metaphors in analogy learning. The patient's culture and living conditions could influence the decision.
	Patient's motor abilities and prognosis?	As regards the patient's motor control, the therapist should consider if a natural recovery is possible or if he/she should use compensation mechanisms. Predicting the patient's recovery by means of models taken from the literature is very important to estimate the feasibility of a particular learning goal.[83-85]
	Patient's cognitive abilities and prognosis?	It is important to assess the patient's cognitive abilities. Long-term memory, working memory capacity, speed of information processing, but also executive functions disorders can influence the learning process and the decision to use a particular approach. (See also the above comments on the strategies of errorless learning, analogy learning and trial and error learning.)
	Details regarding emotions and/or motivation?	Research has shown that motivation is key to the learning process. The therapist has to consider the patient's motivation and emotions during the therapy. Some learning strategies and elements such as errorless learning and positive feedback can be motivating.

Checklist of factors that can influence the decision (continued)

Factor	Information available about:	Clarification and examples
Task	Type of task	Motor tasks can be subdivided in many different ways. The literature often distinguishes between discrete and continuous tasks and between open and closed tasks (e.g., [40,67]) 1. Discrete or continuous tasks: discrete tasks have a clear beginning and ending, while continuous tasks are mostly rhythmic or cyclical without a clear beginning and ending. (See the note on subdividing tasks in the above comments on the element of "organisation"). 2. Open and closed tasks: The learner can begin or end a closed task at any moment because the environment does not change (e.g., walking in a quiet practice room). During an open task, the patient has to react to changes in the environment (e.g., walking in a busy shopping street). The therapy usually starts by learning closed tasks. It is also important to practise open tasks during the learning process, as these are likely to occur in daily life.
	In which situation should the task be realised?	Consider the different environments (home, work, etc.), how often the task has to be repeated (see the above comments on the element of "organisation") and the varieties of the task (e.g., does the patient only have to be able to walk the stairs in their own house or will he/she encounter other stairs as well?).
	What is the goal (safely, efficiently, independently, automatically)?	The goal of the motor task can vary. It is important to check whether the patient especially has to be able to peformede the task safely and independently and whether the quality of performance of the task is important. The efficiency of the movement may be essential for instance as the task needs to be repeated often. The instructions, feedback and organisation of the learning environment should be adjusted to the goal. It is also important to consider if automatic performance of the task is useful and/or achievable. Does the patient always have to perform the task under the same circumstances (e.g., visting the toilet at home) or is it necessary for them to perform it in other situations (e.g., visiting a toilet in a restaurant)?
Learning stage	In which learning stage is the patient?	The literature often distinguishes between three learning stages,[86] assuming that the learning process starts with a cognitive, conscious (explicit) stage. However, recent studies show that the learning process can also start without an initial cognitive stage. The entire learning process could also be more subconscious.[87] Research into the best approach for the different stages in neurorehabilitation is not yet available. When choosing an approach for motor learning in practice, it is important to consider how much experience a patient has had with a motor task, how this has worked out and how stable the performance of the movement was. Some learning strategies such as errorless learning seem to be more suitable for the early learning stage, while strategies such as dual task learning are more appropriate for stages in which the patient's performance has become more stable.

CHAPTER 7

Exploring the utility of analogies in motor learning after stroke: a feasibility study

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ABSTRACT

Individuals who have experienced a stroke need to (re)learn motor skills. Analogy learning has been shown to facilitate motor learning in sports and may also be an attractive alternative to traditional approaches in therapy. The aim of this study was to assess the feasibility and utility of analogies to improve the walking performance in long-term stroke survivors. Three men aged 76, 87 and 70 years who were 6, 1 and 3 years poststroke, respectively, presented with different walking deficits. An analogy, targeted at improving the walking performance was designed with the help of each participant. During a 3-week intervention period, the analogy was practiced once weekly under supervision and daily at home. To assess feasibility, a structured interview was conducted at the end of the intervention period. To assess utility, walking performance was assessed using the 10-Metre Walking Test. All three participants were supportive of the feasibility and benefits of analogy learning. Two of the participants had a meaningful improvement on the 10-Metre Walking Test (0.1 and 0.3 m/s). The third participant did not improve most likely because of medication issues during the week of the retest. Developing analogies in therapy is a creative and challenging process, as analogies must not only guide the correct movement pattern, but also be meaningful to the individual. However, as participants were supportive of the use of analogies, and positive trends were seen in walking speed it seems worthwhile to pursue the use of analogies in future research.

INTRODUCTION

Stroke survivors often need to deal with severe disabilities and as a result, they may face a long and intensive rehabilitation programme. The main aim of rehabilitation is to facilitate the recovery of skills involved in daily living so that patients can return home and participate in society. To facilitate motor learning therapists tend to provide explicit movement instructions outlining the precise steps underpinning skilled movement production.[1] However, for stroke survivors, these explicit instructions may be hard to understand and remember because of cognitive deficits that may affect memory, attention and information processing.[2] A number of motor learning strategies have been developed to minimize working memory involvement and the accrual of explicit rules, including dual-task learning, errorless learning and analogy learning.[3] These strategies originated from the world of sports but are receiving recent attention in the context of rehabilitation.[4,5] The aim of the current research was to initiate enquiry into the possibility of applying an approach using analogy learning within poststroke rehabilitation.

Analogy learning applies one over-arching rule to integrate the complex rule structure of the to-be-learned skill into a simple biomechanical metaphor that can be reproduced by the learner.[6] For example, the analogy of 'reaching your hand into a cookie jar' has been used to describe the appropriate wrist snap required to impart backspin on a basketball during the performance of a free-throw.[7] Analogy learning may be a promising strategy for the rehabilitation of stroke survivors as it reduces the amount of technical information (explicit rules) processed by the working memory system during motor learning.[7] However, current research is limited to healthy populations and it is unclear how therapists and patients experience the use of analogies in rehabilitation. Before a larger trial is set up to evaluate the potential efficacy of analogy learning in stroke rehabilitation, an essential preliminary step is to explore whether analogy learning is feasible and how it might be used within the therapeutic setting.[8] The main aims of the current pilot study were (a) to explore the feasibility of developing and applying personalized analogies to improve walking in long-term stroke survivors and (b) to explore potential benefits to walking performance.

Because of the exploratory nature of this research a case series was adopted.

CASE DESCRIPTION

This study included three randomly selected male volunteers from a nonprofit exercise group called 'Action After Stroke', based at the University of Exeter, UK. All were in the chronic phase of recovery (at least 6 months after stroke), joined the group sessions every week and experienced problems with motor skills during activities in daily life. No participant had serious additional disorders to the locomotor (musculoskeletal) system (e.g., severe rheumatic disorders) or received other healthcare treatments (e.g., physiotherapy). After providing written informed consent, participants were taken through an intake assessment (Table 7.1). None of the three participants had severe cognitive impairments (Mini–Mental State Examination>26).[9] Participants 1 and 2 were able to walk independently and safely (Rivermead Mobility Index: 12/15), whereas participant 3 was wheelchair dependent and needed supervision during walking (Rivermead Mobility Index: 4/15[10]). Participant 2 used a cane for indoor walking and a wheeled walker for outdoor walking.

Table 7.1 Participant demographic information

Participant	1	2	3
Side infarct	Right	Right	Right
Sex	Male	Male	Male
Age	76	87	70
Walking aid needed?	No	Yes	Yes
Years after stroke	6	1	3
Mini-Mental State Sxamination	28	30	28
Rivermead Mobility Index	12	12	4

Intervention and measurements

The ethics review board at the University of Exeter approved the study before commencement, and all participants gave written informed consent. The total study period was 6 weeks and consisted of a baseline period of 3 weeks to obtain a stable measure of subjective walking performance and a 3-week analogy learning intervention. During the entire study period participants attended the Action After Stroke group twice a week, with each session lasting for 1–1½ h. No additional intervention was provided; the measures and intervention of this study were embedded in the Action After Stroke sessions. The baseline phase started with the intake assessment where general information about the study design was provided, and participants were also asked to describe any specific movement or skill deficits they would like to improve (see Table 7.2).

At the end of the baseline phase each participant performed the 10-Metre Walking Test (10MWT) to assess walking performance.[11] The 10MWT is a physical performance test validated for a stroke population, which evaluates the walking speed in m/s over a 10-m distance. Meaningful changes in the 10MWT of above 0.06–0.14 m/s have been described by Perera et al.[11] and the minimal clinical important difference of the 10MWT has been set at 0.16 m/s.[12] After baseline, participants had an individual session with a physiotherapist familiar with the concept of analogy learning (L.-J.J., F.t.L.H.) where they were taught the principles behind analogy learning. Together the therapist and participant then worked to design an analogy (supported by M.K., S.M.B., M.R.W., V.A.G.) using a metaphor that was familiar to the participants.

Table 7.2 Analogies and goals

Participant	Analogy	Goal(s)
1	Imagine you are walking over a frozen lake	Improving lifting and placing of foot Walking in a less conscious manner
2	Imagine you are following footprints in the snow	Creating a step-through gait Walking more fluently, without constantly thinking
3	Imagine you are kicking a football in front of you	Increasing confidence Walking more fluently, with less conscious effort

The selected analogies were practiced together with a therapist, which required 10 min of their regular Action After Stroke sessions. Participants were asked to use the analogy during walking and try to integrate it in their performance. The therapist supported the participants by repeating the analogy but no other instructions were given. No physical guidance was provided. All participants received the same amount of individually guided practice time with a therapist (10 min per session with a maximum of 12 sessions). Participants were encouraged to use the analogy outside of the guided sessions during every day walking. Participant 3 who was wheelchair depended was supervised by his carer or wife when practicing at home. At the end of this period, a structured interview was completed to assess the feasibility of the intervention, and the 10MWT was repeated. The structured interview asked a variety of questions to enable the participants to describe their personal experiences of the intervention process. (The feasibility questionnaire and participant responses are available from the authors on request.)

Outcomes

Feasibility

All three participants completed the entire intervention period and attended at least 10 out of 12 sessions. They reported that there was enough supervision during the training and it was clear how to use the analogies. For participants 2 and 3 a feasible, personalized analogy was found within one session, whereas for participant 1 an additional session was needed (Table 7.2). All three participants agreed that their analogy was meaningful for them, however the way the participants experienced the analogy training did differ in some aspects. For example, participant 1 reported that the analogy training was difficult, as he ‘needed to think a lot’, which was not the case for participants 2 and 3. Participant 1 also found it challenging to visualize the analogy, as it was hard for him to 'change fixed ideas'. Participant 3 also stated difficulties with visualizing 'because the affected leg was not the one he used to kick with'. They all reported that they had experienced some improvements in walking and they would recommend analogy training to others. No adverse side effects were reported.

Utility

Two of the three participants improved on the 10MWT (Figure 7.1). According to Perera et al.,[11] the improvement of participant 1 can be interpreted as a small meaningful change (above 0.06 m/s) and the improvement of participant 2 is a substantial meaningful change (above 0.14 m/s). Because of an unexpected incident (pain in the arm and hand) in the second week which was unrelated to the intervention, participant 3 was exposed to additional medication (tramadol), which negatively affected his post-training 10MWT performance.

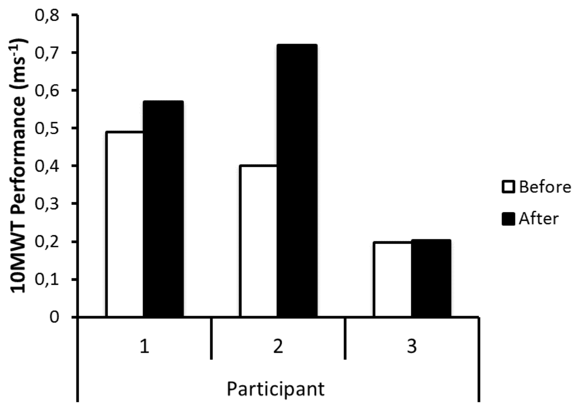

Figure 7.1 10-Metre Walking Test performance (m/s) for the three participants, before and after the analogy intervention

DISCUSSION

There has been recent interest in the application of different motor learning strategies from the world of sport to therapy practice,[13] however, this is the first study to apply analogy learning in rehabilitation after stroke. The aim of this study was two-fold: (a) to assess the feasibility of developing and using personalized analogies and (b) to explore potential benefits to walking performance of analogy learning for stroke survivors who were in the chronic phase of their rehabilitation.

Feasibility of developing and using personalized analogies

Importantly, we were able to find walking analogies for each participant within a relatively short time. The developed analogies seem to need to fulfil two important criteria: (a) they should lead to a biomechanically correct adaptation of the movement and (b) the metaphor used should contain an instruction or image that is meaningful to the participant.

In one case, adjustments were necessary to develop a suitable analogy. Participant 1 originally came up with his own analogy to help improve his foot lift and placement; 'Imagine you are stepping over a rowing machine'. This was meaningful to him because he had previously tripped over one in the gym in which the Action After Stroke group met.

However, this analogy was only related to part of the desired movement improvement; while it helped with his foot lift, his foot placement was still unstable. Therefore, we worked on the 'Imagine you are walking over a frozen lake and do not want to break the ice' analogy to guide both the lifting and controlled placement of his foot while stepping.

The structured interview revealed that in general the participants were positive about the analogy intervention, and felt that it would probably have been more useful in the early stages following their stroke. Indeed participant 1 felt that it was hard to change the movement patterns that he had embedded in the 6 years following his stroke. It is possible therefore that analogy learning might be more effective in improving motor skill in the early, acute or subacute stages of rehabilitation before a certain pattern has been adapted. Future research is needed to test this tentative hypothesis.

The fact that participants suggested that using the analogy was cognitively demanding was surprising. In research with young, healthy athletes, analogy learning has been shown to promote implicit learning. Implicit motor learning strategies are hypothesized to circumvent the information processing of declarative (explicit) knowledge relating to the motor skill, and previous research has revealed that compared with learning through explicit instructions, analogy learning requires fewer attentional resources.[7] However, these results are based on randomized control studies in sports, where one group is given a 'standard' analogy for a particular movement pattern and the other group is provided with a list of explicit instructions. We did not employ a control group in this feasibility study, therefore cannot discuss whether or not the typically found advantage of analogy learning in the sporting literature applies in therapy.

Utility of developing and using personalized analogies

Meaningful improvements in walking speed (10MWT) were gained by two of the three participants. Participant 3 was exposed to additional medication (tramadol), which influenced his daily activities, including walking.

Although we can report anecdotally that his performance in week 2 was perhaps the most improved of all three participants, we have no data to support this, as we unfortunately only assessed performance at the 3-week measuring point. No multiple baseline measures were performed for the 10MWT, which makes the interpretation of the changes difficult; however, given that the participants were in the chronic phase of recovery, the results are still generally supportive of the (potential) efficacy of analogy learning in stroke rehabilitation.

Conclusion

Analogy learning might be a feasible and useful intervention in therapeutic settings. Benefits were evident after only a short training period, despite participants being in the chronic phase of recovery. Future studies are needed to investigate the influence of using analogies on objective gait measures and subjective outcomes that might be related to other therapy aims.

ACKNOWLEDGEMENTS

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CHAPTER 8

The potential influence of implicit motor learning strategies on spatiotemporal gait characteristics in stroke patients: an exploratory study

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Submitted

ABSTRACT

Background

Evidence suggests that implicit motor learning requires few attention resources compared to motor learning that is supported by detailed verbal instructions. Implicit motor learning strategies might therefore be a promising technique for gait training in stroke.

Objectives

To explore whether different implicit motor learning strategies lead to hypothesized changes in gait pattern, and to report experiences of participants when using these strategies.

Methods

A within subject pre-post design in which 56 post-stroke individuals were randomly allocated into one of three strategies: analogy instructions (AI), environmental constraints (EC), and action observation (AO). AI and EC were applied using different conditions. Each condition was hypothesized to change a certain gait parameter. In the AO, only videotaped gait was shown. Spatiotemporal parameters (velocity, step length, step width, step height) of gait were examined using Vicon 3D motion analysis. Patient experiences were assessed by questionnaire.

Results

Repeated measures ANOVA showed that the hypothesized changes occurred in several conditions of the AI and EC strategy, alongside with unintended changes of additional gait parameters. For the AO strategy, no significant changes were found. At an individual level, results showed wide variation in the magnitude of changes. Overall, participants found it easy to walk when using the different strategies.

Conclusion

Changes in spatiotemporal measures of gait can occur if implicit motor learning strategies are used. In practice, individual changes resulting from the use of these strategies should be monitored closely, because responses of patients to the strategies may vary considerably.

INTRODUCTION

Many patients experience walking problems after stroke, which can cause long-term disability.[1,2] Improvement of walking ability is therefore an essential and extensive part of rehabilitation, especially within physiotherapy.[3] Therapists can use a great variety of interventions to help patients improve their walking ability, including treadmill training with or without body-weight support, electromechanical assistance, functional electro-stimulation or circuit class training.[4] Overground gait training, which entails gait training on a regular floor surface (or common surfaces, such as flat ground, ramps or stairs), might be the most applied intervention within physiotherapy practice after stroke.[5] Similar to other interventions in neurological rehabilitation, overground gait training should be task-specific and applied intensively.[4] Therapists tend to support most interventions by providing extensive verbal instructions to facilitate optimal walking performance.[6,7] However, many stroke survivors experience deficits in memory, attention, information processing and communication, which can hamper their ability to understand, process and remember verbal information or instructions during therapy.[8-10]

Implicit motor learning strategies, however, strive to minimize the acquisition and use of verbal knowledge and, consequently, are thought to circumvent the need to explicitly understand, process and remember how to perform the motor task.[11,12] Research has revealed that implicitly learned motor skills are more robust under pressure and secondary task loading than explicitly learned motor skills.[13-16] Therefore, it has been hypothesized that implicit motor learning makes fewer demands on cognitive resources, especially working memory capacity.[11,17-19]

In the context of research, different strategies have been used to operationalize implicit motor learning. In patients with neurological conditions, promising results were reported when analogy instructions (AI), environmental constraints (EC) and action observation (AO) were used to promote implicit motor learning.[13,20-22] An analogy uses understanding of one concept or process to facilitate understanding or learning of a new concept or process. During motor learning, the complex structure of the ‘to-be-learned’ skill can be captured by an appropriate analogy, which is presented to the learner to aid performance of the movements.[23,24] The idea is that the underlying rules of the task are disguised within the analogy and the learner unintentionally (implicitly) employs these rules without gaining explicit knowledge. For example, people with Parkinson’s Disease displayed increased step length when they were presented with an analogy in which they tried “to follow footprints in the sand”. An image of footprints in the sand was provided to support the metaphor.[25] A constrained environment has also been used to promote implicit motor learning. Constraining the environment early in learning has been shown to minimize performance errors,[26] which limits the

opportunity for error correction and discourages the need for hypothesis testing that leads to explicit knowledge.[27] Constrained environments have been used in a variety of populations (children, adults, elderly) to promote implicit learning by controlling the amount of wobble on a balance board or by decreasing the distance between the participant and the target when learning to golf putt or to throw.[13,28-30] Tilborg et al. used action observation (modeling) to teach I-ADL (Instrumental Activities of Daily living, e.g., preparing coffee) tasks to people with dementia.[20] In stroke, positive effects of action observation have been reported,[31] although to date these have not been linked the concept of implicit motor learning.
Until now, most research on implicit motor learning has focused on the outcome (results) rather than the quality of the performance of a motor skill. However, in complex tasks, such as walking, not only results (e.g., being able to walk a certain distance), but also improvements in gait performance (e.g., spatiotemporal characteristics like velocity, step length, step width) are important, as it has been shown that an improvement in these underlying parameters of walking can lead to increased gait efficiency.[32] The provision of detailed (verbal) knowledge about the motor skill, which is common during explicit motor learning, has been described as necessary to improve quality of motor performance in people after stroke.[33,34] However, it remains unclear whether implicit motor learning strategies that seek to minimize accretion of, or access to, verbal knowledge can be used to influence the underlying spatiotemporal characteristics of walking performance.

Therefore, the aim of the study was to explore whether analogy instructions, environmental constraints and action observation lead to hypothesized changes in spatiotemporal parameters of walking by people with stroke (velocity, step length, step width and step height) and to gain insight into the experiences of people when using the strategies.

METHODS

People with stroke were invited to participate in a within subject pre-post design from December 2015 to December 2016. Every participant was randomly allocated to one of the three strategies (analogy instructions (AI), environmental constraint (EC) or action observation (A0)) by a researcher blind to the patient’s characteristic based on a computerized randomization schedule (block size 6). Randomization was performed in order limit risk of selection bias, however, no between group comparison was performed. Ethics approval was provided by the local ethics committees (Zuyderland-Zuyd Ethics Committee 15-N-153, Adelante MEC (MEC15-13)) and all participants provided informed consent.

Selection and recruitment population

Clients after stroke were recruited from two rehabilitation centers, an outpatient clinic of a hospital and from seven physiotherapy private practices in the south of the Netherlands. Further, a call for participation was placed in a local magazine for patients and their relatives. Inclusion criteria were: a stroke (>3 months ago), capacity to walk independently with or without a walking aid over 10 meters (with a self-selected gait speed <1.2m/s), presence of hemiparesis (indicated by a score of <100 on the lower extremity part of the Motricity Index[35] and a score <34 on the lower extremity part of the Brunnstrom Fugl-Meyer assessment[36]). Participants also needed to be able to visit one of the two motion capture laboratories in which data was collected and to have sufficient understanding of the Dutch language. Exclusion criteria were: diagnosed impairments unrelated to stroke but with potential to influence gait pattern (e.g., severe osteoarthritis or amputation of the lower limb), diagnosed additional neurological impairments (e.g., Parkinson's Disease).

Intervention

Depending on randomization, each participant received one of the strategies (i.e., AI, EC or AO). The strategies AI and EC were applied using four different conditions or three different conditions, respectively. In AI these conditions were different analogies and in EC these conditions were different constraints (Figure 8.1).

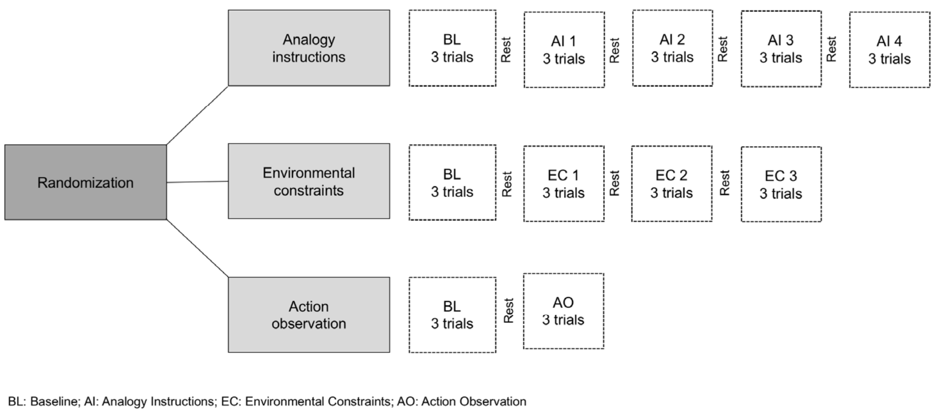
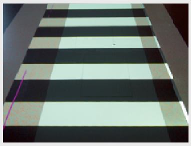
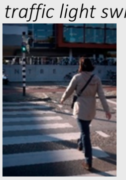
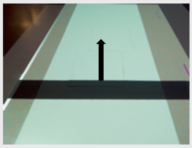
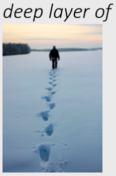


Figure 8.1

The different analogies and constraints were devised to specifically facilitate one of the spatiotemporal gait parameters (see Table 8.1). The order of the conditions was counterbalanced (Latin square) in order to offset the possibility of carry-over effects.

AO was applied using only one condition (observation of a short video clip) and the strategy did not target a specific gait parameter. Each condition was repeated three times and an average of nine complete strides per condition were included in the analysis. After baseline and each condition there was a short break in order to limit fatigue.

Table 8.1 Overview conditions applied within analogy instructions and environmental constrains

Hypothesized change	Analogy instructions with picture	Environmental constrains with instructions
Increased step length	*"Walk as if you follow footprints in the sand"* 	*"Try to alternately step on the black and white stripes of the zebra crossing"* 
Decreased step width	*"Try to cross a small bridge"* 	*"Try to only step on the narrow beam"* 
Increased velocity	*"Try to cross the street before the traffic light switches to red"* 	*"Try to catch the moving bar but do to overtake it"* 
Increased step height	*"Walk as if you are walking through a deep layer of snow"* 	N/A

Analogy instructions (AI)

Four different analogies were devised to influence velocity, step length, step width and step height. The analogies were presented to participants pictorially together with a brief instruction (Table 8.1). Participants were asked to use the analogy during walking.

Environmental constraints (EC)

Three different environmental constraints were used to influence velocity, step length and step width (Table 8.1). To influence step length, horizontal black and white stripes were projected on the floor creating a zebra crossing. Participants were instructed to step on alternate stripes. To influence velocity, a horizontal bar that moved at a constant speed was projected onto the walkway. Participants were instructed to follow the bar without catching up to it. The distance between the stripes and velocity of the bar was incrementally increased by 5%, 10% and 15% of baseline performance. To influence step width, a narrow beam of light was projected onto the floor and participants were instructed to only step on the beam as they walked (decrease step width). The width of the beam was incrementally reduced to be 5%, 10% and 15% narrower than step width at baseline.

Action observation

Videotaped gait was shown. Different clips of a healthy older male or female walking with different walking aids (e.g., stick, walker etc.) were available. The video clip that was viewed was chosen on the basis of gender and type of walking aid used. The person on the video was filmed from a ventral and sagittal plane. Participants were instructed to try to imitate the walking of the person in the video.

Measures

Demographic information was collected with baseline data about the physical and cognitive functioning of the participant. Physical functioning was assessed using the following measures: Motricity Index (voluntary movement activity and maximum muscle strength),[35] Berg Balance Scale (static balance and fall risk),[37] Rivermead mobility index (mobility disability),[38] Fugl-Meyer Assessment of the lower extremity (ability to make movements outside the synergetic patterns).[36] Cognitive functioning was investigated using the Montreal Cognitive Assessment (detection of mild cognitive problems, scores>26 are considerd as normal),[39] the subtest “news story” of the Rivermead Behavioural Memory Test (memory function),[40] and the D2 cancellation test (attention span and concentration).[41] Performance on the Rivermead Behavioural Memory Test and the D2 is presented as percentile scores normalized for age, gender (D2, Rivermead Behavioural Memory Test) and educational level (Rivermead Behavioural Memory Test).

Walking performance, was operationalized by the following spatiotemporal gait parameters: **velocity, step- length, step width and step height.** The gait parameters (Table 8.2) were calculated using a custom Matlab script (version 2012a, The Mathworks, US). Gait events were determined using an algorithm consistent with Zeni et al.[42] Asymmetries ratios of step lengths and swing time were calculated according to Award et al.[43] A value of 0.5 reflects perfect symmetry.

Table 8.2 Operationalization of the spatio-temporal parameters

Variable	Markers	Calculation
Gait velocity	Mean position of the 4 hip markers to estimate the centre of mass	Dividing the distance walked by the ambulation time
Step length	Heel markers	Distance between heel markers at heel strike.
Step height	Ankle marker	Difference in minimal and maximal height within two consecutive heel strikes of the same leg within one step
Step width	Ankle markers	Distance between two ankle markers at double contact
Step length asymmetry	-	Larger step length/(Larger step length + Smaller step length)
Swing time asymmetry	-	Longer swing time/(Longer swing time + shorter swing time)

The participants' experiences of the strategies were explored using a questionnaire designed to gain insight into opinions about feasibility and perceived improvements. Responses were recorded using multiple choice options and free comments. It has been shown implicit that motor learners tend to report fewer verbal rules about their movements during performance than explicit motor learners.[29] After the completion of the session, participants were therefore asked to report in detail all rules and techniques they were aware of, or used, during the walking trials. A rule was defined as any statement that contained at least one movement or position of a limb or joint, the velocity of a limb moving, an angle or directions of a joint, placement of the walking aid, changes in the use of the walking aid or changes in step characteristics (bigger steps, wider steps etc.).

Apparatus

Data was collected in two motion capture laboratories. Both laboratories were equipped with a Vicon motion analysis system (Vicon Motion Systems Ltd, Oxford, UK), consisting of eight infrared motion capture cameras running at 200 Hz. The cameras were spaced around a 10mx 0.9m walkway (Laboratory 1) or a 12mx1.2m walkway (Laboratory 2). Thirty-five markers (14 mm) were affixed to participants according to the Plug-in Gait full body model. Data was processed using Vicon Nexus software version 1.8.5. In a pilot study, the between-laboratory reliability of data was shown to be good to excellent for the spatiotemporal parameters measured (ICC's between .84 -.96, data available on request).

Data analysis

All statistical analyses were conducted in SPSS version 24. Population characteristics are presented using mean values and standard deviations (SD) per strategy and for the entire group of participants. Discrete variables are presented using absolute numbers.

Statistical testing was used to examine differences between baseline performance and performance during the condition, using a within-group comparison for each of the three strategies (AI, EC, AO) separately. Repeated measures Analysis of Variance (ANOVA) and planned contrasts (baseline performances compared to each condition) were used to investigate the analogy instructions over 5 time points (baseline and 4 different conditions), the environmental constraints over 4 time points (baseline and 3 different conditions) and the action observation over 2 time points. Non-parametric tests were performed if there was violation of the normality assumption (Friedman's ANOVA combined with Wilcoxon signed-rank tests for multiple comparison and Bonferonni correction). An alpha level of 0.05 was adopted for all tests. Percentage change from baseline performance for the main outcome parameters are presented using bar charts.

Besides statistical testing, results were analyzed in terms of clinical relevance. Individual changes in gait velocity were assessed using the clinically important change (CIC), which is 0.175m/s according to Fulk et al.[44] To our knowledge, the CIC has not been reported for the other gait parameters. Participant's evaluations were analyzed descriptively and quotes were used to illustrate their experiences.

RESULTS

A total of 79 participants were screened for the study. Seventeen participants did not fulfill one or more inclusion criteria (n=13 gait velocity >1.2 m/s; n= 2 had no presence of hemiparesis; n=1 multiple strokes and n=1 was not able to complete the walking trials). Six participants withdrew before the first measurement session (n=4 health problems; n=1 discharged to other setting; n=1 reason unknown) and the gait data for one participant was not usable. Fifty-six participants completed the study. Table 8.3 presents the demographic information of the participants and the results of the physical cognitive tests at baseline. In Table 8.4, mean values for each gait parameter are presented together with results of the statistical tests.

Table 8.3 Demographic information of participants

	Analogy instruction (n=19)	Environmental constraints (n=17)	Action observation (n=20)	All participants (N=56)
Age in years, mean (SD)	67.0 (11.9)	61.1 (11.9)	63.9 (12.5)	64.1 (12.0)
Gender, n				
Male	10	11	11	32
Female	9	6	9	24
Length in cm, mean (SD)	170.4 (8.8)	174.5 (7.2)	170.1(10.7)	171.5 (9.1)
Weight in kg, mean (SD)	80.7 (19.3)	78.9 (13.7)	77.9 (15.8)	79.15 (16.2)
Side of the stroke, n				
Left	10	8	10	28
Right	9	9	10	28
Time post stroke in months, mean (SD)	87.2 (137.5)	89.4 (84.7)	61.8 (57.7)	78.8 (97.9)
Walking aid, n				
None	4	5	7	16
Cane	6	7	7	20
Quad cane	3	4	1	8
Rollator	6	1	3	10
Crutch	-	-	2	2
Educational Level, n				
Elementary education	4	-	-	4
Secondary education	-	8	11	28
Vocational training	9	4	4	8
University	6	5	5	16
Physical functioning mean (SD)				
BBS (0-56)	43.7 (10.9)	42.0 (8.9)	46.2 (11.0)	44.1 (10.3)
MI total score (0-200)	122.1 (37.7)	98.2 (43.7)	109.1 (40.1)	110.2 (40.9)
Lower extremity (0-100)	63.7 (15.7)	56.1 (19.5)	57.8 (15.1)	59.3 (16.8)
Upper extremity (0-100)	58.4 (28.7)	42.1 (30.0)	51.3 (28.5)	50.9 (29.2)
FMA (0-34) (n=54)[&]	23.8 (2.1)	19.9 (7.9)	22.1 (7.9)	22.0 (7.2)
RMI (0-15)	11.8 (2.1)	12.1 (1.9)	11.85 (2.8)	11.93 (2.3)
Cognitive functioning, mean (SD)				
D2 (n=52)[$]	n=16	n=17	n=19	
TN-F	45.4 (12.3)	19.9 (22.3)	44.7 (13.0)	45.79 (12.04)
CP	45.8 (11.8)	27.8 (28.0)	44.5 (14.3)	46.21 (12.04)
RMBT (n=53)[#]	n=17	n=17	n=19	
immediate recall	27.7 (26.6)	19.9 (22.3)	19.8 (26.7)	22.4 (25.1)
delayed recall	36.8 (33.2)	27.8 (28.0)	26.6 (23.3)	30.3 (28.1)
MOCA (0-30)	22.4 (5.5)	24.5 (3.9)	23.5 (4.7)	23.4 (4.8)

[&] n=2 missing (missed appointment (n=1); test not correct (n=1). [$] n=4 missing (did not understand instructions (n=2); not able to read letters (n=1); missed appointment (n=1); [#] n=3 missing (aphasia)
Abbreviations: RBMT: Rivermead Behavioural Memory Testing; MOCA: Montreal Cognitive Assessment; BBS: Berg Balance Scale; MI: Motricity Index; FMA: Fugl-Meyer Assessment; RMI: Rivermead Mobility Index; RMBT: TN-F: the number of all errors relative to the total number of items processed (measure of precision and thoroughness); CP: number of correctly marked characters minus the number of incorrectly marked characters (measure of attention span and concentration ability)

Table 8.4 Spatio-temporal measures (mean (SD)) of the different conditions

	Analogy instructions (n=19)						Environmental constraints (n=17)					Action observation (n=20)		
	Baseline	Footprints sand	Small bridge	Traffic light	Deep Snow		Baseline	Zebra crossing	Narrow beam	Moving bar		Baseline	Video	
Gait velocity (m/s)	.670 (.23)	**.544 (.18)***	**.493 (.19)***	**.758 (.27)***	**.491 (.18)***	*F(2.10.37.84) = 18.47 p=.000*	.542 (.25)	.465 (.29)	**.375 (.20)***	.586 (.35)	*F(2.28.36.46) =8.99 p=.000*	.686 (.23)	**.635 (.18)***	*F(3.57) =7.95 p=.011*
Step length affected (m)	.438 (.11)	.430 (.10)	**.387 (.10)***	**.471 (.12)***	.415. (.11)	$\chi^2(4)$ *=32.42 p=.000*	.436 (.08)	.417 (.11)	**.380 (.07)***	.432 (.10)	*F(3.48) =3.97 p=.013*	.443 (.07)	.441 (.06)	*F(3.57) =.025 p=.995*
Step length non-affected (m)	.397 (.15)	.409 (.13)	**.352 (14)***	**.436 (14)***	.410 (.13)	*F(2.46.44.32) =12.60 p=.000*	.328 (.15)	.343 (.16)	**.274 (.13)***	.302 (.17)	*F(3.48) =5.06 p=.004*	.394 (.12)	.397 (.11)	*(3.57) =.11 p=.956*
Step width (m)	.247 (.04)	**.286 (.07)***	**.224 (.05)***	.252 (.06)	**.266 (.05)***	*F(1.63.29.26) =14.44 p=.000*	.288 (.05)	.298 (.06)	**.248 (.06)***	.297 (.05)	*F(3.48) =23.47 p=.000*	.250 (.06)	**.244 (.05)***	*F(3.57) =4.70 p=.005*
Step height affected (m)	.098 (.04)	.098 (.04)	.089 (.04)	**.104 (.04)***	**.125 (0.8)***	$\chi^2(4)$ *=29.77 p=.000*	.086 (.04)	**.082 (.04)***	**.072 (.03)***	**.079 (.04)***	*F(2.01.32.16) =6.92 p=.003*	.096 (.04)	.095 (.04)	*F(3.57) =.375 p=.771*
Step height non-affected (m)	.138 (.03)	.140 (.03)	**.130 (.03)***	**.144 (.03)***	**.177 (.07)***	*F(1.24.22.25) =10.65 p=.002*	.132 (.02)	.131 (.02)	.122 (.02)	.127 (.02)	*F(2.08.33.30) =2.70 p=.080*	.134 (.01)	.134 (.01)	*F(3.57) =.037 p=.990*
Step length asymmetry	.56 (.09)	.54 (.05)	.55 (.08)	.54 (.05)	.53 (.04)	$\chi^2(4)$ *=6.04 p=.197*	.61 (.11)	.57 (.10)	.61 (.11)	.63 (.13)	$\chi^2(3)$ *=9.47 p=.024*	.57 (.09)	.56 (.08)	*T=23.00 p=.102*
Swing time asymmetry	.55 (.03)	.55 (.03)	.56 (.05)	.55 (0.3)	.55 (.05)	$\chi^2(4)$ *=7.18 p=.127*	.56 (.03)	.57 (.04)	.58 (.04)	.56 (.03)	$\chi^2(3)$ *=7.12 p=.069*	.55 (.03)	.55 (.03)	*T=56.00* p=.534

*indicates significant difference from baseline (p<.05)

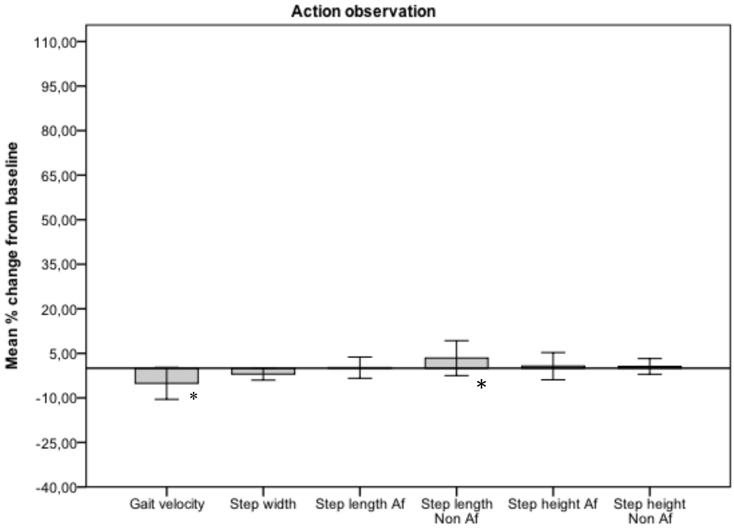
On a groups level, in the AI strategy for three of the four conditions the hypotheses were confirmed. The "small bridge" instruction resulted in a significant mean decrease in step width, accompanied by a decrease in velocity and step length (both affected and non-affected leg). The "traffic light" instruction resulted in the hypothesized increase in gait velocity, accompanied by an increase in step length (both affected and non-affected leg) and an increase in step height (both affected and non-affected leg). Step height of both legs and step width increased after participants received the "deep snow" instruction; however, velocity decreased.
In the environmental constraints strategy, only the "narrow beam" led to the hypothesised change in step width, but velocity, step length (affected and non-affected leg) and step height (affected leg only) decreased in this strategy.
In the action observation strategy, gait velocity in general decreased. No significant changes were evident for the asymmetry ratios.

In the Supplementary Material, percentage change from baseline in the different conditions is presented visually as bar charts. A broad individual range of changes is apparent (indicated by the errors bars). In the AI and EC strategies there are participants who responded to the conditions with large changes in their walking performance, but also participants who deteriorated. Seven participants (n=3 EC, n=4 AI) increased their gait velocity by greater than 0.175 m/s, exceeding the CIC (maximum increase was 0.66 m/s). These participants all displayed higher baseline gait velocity (mean 0.72 m/s), slightly better functioning of the affected leg (mean MI 71.4 and FMA 28.6) and superior balance (mean BBS 47.6), compared to the mean of all participants.

Variation in step length change in the "zebra crossing" condition (EC) and the "footprints in the sand" condition (AI) are particularly broad. For instance, Participant 67 (AI) and Participant 69 (EC) were able to increase the step length of their non-affected leg from 2.4 cm to 14.9 cm and from 2.7 cm to 19.5 cm, respectively. In both cases, this resulted in a better step through gait (Baseline step length asymmetry 0.94 and 0.90, Post-condition asymmetry 0.69 and 0.60).

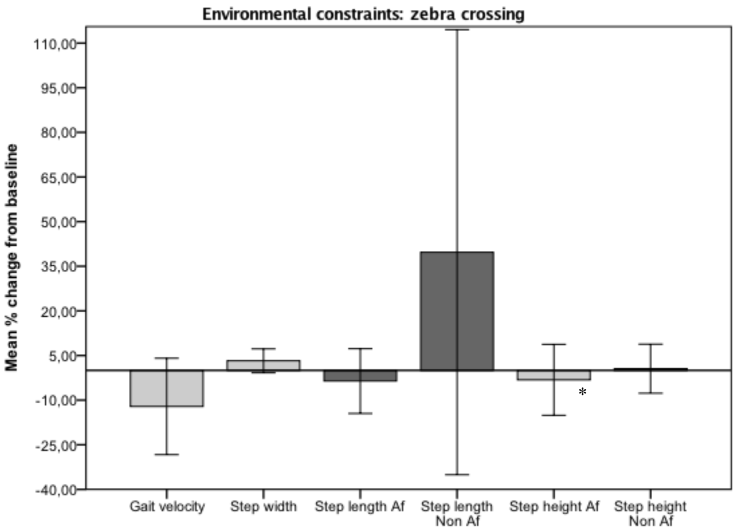
SUPPLEMENTAL MATERIAL

Mean % changes from baseline in the **action observation** condition



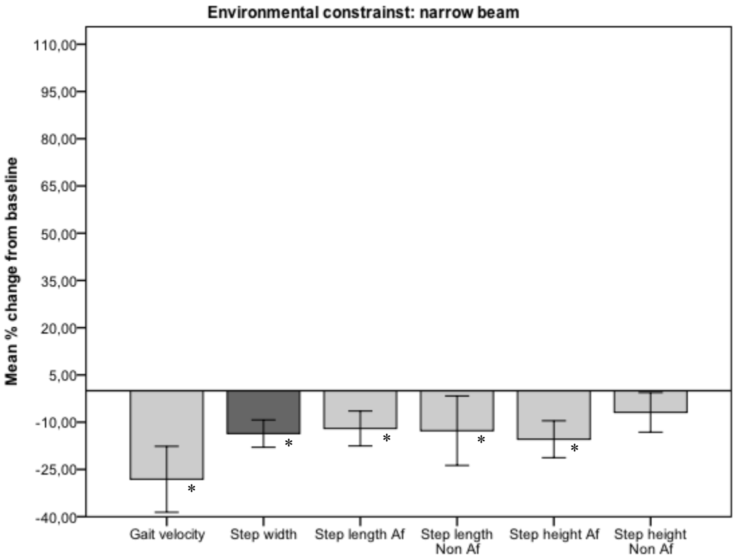
* Significant change from baseline; p<.05; error bars: +/- 2 standard error

Mean % changes from baseline in the **environmental constraints** conditions

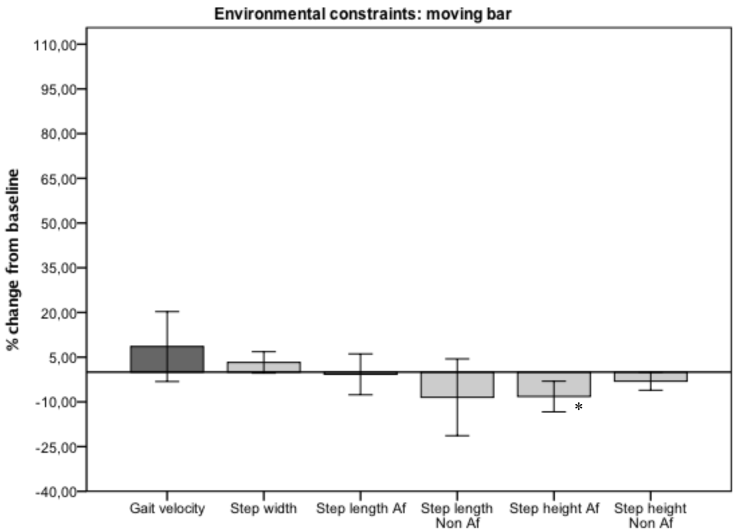


* Significant change from baseline; p<.05; dark grey bars: main hypothesis; error bars: +/- 2 standard error

8

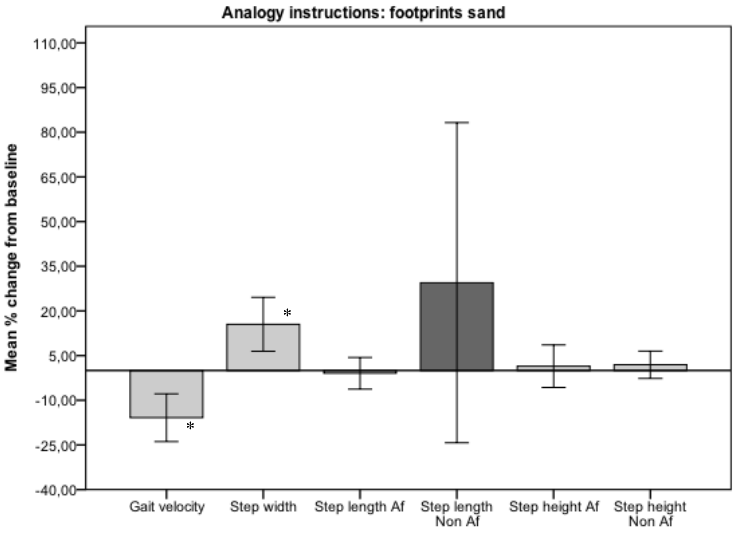


* Significant change from baseline; p<.05; dark grey bar: main hypothesis; error bars: +/- 2 standard error

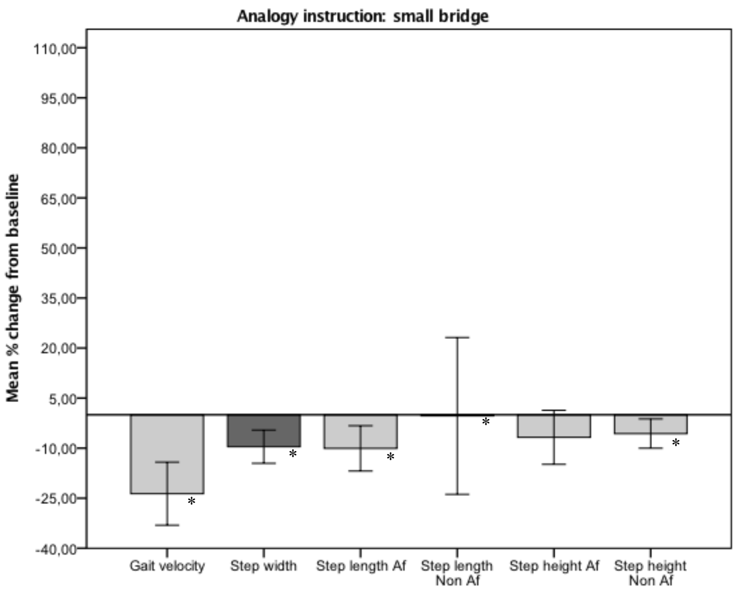


* Significant change from baseline; p<.05; dark grey bar: main hypothesis; error bars: +/- 2 standard error

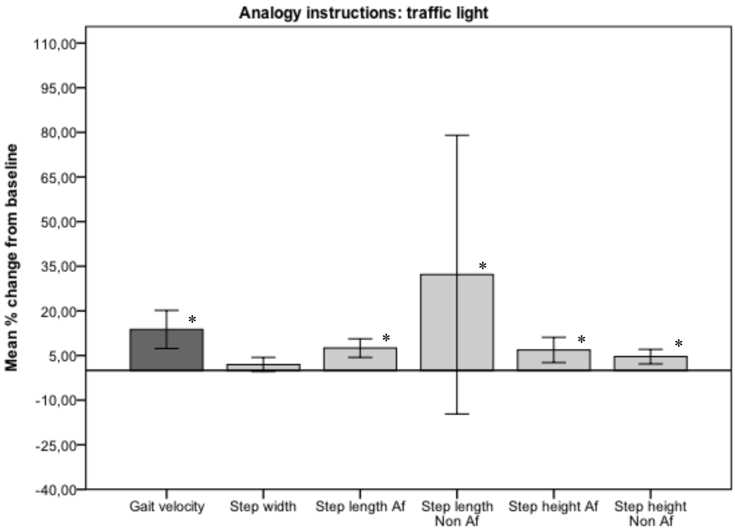
Mean % changes from baseline in the **analogy instruction** conditions



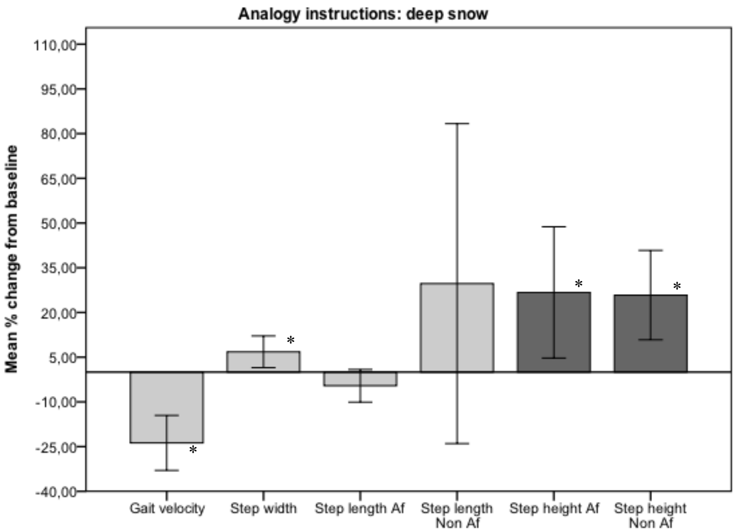
* Significant change from baseline; p<.05; dark grey bars: main hypothesis; error bars: +/- 2 standard error



* Significant change from baseline; p<.05; dark grey bar: main hypothesis; error bars: +/- 2 standard error



* Significant change from baseline; p<.05; dark grey bars: main hypothesis; error bars: +/- 2 standard error



* Significant change from baseline; p<.05; dark grey bars: main hypothesis; error bars: +/- 2 standard error

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Overall, participants found it relatively easy to walk during the different conditions and did not report a need to think much more than usual (Table 8.5). However, some instructions reminded people of difficult situations in daily life. For example, after using the walking in "deep snow" analogy, Participant 10 stated that: *"in real life I cannot walk through snow with my wheeled rollator",* and after using the traffic light analogy, Participant 26 stated that: *"in real life I never make it on time to the other side of the road"*. In general, participants experienced some change in their gait pattern. In the action observation strategy, people frequently reported that they found themselves attending to their *"arm swing"* and to "*walking more upright*".

Table 8.5 Overview results of participants' experiences

	Analogy instructions		Environmental constrains		Action observation	
1. How difficult or easy did you find walking with the instructions? (1=very difficult, 10=not difficult)	7.6 (2.2)		6.2 (3)		8.0 (1.5)	
2. Which instruction did you find easiest to perform?	Traffic light Deep snow Footprints sand Small bridge No preference	(58.8%) (17.6 %) (5.9%) (0%) (17.6%)	Zebra crossing Narrow beam Moving bar	(46.3%) (26.7%) (26.7 %)	N/A	
4. Did you need to think a lot while walking? (1=not at all, 10=need to think a lot)	2.9 (2.3)		3.5 (2.2)		3.0 (2.3)	
5. Do you think your gait changed? (1=no change, 10=a lot of change)	Deep snow Footprints sand Traffic light Small bridge	6.4 (1.3) 4.7 (2.3) 4.2 (2.8) 5.3 (2.4)	Zebra crossing Narrow beam Moving bar	4.0 (3.0) 5.3 (3.3) 3.8(2.8)	3.5 (2.9)	
6. Number of explicit rules	0 rules: 1-2 rules: 3-4 rules:	15.8% 63.1% 21.1%	0 rules: 1-2 rules: 3-4 rules:	23.5% 35.3% 41.1%	0 rules: 1-2 rules: 3-4 rules:	30% 50% 20%

Numbers represent mean (SD) and percentages

DISCUSSION

The aim of the study was to explore whether analogy instructions (AI), environmental constraints (EC) and action observation (AO) lead to hypothesized changes in different spatiotemporal parameters of walking in people after stroke and to explore patients' experiences when using these strategies. The data from the current study suggests that in general AI and EC may be useful for facilitating positive changes in spatiotemporal gait parameters, without using explicit verbal instructions to specifically direct patients' attention to the parameters. At a group level, three out of four a priori hypotheses regarding the AI conditions were confirmed and one out of four was confirmed for the EC conditions. The use of AI or EC even improved walking performance in some individuals with stroke beyond clinically relevant changes, at least temporarily. However, results showed wide variation in the magnitude of changes, and, as a consequence, the average change was relatively small. The large variation may be explained in several ways. First, the strategies were designed to facilitate different aspects of gait, but they were pre-defined rather than tailored to the needs of individual participants. For example, the wide variation within the "zebra crossing" (EC) condition may be explained by large performance differences at baseline. Some participants already walked relatively symmetrically with a step-through gait pattern, whereas others adopted a more asymmetric step-to gait pattern and may therefore have shown greater improvements in step length and step length asymmetry. Similarly, a ceiling effect might have occurred in some participants who already had a small ("normal") step width at pretest, causing any further decrease to culminate in an unnatural walking pattern. Further, in the EC strategy a delayed reaction time to the "moving bar" instruction was evident, which may have influenced average walking speed, explaining why gait velocity of some participants remained stable or even deteriorated. Delayed reactions to a signal have previously been described in stroke patients in other contexts.[45]

Gait is a multivariate phenomenon with a pattern across the several parameters and it is important to consider the overall pattern of change. Therefore, a broad set of measures was used in order to explore potential benefits but also "side-effects" of the learning strategies. Alongside the hypothesized changes, several additional and unintended alterations of the gait pattern were observed. Especially the concomitantly decrease in velocity which occurred in several conditions should be mentioned. This decrease might be explained by the fact, that some participants reported that they consciously tried to control three or more aspects of their walking pattern. This observation is consistent with findings that indicate that even during the late phases after stroke, many patients are still dependent on conscious control of their movements.[46-48] Conscious control of motor performance is highly dependent on working memory.[18] Patients are therefore more likely to experience dual-task interference because resources of working memory need to be diverted to conscious control.[49] The use of additional cues, even a single instruction, may have placed additional demands on working memory,[50] which interfered with conscious control and resulted in decreased gait velocity. It might also be that patients require time to fully assimilate a new motor learning strategy and slow down initially in order to focus on the primary aim (e.g., step height). In patient with Parkinson Disease it was shown, that patient increased step length but initially decreased in velocity after having received an analogy instruction. After using the analogy over time (4 weeks), patients increased velocity even beyond baseline and maintained their new stride length.[25]

The absence of any relevant change within the AO strategy is interesting. Participants often reported that they paid attention to aspects of gait that were either relevant to their own specific walking problem (e.g., stability of the knee joint) or general aspects of gait, such as arm swing and walking more up-right. However, those aspects were not measured in this study. Intuitively, it seems that for particular gait parameters to be influenced by AO, attention may need to be cued externally (perhaps by verbal instructions). However, research in other fields has shown that AO without external cues can promote an implicit form of motor learning and can result in quicker, more efficient performance compared to AO with external cues in the form of verbal instructions.[22]

Participants reported that, in general, following the instructions was easy - especially when the instructions were related to recognizable daily life situations (e.g., traffic lights (AI) and zebra crossing (EC)). Prior research on the longitudinal use of tailored analogy instructions and environmental constraints has already indicated that it may be feasible to use them in daily practice.[51,52] Yet, some participants reported that situations portrayed in the AI strategies were difficult or even impossible to use in daily life. For instance, some participants reported that they enjoyed walking on the beach, whereas others indicated that walking barefoot was not feasible for them or that the sand would create an unstable surface. In these cases, the negative association with the analogies may have led to more unfavorable outcomes. Meaningful, tailored analogies based on individual preferences may have avoided this.[51]

Some limitations should be considered when interpreting the present results.
First, relatively permanent changes in motor behavior, representing learning, are typically only convincingly evidenced by delayed retention tests or during transfer of a motor skill.[53,54] The absence of such follow-up testing is a clear limitation of the study. Future research should investigate the stability of the changes in gait performance over several sessions, in retention and in real-world over ground walking. *Second*, no between-group comparison of the three strategies was performed, and as a consequence no conclusion can be drawn regarding the relative superiority of one these strategies. Future studies should also directly compare the effects of implicit motor learning to an explicit control intervention, because in stroke evidence for the superiority of implicit motor learning is inconclusive.[55] *Third*, the results of the statistical testing on groups level should be interpreted with caution, because there is a chance of “false alarm” as a result of multiple testing. The average changes on groups level are relativly small, and the clincal relevance of these changes might be questionnable. However, on individual level, some participants showed relevant

improvements of the entire gait pattern, whereas other particpants deteriorated under the same condition. The included sample size did not allow subgroup analysis of potential factors which might explain these differences. Baseline gait velocity, balance, motor function might have influenced the physical ability to respond to the motor learning strategy.[56,57] Also cognitive factors might have played a role, especially since attention and memory are required to process additional cues during walking.[58] In addition, personal preferences and expriences might modify the individual responses towards a strategie. In practice, therapist seem to take all these factors (and even more) into account when shaping motor learning in practice which results in highly individualized approaches.[59] However, within one research paradigm it is not possible to take all potential influencing factors into account. In order to unravel the complexity of motor learning, different research designs are needed and should probably be combined with systematic observations of which strategy works for which patient under which circumstances within clincial practice.

Besides these limitations, physiotherapist and other health care professionals involved in motor learning of patients can learn form this study that individual changes in spatiotemporal parameters of gait can occur if implicit motor learning strategies are used. The strategies explored in this study were applied using only a single instruction. They might be an efficient therapy option, especially in participants who experience problems with understanding and processing more detailed verbal instructions. Even though not all patients were capable to complete the cognitive tests because of severe cognitive and communicative problems, they were all able to complete the intervention. Furthermore, research into post-stroke gait rehabilitation has shown that a single therapy session can reveal enough information to predict whether a patient is responsive to a gait intervention.[60] The findings of the current study suggest that even a single instruction might help therapists to evaluate whether the intervention might be beneficial for a patient and support therapists' decisions when choosing an individualized gait training program. Therapist should however monitor individual changes resulting from the use of the researched implicit strategies closely, because responses of patients to the strategies may vary considerably and it remains unclear whether changes are stable over time in terms of retention and transfer. Therapists should also be aware that, using an implicit motor learning strategy does not prevent some patients from consciously controlling their gait.

Implications for practice

- Individual changes in spatiotemporal measures of gait can occur if implicit motor learning strategies are used.
- The researched strategies seem feasible but therapists need to tailor the strategies to the gait problem and individual preferences of the patients.

- Individual changes resulting from the use of these implicit strategies should be monitored closely, because responses of patients to the strategies may vary considerably and it remains unclear whether changes are stable over time in terms of retention and transfer.

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CHAPTER 9

General discussion

GENERAL DISCUSSION

The overall aim of this thesis was to provide therapists in neurological rehabilitation with knowledge and tools to support the justified and tailored use of motor learning in daily clinical practice. To achieve this aim, the thesis was divided into two parts. The aim of the first part was to develop a theoretical basis for applying motor learning in clinical practice, using the implicit-explicit distinction as a conceptual basis. Afterwards, in the second part, strategies identified in first part were tested for feasibility and potential effects in people with stroke.

The main target population of this thesis were patients within neurological rehabilitation, especially people after stroke. Applying motor learning in this target group is particularly complex as people with neurological disorders often experience reduced cognitive functioning, and communication problems, which may hamper the learning process.[1-3] Compared to the field of neurological rehabilitation, more research and knowledge about motor learning is available in other fields (e.g., sport, psychology). For this reason, in the first part of the thesis knowledge from these other fields was compiled and combined with knowledge from neurologic rehabilitation (*Chapters 2-5*). Subsequently, the knowledge, and insight that was acquired, was funneled into a framework for the application of motor learning in practice of neurological rehabilitation (*Chapter 6*). The last part of the thesis focused on motor learning in the stroke rehabilitation, by exploring and testing several hypotheses via empirical studies (*Chapters 7 and 8*). The flow of the entire thesis is visualized in Figure 9.1.

In the following chapter, the main findings are discussed. Afterwards, issues related to content and methodological choices are described. In the subsequent section, potential clinical implications of the thesis are presented and the general discussion rounds off with an overview of possible next steps and future directions within the field of research into motor learning.

One of the main aims of this thesis was to provide clear terminology on motor learning. Based on the results of the thesis, an overview of terms used within the following chapters and their description is provided in Table 9.1.

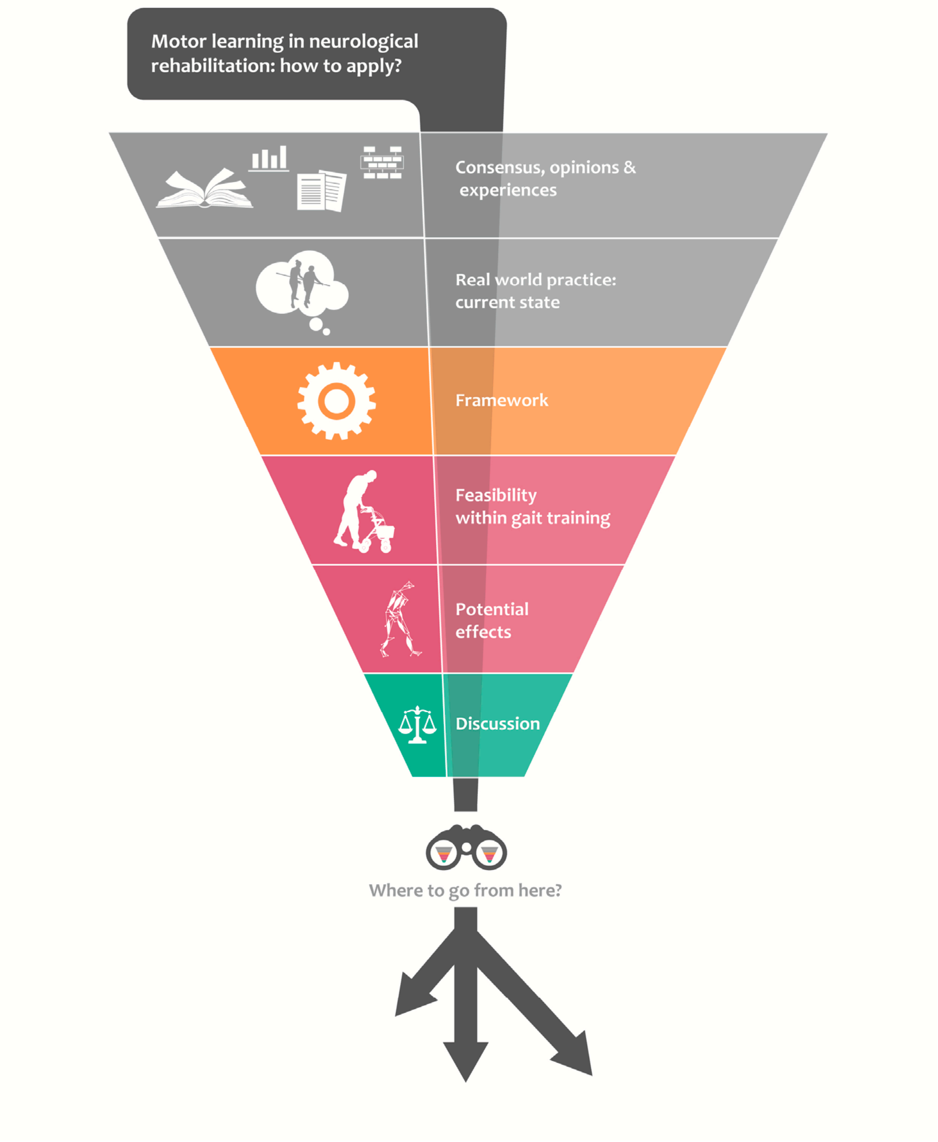

Figure 9.1 Overview of the entire thesis

Table 9.1 Overview of terminology used to describe different aspects of motor learning within the general discussion

Term	Description
Motor learning options	Refers to all applications of motor learning which therapist (or other professionals) use in practice, without further classification.
Motor learning form	Refers to implicit and explicit forms of motor learning
Motor learning strategy	A learning strategy includes motor learning options that share a common background and theory and therefore also have comparable practical characteristics (e.g., errorless learning, analogy learning).
Elements of motor learning	A therapist needs several elements to put motor learning into practice. Within this thesis these elements are clustered into three categories: instructions, feedback, the organisation of the learning environment and the task to be learned.

MAIN FINDINGS

The results of this thesis can be clustered in three main themes: “Speaking the same (motor learning) language”, “The use of the implicit-explicit continuum in theory and practice” and “The potential of implicit motor learning for neurological rehabilitation”. In the following, the main findings of this thesis are presented and discussed in the context of these three themes.

Speaking the same (motor learning) language

There are several examples, which show that knowledge from different fields, especially from the field of sports, can successfully be translated and subsequently further developed for use within (neurological) rehabilitation. Examples are the use of training principles for cardiovascular and strength training,[4,5] the use of movement imagery[6] but also more general ideas and models (e.g., motor program-based theories, dynamic pattern theory or stages of motor learning).[7] Translation and adaptation of knowledge about motor learning from different fields for use in neurological rehabilitation therefore seems appropriate and efficient.

In the first part of this thesis, an attempt was made to create a common basis for the transfer of knowledge about motor learning from different fields for use within (neurological) rehabilitation. An international survey with an integrated Delphi technique was conducted to ascertain level of agreement between experts from different motor learning domains (i.e., therapists, coaches, researchers) (*Chapter 2*). Based on the results of the Delphi technique, definitions and descriptions of terms related to motor learning were proposed in *Chapter 3*. Even though experts who participated in these studies came from a broad variety of fields and had diverse backgrounds, consensus was found on the definitions of implicit and explicit motor learning and on description of several intervention strategies within only two Delphi rounds. It seems that the participating experts shared partly the same theoretical knowledge (e.g., similar underlying theories and working mechanisms), which made the search for consensus on this theoretical level relatively straightforward.

However, speaking the same language and using uniform terms for theoretical constructs does not imply that experts agree on the application of motor learning in practice. For practical application of the defined and described terms (i.e., how to apply implicit motor learning in practice) no consensus was found (*Chapter 4*). This could indicate that a certain motor learning form and/or strategy might have different applications in practice and/or that there are too many variables to reach consensus. For example, during errorless learning, errors can be prevented by verbal or visual instructions, imitation/modeling, shaping/chaining, vanishing cues spaced retrieval or manipulation of the environment.[8-11] All these applications have been described in the literature and/or used in research and they all fit the description of errorless learning in theory. Another reason for the lack of agreement about application of motor learning might be the complex and multifactorial character of the motor learning process in neurological rehabilitation. *Chapter* 5 revealed insights into this complexity, by identifying the large number of motor learning options experienced therapists use within daily practice, and the even larger number of factors they consider during the clinical-reasoning process. This study, however, confirmed that motor learning options may be clustered in three categories, as also indicated by the international experts: instructions, feedback and organization.

The lack of agreement on application and the large number of motor learning options therapists use(d), may indicate that motor learning approaches need variation in order to fit individual patients. On the other hand, the great variation in opinions (*Chapter 4*) and applications (*Chapter 5*) might also be the result of a lack of insight into which approach is most suitable for which patient. The latter might result in a “trial and error” approach in clinical practice until the most suitable (combination) of motor learning options has been found.

Based on of the results of *Chapters 2 to 5* the thesis further focused on the development of a framework to support therapists in their daily practice by supporting their clinical decision-making process (*Chapters 4* and *6*) instead of describing the application of several motor learning options in detail using a “step by step recipe”. The framework was developed through a structured procedure with the international sample of experts, who agreed on the final version of the framework (*Chapter 4*).

The framework focuses on the applications of motor learning by providing an overview of options for motor learning using three layers: forms of learning, strategies and elements. These layers are interrelated rather than hierarchical. Therapists might use the framework to support their clinical reasoning and communicate choices about the application of motor learning with colleagues (*Chapter 6*). The framework not only presents the options for motor learning, but also integrates their possible relation. Many motor learning options (e.g., internal or external focus of attention,[12] knowledge of performance or knowledge of results,[13,14] blocked or random practice[15,16]) can be linked to the framework, which makes it complementary to earlier overview articles in the field of motor learning (e.g.,[17-20]).

In summary, on a theoretical level, experts involved in the current study seem agreed on definitions and descriptions of terms related to implicit and explicit motor learning. Regarding the classification of motor learning strategy, no consensus was found. Therefore, in this thesis a framework was developed to show possible options for motor learning and their relation without assuming a fixed hierarchical structure. Given the lack of consensus regarding the application of forms of learning and learning strategies, it is very important that researchers and educators describe interventions clearly and in detail. Using a single term (e.g., errorless learning) might not be sufficient for their work to be understandable and reproducible by therapists and/or students.

The use of the implicit-explicit continuum in theory and practice

The distinction between implicit and explicit motor learning was chosen as a conceptual basis and starting point for the thesis. This distinction has traditionally been used in the field of psychology of learning in general[21] and a broad range of different fields of motor learning (e.g., sports, fundamental research, surgery orthopedic rehabilitation, children with handicaps and psychiatric disorders, elderly and neurological rehabilitation (e.g.,[22-30]). Within learning, often dichotomous distinctions are used to describe learning processes, accumulated knowledge or related applications. Although textbooks and research paradigms often stick to those clear categorizations, the results of the Delphi study showed that we should rather use a continuum of implicit and explicit motor learning instead of a dichotomous distinction. The underlying argumentation of the expert panel was that in theory a clear distinction between the forms of learning is possible, which is reflected by the definitions that were developed within the Delphi study (*Chapter 3*). However, in practice a clear classification whether a patient is learning a skill more implicitly or more explicitly, is not feasible or even possible as therapists often switch between several motor learning options and/or use mixtures (*Chapter 5*). The expert panel in the Delphi study confirmed earlier suggestions by Reber (1993) who argued that implicit and explicit learning should be seen as “interactive components or cooperative processes” [21] and should be interpreted on a continuum. The choice of an implicit-explicit continuum of motor learning proved feasible for use in daily practice, as a starting point for discussions and knowledge exchange (*Chapters 3 and 4*). However, classifying different motor learning strategies according to this continuum revealed ambiguous results (*Chapter 4*), indicating that most motor learning strategies can promote both implicit and explicit motor learning, depending on their specific application in practice.

The findings from the empirical studies of this thesis (*Chapters 7* and *8*) also showed how difficult a strict distinction between implicit and explicit motor learning can be. A feature of implicit learning, which is included in the developed definitions is "*that learning progresses with no or minimal increase in verbal knowledge of movement performance (e.g., facts and rules)"*.[31] In the studies in *Chapters 7 and 8,* we tried to apply a clear implicit form of learning and restricted the knowledge of movement performance by using analogies, constraints of the environment and action-observations without further verbal instructions or feedback about the details and rules of the movement. Nevertheless, we found that therapists can be a source of explicit knowledge, and patients often "search for" and use explicit knowledge about their movement performance themselves. For instance, some of the participants of the study in *Chapter 7* reported a high number of rules, which they used to control their walking performance. Another feature of implicit learning is that the learner should not consciously process their movements.[31] However, some patients reported they 'needed to think a lot' to follow the instructions provided.

There are some explanations possible for these findings. The first explanation might be given by a phenomena called "reinvestment".[32] Reinvestment has been described as an inward focus of attention in which an attempt is made to perform the skill by consciously processing explicit knowledge of how it works.[33] Research on the propensity of individuals to reinvest in movement performance shows that some people are more likely to control their movements consciously than others, especially when under pressure to perform in an optimal way. The propensity to reinvest seems to be a function of one's personality,[32] but conscious involvement in movements appears to be generally higher post stroke.[34,35] The latter might explain why some participants of Chapter 7 and 8 reported the need to consciously "think" about their motor performance during walking. Another possible explanation might be, that patients who participated in the studies had already completed an intensive rehabilitation period. It is possible that during this rehabilitation phase, patients had been treated in a very explicit way by their therapists. It has been reported that, in general, therapists working in neurological rehabilitation seem to provide extensive verbal information, especially focusing on an internal focus of motor control[36,37] and that once explicit information is provided to the patient, it seems difficult maybe even impossible to switch to a more implicit form of learning.[38]

But even if patients do not use a high number of rules to control their movements, they may find it hard to use instructions intended to promote an implicit form of learning, as they are unaccustomed to this different form of instruction. For instance, some patients in the study (*Chapter 7*) reported that they found it difficult to imagine a certain picture created by the use of analogies. From studies in the field of movement imagery, which shares characteristics with analogy learning, we know that some patients after stroke are just not able to imagine a certain movement/ situation in a structured way.[39]

In summary, a continuum of implicit and explicit motor learning seems feasible for use as a theoretical starting point for discussions and knowledge exchange. In practice, it is important to realize that certain motor learning options might fit the definition of implicit motor learning; however, patients might use features of explicit motor learning based on their personal propensity or because it has been stimulated by earlier therapy sessions.

The potential of implicit motor learning for neurological rehabilitation

Research has revealed that implicitly learned motor skills are more robust under pressure and secondary task loading than explicitly learned motor skills.[33,40-46] More recent research confirms this finding in learning processes of surgeons, people with speech disorders, children with intellectual disabilities and lower motor ability.[8,29,47-48]

There is some literature that suggests that these advantages of implicit motor learning might also be true for neurological rehabilitation,[49,50] especially for patients suffering from stroke.[40,41] However, a recent review concluded that currently no reliable conclusions can be drawn regarding the effect of implicit motor learning, as most of the studies are restricted to non-functional task and laboratory environments.[51]

Based on literature and the results of Chapters 3-4, analogy instructions, environmental constraints and action observation were used to promote implicit motor learning within this thesis. The idea of analogy instructions is, that the underlying rules of the task are disguised within the analogy and the learner unintentionally (implicitly) employs these rules without gaining explicit knowledge.[52] Constraining the environment has been shown to minimize performance errors which limits the opportunity for error correction and discourages the need for hypothesis testing that leads to explicit knowledge.[53] Action observation (learning by observing a motor task) has been used in healthy populations and populations with neurological disorders to promote implicit motor learning. In stroke, positive effects of action observation have been reported, although to date these have not been linked to a specific form of motor learning (implicit or explicit). Earlier research has shown that these three strategies can promote an implicit form of motor learning.[8,41,50,54] Dual task learning might also result in a more implicit form of learning; however, this strategy was not used within this thesis. The reason was the difficulty to find an appropriate secondary task (motor of cognitive task), which results in sufficient distraction from, however, not in disruption of the primary motor task.

Although no direct evaluation of the effectiveness of these implicit motor learning has been performed within this thesis, some results add new evidence to the current knowledge-base regarding the potential of implicit motor learning for patients with neurological disorders. First, within the international survey (*Chapter 4*), the majority of the experts agreed that implicit motor learning should be considered for patients with neurological disorders, especially when suffering from cognitive problems (data not published). Second, the multiple case study (*Chapter 7)* is the first study, in which the feasibility of an implicit motor learning strategy, 'analogy learning', has been investigated in patients after stroke. From this study we can conclude, that the use of analogies to support therapy related to gait seems feasible and results seem promising. Participants were supportive of the use of analogies, and positive trends were seen in walking speed, although the dose of therapy was relative low. Third, from the exploratory study in *Chapter 8* we learned that analogy instructions and environmental constraints seem feasible and can influence spatio-temporal gait characteristics of people after stroke, without providing explicit information on the details of the gait pattern. The most promising results were obtained for analogy instructions, especially when the instructions were related to recognizable daily life situations.

Within Chapters 7 and 8, the implicit motor learning strategies were applied using only a single instruction and even patients with severe cognitive and communicative problems were able to complete the interventions.[55] They might therefore be a feasible and efficient therapy option, especially in participants who experience problems with understanding and processing more detailed verbal instructions. These findings supports the hypothesis that implicit motor learning may need less attention resources and working memory capacity.[56] The results of *Chapter 8* further confirm what has already been indicated by the expert panel of the international survey (*Chapter 4)* - there does not seem to be a "one-fits-all" approach in motor learning and results further indicate how large the variance of individual patient responses can be to certain strategies.

In summary, this thesis confirms the potential of implicit motor learning strategies for use in neurological rehabilitation. Therapists can consider tailored analogy instructions and environmental constraints to improve gait in neurological patients. A single application of these strategies (using a single instructions), might be enough to indicate whether a patient is responsive to a strategy or not.

METHODOLOGICAL CONSIDERATIONS

In this section in particular, the overall methodological considerations of the thesis are discussed. For a more detailed reflection about the methods of the underlying studies, I refer to the discussions of the separate chapters.

Study designs

Within this thesis, data from a variety of sources and stakeholders (literature, experts, therapists and patients) was used. Furthermore, both qualitative and quantitative designs were combined; a survey with an integrated Delphi technique, a qualitative think-aloud study, a case report and a within-subject exploratory design. These designs were chosen carefully to answer the research questions, collect the necessary data and generate knowledge matching the current state of research within the field of motor learning in neurological rehabilitation. In general, this broad approach is a strength of the project, as data from different sources and different levels of specificity and evidence were compiled and compared. No evaluation of the effectiveness of a motor option is included as it is necessary to build up a stable body of knowledge first.[57] Below the overall rationale for the choices of the designs and their limitations is discussed.

Facilitating motor learning in neurological rehabilitation requires a complex intervention. A first step for developing and evaluating complex interventions is to identify what is already known about similar interventions.[57] Often a systematic review of literature is used for this purpose, which was, however, not feasible in this project given the restricted number of studies in the field of implicit and explicit motor learning in patients after stroke. Therefore, the Delphi technique was used as a starting point for the current research project. It is a useful approach in situations where a problem needs to be addressed by a group of experts, especially if component skills of professionals are specified.[58,59] The Delphi technique is said to have high face validity and concurrent validity.[58] In other areas, the Delphi technique has been shown to be a valuable addition to applied research and systematic reviews, particularly in fields where consistency of terms and taxonomy is lacking.[59] In the absence of evidence from "higher-order" research (such as systematic reviews, randomized control trials, well-designed cohorts), expert recommendations based on a plausible rationale or usual practice may be a useful guide.[60] The advantage of the applied Delphi technique was, that in addition to researchers, therapists and coaches with experience in the application and education of motor learning were also included. Their knowledge might add relevant aspects to the available literature and to the more theoretical views of researchers.[61] An important issue when considering the results of the Delphi technique is the chance for selection bias of the expert panel. Although participants of the Delphi study were heterogeneous with regard to their backgrounds, special interest and working experience, response rate for participation was in general low. A few experts explicitly stated that they refused participation or dropped-out because they did not agree with the general set-up of the study and/or the implicit-explicit continuum as a conceptual basis.

The results of the Delphi technique were enriched by insight from the qualitative "think aloud" study (*Chapter 5*). The use of motor learning options and the underlying decision-making process of five experienced physiotherapists in neurological rehabilitation was studied. This study was, to our knowledge, the first to reveal in-depth knowledge of the practical application of motor learning and the results confirmed important findings from the Delphi study and the proposed framework. However, the results should be interpreted with caution because the study was restricted to a small sample of therapists from only one setting.

After the creation of a knowledge base, a next step within the development of complex interventions, should be a carefully phased approach, starting with pilot studies and aiming to gain insights into, for example, acceptability, compliance and delivery of the intervention.[57] As there is only very limited evidence on the use and effects of implicit motor learning for improving functional motor skills in stroke, two pilot studies were performed. Their primary aim was to test the clinical feasibility of implicit motor learning strategies and explore potential effects. Besides these findings, insights were revealed into possible underlying working mechanism and effect moderators, as well as sample size requirements for larger trials, recruitment requirements, adequateness of measures relevant for future studies.[57]

However, based on a recently proposed staging of pilot studies in the field of neurological rehabilitation, the results of the current thesis do not exceed stage 1 (Considerations-of Concept Trials), especially as sample size of the included studies was not based on sample size calculation but on earlier research with comparable designs.[62] It is therefore very important to interpret the impact of the results with caution, as both empirical studies described in Chapters 7 and 8 are restricted in terms of external validity, follow-up testing and proneness to Type 1 error.[63]

Measuring "motor learning"

Motor learning has been described as a process resulting in a relatively permanent change in motor performance.[64] The expression "relatively permanent" in this context has been specified by stable performance under retention and transfer conditions.[17] The studies in Chapters 7 and 8 only evaluated short-term changes in motor performance; neither retention nor transfer of performance (i.e., gait performance) were measured. Therefore, results of these studies can only be interpreted in terms of short-term changes in motor performance.

To gain better understanding of which aspects of movement could be influenced by different applications of motor learning, the laboratory study in *Chapter 8* used a broad variety of measures. Those measures provided a comprehensive scope of demographical, physical and cognitive characteristics of patients and results of *Chapter 8* revealed first ideas on possible relations between motor ability and personal preferences (e.g., the preference for a certain situation pictured by an analogy) and the effect of a certain learning strategy. However, learning and the effect of learning strategies might be altered by more factors. As described in the introduction, implicit and explicit learning processes have been associated with certain brain regions. A stroke (or another central neurological disorder) might alter the functioning of these brain regions and, as a consequence, may change the ability to learn. However, within *Chapters 7 and 8,* no attention was paid to the possible interaction between the location of the stroke lesion and potential effects of the intervention.
Traditionally, research in clinical settings aiming to improve clinical practice uses behavioral and performance measures. Behavioral measures and their results are easy to interpret for therapists in terms of possible gains for patients. Therefore, all studies included in this thesis used a behavioral approach to investigate motor learning in neurological rehabilitation. However, motor learning seems also to be dependent on activity-dependent plasticity (e.g., [65,66]) and it would have been interesting to know whether the observed changes in motor performance were accompanied by changes in brain activation. Further, the role of personality[32] and general preferences regarding learning, as described for example by Kolb,[67] may influence the success of a motor learning strategy. However, as evidence of their assessment and influence is limited,[68] they were not integrated in the empirical studies.
Although not included in the research designs of this thesis, the considerations made above regarding the assessment of motor learning and potential influencing factors (i.e., underlying brain regions, pre-morbid preferences for learning, personality) are described within the framework (*Chapter 6*) so that therapists can consider them when searching for optimal learning strategies.

9

Involvement of stakeholders

A last methodological consideration to mention when reflecting on the results is the involvement of stakeholders within the thesis. In all of the studies, both therapists and patients were active stakeholders and part of the research team. They participated on different levels and in different ways. Their involvement can be classified by the amount of control and contribution according to the participation ladder described by Arnstein[69] and the research phases they were involved in.[70] including: (1) Preparatory phase (agenda setting, prioritization of research topics and funding), (2) Execution phase (study design and procedures, study recruitment, data collection, and data analysis) and (3) Translation phase (dissemination, implementation, and evaluation of results). Table 9.2 provides an overview of the involvement of stakeholders within the different studies of the thesis.

The participating patients had backgrounds in physiotherapy and/or other healthcare-related areas and were specifically trained to advise researchers with regard to patient perspectives on recruitment, measurement and treatment issues. Their contribution ranged from advice regarding the practical feasibility of the interventions, impact of the results, sharing experiences and adapting information about the studies and results for patients and spouses.

Participating therapists had a broad range of experiences in the field of neurological rehabilitation in different settings and were often involved in education. They confirmed (or negated) the need for a research question from a clinical view, provided advice regarding the practical feasibility of the studies, the potential use of the results within daily practice and the translation of results for use in education.

From our experiences, we can definitely recommend active stakeholder involvement and results from the research confirm the value of the inclusion of stakeholders.[70-72] In this thesis, in particular the recruitment of participants might have profited from the involvement of stakeholders. Further, the studies were embraced and well-supported by the participating clinical settings. However, there a logistical and methodological challenges, which should be taken into account. In some cases, the involvement of therapists and patients as partners might have led to pragmatic choices to fit the situation of clinical practice and/or preferences of the target population. Within the current thesis, these choices were always thought through critically, taking methodological consequences and potential biases into account, and were, if applicable, discussed within the individual studies.

It is important to plan, monitor and evaluate the process of stakeholder involvement carefully. Active engagement of patients and therapists is often limited due to time constraints of both the stakeholders and the researchers. Therefore, in the thesis contribution of stakeholders was carefully discussed and planned in good time. We used video conferencing to overcome additional travelling, which was fatiguing for patients. Further, the involvement of stakeholders was taken into account in planning research budgets and applying for funding. Fortunately, funding agencies are starting to advise and support (and sometimes even require) the involvement of stakeholders within research teams.

Table 9.2 Overview of the involvement of stakeholders within the different studies of this thesis

		International survey (*Chapters 2-4*)	Think-aloud (*Chapters 5*)	Developement of framwork and cases (*Chapter 6*)	Case-study (*Chapter 7*)	Exploratory study (*Chapter 8*)
Control	Patients					
Research is controlled by stakeholders, researcher supports	Therapists			PP, EP, TP		
Collaboration and partnership	Patients					PP, EP, TP
Stakeholders decide and actively participate in the research project	Therapists	PP, EP, TP	PP, EP, TP		PP, EP, TP	PP, EP, TP
Advising	Patients					
Stakeholders advise, but researchers decide	Therapists					
Consulting	Patients				PP, EP, TP	
Stakeholders are consulted, provide information & ideas	Therapists					
Information	Patients	PP, EP, TP	TP	PP, EP, TP		
Stakeholders are informed by researcher	Therapists					

PP: Preparatory phase; EP: Execution phase; TP: Translation phase

9

IMPLICATIONS FOR PRACTICE

The following section discusses some implications of the thesis for clinical practice of (physio)therapists working within neurological rehabilitation. These implications are primarily based on the findings presented within the included studies; however, they are informed by my personal experiences as a physiotherapist, lecturer and researcher. Physiotherapists and other members of the (neurological) rehabilitation team provide complex treatments and work with a vulnerable and heterogeneous group of patients. They need to make informed, shared decisions about the best plan of care which matches the complex interactions between the patient's needs, capabilities and the characteristics of the tasks to be learned. In addition, they need to keep in mind information about recovery and prognosis,[73] as well as restrictions in the amount of individual therapy time that may be available.

Guidelines and overview articles (e.g.,[17,50,74-78]) give some foundation and tools to support physiotherapists, but clinical practice extends beyond what can be learned from these sources.[79] The higher-level evidence included in guidelines is often restricted to specific motor skills and interventions in highly selected target populations often without severe cognitive and/or communicative problems[80,81] and is not presented sufficiently patient-specific.[82]

Therapists need to translate knowledge from these sources for 1) patients who fall outside the target groups for studies that form the basis for evidence included in guidelines and for 2) motor skills which may be exceedingly meaningful for patients (e.g., transferring from a wheelchair to a toilet, turning over in bed or getting up independently) but have rarely been studied. Translating the evidence and adapting it to the individual patient can be time consuming and especially challenging for students and less experienced therapists.

Although not all of the above-mentioned issues are addressed within this thesis, the results can support therapists facing these daily challenges. On the one hand, findings might contribute to more structured clinical reasoning and decision-making related to motor learning, but on the other hand, results might add concrete examples and advice for how (implicit) motor learning can be applied in practice.

Clinical reasoning and decision-making related to motor learning

Clinical reasoning is the sum of thinking and decision-making processes associated with clinical practice[83], which should, inter alia, support an informed choice regarding management and treatment of a patient. The results of this thesis might support clinical reasoning and decision-making related to the choice and application of motor learning of physiotherapists and other health care professionals in several ways. First of all, the results from the first part (*Chapter 3 to 5*) of the thesis provide an overview of concrete options for and examples of the application of motor learning in practice. To make an informed decision, therapists need to know which option they have at their disposal.

Although the overview of motor learning options provided is probably not comprehensive, it might be an adequate starting point for novice therapist and students with less experience. Results show therapists which options they have in their "toolbox"; whether the use of one of these tools require specific skills; and whether there several tools available for the same purpose. But also more experienced therapists could use the overview to check whether their "toolbox" might be updated with additional motor learning options (tools).

Second, the framework (*Chapter* 6) structured the identified motor learning options and puts them in relation to each other, which can support therapists in the process of intentionally choosing a particular motor learning option. Currently, is seems that therapists often switch between motor learning options during therapy.[37,84] Although switching might be unavoidable to find the best approach, at some point a motor learning option should be chosen, structurally applied and evaluated. Therapists can use the framework to make a deliberate choice for a single option or a combination of options presented.

It is important to support the choice of each option with evidence, either from literature or, alternatively, at least with a well thought out rationale. Neurorehabilitation research has not yet produced enough evidence on motor learning to give clear indications which form of learning is most suitable for which patient and which task. However, it has been shown that some options within motor learning seem to be work better in specific situations. The overview provided in *Chapter 6* summarizes evidence and arguments from literature about the pros and cons of the different motor learning options.

Third, therapists can also use the framework to tailor interventions that are proven to be effective to improve (parts of) motor skills (e.g., Constraint Induced Movement Therapy (CIMT), electro-mechanical assisted gait training or circuit-class training).[85-87] These interventions often need further specification before they can be used in practice. For example: *Which form of feedback should be provided and when? Should I provide details on the motor skill that is practiced and how often should I vary the practice conditions?*

Fourth, the results of this thesis (in particular the framework) might also be used to support <u>communication and alignment with colleagues</u> in an interdisciplinary team. As there seems to be no consensus regarding the application of motor learning options, therapists need to be clear and detailed when documenting and communicating a choice in patient records. The terminology provided in this thesis may be supportive for more unambiguous communication about motor learning with colleagues.

Some of the above-mentioned recommendations and suggestions have already been implemented in practice and education: The framework has recently been integrated within an upper-limb rehabilitation program[88] with the aim to align the use of motor learning options between different therapists. Figure 9.2. shows an example of how the framework is used in practice.

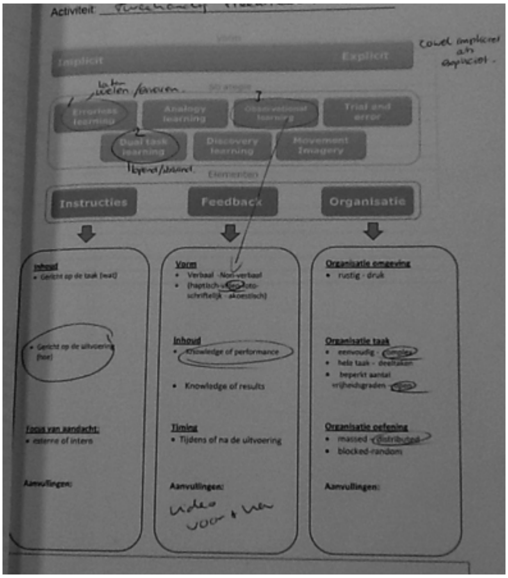

Figure 9.2 Example of how the framework is currently used in practice (in Dutch)

Further, the framework has been integrated within physiotherapy education of students and professionals working in neurological rehabilitation (Zuyd University of Applied Sciences and Dutch Institute of Allied Health Care (NPi)). From personal experience, the framework helps to explain the different motor learning options, their possible relationship and underlying rational, but also to share and discuss experiences and to coordinate the motor learning process at an interdisciplinary level. In particular, undergraduate students find the framework helpful to keep an overview of possible options within motor learning and to understand that there are several basic concepts (e.g., implicit explicit learning, internal-external focus of attention), which are often related and might be combined in practice.

Application of implicit learning strategies

Results of this thesis confirm that therapists might consider more implicit forms of learning when treating patients, especially those who have difficulties processing verbal information about motor performance. The use of analogy instructions and environmental constraints, have both been shown to be feasible and potentially beneficial. Both strategies require minimal verbal information and effects of the strategies might already be noticed after during a single.

When using these strategies, therapist should take the following considerations into account. Developing analogies in therapy is a creative and challenging process, as analogies should lead to the desired movement pattern (on a biomechanical level), but should at the same time be meaningful to the individual.[56] Analogies which do not fulfill these criteria might lead to undesired hypothesis testing and even deterioration of performance.[89,90] Therefore, analogies should be personalized and developed together with the patients and their spouses. Once a suitable analogy is found, the benefits can often be seen immediately and may exceed clinically important differences.[90] From personal experiences in clinical practice and within currently ongoing studies, I can add that finding an analogy together with a patient reveals valuable information about the patient. Further, it increases the patient's feelings of autonomy, as the patient actively contributed to the therapeutic approach. Using an analogy adds a personal note to the rehabilitation approach and once such an analogy is found, patients are very unlikely to forget it.

The use of environmental constraints has already been reported and successfully used as part of errorless learning[10,53] and the Constraint-Led Approach described by Davids et al.[91] Therapist also often use changes within the environment to initiate a certain motor performance,[84] however, they often do not implement the constraints in a structured way (i.e., repeat until motor performance is stable and change constraints slightly). In the study in *Chapter 8,* a beamer was used to project stripes onto the floor to create a constraint which should influence the gait pattern. This approach had the advantage that participants were often not aware that these constraints were slightly changed in order to increase or decrease a certain gait parameter. In practice, creating an environment that seduces the learner towards a certain motor learning behavior, without creating conscious control of the movement is challenging. Patients are easily aware that stripes on the floor change if therapists need to move them manually. But if therapists are able to create such an environment, they can probably stimulate a very clean implicit form of learning.[92] In this context, new technologies, such as interactive environments[93] and treadmills projecting visual cues on the walking surface[94] are promising to support a constraints approach. These technologies can create easy-to adapt environments and often distract the learner's attention away from her/his motor performance by using elements of gamification.

Although the results of the empirical studies are promising, and therapists can consider analogy learning and environmental constraints, it is far too early to consider structural, broad implementation of these strategies within daily practice, given the methodological issues discussed earlier. It is however important to mention and explain these potential and feasible motor learning strategies in education, so that therapists can add them to their "tool-box" of possible motor learning options. How better this toolbox is equipped with informed motor learning options and experiences about their use, how more likely it is that therapists find the right match between motor learning options and the patient.

WHERE TO GO FROM HERE?

Based on the results of this thesis, several concrete follow-up steps for future research can be considered, which will be discussed first. Besides these short-term steps, two more general directions for future research are outlined within this section: 1) the relation of motor learning and physical activity and 2) the need for a more personalized approach to research in motor learning.

Currently, as a direct follow-up to this thesis, the effectiveness of implicit motor learning compared to explicit motor learning is evaluated within a randomized controlled trial. Results of the current project were used to develop the intervention for this trial. The trial includes tests of retention and transfer of the to-be learned skill and uses a pragmatic approach, as research from designs in controlled settings remains inconclusive.[51] Within this trial, in a process evaluation the feasibility, usability and applicability of the intervention is evaluated in detail, as those are important criteria to base therapy decisions on, but still are often ignored in clinical trials.[95]

In general, future research in the area of motor learning should combine behavioral outcomes and measures of underlying neural changes, as it has been shown that this combination best predicts treatment-induced changes in gait performance.[96] These measures should be used in longitudinal way and should be repeated frequently in order to assess dynamic changes.[97] Wearables devices might support the collection of these continuous data within the patient's home environment and without the need for extensive measurement sessions.[98] Research in the area of developing and evaluating easy-to-use technology, which might be used for this purpose, is currently increasing quickly.[99]

It would further be helpful to investigate which additional measures can be used to identify whether learning progresses though more implicit or explicit processes. This research could confirm the taxonomy of the learning strategies presented in this thesis and probably expand the options included in the framework. Currently, often verbal reports of explicit rules, and dual task performance, are used to distinguish between implicit and explicit processes (e.g., [8,41]). The feasibility and validity of these measures in the stroke population is restricted as people after stroke generally experience difficulties reporting verbal information, especially responses to abstract questions.[100] They also experience difficulties performing under dual task conditions in general.[101] Therefore, there is a need for additional measures to investigate the character of learning processes during stroke. Electroencephalography (EEG) might be a promising tool to investigate activation of verbal-analytic regions during motor performance[102] as reduced activation of these regions might be an indicator of prevailing implicit processes.[33,61] Within neurorehabilitation, research using advanced mobile technologies to measure brain activation patterns by EEG is currently ongoing.[103]

Finally, an evaluation of the merit of the presented framework (*Chapter 6*) should focus on whether the framework is usable to support clinical-reasoning regarding and communication about motor learning in education and daily practice. A systematically evaluation, using a qualitative method (e.g., longitudinal focus groups) should investigate how the framework is (might be used) within different settings and which advantages the users of the framework experience.

The relation between motor learning and physical activity

Motor learning aiming at the improvement of motor skills is the key topic of this thesis and an important issue within rehabilitation. Learning and improving motor skills is essential for patients to return home after rehabilitation, to stay independent and generally to participate within society.

However, in a broader perspective, physical activity of stroke survivors (and other people with neurological impairments) might even be more important. After discharge from rehabilitation, it has been shown that physical activity levels of people are likely to deteriorate,[104] which can also result in diminishing of the earlier learned motor skills. People who do not use their learned motor skills are likely to experience a phenomenon called “learned non-use”, which has especially been described in the field of upper limb activities,[105] but might also be true for walking or other motor skills.[106]

For the long-term benefits of motor learning initiated within rehabilitation, it is therefore important that future research sheds light on the question of how therapists and other health care professionals find solutions to keep patients “moving”, without extending the amount of face-to-face therapy. Possible solutions for this problem might be specific lifestyle interventions for stroke survivors[107] to support self-induced physical activity after discharge. Also, informal caregivers might support patients to stay active.[108] In addition, the use of technological tools (e.g., activity monitors, augmented feedback systems) to stimulate activity of patients by providing feedback on their motor performance and/or activity level is promising and should be further investigated.[109-111]

The need for holistic approach to research in motor learning

Within clinical practice, the person and his/her functioning, needs and whishes are the starting points for the provision of therapy. The underlying diagnosis, which has led to the changes in functioning, is taken into account but is not necessarily considered to be the leading factor.[112] Patients with the exact same diagnosis might need totally different treatments, as they have other needs, wishes and abilities. On the contrary, patients with a different diagnosis (cortical stroke and Parkinson’s Disease), which seem not comparable in terms of underlying neuroanatomical substrate and prognosis may benefit from comparable motor learning strategies.

It has been shown that clinicians and therapists are more likely to use new strategies if they were evaluated regarding potential improvements of a disease-unrelated problems and can be applied within several populations.[113] However, research into motor learning (as well in many other fields), is often organized according to a certain diagnosis and also guidelines concentrate on summarizing research regarding a specific (sub)population. In addition, research is often lead by a reductionist view resulting in designs that are limited to evaluate interventions using a single compound for a specific symptom.[114] However, as confirmed within the thesis, this “one-size-fits-all” idea is not feasible in the area of motor learning.

To better match what is done and needed in clinical practice, research in the field of motor learning should shift towards a more holistic approach in which several disciplines joint forces and the person is leading, not his/her diagnose:

- *From diagnosed-based research to person-based research*

Within the field of neurological rehabilitation, it has already been suggested that potential rehabilitation strategies should not only be researched within but also across populations.[113] Despite the anatomic and pathophysiological differences of target populations within neurological rehabilitation, the groups share many similarities, ranging from comparable cellular and neuro-physiological responses and recovery mechanisms to effects of training in motor learning and potential confounders of this process.[113] Although still spare in the literature, there are some examples of "diagnosis exceeding" studies combining populations and focusing on the improvement of the common impairments.[115,116] The field might move even further. Instead of just comparing the effects of interventions in groups with different diagnoses, the person and his/her needs for care as should be seen as a starting point. This implies that instead of evaluating a single component, complex multicomponent interventions should be developed.[31,84,117,118]

- *From monodisciplinary to interdisciplinary research*

To develop complex multicomponent interventions, interdisciplinary research teams are needed, which combine knowledge from fundamental neurosciences, psychology, different target populations and clinical practice. Stakeholders (patients and therapist) should also be engaged to help making the interventions feasible and translating the knowledge for the use in practice. The results of this thesis might support interdisciplinary research by providing a common basis for discussion about motor learning.

- *From a leading gold standard design to designs which fit the complexity of clinical practice*

For 70 years, randomized, controlled trials (RCT) have been regarded as the gold standard for medical research.[119] However, clinical researchers have always struggled to apply the RCT in its cleanest form. It has been argued earlier that long-term, highly individualized interventions, as needed in the field of motor learning, can just not be evaluated appropriately by using an RCT.[120] In particular, the use of rigid intervention protocols and strict inclusion criteria should be reconsidered. If therapists document the application of motor learning in detail, observational methods and controlled registry might be interesting alternatives which can easily include large numbers of participants from different settings[120] and might shed better light on the complex relationships between the applied motor learning option and the responses of the individual person. For this kind of research design, other statistical (non-linear) models need to be contemplated (e.g., Network analysis[121]). Further, qualitative research should be combined with quantitative research in order to explore patients and therapists' experiences and opinions of the use of motor learning interventions and to identify barriers towards their implementation.

Taken together, research in the area of motor learning needs to shift towards a more personalized, holistic approach, developing and evaluating multi-component interventions within interdisciplinary research teams.

I am very curious about how the field of research into motor learning in neurological rehabilitation will develop during the next years and I hope to provide a contribution to this exciting and dynamic field.

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Summary

SUMMARY

Movement is an essential part of our lives. Throughout our lifetime, we acquire many different motor skills that are necessary to take care of ourselves (e.g., eating, dressing), to work (e.g., typing, using tools, care for others) and to pursue our hobbies (e.g., running, dancing, painting). However, as a consequence of aging, trauma or chronic disease, motor skills may deteriorate or become “lost”. Learning, relearning, and improving motor skills may then be essential to maintain or regain independence. There are many different ways in which the process of learning a motor skill can be shaped in practice. The conceptual basis for this thesis was the broad distinction between implicit and explicit forms of motor learning.

Physiotherapists and occupational therapists are specialized to provide therapy that is tailored to facilitate the process of motor learning of patients with a wide range of pathologies. In addition to motor impairments, patients suffering from neurological disorders often also experience problems with cognition and communication. These problems may hinder the process of learning at a didactic level, and make motor learning especially challenging for those with neurological disorders. This thesis focused on the theory and application of motor learning during rehabilitation of patients with neurological disorders. The overall aim of this thesis was to provide therapists in neurological rehabilitation with knowledge and tools to support the justified and tailored use of motor learning in daily clinical practice.

The thesis is divided into two parts. The aim of the **first part** (Chapters 2-5) was to develop a theoretical basis to apply motor learning in clinical practice, using the implicit-explicit distinction as a conceptual basis. Results of this first part were used to develop a framework for the application of motor learning within neurological rehabilitation (Chapter 6). Afterwards, in the **second part**, strategies identified in first part were tested for feasibility and potential effects in people with stroke (Chapters 7 and 8).

In *Chapter 1,* the general meaning of motor learning for rehabilitation is described and an explanation is provided for why motor learning has become a central topic within neurological rehabilitation. The distinction between implicit and explicit forms of motor learning is introduced. Afterwards, challenges and problems in the practical application of motor learning in neurological rehabilitation are outlined. The introduction ends with a description of the aims and structure of the thesis.

Chapter 2 presents the design of an international survey with an integrated Delphi technique. The aim of this survey was to reach consensus on definitions, descriptions, and taxonomy of terms used within motor learning and to explore experts’ opinions and experiences about the application of motor learning in practice. Experts from the field of scientific research, lecturers, experienced therapists, and coaches working in the field of motor learning were invited to participate. The survey was administered via an online survey program and consisted of three rounds. Round 1 focused on the theoretical definitions, descriptions, and taxonomy of implicit and explicit forms of motor learning and a variety of motor learning strategies. The aim of Round 2 was to confirm answers from the first round and to investigate experts' opinions and experiences about how motor learning can be facilitated in a single therapy session. The main aim of last round (Round 3) was to identify factors influencing and directing choices made within the motor learning process.

The questionnaires for the three rounds consisted of closed/multiple choice questions and some open questions. Closed/multiple choice questions were used if there was already knowledge available with regards to the answers (e.g., from the literature or earlier survey rounds). Consensus was considered to be reached when at least 70% of the experts agree on a certain topic. The answers to the more exploratory questions were also analysed by using majorities and trends (e.g., ≥50%). Further, free text comments and answers from open questions were described and clustered into themes.

Chapter 3 describes the more theoretical results of the Delphi technique (Rounds 1 and 2 of the survey) regarding the definitions, description and taxonomy of terms related to motor learning. Forty-nine international experts with expertise related to motor learning participated in the survey. Experts were heterogeneous with regard to age, background and current working situation, but most were based in Europe. Consensus was reached with respect to definitions of implicit and explicit motor learning. 95.5% of the experts agreed on the following definition of explicit motor learning: "*Explicit motor learning can be defined as learning which generates verbal knowledge of movement performance (e.g., facts and rules), involves cognitive stages within the learning process and is dependent on working memory involvement".* Implicit motor learning was defined as *"learning which progresses with no or minimal increase in verbal knowledge of movement performance (e.g., facts and rules) and without awareness. Implicitly learned skills are (unconsciously) retrieved from implicit memory"* and 88.6% of the experts agreed upon this definition.

Seven common motor learning strategies were identified in the context of implicit and explicit motor learning: *trial and error learning, observational learning, errorless learning, movement imagery, discovery learning, dual task learning and analogy learning.* Responses regarding the classification of whether these strategies are likely to result in (more) implicit or (more) explicit forms of motor learning were diverse. Analogy learning, errorless learning and dual task learning were classified as strategies likely to promote more implicit learning; however, no consensus was reached. A common argument was that most strategies can promote both implicit and explicit motor learning, depending on how they are applied in practice.

In ***Chapter 4,*** the underlying practical application of the terms identified by the Delphi technique (Chapter 3) are described. These results are based on Round 2 and 3 of the survey. The central question of these parts of the survey was how instructions, feedback, and the organisation of the learning and environment and the task can be used to promote implicit and explicit motor learning. Answers by experts were widely distributed, but some trends were identified: Explicit motor learning can be promoted by using instructions and various types of feedback, but when promoting implicit motor learning, instructions and feedback should be restricted. Further, for implicit motor learning, an external focus of attention can be considered, as well as practicing the entire skill instead of splitting it into smaller parts. The participating experts, agreed on three factors that influence motor learning choices: the learner's abilities, the type of task, and the stage of motor learning. In the last part of the survey, a summary figure was developed to illustrate a taxonomy of earlier identified and defined or described terms, which most experts agreed upon (64.7%).

Chapter 5 presents a qualitative study in which the application of motor learning in daily practice of physiotherapists is explored. Experienced therapists working in neurological rehabilitation know through experiences how to tailor motor learning to the individual needs of a patient; therefore, the aim of this study was to explore which motor learning options therapists use and how they choose between these different motor learning options. Five expert physiotherapists from the neurological ward of a rehabilitation centre participated. Data were collected using nine videotaped therapy situations of nine different patients (four therapists two sessions; one therapist one session). During retrospective think-aloud interviews, the physiotherapists were instructed to constantly ''think aloud'' while they were watching their own videos. The following prompting questions were repeatedly asked: What are you doing (on the video)? What are you thinking? Why are you doing this? Five ''operators'' were identified: ''act'', ''know'', ''observe'', ''assess'' and ''argue''. The ''act'' operator consisted of 34 motor learning options, which were clustered into ''instruction'', ''feedback'' and ''organization''. The ''know'', ''observe'', ''assess'' and ''argue'' operators explained how therapists chose one of these options. The four operators seem to be interrelated and together lead to a decision to apply a particular motor learning option. Results show that the participating physiotherapists used a great variety of motor learning options in their treatment sessions. The results added additional motor learning options to the ones identified in earlier chapters.

Based on the results of Chapters 3 to 5, and knowledge from the literature, a framework was developed to support therapists in the application of motor learning in routine practice. ***Chapter 6*** presents the framework, illustrated by cases from practice. The framework consists of three different “layers”. The basis for the framework is the continuum of implicit and explicit forms of motor learning. In the second layer, the seven learning strategies are presented (e.g., errorless learning, analogy learning). The bottom, most practical layer, consists of three elements: “instructions, “feedback” and “organisation”. These elements can be used to tailor a certain form of learning or learning strategy for an individual patient. The element “instructions” contains different options (e.g., verbal instructions, manual guidance, demonstration or a rhythm/music) that therapists can use to instruct their patient to initiate a movement.
Under “feedback”, various forms of feedback (e.g., feedback on the performance of the task and feedback on the results) and the timing of the feedback are clustered. “Organisation” contains elements, which therapists have at their disposal to organize the practice environment (e.g., a quiet or crowded environment, an open or constrained environment) and the task that is practiced (e.g., the use of variation, practice of the entire task or splitting the task into smaller pieces). Factors that are important to consider regarding the choice for a specific application of motor learning are also integrated in the framework. Next to the description of the framework and its content, Chapter 6 discusses the use of the framework and provides suggestions and conditions for its implementation in daily practice.

Evidence from the literature and the earlier chapters suggests that implicit motor learning requires few attention resources compared to motor learning that is supported by detailed verbal instructions (explicit). Therefore, it has been hypothesized that implicit motor learning makes fewer demands on cognitive resources, especially working memory capacity and might therefore be a promising technique for neurological rehabilitation. In ***Chapter 7 and 8,*** the results of two empirical studies are described in which feasibility and potential effects of implicit motor learning is investigated. Within these studies, analogy instructions, environmental constraints and action observation were identified as promising ways to induce implicit motor learning. An analogy uses understanding of one concept or process to facilitate understanding or learning of a new concept or process. During motor learning, the complex structure of the ‘to-be-learned’ skill can be captured by an appropriate analogy, which is presented to the learner to aid performance of the movements. The idea is that the underlying rules of the task are disguised within the analogy and the learner unintentionally (implicitly) employs these rules without gaining explicit knowledge. A constrained environment has also been used to promote implicit motor learning. Constraining the environment has been shown to minimize performance errors (as in errorless learning), which limits the opportunity for error correction and discourages the need for hypothesis testing that leads to explicit knowledge. Action observation (learning by

observing a motor task) has been used in several healthy populations and populations with neurological disorders to promote implicit motor learning.
The studies described in Chapters 7 and 8, focused on the target group 'stroke' and the motor skill 'gait'. The reasons for the choice of this focus were that stroke is a large subpopulation within the group of patients with neurological disorders and gait problems are common after stroke and often result in disrupted functioning in daily life.

In *Chapter 7*, the feasibility and utility of analogies to improve walking performance in long-term stroke survivors was assessed. Three men aged 76, 87 and 70 years who were 6, 1 and 3 years post-stroke, respectively, presented with different walking deficits participated. An analogy, targeted at improving the walking performance was designed with the help of each participant. During a 3-week intervention period, the analogy was practiced once weekly under supervision and daily at home. To assess feasibility, a structured interview was conducted at the end of the intervention period. To investigate utility, walking performance was assessed using the 10-Metre Walking Test. All three participants were supportive of the feasibility and benefits of analogy learning. Two of the participants demonstrated meaningful improvement on the 10-Metre Walking Test. During this study, we experienced that developing analogies in therapy is a creative and challenging process, as analogies must not only guide the correct movement pattern, but also be meaningful for the individual.

The aim of the study described in *Chapter 8* was to explore whether different applications of analogy instructions, environmental constraints and action observation lead to immediate changes in spatial-temporal parameters of walking by people with stroke (velocity, step width, step length, and step height) and to gain more insight into the experiences of people when using these motor learning options. The study adapted a pre-post measure design in which 56 post-stroke individuals were randomly allocated into one of three motor learning options: analogy instructions, environmental constraints, and action observation. Analogy instructions and environmental constraints were applied using different analogies and different constraints. Each of these conditions was hypothesized to change a certain gait parameter. Spatiotemporal measures (velocity, step length, step width, step height) of gait were examined using Vicon 3D motion analysis. Patient experiences were assessed by a questionnaire. Hypothesized changes occurred in several conditions of the analogy instructions and environmental constraints. Most promising results were obtained for the use of analogy instructions. In action observation, no relevant changes were found. At an individual level, results showed a wide variation in the direction and the magnitude of changes. The researched motor learning options seemed feasible but it was confirmed that therapists need to tailor these options to the gait problem and individual preferences of the patients.

In *Chapter* 9, the main findings of this thesis are presented and discussed within three different themes: "Speaking the same (motor learning) language", "The use of the implicit-explicit continuum in theory and practice" and "The potential of implicit motor learning for neurological rehabilitation". Subsequently, issues to consider, related to content and methodological choices, are described. Afterwards, in the clinical implication paragraph, it is discussed how the results of this project may support physiotherapists, occupational therapists and other health care professionals within their clinical reasoning and the communication about motor learning with peers and students. Further, it is described how therapists can integrate the findings of the thesis when applying (implicit) motor learning in practice. Finally, an overview of possible next steps within the field of research is provided and it is argued that in general research in the field of motor learning needs to shift towards a more personalized, holistic approach, developing and evaluating multi-component interventions.

Samenvatting

SAMENVATTING

Bewegen is een belangrijk onderdeel van ons dagelijks leven. In de loop van ons leven, leren wij veel verschillende motorische vaardigheden. Deze vaardigheden zijn nodig om ons zelf te verzorgen (bijv. eten, aankleden), om te kunnen werken (bijv. typen, gereedschap gebruiken, of aan anderen hulp te verlenen) en onze hobby's uit te oefenen (bijv. hardlopen, dansen of schilderen). Echter, door verouderingsprocessen, trauma of een chronische ziekte kunnen deze verworven motorische vaardigheden achteruit of zelfs helemaal verloren gaan. Leren, herleren en verbeteren van motorische vaardigheden is dan essentieel om onafhankelijk van derden te blijven of weer te worden. In de praktijk, zijn er veel verschillende manieren om een motorische vaardigheid te leren.

Fysiotherapeuten en ergotherapeuten zijn experts in het faciliteren van het motorisch leren van mensen met veel verschillende ziektes. Patiënten met een neurologische aandoening ervaren naast motorische problemen veelal ook problemen op gebied van cognitie en communicatie. Deze problemen kunnen het motorisch leerproces op didactisch gebied bemoeilijken, en maken het aanleren van motorische vaardigheden voor deze doelgroep vaak bijzonder lastig. Dit proefschrift focust op de theorie en de toepassing van het concept 'motorisch leren' in de revalidatie van patiënten met neurologische aandoeningen. Het overkoepelende doel was om therapeuten, werkzaam in de neurologische revalidatie, kennis en tools te bieden die het toepassen van motorisch leren in de praktijk ondersteunen en onderbouwen. Het conceptueel uitgangspunt hierbij vormt de indeling in meer impliciete (onbewuste) en meer expliciete (bewuste) vormen van motorisch leren.

Dit proefschrift bestaat dan uit twee delen. De doelstelling van het **eerste gedeelte** was de ontwikkeling van een theoretisch concept ter onderbouwing van de toepassing van motorisch leren (Hoofdstukken 2-5). Resultaten uit dit eerste deel van het proefschrift zijn vertaald naar een raamwerk voor de toepassing van motorisch leren in de praktijk van de neurologische revalidatie (Hoofdstuk 6). In het **tweede gedeelte**, zijn motorische leerstrategieën die geïdentificeerd zijn in de voorgaande studies, getest op hanteerbaarheid en eerste effecten (Hoofdstukken 7 en 8).

In ***Hoofdstuk 1*** wordt de betekenis van motorisch leren voor de revalidatie beschreven en wordt er een toelichting gegeven waarom motorisch leren de afgelopen jaren een centraal thema binnen de neurologische revalidatie is geworden. De begrippen impliciet en expliciet motorisch leren worden geïntroduceerd. Aansluitend worden uitdagingen en problemen met de toepassing van motorisch leren in de praktijk geschetst. De inleiding eindigt met een beschrijving van de doelstelling en structuur van dit proefschrift.

Hoofdstuk 2 beschrijft het design van een internationale enquête met een geïntegreerde Delphi-methode. Doelstelling van deze enquête was het bereiken van consensus met betrekking tot de definities, beschrijvingen en taxonomie van termen die gebruikt worden binnen het domein 'motorisch leren'. Daarnaast zijn meningen en ervaringen van experts op het gebied van de toepassing van motorisch leren in de praktijk in kaart gebracht. Experts (onderzoekers, docenten, ervaren therapeuten en coaches) werden uitgenodigd om deel te nemen aan deze onlinestudie die uit drie op elkaar opbouwende vragenlijsten bestond. De focus van de vragen uit de eerste vragenlijst was gericht op de definitie, beschrijving en taxonomie van impliciete en expliciete vormen van motorisch leren en een aantal motorische leerstrategieën. De doelstelling van de tweede vragenlijst was tweeledig. Enerzijds werden de antwoorden uit de eerste vragenlijst geverifieerd en anderzijds werden meningen en ervaringen omtrent het faciliteren van motorisch leren in een therapiesessie verzameld. De doelstelling van de afsluitende vragenlijst was het om na te gaan welke factoren het motorische leerproces beïnvloeden. Elke vragenlijst bestond uit gesloten/meerkeuze vragen en een aantal open vragen. De gesloten vragen werden gebruikt indien er voorkennis beschikbaar was (bijv. vanuit de literatuur of antwoorden uit eerdere vragenlijsten). Indien ten minste 70% van de experts het eens waren over een vraag, werd dit als 'consensus' beschouwd. Indien tussen de 50% tot 70% van de expert het eens waren, werd gesproken van een 'trend'. Antwoorden op open vragen werden in thema's geclusterd en beschrijvend weergegeven.

Hoofdstuk 3 beschrijft de resultaten van de Delphi-methode (onderdeel van de eerste en tweede vragenlijst). Deze resultaten hebben betrekking op de definities, beschrijvingen en taxonomie van termen die gebruikt worden binnen het domein 'motorisch leren'. Negenenveertig internationale experts namen in aan dit gedeelte van de studie deel. Experts waren heterogeen wat betreft de leeftijd, achtergrond en huidige werksituatie, maar de meeste experts waren afkomstig uit Europa. Consensus werd bereikt met betrekking tot de definities van impliciet en expliciet motorisch leren. 95,5% van de experts stemde in met de volgende definitie van expliciet motorisch leren: "*Expliciet motorisch leren kan gedefinieerd worden als leren dat verbale kennis van de beweging (bijv. feiten en regels) genereerd, cognitieve fases heeft en afhankelijke is van de betrokkenheid van het werkgeheugen.* Impliciet leren werd gedefinieerd als "*leren dat verloopt met geen of minimale verbale kennis van de beweging (bijv. feiten en regels) en zonder dat de lerende zich bewust is van het leerproces. Impliciet geleerde vaardigheden kunnen (onbewust) uit het impliciete geheugen worden opgeroepen"*. 88,6% van de experts was het eens over deze definitie. Zeven motorisch leerstrategieën zijn geïdentificeerd in de context van impliciet en expliciet motorisch leren: *trial and error leren, observationeel leren, foutloos leren, bewegingsvoorstelling, ontdekkend leren, dubbeltaak leren en analogie leren*. De vraag of deze strategieën te classificeren zijn als impliciete dan wel expliciete vormen van leren is door de experts uiteenlopend beantwoord. Analogie leren, foutloos leren en dubbeltaak leren werden over het algemeen door de experts beoordeeld als meer impliciete strategieën. Trial and Error werd doorgaans beschouwd als een meer expliciete strategie. De andere strategieën werden als zowel als impliciet en expliciet geclassificeerd. Er was echter geen consensus over al deze classificaties. Een veel gebruikt argument was, dat de meeste strategieën in de praktijk zowel impliciete als expliciete vormen van leren kunnen stimuleren, afhankelijk van de manier waarop zij toegepast worden.

In *Hoofdstuk 4* worden de resultaten met betrekking tot de praktische toepassing van de termen uit de Delphi-methode beschreven. De resultaten in dit hoofdstuk zijn gebaseerd op de tweede en derde vragenlijst van de studie. De centrale vraag van deze vragenlijsten was hoe feedback, instructies en het organiseren van de omgeving en de motorische taak gebruikt kunnen worden om impliciet en expliciet leren in een therapiesessie te stimuleren. Hoewel, de antwoorden van de experts varieerden en meningen verdeeld waren, konden een aantal trends geïdentificeerd werden. Volgens de experts kan expliciet motorisch leren gestimuleerd worden door het gebruik van instructies en verschillende typen van (verbale) feedback. Om impliciet motorisch leren te stimuleren zouden instructies en feedback juist beperkt moeten worden. Daarnaast wordt bij impliciet leren een externe focus van aandacht aangeraden, evenals het oefenen van de gehele taak in plaats van het opsplitsen van de taak in delen.
De experts waren het eens over drie factoren die het motorische leerproces beïnvloeden en daarom de toepassing in de praktijk kunnen sturen (94,5%): 'de mogelijkheden van de lerende', 'de kenmerken van de te lerende taak of vaardigheid' en 'de fase van motorisch leren waarin de lerende zich bevindt'. In het laatste gedeelte van de vragenlijst werd er een door het onderzoeksteam ontwikkeld overzichtsfiguur gepresenteerd dat de taxonomie van de eerder geïdentificeerde termen zou kunnen illustreren. Resultaten uit eerdere vragenlijsten en feedback van de experts op een conceptversie van het figuur zijn hierin meegenomen. De meeste experts gingen akkoord met deze illustratie (64,7%).

Hoofdstuk 5 beschrijft de resultaten van een kwalitatieve studie waarin de toepassing van motorisch leren in de neurorevalidatie vanuit het perspectief van de behandelend fysiotherapeut verder is onderzocht. De doelstelling van deze 'think-aloud' studie was tweeledig. Enerzijds werd in kaart gebracht welke verschillende opties ervaren therapeuten gebruiken om motorisch leren te stimuleren en anderzijds hoe zij tussen de verschillende opties een keuze maken. Vijf fysiotherapeuten, werkzaam op een gespecialiseerde revalidatieafdeling voor mensen met verworven neurologische aandoeningen, namen deel. Negen therapiesessies van negen verschillende patiënten zijn gefilmd (van vier deelnemende therapeuten zijn twee sessies en van één therapeut is één sessie gefilmd). Tijdens retrospectieve 'think-aloud' interviews, zijn de

fysiotherapeuten gevraagd om hardop te denken terwijl zij naar hun eigen sessies keken. De volgende stimulerende vragen werden steeds weer gesteld: Wat doe je hier (op het stukje film)? Wat denk je daar? Waarom handel je zo?
Vijf stappen zijn in het besluitvormingsproces geïdentificeerd: "handelen", "weten", "observeren", "inschatten" en "beredeneren". De stap "handelen" bestond uit een grote variatie van opties (n=34) die therapeuten gebruiken om motorisch leren te stimuleren. Deze 34 opties konden in de volgende categorieën worden ingedeeld: "organisatie", "feedback"" en "instructies". De stappen "weten", "observeren", "inschatten" en "beredeneren" verklaren hoe therapeuten tussen de verschillende opties kiezen. De uitkomsten van deze studie bevestigen enerzijds resultaten uit de eerder hoofdstukken (bijv. de indeling van opties voor motorisch leren in "organisatie", "feedback"" en "instructies"). Anderzijds werd extra informatie opgehaald in de vorm van aanvullende opties die therapeuten gebruikten in de praktijk, maar die niet genoemd staan in richtlijnen of uit de vragenlijsten naar voren kwamen.

De resultaten van de Hoofdstukken 3 tot 5 en kennis vanuit de literatuur zijn vervolgens gebruikt om een raamwerk te ontwikkelen om therapeuten te ondersteunen bij de toepassing van motorisch leren in de dagelijkse praktijk. Dit raamwerk wordt beschreven in ***Hoofdstuk 6***. Het gebruik hiervan wordt geïllustreerd aan de hand van casussen uit de praktijk. Het raamwerk bestaat uit drie verschillende lagen. De basis (eerste laag) vormt het continuüm van (meer) impliciete naar (meer) expliciete vormen van leren. In de tweede laag worden verschillende motorische leerstrategieën gepresenteerd (bijv. foutloos leren, analogie leren). De derde, meest praktische laag, bestaat uit de drie elementen: "instructies", "feedback" en "organisatie". Deze elementen kunnen gebruikt worden om een vorm van motorisch leren en/of een motorische leerstrategie op maat toe te passen. Het element "instructie" omvat verschillende opties (bijv. verbale instructies, manuele sturing, demonstratie of ritme/muziek) die therapeuten kunnen gebruiken om bij patiënten een beweging te initiëren. Onder het element "feedback", vallen alle verschillende vormen van feedback (bijv. feedback over de uitvoering van de taak, feedback over het resultaat van de beweging) en de timing hiervan. "Organisatie" omvat elementen die therapeuten ter beschikking hebben om de omgeving (bijv. wordt geoefend in een drukke of rustige omgeving) en de motorische taak te organiseren (bijv. het gebruik van variaties, het oefenen van de gehele taak of het opsplitsen in deeltaken). De drie eerdergenoemde factoren die keuzes voor de praktische toepassing kunnen sturen ('de mogelijkheden van de lerende', 'de kenmerken van de lerende taak of vaardigheid' en 'de fase van motorisch leren waarin de lerende zich bevindt'), zijn ook onderdeel van het raamwerk. Naast de inhoudelijke beschrijving, wordt in Hoofdstuk 6 ook het gebruik van het raamwerk bediscussieerd en worden suggesties en voorwaarden gegeven voor implementatie in de dagelijkse praktijk.

Bewijs vanuit de literatuur en uit voorgaande hoofdstukken impliceert, dat bij impliciet motorisch leren minder aandacht nodig is dan bij leren op basis van verbale instructies (expliciet). Er wordt daarom verondersteld dat impliciet motorisch leren minder vraagt van de cognitieve capaciteiten, in het bijzonder het werkgeheugen, en daarom veelbelovend is voor mensen die problemen ervaren op het gebied van cognitie. In de ***Hoofdstukken 7 en 8***, worden de resultaten van twee empirische studies beschreven waarin de hanteerbaarheid en potentiële effecten van impliciet motorisch leren bij mensen met een beroerte in kaart zijn gebracht. In deze studies wordt nader onderzocht of beeldspraken (gebruik van analogieën als instructie), het aanpassen van de omgeving met projecties op de grond (omgevingsaanpassingen) en het bekijken van opgenomen voorbeelden (observaties) in potentie gebruikt kunnen worden om impliciet motorisch leren te stimuleren. Bij het gebruik van een analogie wordt de complexe structuur van de te leren motorische taak, vertaald naar een beeld. Het idee is dat de onderliggende regels van de motorische taak in de analogie zijn ingebed, en dat de lerende deze onbewust (impliciet) uitvoert. Ook het aanpassen van de omgeving kan gebruikt worden om impliciet motorisch leren te bevorderen. Aanpassingen van de omgeving (zoals ook gebruikt bij foutloos leren) zorgen ervoor dat er geen of minimaal fouten in de uitvoering van een beweging optreden. Op deze manier zal de lerende gestuurd door de omgeving direct (en onbewust) de juiste manier van bewegen leren. Ook het observeren van een beweging (bijv. met behulp van een video-opname), zonder aanvullende instructies, is bij gezonde doelgroepen en patiënten met neurologische aandoeningen gebruikt om impliciet motorisch leren te stimuleren. De studies in de Hoofdstukken 7 en 8, richten zich op de doelgroep mensen met een beroerte, omdat dit de grootste subpopulatie is in de neurologische revalidatie. Als taak of motorisch vaardigheid is voor “lopen” gekozen, omdat het verbeteren van het lopen een vaak voorkomende hulpvraag is voor deze doelgroep.

In ***Hoofdstuk 7***, zijn de toepasbaarheid en hanteerbaarheid van analogieën onderzocht om de loopfunctie te verbeteren bij patiënten in de chronische fase na beroerte. Bij de drie mannelijke deelnemers (76, 87 en 70 jaar oud) had de beroerte resp. 6, 1 en 3 jaren geleden plaats gevonden. Zij ervaarden allemaal problemen op gebied van het lopen. Samen met elke deelnemer is er een individuele analogie ontwikkeld om het lopen te verbeteren. Er vond gedurende drie weken één wekelijkse therapiesessie plaats waarin het lopen met behulp van deze analogie werd geoefend. Daarnaast hebben deelnemers dagelijks thuis geoefend. Alle drie deelnemers waren positief over de hanteerbaarheid en de voordelen van het gebruik van analogieën. Twee patiënten lieten betekenisvolle veranderingen op de 10 meter looptest zien. Tijdens de studie werd duidelijk dat het ontwikkelen van analogieën een creatief en zeer individueel proces is. Analogieën moeten niet alleen leiden tot de gewenste verandering in de bewegingsuitvoering, zij moeten ook betekenisvol (en dus herkenbaar) zijn voor de persoon.

In *Hoofdstuk 8* wordt beschreven, of en hoe analogieën, omgevingsaanpassingen en het oberserven van een beweging leiden tot verandering in spatio-temporele parameters van het looppatroon bij mensen met een beroerte. Hierbij is gekeken naar veranderingen in loopsnelheid, stapbreedte, staplengte en staphoogte. Ook werden de ervaringen van deelnemers met het gebruik van deze opties voor motorisch leren beschreven. In de studie is een voor- en nameting design gebruikt waarin 56 mensen met een beroerte op basis van toeval zijn toebedeeld aan een van de volgende drie opties voor motorisch leren: analogieën, omgevingsaanpassingen en het oberserven. Er zijn verschillende variaties van analogieën en omgevingsaanpassingen toegepast. Voor observationeel leren was er enkel één optie. Elke variatie van analogieën en omgevingsaanpassingen was bedoeld om een specifieke parameter van het lopen te veranderen. Veranderingen in spatio-temporele parameters (snelheid, stapbreedte, staplengte en staphoogte) zijn gemeten met behulp van een 3D bewegingsanalyse (Vicon). Ervaringen van deelnemers zijn geïnventariseerd met behulp van vragenlijsten. Een aantal variaties van analogieën en omgevingsaanpassingen hebben geleid tot de verwachte verandering van het looppatroon. Het observeren van lopen leverde geen relevante veranderingen op. Op een individueel niveau was er sprake van een grote spreiding wat betreft de grootte en de richting van de verandering (bijv. de mate van het vergroten of verkleinen van de staplengte). De onderzochte opties voor motorisch leren lijken over het algemeen goed toepasbaar; deelnemers begrepen de instructies en waren doorgaans positief over het gebruik. De resultaten van de studie bevestigen wederom, dat de individuele voorkeuren van de patiënt en diens loopprobleem leidend moeten blijven bij het stimuleren van een motorisch leerproces.

In *Hoofdstuk 9*, worden de hoofduitkomsten van dit proefschrift gepresenteerd en bediscussieerd binnen drie verschillende thema's: "Dezelfde taal spreken (op het gebied van motorisch leren", "Het gebruik van het impliciet-expliciet continuüm in theorie en de praktijk" en "De potentie van impliciet motorisch leren voor de neurologische revalidatie". Daarnaast worden afwegingen beschreven betreffende inhoudelijke en methodologische keuzes die in het kader van dit proefschrift zijn gemaakt. In de aansluitende paragraaf over de klinische implicaties van de resultaten, wordt besproken hoe de resultaten van dit proefschrift fysiotherapeuten en andere zorgverleners kunnen ondersteunen bij hun klinisch redeneren en in de communicatie over motorisch leren met collega's en studenten. Er wordt ook beschreven hoe therapeuten de resultaten van dit proefschrift kunnen gebruiken bij de toepassing van (impliciet) motorisch leren. Afsluitend wordt een overzicht gegeven van mogelijke te nemen vervolgstappen op het gebied van onderzoek. Hier wordt ook beargumenteerd waarom onderzoek op het gebied van motorisch leren zou moeten focussen op het ontwikkelen en evalueren van multi-component interventies, die gebaseerd zijn op een (nog) meer gepersonaliseerde, holistische aanpak.

Valorisation

VALORISATION

In order to be valuable, scientific knowledge should be available to end-users in a form (or product) that can be implemented in daily practice. However, research does not automatically reach all potential end-users and often further translation of the knowledge into concrete products is necessary. Valorisation has been described *as the process of value-creation out of knowledge, by making this knowledge suitable and available for economic or societal utilization and to translate this into products, services, processes and industrial activity.*[1]
This chapter explains how the results of PhD-project are of relevance for society. The chapter also identifies potential end-users who may benefit from the knowledge generated and describes how the findings add to the current state of knowledge (innovation). Finally, the chapter outlines the steps that have been taken and/or are planned to implement the knowledge within practice and education.

Relevance

It has been estimated that about 650,000 people in the Netherlands live with the consequences of acquired brain injury (e.g., stroke) and more than one million people suffer from a chronic neurological disease (e.g., Parkinson's disease).[2] These people often need to cope with long term disability due to motor, cognitive, emotional and behavioural problems. In order to become and/or stay as independent as possible they often need to (re-)learn or improve basic motor skills, such as dressing, walking and eating. Other motor skills are necessary to regain the ability to work or enjoy hobbies, which are important for experienced quality of life.[3] Learning and improving motor skills is consequently an important part of therapy provided in neurological rehabilitation. Therapies aiming at improving motor skills should be provided with a high intensity.[4] However, patients in rehabilitation often receive only limited guided therapy.[5] Therefore, therapies provided should be as effective and efficient as possible. The findings from this thesis might contribute to an increase in quality and efficiency of therapy regarding motor learning as they help health care professionals (e.g., physiotherapists, occupational therapists) involved in motor learning by patients to (1) make deliberate choices when designing motor learning therapy sessions, (2) to communicate efficiently about motor learning with colleagues and (3) to extend their options for tailoring motor learning in practice.

Target groups

The findings of this thesis might be relevant for several target groups.

Health care professionals

Often physiotherapists and occupational therapists are responsible for facilitating motor learning in the first place, but other health care professionals are more and more involved in motor learning of patients during rehabilitation. As a result of limits in guided therapy time, rehabilitation centres strive to increase additional possibilities for patients to practice. Examples are training of (motor) skills during care situations or in lunch groups. Consequently, nurses, sport and exercise teachers (Dutch: bewegingsagogen), and speech and language therapists who participate in these activities, also support patients performing motor skills (e.g., walking and carrying when setting the table). Hence, (re)learning of motor tasks should be regarded as an interdisciplinary task of rehabilitation teams. A shared language and thinking model is a key factor in successful interdisciplinary collaboration.[6] The terminology, framework and motor learning options presented and researched within this thesis might therefore support communication, coordination and application of motor learning options by these different disciplines. If motor learning is a fixed item within interdisciplinary team meetings, psychologists might also profit from the increased awareness of the rehabilitation team regarding learning behaviour in general. Discussing how motor learning develops and which approaches were successfully applied in practice, might provide the psychologist with a more comprehensive overview of (cognitive) abilities of a patient.

Patients and spouses

Patients can also benefit from the results. On the one hand, patients might benefit indirectly from the support of health care professionals and interdisciplinary teams. On the other hand, the results of this thesis emphasise that motor learning needs to be tailored to an individual's abilities and preferences. Increased engagement by patients in the process of choosing a motor learning option and/ or the development of individual instructions (e.g., analogies) can lead to an increased feeling of autonomy.[7] In addition, spouses (or other informal caregivers) might benefit from the knowledge generated by this thesis. It has been suggested that spouses of patients should be involved in (physical) practice.[8] If the rehabilitation team has determined how motor learning should be facilitated and use clear language about the chosen approach, then for spouses it might be easier to support a patient's motor learning outside therapy time.

Students and lecturers

Besides graduated health care professionals, students (e.g., physiotherapy, occupational therapy or nursery) with less experience or novices can use the concrete examples provided in this thesis, especially regarding the implicit motor learning approach. Furthermore, the framework can support them in clinical decision-making and aid understanding of which factors need to be considered when searching for the optimal motor learning option. Lecturers can use the framework presented in this thesis to structure discussions about the topic of motor learning, and also to clarify and visualize clinical decision-making (see Chapter 6 for examples) within bachelor, master and professional education.

Researchers

The findings of this thesis contribute to the general body of knowledge about motor learning. Besides this scientific knowledge, researcher might benefit from our experiences. The project revealed advantages of using a broad scope of different methodologies (e.g., qualitative and quantitative approaches) and combining knowledge from the different fields of motor learning. Further, a variety of potential future research questions emerged from the finding of this thesis.

Innovation

Many studies in the field of rehabilitation and motor learning investigate one specific treatment or motor learning option in a well-defined target group. However, daily practice is often not so simple, especially within neurological rehabilitation. Health care professionals treat a great diversity of different target groups in different stages of recovery. The innovative character of this thesis is that it focused on a shared aim of many patients regardless of their underlying diagnosis: learning and improving motor skills. As a consequence, findings of this thesis might be applied in different settings, to different subpopulations within neurological rehabilitation and for many different motor skills. For instance, a physiotherapist might use the findings during treatment to improve the gait problems of a stroke patient in the chronic phase of recovery. At the same time, a nurse might consider the framework when practicing a transfer from bed to wheelchair of a patient with traumatic brain injury who has just been admitted to the hospital.

Combining different research methodologies to approach the complex topic of motor learning and using knowledge from different field (e.g., sport, psychology) might also be seen as innovative. The knowledge was further translated and summarized within a framework for health care professionals to facilitate use of this knowledge in daily practice. The framework can (and should) be seen as dynamic and easily adapted (for instance, motor learning strategies can be added or rearranged). Although the idea of using a framework is not new,[9,10] the use of frameworks is still rare in research and in practical guidelines for therapists. The great advantage of a framework over a recipe-like protocol is, however, that it facilitates possibilities of tailoring interventions towards the needs and abilities of the patients.

The fact that client representatives were part of the research team and involved in all phases of this project can also be seen as innovative. For example, ideas on research planning and execution were constantly discussed with the client representatives to ensure feasibility for participants. This might explain why we received a lot of positive feedback on the organization of the measurement sessions (Chapter 8) from participants and their spouses.

Activities and dissemination

Within this PhD-project, there was a close link between research, education and practice. The starting point was a clinical problem, which the research team identified and translated into a research question(s). Therapists who participated within the planning and performance of the studies ensured that the link with the practical problem was closely maintained. They also ensured constant communication between research and practice. Preliminary results were discussed and tested in practice and findings were communicated to researchers. At the same time, lecturers and students were involved in the project to achieve an ongoing link with education (e.g., physiotherapy bachelor and professional education). During the project, the interaction between the three pillars 'research', 'practice' and 'education' became more and more intensive, resulting in a flywheel effect in which questions, knowledge and results were constantly discussed, evaluated and developed into new ideas and connections.
The key players in the project were universities, primary care settings and a rehabilitation centre in the South of the Netherlands (Zuid Limburg). Within this local network, the collaboration between parties (e.g., research and practice) but also within practice (e.g., different care settings) was enhanced. For example, through the exchange of students working in both of the motion laboratories (Zuyd and University of Maastricht), knowledge and experience were exchanged. Also, partners from care settings met each other and informally discussed cases and practical problems.
On a national and international level, the project led to new connections and collaborations (e.g., with Avans Hogeschool) and to the consolidation of existing collaborations (e.g., with VU Amsterdam and Fontys Hogeschool).
Besides these effects on networks and collaboration, several concrete products were developed and a variety of activities were performed in order to ensure dissemination of knowledge within and beyond the network.

Congresses and symposia

The results of this thesis were presented to researchers, therapists and students in different ways. For example, project results were presented at the World Congress of Neurorehabilitation (Istanbul, 2014) and two joint symposia around the topic of motor learning were organized at the congress of NeuroRehabilitation and Neural Repair

(Maastricht, 2015) and the Dutch Congress of Rehabilitation Medicine (Maastricht, 2016).

Education

Based on the results of this thesis, and earlier and ongoing research, 13 short video clips were produced and made available for students and staff of Zuyd University of Applied Sciences. These video clips are already integrated in the curriculum of the Physiotherapy Department and the Occupational Therapy Department. Students watch the videos in preparation for practical classes and as an addition to literature ("flipped classroom"). About 360 students have used these video clips already. Students of the interprofessional minor "growing older" (Zuyd) are informed about the use of implicit motor learning (in particular the use of analogy learning) within an annual lecture. Another online lecture regarding the potential of implicit motor learning was produced for German physiotherapists studying at Zuyd University of Applied Sciences to receive their bachelor diploma (EPEPE program).
In addition to being informed about the results, students from various disciplines (e.g., Physiotherapy, Communication and Multimedia Design and Biometrics) participated in the project as part of their bachelor and master studies. Thirty-eight bachelor students and four master students were involved and a total of 14 theses (bachelor and master) supporting or extending the work of this PhD-project were completed.

Within the national course "neurorehabilitation/stroke" (Nederlands Paramedisch Institute, NPi) the framework (Chapter 6) has been integrated in the course material, used in practical sessions and participants are informed about it by lecture. Between 2014-2017, about 200 physiotherapists and occupational therapists were informed and trained in this way.
Results of this thesis and the video clips are also part of an interdisciplinary course for physiotherapists, occupational therapists and nurses working in neurological rehabilitation (CVA Ketenzorg, Parkstad) and an incompany course for physiotherapists on gait rehabilitation for elderly (nursing home setting).
Within two courses for German physiotherapists who want to specialize within neurological rehabilitation, the framework is used to support discussion about the organization and content of therapy sessions (Fortbildungszentrum Bad Pyrmont and Akademie Klinikum Osnabrück, Germany).
The framework is also used within a post-graduate course for psychologist to illustrated how complex the choice for a (motor) learning strategy can be and which factors might influence this choice (Rino groep, about 100 students a year).

Daily practice

Within the brain injury department of the rehabilitation centre Adelante, the framework is used as a departure point for discussion about treatment plans.
In the experimental study in the laboratory setting (Chapter 8), data on gait characteristics and the potential of different learning strategies were collected. In several cases these data were shared with the treating therapist of the participant and led to changes in the treatment plans.
Results and experiences generated within this thesis created the basis for the development of an intervention guideline/framework for implicit and explicit motor learning in gait rehabilitation of stroke patients living in the community. The effects of these two interventions are currently being explored within a randomized controlled trial.[11]

Multimedia and future plans

On a regular basis, results, news and plans have been published on a project website (www.m-i-n-d.org) and shared on twitter (@zuyd_mind). On Research Gate (www.researchgate.net/project/The-power-of-implicit-motor-learning-20) updates of the project (and follow-up projects) are shared (42 followers). Besides the scientific publication, a national publication about the participation of the clients within this project was published in a journal for clients (Zorgbelang; gezond lijfblad voor alle Limburgers).
Currently, we are working on a digital platform to enable sharing of knowledge from this project and ongoing projects. Scientific knowledge will be enriched with practical examples, cases and video clips. The goal is to make knowledge freely available on this platform so that hopefully even more health care professionals, students, researcher, patients and other potential users can benefit from our results and experiences.

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Curriculum vitae

CV

CURRICULUM VITAE

Melanie Kleynen was born as oldest of six children, on 15 October 1983 in Würselen, Germany. In 2003, she graduated from secondary school (Gymnasium der Stadt Würselen). Afterwards, Melanie studied physiotherapy at Zuyd University of Applied Sciences, Heerlen, The Netherlands. During her study, she went to Oxford (Oxford Centre for Enablement, UK) for a combined research and physiotherapy internship. Her thesis was on the use of mental practice in stroke rehabilitation and was awarded by the Royal Dutch Society for Physical Therapy (KNGF) in 2007 and published in the National Journal for Physiotherapy (Nederlands Tijdschrift voor Fysiotherapie). She was the first student who graduated with summa cum laude.

Melanie started working as a physiotherapist at the brain injury department in Adelante (rehabilitation center, Hoensbroek, The Netherlands), which she enjoyed doing for nearly a decade. At the same time, she started working as a research assistant for the Centre Expertise in Life Sciences (CEL) at Zuyd University of Applied Sciences. Melanie took several courses to specialize within neurological rehabilitation, gait analysis and research methodology and statistics. In 2008, she started following the Master of Science program 'Public Health, Epidemiology' at Maastricht University, The Netherlands and graduated in 2010 (cum laude). Her thesis focused on measuring conscious attention to and control of body movements using a translated Dutch version of the Movement Specific Reinvestment Scale in athletes and patients after stroke. After graduation, Melanie combined her practical work in Adelante with a job as researcher and lecturer at Zuyd University of Applied Sciences. As a member of the Research Centre for Autonomy and Participation of Persons with a Chronic Illness, she was involved in many projects in the area of physical activity and motor learning, especially in elderly and stroke. Further she supervised students during their bachelor thesis and she developed and conducted a great variety of educational activities within the Department of Health, including professional education (Life Long Learning).
In 2014, she officially started with this PhD-research project on the use of motor learning within neurological rehabilitation. The PhD-project was embedded in the Department of Family Medicine and the Department of Rehabilitation Medicine, both part of the school CAPHRI at Maastricht University, The Netherlands. Melanie is co-author of 15 international publications and she has contributed to several national and international congresses and workshops (e.g., World Congress of NeuroRehabilitation, 2-day workshop for the Australian Occupational Therapy Association, Congress of the European Union Geriatric Medicine Society).

Currently, Melanie is working at the Research Center for Nutrition, Lifestyle and Exercise (Zuyd University of Applied Sciences). She remains doing a combination of research and education, with a close link to clinical practice. She would like to continue working on the development and evaluation of personalized approaches in the area of skill acquisition and physical activity.

List of publications

P

LIST OF PUBLICATIONS

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Kleynen M, Bleijlevens MC, Beurskens AJ, Rasquin SM, Halfens J, Wilson MR, Masters RS, Lexis MA, Braun SM. Terminology, taxonomy and facilitation of motor learning in clinical practice: design of a Delphi study. *JMIR Res Protoc* 2013; 17:2(1): e18.

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