Motor Imagery in Neurological Rehabilitation

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PhD

2009

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In collaboration with
the Oxford Centre for Enablement

A thesis submitted in partial fulfilment of the requirements of Oxford Brookes University for the degree of Doctor of Philosophy

October 2009

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ABBREVIATIONS

95%CI	95% Confidence Interval
ADL	Activities of Daily Living
AMED	Allied and Complementary Medicine
ANOVA	Analysis of Variance
CINAHL	Cumulative Index to Nursing and Health Literature
DVD	Digital Video Disc
EU	European Union
GAS	Goal Attainment Scaling
ICC	Intraclass Correlation Coefficient
ICF	International Classification system of Functioning
IQR	Inter-quartile range
KP	Knowledge of Performance
KR	Knowledge of Results
LoA	Limits of Agreement
MAS	Modified Ashworth Scale
MRC	Medical Research Council
MS	Multiple Sclerosis
PMR	Progressive Muscle Relaxation
RCT	Randomised Controlled Trial
ROM	Range of Movement
SD	Standard Deviation
SMART	Specific, Measureable, Achievable, Realistic/Relevant, Timed
SOMCT	Short Orientation-Memory-Concentration Test
TBI	Traumatic Brain Injury
UK	United Kingdom
WHO	World Health Organization

ACKNOWLEDGEMENTS

Writing a thesis is seldom the work of one person and this thesis is no different. Many people have directly or indirectly contributed to this work which was carried out at the Oxford Centre for Enablement (Nuffield Orthopaedic Centre NHS Trust) and at the Human Performance Laboratory at Oxford Brookes University with funding from Joan Warren.

First of all I would like to thank all the persons who volunteered to participate in these studies; patients as well as their family/ friends/ carers who collaborated in the studies. I am thankful for their time, open-mindedness and their efforts to adhere to the study protocols. I admire their perseverance and hard work; they have made this work rewarding and without them it would not have been possible.

Without the staff and patients at the Oxford Centre for Enablement and in the Oxfordshire community these research projects would have been impossible. I am indebt to the physiotherapists and occupational therapists who delivered the interventions. I would like to thank the doctors, nurses, physiotherapists, occupational therapists, therapy-assistants, psychologists, speech and language therapists, secretaries and all the other supporting staff for their support, enthusiasm and encouragements. I greatly value their clinical expertise and they have made the work very enjoyable. I miss working with them.

My friends and colleagues in the Movement Science Group have been a crucial source of support, in many ways, and they are a joy to work with. Thank you: Johnny, Charlie, Emad, Patrick, Elham, James, Charlotte, Pedro, Ken, Martyn, Andrea, Andy, Anique and Steve. I really miss you guys.

I would like to thank the attendees at the OCE research meetings, the researchers at the fMRIB, at the Nuffield Orthopaedic Centre, at the Berlin Neuro-imaging Centre, at Maastricht University and all the other researchers I was lucky to meet for their helpful advice and inspiring discussions.

Also, I would like to thank prof. Cath Sackley for her supervision; Dr. Hooshang Izadi for his statistical support; Ischa Kummeling and family for their support; everybody at the School of Life Sciences; my dedicated sporting buddies and the students that have helped me.

Not only am I thankful for Joan Warren's financial support but also for her enthusiasm, trust and commitment.

Most of all I am grateful to Helen Dawes and Derick Wade. They have given me the opportunity to do this work and have always been there for me. Their guidance, experience and knowledge, but also their vigour and dedication have been an enormous support.

Finally, I am very grateful to my parents, my sisters and my friends for their support, patience and for always making me feel welcome again.

Thamar
(aka Taco)

ABSTRACT

Background Rehabilitation interventions have been shown to benefit individuals with neurological disorders. More intensive treatments, whilst being expensive on resources, have been observed to attain greater impact. Motor imagery is a promising intervention for use in rehabilitation as it can be used to safely increase treatment dose at low cost. However, motor imagery is a complex intervention and there is limited evidence on the optimal content and delivery of the motor imagery intervention and on the effectiveness of motor imagery in neurological rehabilitation.

Methodology/Principal findings A literature review was performed to make an inventory of the content of motor imagery interventions used in neurological rehabilitation. This showed that the interventions were heterogeneous and often poorly described with evidence from other fields rarely implemented. To effectively embed motor imagery in clinical practice it should be client-tailored. The literature review and experiences from a pilot study resulted in a comprehensive client-tailored motor imagery strategy for increasing motor function. Goal attainment scaling is a client-centred outcome measure evaluating the attainment of goals. The attainment of goals can be scored by the clinician but in a randomised controlled trial scoring is preferably performed by an independent person. This thesis, whilst demonstrating low agreement ($ICC_{(A,k)}$=.478; Limits of Agreement -1.52 ± 24.54) between the clinician and the independent assessor in scoring the goal attainment, found that change scores in goal attainment scaling scored by the independent assessor were stronger correlated with change scores on the Barthel Index (r=0.36, P=.049) and the Rivermead Mobility Index (r=0.41, P=.025) than the change scores by the clinician. The developed client-tailored motor imagery strategy and goal attainment scaling were employed in a phase II randomised clinical trial which investigated the effectiveness and feasibility of service-delivered motor imagery in neurological rehabilitation. The experimental as well as the control group improved significantly over time ($F(2, 27) = 45.159$, $P=.000$). The group by time effect was not significant: $F(2, 27) = 0.085$, $P=.919$ and the main effect of Group was not significant: $F(1, 28) = 0.039$, $P=.845$.

Conclusions/Significance In this thesis a comprehensive motor imagery strategy and a standardisation of the goal attainment scaling method were developed and tested. Although the intervention did not demonstrate statistically significant positive benefits, it also did not show a negative effect, whereas the patients in the motor imagery group employed less physical practice. It does show that the goal attainment scaling method can be used as a client-centred outcome measure in clinical practice and that the motor imagery strategy can be client-tailored and service-delivered.

Chapter 1

Introduction

SUMMARY

It is widely accepted that people with neurological conditions benefit from rehabilitation.[1, 2] Literature suggests that more and high intensity rehabilitation leads to better results[3-6] advocating intensive and long rehabilitation programs. However, rehabilitation is expensive on resources[7] limiting the intensity and amount of rehabilitation delivered.

Motor imagery has gained in popularity as an intervention modality in rehabilitation.[8, 9] It can be used outside rehabilitation safely, is potentially cost-effective and offers a method that can increase the intensity and amount of rehabilitation. However, motor imagery is a complex intervention consisting of many components making the active components difficult to evaluate and lacking the consensus on the best way to deliver motor imagery in clinical practice. This thesis explores motor imagery as an intervention in people with neurological conditions.

This first chapter is a general introduction and sets out definitions and concepts on which this thesis is based. It discusses the concept of rehabilitation and the use of the International Classification system of Functioning (ICF) which is employed to manage assessment and intervention in rehabilitation. The neurological disorders and conditions utilised in this thesis are introduced, as well as the Medical Research Council (MRC) guidance on complex interventions which is applicable to motor imagery. Finally, the target behaviour (i.e. motor function and control) and the definition of motor imagery and its possible application in neurological rehabilitation are discussed.

REHABILITATION

Rehabilitation is defined by the World Health Organisation (WHO) as a process that enables people with disabilities to reach and maintain optimal physical, sensory, intellectual, psychological and/or social function.[7] Rehabilitation includes a wide range of activities and services aimed at reducing the impact of disabling and handicapping conditions,[7, 10] involving a coordinated and cyclic problem-solving process. This cyclic process consists of four steps: assessment, assignment, intervention and evaluation. Assessment refers to the identification of the person's problems; assignment refers to the assignment of a service and intervention programme; intervention refers to the specification of the intervention techniques and evaluation to the achievement of the goals. Successful rehabilitation depends on thorough understanding and robust measurement of functioning and effective interventions and services.[7]

Rehabilitation is often described as a 'black box' without adequate models[11-13] and often consists of complex interventions of which the active ingredient is unknown.[14] It is usually characterised as being labour-intensive, multi-disciplinary and individually-tailored but it often lacks standardisation.[11-13, 15] Although research suggests that rehabilitation is effective[1, 2] there is a need to increase standardisation of rehabilitation processes and to classify, describe and measure complex interventions and make the interventions as efficient as possible[11-13, 15] in order to ensure the optimum quality of health care for everybody.

The national service frameworks, created by the UK government's department of Health, cover some of the highest-priority conditions in the UK.[16] The national service framework for long-term conditions is a priority plan to raise standards of treatment, care and support for people with long-term conditions; mainly people with long-term neurological conditions.[16] The national service framework for older people includes stroke patients.[17] People with long-term neurological conditions and older people are intensive users of health and social care services and the numbers are predicted to increase due to factors such as ageing and lifestyle choices. One in three of England's population (15.4 million) suffer from a long-term condition and the treatment and care of those accounts for 69% of the primary and acute care budget.[18] It should be noted that besides long-term neurological conditions such as brain injury and multiple sclerosis this category also includes conditions such as heart and lung diseases.

Eleven quality requirements have been set in the national service framework for long-term conditions[16] to improve the services and support people with long-term neurological conditions to live as independently as possible. These requirements are:

1. a person-centred service;
2. early recognition, prompt diagnosis and treatment;
3. emergency and acute management;
4. early and specialist rehabilitation;
5. community rehabilitation and support;
6. vocational rehabilitation;
7. providing equipment and accommodation;
8. providing personal care and support;
9. palliative care;
10. supporting family and carers;
11. caring for people with neurological conditions in hospital or other health and social care settings.[16]

Five of these requirements (i.e. 1, person-centred service; 4, early and specialist rehabilitation; 5, community rehabilitation and support; 8, providing personal care and support and; 11, caring for people with neurological conditions in hospital or other health and social care settings) relate to this thesis and can be targeted by using motor imagery in rehabilitation.

INTERNATIONAL CLASSIFICATION OF FUNCTIONING

Rehabilitation entails the management of a person's functioning and health and can be defined with respect to the concepts of functioning, disability and health.[19] Assessment and intervention management rely on these concepts which are defined in the International Classification of Functioning, Disability and Health, also known as the ICF; a classification of health and health related domains coordinated by the World Health Organization (WHO).[19-21]

In contrast to the traditional 'medical model' focused on disease and death the ICF acknowledges the complex interaction between the individual's health condition and the personal and environmental factors; creating a unifying structure. The structure is based around the following components:

- body functions and structure;
- activities and participation, and;
- personal and environmental factors.

The result is a uniform standardised system; allowing for a common international language that covers dynamic processes and is applicable to any health condition and any population.[19, 21]

The ICF is used in this thesis as a classification system to characterise the target areas of the intervention and to base the outcome measures around.

NEUROLOGICAL DISORDERS

Neurological disorders are diseases or damages of the central or peripheral nervous system. They are of the highest-priority to raise standards of treatment, care and support, described in the national service frameworks.[16] Many neurological disorders or conditions affect a person's functioning and result in problems in the components defined above, namely: body functions and structure, activities and participation and personal and environmental factors.[7] In this thesis three main groups of neurological disorders will be discussed, namely, stroke, traumatic brain injury and multiple sclerosis.

Stroke

Stroke is a vascular disease of the brain and is defined as a sudden neurological deficit due to localised brain ischemia or haemorrhage lasting more than 24 hours, unless interrupted by surgery or death, with a vascular cause.[7] The result of the stroke is a deprivation of oxygen of brain tissue usually leading to irreversible injury or death of the tissue.[22] In Western countries 75-80% of strokes are attributed to brain ischemia and 20-25% to brain haemorrhage. About 30% of individuals after stroke die within one year; generally due to complications of the brain lesion and later due to complications of dependency (e.g. infection) making it the third commonest cause of mortality in more developed countries[7, 23] and the second commonest cause of death in the world population.[24] More specifically, in the 27 European Union members the yearly number of stroke deaths is estimated at 508,000 per year.[24] Approximately half of stroke survivors are left dependent with self-care often resulting in long-term disability. Approximately 75% are expected to walk independently and an estimated 20% will require institutional care.[7] Stroke has an enormous impact on the emotional status of patients and their families and on the socioeconomic status of health services. Internationally an average of 0.27% of the gross domestic product was spent on stroke by national health systems. Stroke care accounted for an approximate 3% of total health care expenditure with an estimated total annual cost of €27 billion in the 27 EU countries.[24] It is expected that by the year 2020 stroke and coronary artery disease together are the leading causes of lost healthy life years worldwide.[7]

The prevalence of stroke in white populations varies from 46.1 to 73.3 per 1000 for people aged 65 years or more.[23] Incidence of stroke varies between different parts of the world, ranging between 4.2 - 6.5 per 1000 person-years in Australia, Denmark, United Kingdom, Germany, Greece, Italy, New Zealand, Norway and the French West Indies. Incidence rates in Japan, Russia and Ukraine were higher.[23] The incidence increases with age, with the highest rate in people 85 years and older. Stroke is more frequent in men than women. [7, 23]

Several overlapping processes characterise the recovery after stroke.[7] Initially this comprises of resolution of the ischemia, cerebral oedema and co-morbidities that exacerbate the effects of the stroke. In this acute phase four interventions have been proven to be beneficial based on level 1 evidence.[22] The specialised stroke unit is a multidisciplinary unit delivering effective and professionally focussed care for all stroke types. Stroke units have proven to reduce mortality by about 20%, however, the exact active components of the stroke unit are unclear (e.g. blood pressure control, early mobilisation etc). The other beneficial interventions focus on the acute management of limiting brain tissue damage by using thrombolysis, aspirin or decompressive surgery.[22] The benefit of aspirin, however, is quite small but the advantages are low cost, easy administration and low toxic effects.[22]

Later, functional gains may occur through neural plasticity, skill acquisition through practice and modification of the patient's environment.[7] Different types of rehabilitation services have been shown to improve outcome such as physiotherapy and occupational therapy.[7] Typically, rehabilitation is started in hospital. It is recommended to start rehabilitation as soon as possible after stroke onset but it may be effective in any phase after stroke onset. A multidisciplinary team approach and carer's involvement and support are essential.[1, 7, 25] However, there is no consensus about the optimum intensity and duration of specific interventions.[7]

Traumatic brain injury

Traumatic brain injury (TBI) is defined as damage to the brain due to acceleration and deceleration forces mainly caused by road traffic accidents, falls and violence.[7] The event may have disrupted the nervous tissue and blood vessels of the brain usually leading to irreversible injury or death of the tissue. Secondary brain injury, injury evolved after the incident usually caused by brain swelling, is a major cause of death and disability.[26] Classification of TBI is usually based on the clinical examination of the physician and is in approximately 90% of TBIs mild, implying that the patient is awake but may have had a loss of consciousness and/or amnesia. Three to five percent of TBIs are classified as severe, implying unconsciousness upon admission.[7] In severe TBI 20-50% die, whereas less than 1% dies after mild TBI. Even after a mild event, TBI often results in disability. In people under 40 years old TBI is the leading cause of disability. After a mild or moderate TBI half of the survivors are disabled, whereas approximately 75% of the survivors after a severe TBI are disabled.[7]

In the United States an estimated 1-2% of the population lives with a disability due to a TBI. The incidence differs widely between countries. In Europe an estimated 2.35 per 1000 suffer a TBI each year. Overall, especially children, young adults and elderly people show a high incidence rate with men suffering a TBI 2-3 times more often than women.[7] In England an estimated 746,930 suffer a head injury each year of which 2.6% (19,420) are moderate to severe.[27]

Rehabilitation is of great importance after TBI since it often involves young individuals.[7] Especially patients with moderate to severe TBI should be followed up to assess the need for rehabilitation. Formal programmes, especially the ones that start in the acute stage and that are more intensive, are beneficial.[7, 26] However, there are large variations within and between countries in acute and sub-acute care of patients with traumatic brain injury.[26, 28] Guidelines have been developed in response.[26]

Multiple Sclerosis

Multiple sclerosis (MS) is defined as an inflammatory demyelinating disorder of the central nervous system and is autoimmune in nature.[7, 29] Targets are myelinated central nervous system tracts where chronic plaques are formed.[29] Myelin is spiralled around axons and forms an insulating sheath, needed for saltatory axonal conduction, and demyelination causes reduced axon conduction velocity, spontaneous axonal discharges, crosstalk between axons and increased mechanical sensitivity.[29] This usually leads to physical disability and cognitive decline.[7, 29]

The diagnosis of MS is usually clinically based on a number of criteria (McDonald criteria) and on exclusion of differential diagnosis.[7] MS can present with a wide variety of symptoms, with varying severity, affecting different parts of the body and with a varied course.[7, 29] MS type is usually defined by the course of the disease: relapsing/remitting, secondary progressive or primary progressive.[7, 29] The most common form is relapsing/remitting MS which develops into secondary progressive MS in approximately 50% of cases within

10 years. Primary progressive MS affects 10-15% of all MS patients.[7] Men usually present with a more severe course than women. Life expectancy is near-normal in people with MS and is seldom terminal. Most people with MS develop some level of disability during their lifetime and up to 60% are no longer fully ambulatory 20 years after onset.[7]

An estimated 2.5 million people worldwide have MS.[7, 29] Incidence varies by geographical region over the world with more women than men acquiring MS.[7] It is estimated that in England and Wales the incidence is 1800 to 3400 each year and that the prevalence is between 52,000 and 62,000.[30]

Rehabilitation of MS is aimed at improving independence and quality of life through patient education and self-management.[7, 30] Rehabilitation guidelines recommend expert multidisciplinary assessment, goal-oriented programmes and clinically appropriate and scientifically based evaluation.[7, 30] Intensive inpatient rehabilitation benefits the patient up to 9 months after discharge.[31] There is still only a limited understanding of the pathogenesis of multiple sclerosis resulting in interventions that focus on limiting, repairing and preventing the damage caused by MS.[29]

A wide variety of interventions are available in the rehabilitation of stroke, traumatic brain injury and multiple sclerosis.[30, 32-34] Most interventions (e.g. acute management of stroke in a stroke unit) consist of numerous elements making it difficult to define the active ingredient. The MRC has developed guidance to develop and evaluate such complex interventions.[14, 35]

COMPLEX INTERVENTIONS

A complex intervention is "built up from a number of components, which may act both independently and inter-dependently."[36] It is difficult to define the active ingredients of a complex intervention and to establish which component or combination of components is important. In 2008 the Medical Research Council (MRC) has updated its guidance on how to evaluate complex interventions.[14, 35]

Figure 1 presents the key elements of developing and evaluating complex interventions as suggested by the MRC.[14] The suggested method is systematic where the best available evidence and theories are used. This should then be tested in a phased approach starting with pilot studies and exploratory work and then a definitive evaluation. Further research should assist and monitor the implementation process.[14, 35]

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Figure 1. Flowchart for the development and evaluation of complex interventions. Source: MRC 2008; Developing and evaluating complex interventions: new guidance.[35]

Motor imagery in neurological rehabilitation is a complex intervention. This thesis uses the MRC framework to develop and evaluate motor imagery use in neurological rehabilitation. Motor imagery may affect patients on many levels (e.g. anxiety, concentration etc) but this thesis focuses on the impact on motor function and control.

MOTOR FUNCTION AND CONTROL

The conditions described above can result in a wide range of problems which can be divided into: physical, communicative, cognitive and behavioural/emotional.[33] The range of potential deficits is large and includes: paralysis, spasticity, sensory loss, visual deficits, pain, ataxia, dysarthria, memory, attention, insight, mood changes, disinhibition, emotional liability, etc. This thesis is mainly concerned with motor deficits and although motor deficits are rarely a problem on their own this thesis will limit its discussion to motor function and control.

Disturbance of motor function and control is a consequence of the interruption of motor signals from the brain to the motor neurons[37] and is well recognised after neurological damage. A few common clinical features due to this interruption are: muscle weakness, loss of dexterity, fatigueability, altered reflexes and spasticity.[38]

Therapeutic approaches focus on the modification of impairment and improvement of physical function and independence. There is little evidence to support specific techniques; however, therapies employing functional training have been shown to being more beneficial than impairment-focused programmes.[6, 33, 39] Interventions that are typically recommended facilitate motor function and control and emerging evidence supports the use of practicing functional task-specific activities.[30, 33] Approaches differ in the type of stimuli used, the emphasis on task-specific practice and/or the principles of learning pursued.

This thesis is mainly concerned with the functional domain, the ICF activities category, in neurological rehabilitation. However, spasticity, which is in the ICF function category, is also briefly discussed in this thesis (chapter 3). Spasticity is defined as involuntary muscle tightness and stiffness, which is velocity-dependent and associated with increased resistance to passive muscle stretch.[40-43] In other words; greater resistance is felt with faster stretches. Spasticity often leads to motor deficits but not necessarily to disabilities.[43]

There are many techniques that aim to improve motor control and one that has become used more frequently in the last few years is motor imagery. No research has yet investigated motor imagery use to reduce spasticity.

MOTOR IMAGERY

Research in the field of motor imagery is bedevilled by varying and imprecise use of terms. A term often used is mental imagery. Richardson's definition of mental imagery that is often used is: *Mental imagery refers to all those quasi-sensory or quasi-perceptual experiences of which we are self-consciously aware, and which exist for us in the absence of those stimulus conditions that are known to produce their genuine sensory or perceptual counterparts.*[44, 45]

Three important characteristics of imagery are mentioned in this definition: imagery mimics sensory or perceptual experiences, the person who performs imagery is consciously aware that he or she is imagining and imagery takes place without the immediate stimulus. More specifically, the principle of motor imagery is that the person imagines himself or herself undertaking the movement without actually doing the movement.

With regards to Richardson's definition one can add that motor imagery is primarily aimed at moving, at motor actions. The intention of the actor and the environment determine the type of action that is performed. For example, raising one's hand above the head during stroke rehabilitation (motor action) should be distinguished from a similar movement during a discussion (communicative action). Because motor imagery is primarily directed at movement goals this characteristic could be added to Richardson's definition; imagery is not only a quasi-sensory or quasi-perceptual experiences but also a quasi-response (movement) experience. In addition to this, three elements of motor imagery can be distinguished. First, the person imagining can imagine from two different perspectives. From an external perspective the person is observing him/herself from a third person's perspective. In internal imagery the person imagines from an actual perspective, from inside his/her body. Second, all sensory modalities (visual, kinaesthetic, tactile, auditory, olfactory and taste) may be involved in internal motor imagery but external motor imagery only involves the visual modality. Finally, task specific somatic responses are frequently observed during motor imagery.[46]

Terminologies used in the literature are terms such as: motor imagery, mental practice, visual imagery, guided imagery, mental movement and mental rehearsal. These terms include different concepts of imagery, which makes the correct terminology confusing. In this thesis the term motor imagery will be used when referring to the mental process or cognitive function of creating a mental image of an action.[46] Many authors refer to *mental practice* as a technique to *rehearse* imagery scenes or tasks.[8, 47] However, mental practice can constitute any imagined scene or task, i.e. spatial navigation (travelling a route in the mind) or visual imagery of objects or persons to improve memory. Because the main aim of this thesis is enhancing motor performance, I will use *motor imagery practice* when referring to the rehearsal of motor imagery.

Martin et al.[48] categorised imagery effects in three broad fields: cognitive modification; arousal and anxiety regulation; and skill and strategy learning and performance. These fields can be targeted with specific imagery techniques. Sports psychologists have shown that imagery is effective in changing an athlete's self-efficacy[49, 50] and self-confidence[51, 52] (cognitive modification). It may boost motivation and effort and facilitates goal setting.[53] However, it is unlikely that this cognitive modifying type of imagery will directly lead to performance enhancement.[48]

There is also evidence suggesting that imagery that includes feelings of relaxation, anxiety, stress and excitement (i.e. arousal and anxiety regulation) can have an effect on the athlete's regulation of arousal and anxiety.[52, 54-56] Finally, imagining performance of specific skills (i.e. skill and strategy learning and performance) is the best method for skill and strategy learning and performance.[48, 55, 57, 58]

Developments in the field of human motor cognition have led to a better understanding of higher-order motor functioning. Jeannerod[59, 60] has proposed the simulation theory which suggests that actions involve a covert stage. This covert stage is thought to be a representation of the future, including the goal of the action, the way to reach the goal and its consequences. The theory postulates that these covert actions are in fact actions; however, the actions are not executed, so motor imagery is suggested to simulate actions.

A large amount of evidence on motor imagery comes from the sports field and more recently from neuroimaging studies. Below follows a brief description of two meta-analyses on the effectiveness of motor imagery in sports.

Motor imagery in sports

A meta-analysis on the effects of imagery on motor skill learning and performance was carried out by Feltz and Landers in 1983.[58] This meta-analysis included 60 studies which used control groups, imagery groups, physical practice groups and imagery combined with physical practice groups. Subject characteristics varied largely; novice as well as experienced imagery users were included and variations of imagery techniques were used. Even after comparing these highly varied studies the overall average effect size was 0.48, suggesting that imagining a motor skill improves performance. However, this meta-analysis also included other techniques than motor imagery, such as modelling interventions and psyching up. A later (1994) meta-analysis by Driskell et al[57] used more stringent criteria for the motor imagery intervention and still found a significant effect size (i.e. 0.255), although lower than the effect size of physical practice (i.e. 0.364).

The evidence on imagery, especially from sports, suggested that this technique may be a useful technique in the rehabilitation of people with central neurological damage or disease. This has led to an increased interest in using imagery in the rehabilitation of people with central neurological damage or disease around the turn of the century.[61-65]

Motor imagery in neurological rehabilitation

Motor imagery is a particularly attractive intervention in neurological rehabilitation because; it is cheap; it doesn't need expensive equipment; it can be used at any time of the day, within and outside therapy sessions; it is easy to use and one can imagine almost anywhere (e.g. bedroom, gym, between points of travel), at any time of day (e.g. during therapy, while lying in bed), for any amount of time (i.e. from seconds to tens of minutes), with minimal physical fatigue (although it can cause mental fatigue). In this way it covers many of the national service framework requirements (see earlier this chapter). Motor imagery is a person-centred approach with potential in the acute, the specialist rehabilitation and the community rehabilitation and palliative management with minimal cost.

A systematic review by Braun et al.[8] examined the evidence for using imagery in stroke rehabilitation. Ten studies were identified, of which four were randomised controlled trials (RCT's),[62, 63, 66, 67] one was a controlled clinical trial (CCT),[68] two were patient series[69, 70] and three single case studies.[64, 71, 72] The methodological quality of the RCT's and the CCT ranged between poor[62] and good.[63] Three of the five studies were reported to have sufficient methodological quality, defined as a score of six or higher (out of 11 points) on the Amsterdam-Maastricht Consensus List for Quality Assessment. All three studies of sufficient quality showed a positive effect of motor imagery on performance enhancement. In general, nine of the ten studies included in the systematic review showed significant positive effects of motor imagery.

The delivery of the motor imagery varied considerably between the studies. In all the studies by Page[62-64, 67] motor imagery was delivered by tape. In two studies by Liu[66, 70] motor imagery was embedded in occupational therapy, whereas Dijkerman et al.[68] used visualisation of the task after observing the task. The other three studies[69, 71, 72] combined motor imagery with overt movement.

Six of the ten studies used motor imagery to train arm tasks[62-64, 67-69] usually involving drinking from a cup, whereas Liu et al.[66, 70] used fifteen functional ADL tasks ranging from folding laundry to going shopping. Dickstein and colleagues[71] used motor imagery to improve functional gait-oriented tasks and Jackson and colleagues[72] trained a foot sequence task. The frequency of motor imagery delivery ranged between trice weekly and daily practice of 10-30 minute sessions with an intervention period between two[69] and six weeks.[63, 64, 67, 71]

The systematic review[8] concluded that further studies were needed because sample sizes were too small, there was no consistency in the intervention protocol and dose, compliance was difficult to measure and it was not clear who would benefit most from the intervention. Finally, the systematic review concluded that linking physical activities with motor imagery was essential for effective implementation, suggesting that motor imagery should not be used alone but should be implemented in physiotherapy and/or occupational therapy.

Although studies have used motor imagery in combination with other physical practice methods only three have implemented motor imagery in the patient's usual care package.[66, 69, 70] Most patients were recruited through advertisements and databases. However, none of the studies employing patients that were currently receiving therapy had defined the motor imagery intervention in any detail and only a limited set of tasks was practiced. This limited evidence makes motor imagery interventions difficult to implement in everyday clinical practice. For motor imagery to be integrated in clinical practice (e.g. during physiotherapy or occupational therapy) it should be easy to use by the therapist and by the patient, it should be applicable to a wide range of patients, to a wide range of tasks and without using (expensive) equipment.

Most studies investigating the effectiveness of motor imagery in a neurological population have researched stroke patients. However, there is some evidence on the effects of motor imagery in people with Parkinson's disease. These studies[47, 73, 74] also show positive effects of motor imagery on movement performance but because of the different pathology, symptoms and treatment goals (e.g. unfreezing versus (re)learning of movements) of subjects with Parkinson's disease, these studies will not be discussed here.

From the 1980's more evidence has become available on the somatic consequences of imagery and the cortical activity during motor imagery. A brief summary of several of these physiological consequences and cortical activity networks will be discussed next.

Physiological responses to motor imagery

Some of the physiological responses of imagery that have been investigated are heart rate, blood pressure, blood flow, sexual response, physical chemistry, ocular responses, electrodermal activity, electromyographic activity, immune system and other physiological effects.[54, 75-91] Most of these responses are specific for the imagery that is used. For example, imagery of emotional arousal (e.g. anger) elicits an increase in heart rate and blood pressure, whereas imagining relaxing situations decreases heart rate and blood pressure, imagining specific skin regions to feel cold or hot causes changes in skin blood flow, salivary pH changes occur during imagery of specific tastes and visual imagery can affect the dilation of the pupil. Moreover, for many of these responses a positive correlation was found between the response change and the vividness or quality of imagery.[92]

More specific on motor imagery; electromyographic studies have shown that imagining movements causes electromyographic activity, without overt movement.[82, 85, 93]

Functional neuroimaging studies

Imagining a movement has shown to activate largely the same cortical networks as to the preparation[94] and the actual execution of the movement.[95, 96] Although no overt movement is performed, motor imagery can be conceptualised as an 'active' performance of the movements imagined, in the way that the activity induced in the associated brain areas resemble the activity during overt performance.[97-99] Several studies[100, 101] have investigated the brain activation patterns of simple movements, such as finger tapping, during overt and imagined performance. These studies have shown that the lateral and medial premotor cortices, the inferior and superior parietal cortices and the basal ganglia are active during overt and imagined performance. There is considerable debate about the involvement of the primary motor cortex during motor imagery,[96] however, a recent study by Sharma et al.[102] has shown that mainly a sub-division of the primary motor cortex (i.e. 4p) is activated during motor imagery.

In rehabilitation usually more functional movements are practiced, such as using utensils for eating or writing, which are different from simple movements used in functional neuroimaging studies such as finger tapping. Szameitat et al.[97] have demonstrated that a comparable cortical network (lateral and medial premotor cortices bilaterally, the left parietal cortex and the right basal ganglia) is activated during everyday arm movements (usually bilateral; e.g.

eating with knife and fork, tie shoe laces) and whole body movements (e.g. swimming, running).

A recent study by Sharma et al.[103] showed that the activation pattern in well-recovered stroke subjects was similar to that in healthy controls during motor execution. During motor imagery the activation pattern was very similar but remained disorganised in proportion to the residual motor impairment.

THESIS

Many people have disabilities as a result of a neurological disorder or neurological damage, and this population is growing due to lifestyle factors and ageing.[16, 17, 20] The needs of these patients vary widely and are often complex. Rehabilitation has been shown to reduce the impact of disabling and handicapping conditions, but the actual effective components remain unknown.[1, 30, 33, 34]

Motor imagery, as an intervention modality in neurological rehabilitation, may be effective on the grounds that it has shown an increase in performance from sports literature[48, 57, 58] and that it activates similar cortical networks as during physical practice.[94-96] However, the evidence supporting the effectiveness of motor imagery in neurological rehabilitation is limited and further studies are needed.[8, 96]

This thesis starts with a review of the content of motor imagery interventions in neurological rehabilitation (chapter 2). Motor imagery has not been used in the treatment of spasticity yet. Spasticity is a fairly common problem in people with neurological disorders[43] and in clinical practice stretching is often used to reduce spasticity.[104] In this thesis, motor imagery and stretching were combined in an attempt to reduce spasticity (chapter 3).

As described earlier, patients present with a variety of often complex issues. This makes it very difficult for any outcome measure to investigate the effectiveness of an intervention.[12] An individualised outcome measure was required in order to measure changes due to motor imagery over time, resulting in the use of goal attainment scaling (chapters 4 and 5).

In this thesis a comprehensive motor imagery strategy is developed (chapter 6) and the effectiveness and feasibility of this service-delivered strategy is investigated in a randomised clinical trial (chapter 7).

The next chapter will continue with a literature review of the content of motor imagery interventions in neurological rehabilitation.

Chapter 2

Thematic Review of the Content of Motor Imagery Interventions

Publications relevant to this chapter:

- Bovend'Eerdt TJH, Dawes H, Wade DT. Thematic Review of Motor Imagery Interventions in Neurological Rehabilitation (submitted)

SUMMARY

This chapter reports a systematic literature search performed to identify studies using motor imagery in neurological populations. The motor imagery interventions used in studies with neurological populations were evaluated on their practical applications and their specific content. Overall the motor imagery interventions were poorly described and techniques from other disciplines (i.e. sports psychology and fundamental research) were used in varying degrees. Motor imagery interventions in neurological rehabilitation appear to be sub-optimal and the full theoretical potential of motor imagery has not been reached yet.

INTRODUCTION

As suggested in chapter 1, the content of motor imagery interventions used in studies is rarely described in any detail despite extensive investigation of its effects in sports and fundamental research.[48, 57, 58] The effectiveness of some of the techniques from sports psychology and fundamental research (sometimes called basic research: research driven by a search for knowledge via scientific study rather than by clinical needs or for practical application[105]) are very robust, such as the larger effect of motor imagery in tasks involving cognitive elements.[57, 58] However, little evidence from sports psychology and fundamental research has found its way into motor imagery interventions in neurological rehabilitation.[98, 106] Various motor imagery techniques can be identified from sports psychology and fundamental research that may be used in motor imagery interventions in neurological rehabilitation. With motor imagery techniques, in this thesis, specific techniques are meant that can only be used in motor imagery, for example; response propositions which are assertions about physiological and behavioural responses during the motor imagery that describe the responses to movements (e.g. the muscle tension in the quadriceps when practicing sit-to-stand). These responses are modifiable and can be used to increase the information about reactions and/or to modify the learner's behaviour.[48, 76, 93] This is a technique specific to motor imagery.

Furthermore, other, more general components may be identified from the literature that can increase the theoretical potential of motor imagery interventions for clinical practice. Here such components are usually part of an intervention and are known to be effective from a large evidence base, for example; it is known that to become better at a task it is necessary to repeat the task in order to improve performance.[107, 108] The term component is used here because to improve performance, more than just practice is needed and more components constitute the intervention, for example, feedback or changing the speed the movement is performed at can all be components of one intervention.[107, 108]

Motor imagery is an attractive intervention opportunity in neurological rehabilitation because:

- it may be relatively easy to use;
- it is potentially cost effective;
- it does not require any equipment;
- it can be used independently and safely by the patient;
- it can be used for nearly any task without physical fatigue.

In order for motor imagery to be integrated as an intervention in clinical practice it is important to develop practical guidance for motor imagery delivery and to evaluate the specific content of the intervention. This is necessary to educate clinicians and standardise their treatments so that every patient receives the same optimal therapy. Practical applications of motor imagery are important to consider (i.e. dosage and duration etc.), but also the actual content of the intervention (i.e. instructions, imagery perspective and other techniques and components).

In this chapter a systematic literature search is presented of studies using motor imagery in neurological populations. These studies were used to:

1. evaluate applications of the motor imagery interventions, and;
2. characterise the content of the motor imagery interventions (motor imagery techniques and other components) to date.

This information can be used to develop a model for motor imagery delivery (chapter 6).

METHODS

An inventory of motor imagery interventions in neurological rehabilitation was performed using a systematic search approach. The search syntax consisted of ((*imagery* OR *mental practice* OR *mental rehearsal*) AND *rehabilitation*). The following databases were searched up to July 2008:

- PubMed
- Cochrane library
- PsycINFO
- Cumulative Index to Nursing and Health Literature (CINAHL)
- Allied and complementary medicine (AMED)
- Web of Science.

The titles of the search results were screened and if in doubt about eligibility, the abstract and/or the full paper was read.

The selected articles were cross-referenced with three reviews on the subject[8, 9, 96] to ensure all relevant articles were included and reference lists of the included articles were searched for potential other studies.

Study selection

Articles were included if they were available in English and investigated motor imagery practice in adult subjects with multiple sclerosis, acquired brain injury or stroke. Articles were included that investigated the effectiveness of the motor imagery intervention or articles that described the methods of the intervention; conference abstracts were excluded. Motor imagery interventions that focused on imagery of movements or skills were included; studies of imagery of pain, attention or emotions were excluded. As the aim of the study was to evaluate clinically applicable motor imagery, studies were also excluded that required the use of specialised equipment for the imagery intervention, such as EMG, force plates, mirror boxes or virtual-reality equipment.[109-113] Use of video equipment or (computer-generated) pictures or movies, however, were allowed.

Practical applications

Interventions in rehabilitation vary greatly. For interventions to be reproducible it is important to define some practical aspects of the interventions, such as; how many times should a technique be repeated and which is the best way to teach the patient the technique (e.g. by tape recordings or face-to-face).

The practical aspects of motor imagery considered in this review were:

- the task practiced;
- the participant's position;
- the delivery method;
- the frequency and dosage;
- the number of repetitions, actual duration of motor imagery and the order of delivery of physical and imagery practice, and;
- potential additional technique(s) used in combination with motor imagery.

Motor Imagery Techniques and Components

The motor imagery techniques and components used in this chapter are a selection of a wide range of techniques and components available. They were identified by the researcher from sports psychology and fundamental research literature[48, 57, 58, 76, 93, 107, 108, 114-122] and are commonly recurring techniques and components in the literature. Below follows a brief description of the techniques and components used in this thematic review:

- movement sequence;
- response propositions;

- success;
- imagery ability;
- progression;
- temporal aspects.

Movement sequence

Evidence suggests that the largest effect sizes of motor imagery in healthy subjects (i.e. r=0.327, d=0.692)[57] are in tasks with relatively great cognitive elements such as preparing a meal – compared to lifting a bag of groceries.[57, 58] Although, motor imagery appears to be also effective in tasks with less cognitive elements, such as motor, strength and power tasks,[57, 58, 116, 122] but to a somewhat lesser extent (i.e. r=0.166, d=0.337).[57] It is implied that motor, strength and power tasks require a higher amount of motor imagery practice to reach the same level of effect size than for cognitive tasks.[57, 58] Tasks with relatively great cognitive elements often have more difficult movement sequences which can be described in consecutive steps (consider preparing a meal) compared to a motor task such as lifting a bag of groceries which consists of only 1 step, namely bending the elbow. Thus this review investigates whether the movement sequence of the task was analysed or learned by the patients.

Response propositions

Response propositions are assertions about physiological and behavioural responses during the motor imagery delivery.[76, 93] In the case of motor imagery they describe the responses to imagined movements (e.g. the muscle tension in the quadriceps when practicing sit-to-stand). These responses are modifiable and can be used to increase the information about reactions and/or to modify the learner's behaviour.[48, 76, 93] The review investigates whether response propositions were used during the intervention.

Success

It is important to imagine a skill correctly, in the way it is to be performed.[117, 120] When a movement is executed incorrectly this can lead to inaccurate learning, similarly an incorrect imagined movement can lead to inaccurate learning, including all temporal and spatial aspects.[114, 117, 120] The aspects studied in this review were the correct and successful imagining of the task performance.

Imagery ability

Individuals with high imagery ability improve more than individuals with low ability,[123] suggesting that one should aim to try and improve or optimise the imagery ability.[47, 48, 123-126] Indeed, in a meta-analysis Driskell et al.[57] found that motor imagery experience increased the effect of motor imagery, especially on motor tasks. The ability to imagine movements varies between people and between tasks.[123, 125, 126] Imagery ability can be investigated by asking the subject about the intensity, referring to the quality of the sensations during motor imagery. The review investigates whether attention is paid to developing or evaluating imagery ability.

Progression

In practice there should be a logical progression in the difficulty levels within a task, in difficulty level between tasks and possibly of the technique used[107, 108, 127] (e.g. progression from walking with a stick to walking without an aid; progression from using only a fork to eat to using knife and fork to cut a piece of meat; progression from only using visual imagery to using visual as well as kinaesthetic imagery). The review investigates whether there was a logical progression in; difficulty level within and/or between tasks practiced and/or of the imagery technique(s) used?

Temporal aspects

Learning a movement usually results in reduced speed to execute the movement. Fitts' law describes a relationship between speed and accuracy tradeoffs in aimed movements. It predicts that the time needed to point to a target (of a certain width and at a certain distance) is logarithmically related to the inverse of the spatial error.[107, 108] Evidence shows that this also applies to motor imagery.[128, 129] Therefore, in patients for who movements are difficult and performed slowly, it may be necessary to increase the speed of a movement during motor imagery. This should correspond to the physical goal (e.g. perform a transfer within 5 minutes instead of 10 minutes). The review investigates whether the speed of the imagined movement was altered.

RESULTS

Figure 2 shows an overview of the literature search and study selection. From an initial list of 1665 articles, 50 were retrieved. After reading the full articles, 35 of the 50 were excluded because they either used specialised equipment (e.g. EMG, force plates, mirror boxes, virtual-reality equipment) or they did not actually investigate the effectiveness of the intervention but rather the physiological responses of motor imagery. Thus, 15 articles met the criteria. This is 5 more articles than presented by the most extensive systematic review currently available on the subject performed by Braun et al. in 2006.[8] The reason more articles are included here is because this review included brain injured and MS patients (n=1)[130] as well as study protocols (n=2)[131, 132] and 2 articles[133, 134] that were published after their systematic review.

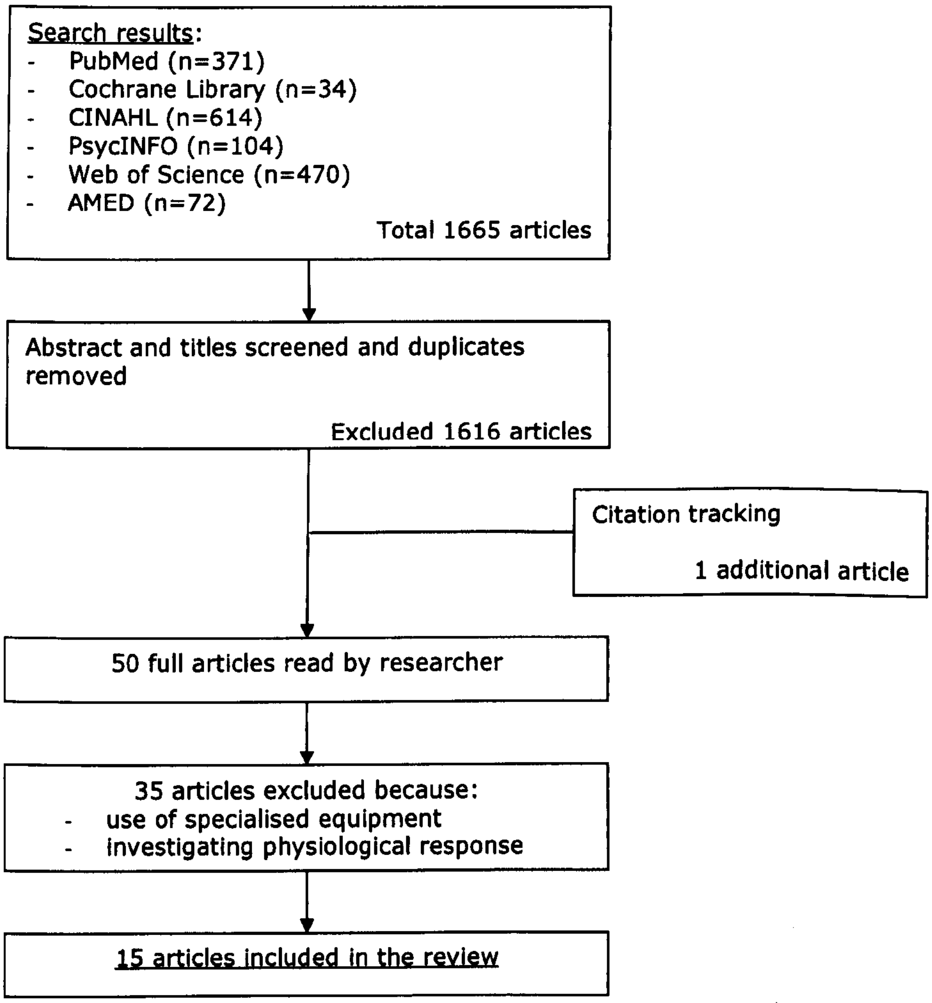

Figure 2. Flowchart of the review process.

Summary of study characteristics

Table 1 provides an overview of the study designs included in this review.

Table 1. Overview of study designs of the studies included in the review.

Study design	**References**
Randomised Controlled Trial (RCT) (n=5)	62, 63, 66, 67, 134
Controlled Clinical Trial (CCT) (n=1)	68
Patient series (n=3)	69, 70, 133
Case report (n=4)	64, 71, 72, 130
Study protocol for RCT (n=2)	131, 132

Practical applications

Table 2 provides a summary of the practical aspects of the included studies. The motor imagery interventions varied greatly between the articles. Several research groups have repeated their motor imagery interventions in more than one study and appear to be (nearly) identical. In such cases the studies are presented as clusters to improve readability and save space.

The interventions were described in varying detail, but in general there is not enough information to repeat any of the studies. Standardisation of the practical applications of the interventions was poor. In most of the studies upper limb tasks were practiced (n=11), balance or gait was practiced in three studies and in one study a foot sequence task was used. Activities varied between the ICF function and activity categories. Most articles failed to report the position of the participant. The interventions were usually delivered by the therapist or by using recorded instructions. Frequency, dosage, repetitions, duration of the actual motor imagery intervention and the order of delivery of physical and imagery practice was described poorly. Several studies used additional techniques such as pictures, films and mirrors.

Table 2. Overview of some practical aspects of motor imagery interventions in neurological rehabilitation.

Reference(s)	Task/ skill imagined	Participant position	Delivery method	Frequency/ dosage	Repetitions/ duration	Additional technique(s)
Crosbie 2004[69]	Reach and grasp task (drinking from cup)	Not reported	Verbally by therapist	Two weeks of daily MI sessions with the therapist and after each session independent MI	Less affected arm: 10 reps PP, 10 reps MI (x2) More affected arm: 1 rep PP, 10 reps MI (x2)	Video observations of task performance
Dickstein 2004,[71] Dunsky 2006[133]	Walking	Sitting in reclined position	Verbally by therapist	Six weeks, three times per week	15-20 min sessions; 5-6 min of external MI and/or 5-6 min of internal MI; no PP	Not reported
Dijkerman 2004[68]	Moving 10 blocks or buttons across and back (25 cm)	Sitting posture	Verbal instructions	Daily practice for 4 weeks	Moving the tokens or blocks across and back: PP (x1) and MI (x3)	Not reported
Fell 2000[130]	Various balance tasks	Lying on bed or sofa	Tape recording	Listen to tape once per day for 2 weeks, and 4 weeks of independent mental imagery/ practice	Tape contained facilitated mental imagery (10 min); and mental practice (15 min) Instructed not to physically practice tasks	Not reported
Ietswaart 2006[131]	Both elementary movements and activities of daily living of the upper limb	Not reported	Verbally by therapist	Four weeks, sessions with the research therapist and independently, twice per week, not further specified	Sessions with therapist took 45 min; operational manual was used to make sure repetitions between experimental and control groups are similar, not further specified	Mirrors and video display
Jackson 2004[72]	Foot sequence task	Sitting or supine position	Verbal instructions before MI	First 2 weeks consisted of PP; week 3 consisted of PP plus MI (5 sessions) and week 4-5 of MI alone (12 sessions)	Week 3: 5 sessions of PP x 30 reps plus MI x 120 reps; Week 4-5: 12 sessions of 60 reps	Not reported
Liu 2004[66, 70]	Ten daily tasks were imagined; 5 tasks per week	Not reported	Verbally by therapist	Two weeks of MI, 5 times per week, 1 hour per session	MI and PP were alternated, not further specified	Video observations of own performance and picture cards
Page 2000[62]	Weight-bearing of affected arm and functional tasks of the affected arm practiced during the OT session	Not reported	Tape recording	Four weeks, listen to tape three times per week after OT (1/2 hour) sessions	20 min tape recording consisting of suggestions for external, cognitive visual images (10 min)	Not reported

Table 2 (continued). Overview of some practical aspects of motor imagery interventions in neurological rehabilitation.

Reference(s)	Task/ skill imagined	Participant position	Delivery method	Frequency/ dosage	Repetitions/ duration	Additional technique(s)
Page 2001[64]	Week 1 – 2: reaching and grasping of cup or object Week 3 – 4: turning a page Week 5 – 6: reaching and grasping an item on a high shelf	Supine position	Tape recording	Six weeks, listen to tape twice per week after physical therapy (3 times per week, 1 hour each) sessions and tape was taken home to practice twice per week	10 min tape recording consisted of suggestions for internal, cognitive visual images (5-7 min)	Not reported
Page 2001[63]	Three taped scripts concentrated on different functional movements, including: shoulder internal/external rotation, pronation/supination, shoulder flexion and other movements that facilitate grasp	Not reported	Tape recording	Six weeks, listen to tape three times per week after physical and occupational therapy sessions (1 hour) and tape was taken home to practice twice weekly	10 min tape recording consisted of suggestions for external, cognitive visual images (5-7 min)	Not reported
Page 2005 + 2007[67, 134]	Week 1 – 2: reaching and grasping of cup or object Week 3 – 4: turning a page Week 5 – 6: proper use of a writing utensil	Not reported	Tape recording	Six weeks, twice weekly after each physical practice (1/2 hour) session	30 min tape consisted of suggestions for internal, cognitive polysensory images (20-22 min)	Not reported
Verbunt 2008[132]	Five different arm tasks derived from the Frenchay Activities Index	Not reported	DVD recording	Six weeks, at least three times per day	Five MI repetitions with movement shown on screen and 5 MI repetitions without visual instructions; 10 min per session	DVD showing movements

Legend: PP, Physical Practice; OT, Occupational Therapy; MI, Motor Imagery; reps, repetitions; min, minutes

Motor Imagery Techniques and Components

Table 3 provides a summary of the specific content of motor imagery interventions in these studies. Several research groups have repeated their motor imagery interventions in more than one study and appear to be (nearly) identical. In such cases the studies are presented as clusters. In general, the interventions are described poorly.

Seven articles paid specific attention to the movement sequence of the imagined task. This was done in various ways. Some studies simply explained the movement sequence; others asked the patients to order the movement on picture cards.

Response propositions were administered in varying levels. For example; Liu et al[66] gave verbal explanations of the physical and mental demands during each step of the movement while showing patients pictures of the movement.

It is interesting that in a population with motor deficits where movements are often performed incorrectly, if at all, only a few studies reported paying attention to the correct execution of the imagined movement(s).[66, 69-71]

Practice of certain tasks usually improves the performance of that task. In this case motor imagery is also a task that can presumably improve over time.[126] Interestingly, no study reported trying to improve the patient's ability to perform motor imagery.

Some articles reported progression in the level of difficulty, in task or in imagery technique, but only two articles[66, 70] reported progression in all.

Practice of a task can be performed in order to gain skills but can also be performed to reduce the time spent on the task (e.g. instead of taking 30 minutes to dress one self reduce the time to 10 minutes). Only four articles[68, 71, 72, 133] recognised that reducing the time to perform a task can be a treatable variable during motor imagery.

Table 3. Overview of the motor imagery techniques and components.

Reference(s)	Summary/ instructions	Movement sequence	Response propositions	Success	Imagery ability	Progression	Temporal aspects
Crosbie et al. 2004[69]	• Initially participant was shown a video of drinking from cup • Participant was asked to explain the sequence of the task • Instructed to visualize the task • After each imagery block the quality was checked by the therapist • Task was practiced with the less and the more affected arm using physical practice and motor imagery practice • Visualize the task and explain the sequence of the task	Participant was asked to explain the sequence of the task	Not reported	Quality was checked by therapist after each MI block; not known whether 'quality' was success or clarity/ intensity	Quality was checked by therapist after each MI block; not known whether 'quality' was success or clarity/ intensity	Initial use of video to observe movement; no progression in MI technique or task difficulty	Not reported
Dickstein et al. 2004[71]	• Imagery of gait directed toward improving speed, symmetry and negotiating walking routes • Imagery exercises applied randomly and explicit information on the nature of the task provided • Week 1; familiarization with imagery • Week 2; practicing gait focusing on impairments (knee flexion, swing, heel strike, push off) • Week 3; as week 2 with additional emphasis on loading affected side and speed • Week 4; focus on integrating prior practiced components into step cycle and on increasing symmetry and velocity • Week 5-6; imagined walking with desired gait pattern toward meaningful targets and on different terrain Each session consisted of: 1. deep muscle relaxation (1-2 min); 2. explicit information on task characteristics and environmental circumstances (1-2 min); 3. imagine from external perspective (3-8 min); 4. imagine from internal perspective (3-8 min); 5. and refocusing on present (1 min)	Components of gait were practiced; movement sequence not explicitly reported	Explicit information on the nature of the task was provided prior to performance; not further specified	Reinforcement through imagery of confidence and of successful accomplishment	Not reported	Content of each imagery session was adjusted to performance level and modified in accordance with changes; first 4 weeks focused on specific gait impairments and on improving speed and symmetry, last 2 weeks focused on performance of functional task-oriented gait activities	Gait speed

Table 3 (continued). Overview of the motor imagery techniques and components.

Reference(s)	Summary/ Instructions	Movement sequence	Response propositions	Success	Imagery ability	Progression	Temporal aspects
Dijkerman et al. 2004[68]	• Imagine moving 10 tokens, either blocks or buttons, across and back 3 times per day • Standard instructions • Instructions: "the tokens are on the white dots. I want you to move the tokens in your head. You are going to move the tokens in your mind's eye... Imagine you are lifting them with your hand and putting them on the dots above. Make sure you are imagining using your weak hand, the same hand you used in the earlier task... Imagine your hand grasping the token and your arm lifting it to the dot above, then imagine picking up the next one. Imagine you are moving the tokens with your hand not just your eyes. Try to let your hand work as quickly and accurately as you can without rushing it."	Not reported	Not reported	Not reported	Not reported	Not reported	Instructed to imagine the task as quickly possible
Dunsky et al. 2006[133]	• Week 1; familiarization with MI practice, imagery gait practice in an isolated place on a flat road • Week 2; focus on the timed application of propulsive force during push-off • Week 3; emphasis on loading of the affected side during stance and on increasing gait speed • Week 4; integrating prior practice in gait cycle, imagery walking with increasing cadence while stressing gait symmetry • Week 5-6; imagery walking towards meaningful targets within as well as outside the participant's home, walking on different terrains (grass, roads, carpets) A session consisted of: 1. deep muscle relaxation (1-2 min); 2. explicit information on task characteristics and environmental conditions (1-2 min); 3. imagine from external perspective (5-6 min); 4. imagine from internal perspective with kinaesthetic experience, focus on the body-centered sensation of self-walking (5-6 min); 5. and refocus of attention on the immediate surroundings and genuine body position (1 min)	Components of gait were practiced; movement sequence not explicitly reported	During internal perspective MI kinaesthetic experiences were given and participant focused on the body-centered sensation of self-walking	Not reported	Not reported	Initially focus on performance of push-off and loading of the affected lower limb and later on the practice of global gait variables such as speed and symmetry	Gait speed

Table 3 (continued). Overview of the motor imagery techniques and components.

Reference(s)	Summary/ Instructions	Movement sequence	Response propositions	Success	Imagery ability	Progression	Temporal aspects
Fell 2000[130]	• Initial education on mental practice and mental imagery after which a tape was provided for 2 weeks consisting of: facilitated relaxation exercises (20 min); facilitated mental imagery (10 min); and imagery practice (15 min); followed by independent mental imagery and mental practice: relaxation (10 min); mental imagery (10 min); and mental practice (15 min) • The mental imagery consisted of: driving home from shopping centre, encountering traffic jam and formulation of alternative route; imagery of walking through the brain, encountering a sclerotic plaque and formulation of an alternative route for the impulses; and imagery of various athletes, birds and animals who are particularly graceful and demonstrate excellent balance • The mental practice consisted of various balance tasks from the initial balance examination	Not reported	Participant was encouraged to focus on normal proprioceptive sensations	Not reported	Not reported	Not reported	Not reported
Ietswaart et al. 2006[131]	• Imagery training program has been specifically developed to promote recovery of hand function through MI by recruiting areas of the brain that could stimulate functional redistribution of brain activity • Structured MI of a variety of elementary movements and ADL • MI facilitated through verbal instruction and feedback, observation of movement and visual display • MI is further evoked through movement illusion through the use of mirrors and video display • The researchers providing the training closely follow a detailed operational manual to ensure that instructions, number of repetitions and the length of training are closely matched between groups • Patients are asked to imagine upper limb movements and are trained to involve visual, kinaesthetic and combined images of movement	Not reported	Participants were trained to involve visual, kinaesthetic and combined images of movements; MI is facilitated through verbal instructions	Not reported	Not reported	Not reported	Not reported

Table 3 (continued). Overview of the motor imagery techniques and components.

Reference(s)	Summary/ instructions	Movement sequence	Response propositions	Success	Imagery ability	Progression	Temporal aspects
Jackson et al. 2004[72]	• Foot sequence task was practiced; in the first 2 weeks physically, in week 3 physically as well as mentally and in week 4 and 5 mentally only Instructions: 1. assume a comfortable sitting or supine position 2. imagine movements using first person perspective, as if you were actually executing them 3. avoid moving or contracting muscles from your leg and head, keep a relaxed position 4. remember to try seeing and feeling the movements as you do when you execute them 5. keep your eyes closed for the duration of the whole block of trials 6. keep track of the number of sequences imagined with your fingers, imagine that you perform the sequence 6 times per block 7. if you lose your concentration during a block, open your eyes, relax for a few moments and then start over the same block 8. remember to imagine the sequence as quickly as possible, while making as few errors as possible	Task was a foot sequence	Not reported	Not reported	Not reported	Not reported	Participants were instructed to imagine the task as quickly possible
Liu et al. 2004[70]	• Three week intervention period but MI was only used in week 2-3 • Ten functional tasks were used with increasing level of difficulty The imagery process consisted of: 1. recall the procedural performance of the task prompted by picture cards showing snap-shots of the different steps 2. mentally perform the task 3. visualize potential problems 4. describe verbally how problems could be rectified 5. repeat imagery of same task by incorporating rectified steps 6. perform actual task	Participant was asked to recall procedural performance using picture cards and by visualizing and verbalizing potential problems	Not reported	Problems were identified and solutions to each problem were discussed and practiced; next task if mental performance resembled actual task performance	Not reported	Initial use of video to observe own performance; from easy to more difficult tasks; progression within each task; from impaired to successful movement	Not reported

Table 3 (continued). Overview of the motor imagery techniques and components.

Reference(s)	Summary/ instructions	Movement sequence	Response propositions	Success	Imagery ability	Progression	Temporal aspects
Liu et al. 2004[66]	• Three week intervention period but MI was only used in week 2-3 • Tasks included mobility functioning, balance and upper-limb coordination and difficulty level increased • Strategies were developed to overcome problems The imagery process consisted of: 1. show beginning and ending steps 2. identify the steps in the task through imagery 3. present participant with randomly sequenced picture cards 4. rearrange picture cards into correct sequence 5. visualize task with help of picture cards in correct sequence 6. identify potential problems and solutions in each step by going through imagery process 7. repeat imagery of same task by incorporating rectified steps 8. perform actual task and videotape performance 9. evaluate performance on video tape to adjust problems and solutions 10. repeat steps 6-9	Participant analyzed task sequences using computer-generated movies, pictures and picture cards	Pictures with verbal explanations of the physical and mental demands were used for each step of the movement	Problems were identified and solutions to each problem were discussed and practiced	Not reported	Initial use of video to observe own performance; from easy to more difficult tasks; progress within each task; from impaired to successful movement	Not reported
Page 2000[62]	• After OT sessions participants listened to a 20 minute tape of the task practiced before and of weight-bearing with affected arm The tape consisted of: 1. relaxation (5 min) 2. suggestions for external cognitive visual images related to using the affected arm in weight-bearing tasks and functional tasks practiced during the therapy session, such as imagining themselves shifting their weight from their unaffected arm to their affected arm in a seated position, or imagining themselves performing transfers to the weak side (10 min) 3. refocusing (5 min)	Not reported	External imagery was used so no response propositions possible	Not reported	Not reported	Not reported	Not reported
Page et al. 2001[64]	• After physical practice sessions and at home the participant listened to a 10 minute tape of the task practiced before • Three tasks were practiced, each for 2 weeks (reaching and grasping object, turning page and reaching and grasping item on high shelf) • Imagery from a third-person perspective The tape consisted of: 1. relaxation (2-3 min) 2. suggestions for internal cognitive visual images as well as sensations (5-7 min) 3. refocusing (2 min)	Participants were taken through the visual images of the task	Participants were taken through the visual images as well as the sensations	Not reported	Not reported	Progression consisted of changing the task	Not reported

Table 3 (continued). Overview of the motor imagery techniques and components.

Reference(s)	Summary/ instructions	Movement sequence	Response propositions	Success	Imagery ability	Progression	Temporal aspects
Page et al. 2001[63]	• After the physical practice sessions and at home the participant listened to a 10 minute tape of the task practiced before • Three tape scripts were practiced The tape consisted of: 1. relaxation (2-3 min) 2. suggestions for external cognitive visual images related to affected arm in functional tasks (5-7 min) 3. refocusing (2 min)	Not reported	External imagery was used so no response propositions possible, but instructions are feel your arm and fingers extending as you reach for the cup	Not reported	Not reported	Progression consisted of changing the task	Not reported
Page et al. 2005[67]	• After the physical practice sessions the participant listened to a 30 minute tape of the task practiced before • Three tasks were practiced, each for 2 weeks (reaching and grasping object, turning page and proper use of a pencil or pen) The tape consisted of: 1. relaxation through imagining themselves in a warm, relaxing place and through progressive muscle relaxation (5 min) 2. suggestions for internal cognitive polysensory images related to using the affected arm in the functional task corresponding to the weeks (20-22 min) 3. refocusing (3-5 min)	Not reported	Suggestions for internal cognitive polysensory images were given	Not reported	Not reported	Progression consisted of changing the task	Not reported
Page et al. 2007[134]	• After the physical practice sessions the participants listened to a 30 minute tape on of the task practiced before • Three tasks were practiced, each for 2 weeks (reaching and grasping object, turning page and using writing utensil) The tape consisted of: 1. relaxation (5 min) 2. internal, cognitive polysensory imagery with mental rehearsal of tasks (first describing the setting, then taken through visual image of task as well as sensations) (20 min) 3. refocusing into room (5 min)	Participants were taken through the visual images of the task	Participants were taken through the visual images as well as the sensations	Not reported	Not reported	Progression consisted of changing the task	Not reported

Table 3 (continued). Overview of the motor imagery techniques and components.

Reference(s)	Summary/ Instructions	Movement sequence	Response propositions	Success	Imagery ability	Progression	Temporal aspects

Verbunt et al. 2008[132]	• Patient is educated as to basic imagery principles and the importance of regular imagery training in increasing therapy success
	• In the first week patient will be taught how to use the MI technique to improve arm function by the OT
	• A training task tailored to the functional level of the individual patients will be selected by the OT
	• Five different MI training tasks derived from the Frenchay Activities Index are available with gradually increasing difficulty
	• For all tasks a training DVD will guide the patient
	• Each DVD is programmed in 3 steps starting with a relaxation task to focus attention and performance of all activities is shown from a 1st person perspective
	  o Step 1; correct task performance is shown on screen combined with a verbal explanation. 5 repetitions.
	  o Step 2; task performance is repeated on screen but without verbal explanation; patients are asked to mentally practice the movement. If they are able to actually perform (part of) the task, they may do so concurrently with the imagination of the movement. 5 repetitions.
	  o Step 3; no guidance during the task performance is given except a visual and verbal cue indicating the end of the task performance over 5 repetitions. Patients already familiar with this task can immediately start on step 2
	• DVDs are available for every task for R and L handers
		Correct task performance was shown on screen combined with a verbal explanation	Not reported	Not reported	Not reported	Functional arm/hand progress was evaluated by the OT every 2 weeks; if functional level improved, a new task was chosen	Not reported

Legend: OT, Occupational Therapist; min, minutes; R, right; L, left

DISCUSSION

This chapter investigates the specific content and application of motor imagery interventions used in patients with stroke, traumatic brain injury or multiple sclerosis by reviewing the literature. A variety of skills are described in the studies found in this review; ranging from functional tasks such as gait[71, 133] and drinking from a cup[67, 69, 134] with relatively large cognitive components to basic motor skills such as shoulder rotation.[63] Most articles report practicing up to 3 tasks. Only the two studies performed by Liu et al[66, 70] used more tasks (i.e. 10), including mobility, balance and upper limb tasks. It was only these two studies that employed a structured outline of the imagery process applicable to almost any task.

Interestingly, most articles describe demonstration of the correct performance of a skill, for example by using picture cards and videos. However, only a few articles report checking that the imagined performances were correct or have made an effort to improve imagery control.

Frequency, dosage, repetitions and duration varied greatly between the articles. Delivery methods were usually verbal or taped. Only Verbunt et al.[132] employ DVD recordings. Most articles report using motor imagery as separate sessions, instead of alternating it with physical practice. Instead, it was often used in combination with other techniques such as mirrors, picture cards and video recordings.

In one of the studies by Page et al.[64] the authors describe using imagery from a third person perspective but also report using kinaesthetic imagery at the same time. This is contradictory because it is generally agreed that one can only use visual imagery, and not kinaesthetic imagery, from a third person perspective.

Fell[130] reports using various types of imagery in her case report such as imagining birds and animals that demonstrate excellent balance in order to improve the patient's balance. This type of *metaphoric* imagery should not be classified as motor imagery.

Motor imagery interventions in neurological rehabilitation are generally described poorly. Because no interventions or components of interventions were compared it is impossible to conclude which intervention or which components should be preferred. Future research should be more specific in reporting the interventions in order to translate the research into treatment concepts and comparisons should be made in order to discern preferable techniques.

This review confirms that limited evidence from sports psychology and fundamental research has found its way into motor imagery interventions in neurological rehabilitation. Not many studies apply techniques from these other fields in their motor imagery interventions. For example, in most studies imagining the task correctly does not appear to be important, suggesting that imagining the task incorrectly would also lead to improved performance, which is very unlikely, or; improvement of the temporal aspects of tasks are not targeted in order to shorten the time to perform the tasks.

This lack of transfer of knowledge suggests that there is room for optimising the effectiveness of motor imagery in neurological rehabilitation. Future clinical research should consider maximising its potential and should collaborate with other experienced disciplines (e.g. sports psychology).

This review highlights that most motor imagery interventions lack a theoretical framework; it has been suggested that any intervention should have a conceptual structure to outline the course(s) of action and to model processes.[14, 35, 135]

There is no definite guidance on motor imagery interventions for neurological populations. However, there is a large body of evidence on acquiring motor skills and motor adaptation under the term *motor learning*.[107, 108, 136, 137] Because of the similarities in neural networks between physical practice and motor imagery[94-96] and because of the positive effects of motor learning from the sports and fundamental research literature,[107, 108, 138] motor learning would be a good base for motor imagery interventions. Motor learning is defined as; the changes in behaviour as a result of practice or experience and takes place when the skill is retained and results in a relatively permanent change in behaviour (i.e. motor skill), as opposed to an impermanent short-lived change in behaviour. The behaviour that is observed in this case is motor performance.[108, 139]

It should be noted that although a review investigating the content and application of motor imagery interventions in neurological rehabilitation was performed; it was not a systematic review of the effectiveness of motor imagery in neurological rehabilitation. Neither was it a systematic review of the motor imagery techniques and other important components discerned from other literature than neurological rehabilitation (e.g. sport psychology). A meta-analysis is required to investigate the effectiveness which was impossible due to the wide variety in interventions, tasks and outcome measures. Some of the major techniques and components have been recognised by the researcher in this thematic review, however, this selection is not confirmed and is incomplete and limits the conclusions of this review. Because, to my knowledge, there is no evidence on the optimal content of motor imagery interventions for neurological rehabilitation the performed search was as comprehensive as possible. However, studies may have been missed because the criteria were limited to publications in English and in people with stroke, multiple sclerosis or brain injury. Literature in other languages and other neurological populations may add to the evidence. Moreover, the literature search and review was performed by only one person whose results should be verified by another researcher. Also, studies may have been missed that have used different terminology from motor/mental imagery.

Studies requiring the use of specialised equipment were excluded from this review as the aim was to evaluate clinically applicable motor imagery and most clinics do not have the availability of equipment such as force plates and/or virtual-reality equipment. Studies using this kind of equipment may provide interesting additional information of the content of motor imagery interventions, but this would blur clinically used motor imagery interventions and was not further considered in this review.

In conclusion, only a very limited amount of evidence from sports psychology and fundamental research has found its way into motor imagery interventions for people with neurological conditions. This is probably because there is no clear guidance on how to apply motor imagery in neurological populations. Motor imagery interventions in neurological rehabilitation so far have been sub-optimal and the full theoretical potential of motor imagery has not been reached yet. The review provides insight into practical applications and techniques and components that can be used in motor imagery interventions, however, a more comprehensive review of the techniques and components that were chosen here may be beneficial. The evidence for specific motor imagery methods is limited but a theoretical foundation can be build using evidence from sports psychology, fundamental research and from motor learning literature.

In the literature search no studies were found that employed motor imagery in the treatment of spasticity. The next chapter describes a pilot randomised controlled trial using motor imagery in the treatment of spasticity in order to gain experience in employing motor imagery in clinical populations, to investigate the characteristics of some outcome measures and to investigate whether motor imagery can be used in the treatment of spasticity. A simple motor imagery strategy was developed in order to use it in any patient for the treatment of any limb.

Chapter 3

Motor Imagery during Stretching in Spasticity

Publications relevant to this chapter:

- Bovend'Eerdt TJH, Dawes H, Sackley C, Izadi H, Wade DT. Mental Techniques During Manual Stretching in Spasticity - a Pilot Randomised Controlled Trial. Clin Rehabil 2009:23(2);137-45
- Bovend'Eerdt TJH, Newman M, Barker K, Dawes H, Minelli C, Wade DT. The effects of stretching in spasticity: a systematic review. Arch Phys Med Rehabil 2008:89(7);1395-406

SUMMARY

This chapter reports a pilot study investigating the feasibility and effects of using motor imagery during therapeutic stretching in individuals with spasticity. Eleven patients with spasticity who received regular stretches of the arm participated in this randomised single-blind controlled pilot trial. In addition to their normal stretching routine, patients in the experimental group (n=6) received motor imagery during their stretches, whereas the control group (n=5) received progressive muscle relaxation during their stretches. No significant differences were found between the experimental and the control group on resistance to passive movement, range of movement, the Modified Ashworth Scale and the patient's level of discomfort. Experiences from this study have guided the development of the motor imagery intervention (chapter 6), the development of the primary outcome measure (chapters 4 and 5) and the utilisation of this intervention and outcome measure in a larger scale randomised controlled trial investigating the effects of motor imagery on motor performance (chapter 7).

INTRODUCTION

Spasticity is defined as involuntary muscle tightness and stiffness, which is velocity-dependent and associated with increased resistance to passive muscle stretch. The term includes a wide variety of phenomena that form part of the 'upper motor neurone syndrome' observed when descending motor pathways are damaged.[38, 140, 141] Spasticity is common in neurological conditions such as stroke, brain injury and multiple sclerosis with the prevalence varying between 19 and 70%.[43, 142-144] Spasticity is often associated with painful stiff joint movements affecting everyday functioning, physical activity levels, quality of life[144-146] and a greater carer burden.[147]

The care of subjects with spasticity is complex and currently many techniques are used in its management[25, 38, 40, 148-150] with no clear treatment approach.[151, 152] Current techniques include pharmacological management, injection of botulinum toxin, destructive techniques such as tenotomy or phenol injection into a nerve, insertion of a baclofen pump, orthotic prescriptions, exercise and stretching exercises.[30, 38, 40, 140, 153] Stretching is one commonly used approach that can be delivered by therapists, patients or carers in both domestic and clinical environments. The effectiveness of stretching interventions may be affected by the degree of discomfort felt by the person being stretched and the degree of required effort of the therapist or carer to produce a stretch.

A carer of a patient locally reported that stretching could be more comfortably and effectively delivered if performed whilst simultaneously imagining the movement led to consideration of this pilot study. This observation could be substantiated by studies in healthy people which have shown that if a visual input concerning the movement of a limb conflicts with the proprioceptive input, people experience marked pain. For example, if someone believes (through visual input) that their fingers are flexing (by using mirrors) while someone else is in fact extending them, they feel pain.[154]

In this pilot study it was hypothesised that discomfort on stretching spastic limbs might be reduced if the patient's internal representation coincides with the passive movement. Motor imagery is suggested to facilitate attainment of movement in patients after stroke,[66, 69, 155] however, to date there is limited evidence of its use in people with neurological conditions who present with cognitive, sensory and motor difficulties.[8] Studies show that imagery ability is reduced in elderly subjects[123, 156] and clinical reports from stroke subjects reveal difficulty imagining 'normal' performance of skills.

Considering the lack of high quality evidence for using motor imagery during stretching in order to estimate appropriateness and sample size for a phase II study, this study examined the feasibility and effect of using imagery during stretching and the integrity of the spasticity outcome measures in a small number of individuals with a range of impairments presenting with spasticity. The feasibility results would be used to design a phase II randomised clinical trial (chapter 7) investigating the effectiveness of a service-delivered motor imagery programme on functional motor recovery in a neurological population.

METHODS

A randomised controlled trial design with masked assessment was carried out in a specialist Neurological Rehabilitation Unit. A randomised controlled trial was chosen as it is the most rigorous design to determine a cause-effect relation between treatment and outcome.[157] This study was approved by the Oxfordshire ethics committee (reference nr 06/Q1604/93).

Procedure

Figure 3 shows a flowchart of the study design and the assessments. Patients were recruited through referrals from consultants and physiotherapists working with neurologically impaired patients in hospital or in the community. Patients expressing an interest were given written information after which they were contacted in person or by phone to answer any questions and discuss procedures after which they were screened for suitability.

Suitable patients were assessed by an independent assessor after which they were randomised to Motor Imagery or Progressive Muscle Relaxation using a computer-generated sequence. Group allocation was revealed to the treating therapist after baseline assessment.

Participants

Participants were eligible if:

they had spasticity (due to stroke, multiple sclerosis, brain injury or other acute insults of the brain) in at least one arm requiring stretching as part of the participant's normal treatment routine;

1. they had sufficient language and cognitive skills to follow a two-stage command (e.g. tap your chair twice while looking at the ceiling);
2. they were in a relatively stable phase of their illness, usually not within 2 weeks of any sudden change;
3. they were 18 years of age or older, and;
4. they gave informed consent.

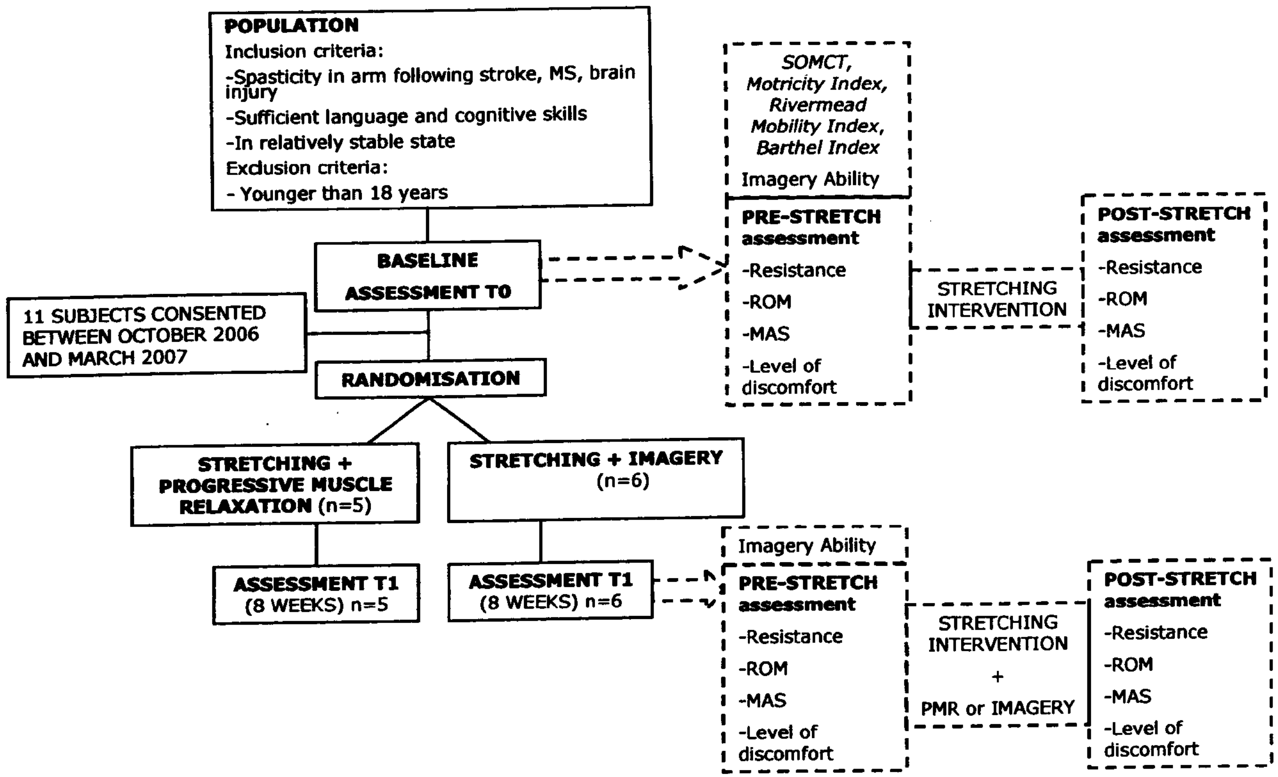

Figure 3. Flowchart of the study design and the assessments.
Legend: SOMCT, Short-Orientation-Memory-Concentration Test; ROM, Range of Movement; MAS, Modified Ashworth Scale; PMR, Progressive Muscle Relaxation.

Assessments

Patients were assessed at baseline and after 8 weeks by a researcher masked to group allocation. The baseline assessment consisted of the:

- Barthel Index, a 10-item generic ADL assessment with higher scores representing greater independence (score range 0-20);[158]
- Short-Orientation-Memory-Concentration Test (SOMCT), a short and simple test comprising of 6 questions covering cognitive areas such as orientation, concentration on a short task and learning and recalling some simple information (score range 0-28);[159]
- Motricity Index, assessment of general motor function with scores based on the MRC strength grades. The higher the score the less motor impaired (score range 0-100);[160]
- Rivermead Mobility Index, comprising of 14 questions and 1 direct observation with higher scores representing better mobility (score range 0-15).[161]

A more detailed description of the Barthel Index, Short-Memory-Orientation-Concentration Test, Motricity Index and Rivermead Mobility Index is presented in appendix 1.

Both at baseline and after 8 weeks the patient's Imagery Ability was assessed. The Imagery Ability questionnaire was a custom designed questionnaire consisting of 4 items based on the Movement Imagery Questionnaire developed by Hall et al.[162] The patient was asked to score the ability to imagine on the visual and kinaesthetic domain on a 7-point scale, 1 being 'very hard to see/feel' and 7 being 'very easy to see/feel.' Because some neurological patients might not be able to actually perform the movement and because the intervention in this study was a passive movement; the investigator performed the movement for the patient. The questionnaire was administered in the following way:

- The patient was sitting in a (wheel)-chair or at the bedside with the legs supported.
- The investigator performed the passive shoulder abduction/ hip flexion movement while the patient relaxed.
- The patient was asked to see/ feel the movement and rate the ability to do accordingly.
- A consistent set of instructions was used.

The assessor undertook the measures before and after a stretching intervention. Because there is no one outcome measure for spasticity[163] a selection of measures were used:

- Resistance to passive movement, assessed using a handheld dynamometer (Biometrics Ltd, Gwent, UK).
- Range of Movement, assessed using an electro-goniometer (Biometrics Ltd, Gwent, UK);
- Modified Ashworth Scale;[164]
- Level of discomfort (0-10 rating scale) on performing the Modified Ashworth Scale.

Although the biomechanical device, measuring resistance to passive movement and range of movement, showed good construct validity[165] and resistance to passive movement proved to be an objective measure,[166] the reliability of this method has not been established yet.

The Modified Ashworth Scale was measured by giving a slow movement of the arm through its full range, during which the range of movement was measured, followed by a brisk movement going through its range while counting 'one thousand one,' during which the maximum resistance was measured. The Modified Ashworth Scale was then scored accordingly, from 0-4. The electro-goniometer was placed on the lateral side of the elbow and the torque transducer was placed on the distal part of the forearm, as described by Pandyan et al.[165, 167] The anvil of the torque transducer was attached to a splint that participants wore, to standardise for the position. Level of discomfort was assessed on a 0-10 scale; 0 being no discomfort, and 10 being the worst imaginable discomfort.

The researcher used an informal interview to evaluate the motor imagery intervention and compliance with the therapist, the carer and/or the carer.

Interventions

The participant, the therapist and/or the carer were taught the specific techniques (described below) by a research therapist in addition to the normal stretching routine. The therapists were taught both techniques in a one hour session. The participant and carer were taught only the technique they were to use in a 15 minute session with the research therapist. During the intervention period the research therapist informally evaluated the intervention with the participant, the therapist and the carer and the intervention was adjusted if necessary. The interventions were defined in standard operating procedures. Participants were prompted to practice the techniques outside stretching sessions.

During *Progressive Muscle Relaxation* the participant was instructed to tense his/her muscles, preferably on the unaffected side, for several seconds (usually 5-10 seconds), then relax and feel the tension flow out of the body. The unaffected side was chosen to avoid the potential risk that tensing of the affected side might increase spasticity. In participants that had no voluntary contraction in any limb, neck, facial and tongue contractions were performed. During the relaxation the stretch was performed.

During *Motor Imagery* the participant was instructed to close their eyes and imagine their limb in their mind's eye and then imagine that they themselves moved the limb to its end range and kept it there. While the participants imagined that they were doing the movement the therapist/carer performed the stretch.

Both techniques consist of 4 steps which were taught to the therapist/carer, namely:

	Progressive Muscle Relaxation	*Motor Imagery*
1.	Name the body part that will be stretched	Name the body part that will be stretched
2.	Tense the muscles	Picture, see and feel, your limb
3.	Relax your body	Move the limb, see and feel, in your mind
4.	Apply the stretch	Apply the stretch

Stretches were held at end range for 10-30 seconds, with three repetitions per stretch. The end range was determined by the resistance felt and the level of comfort being bearable. Any other spasticity management techniques were recorded.

Data analysis

Range of movement and resistance to passive movement were recorded and analysed off-line. Range of movement was the total range of the electro-goniometer during the slow movement, in degrees, and resistance to passive movement was the maximum force recorded during the brisk movement, in kilograms.

Pre-stretching measurements of the Imagery Ability, resistance, range of movement, Modified Ashworth Scale and level of discomfort were used to examine the effect of the 8 week program. Pre- to post-stretching scores of resistance, range of movement, Modified Ashworth Scale and level of discomfort were calculated by deducting post-stretching measurement data from pre-stretching measurement data to examine the effect size within one stretching session.

Between-subjects one-way ANOVA was used to compare the groups at baseline on the Rivermead Mobility Index, the Short-Orientation-Memory-Concentration test, the Motricity Index and the Barthel Index. A mixed ANOVA design was used to analyse the imagery ability questionnaire at baseline and 8 weeks. A mixed ANOVA design was also used for both the pre-stretching and pre- to post-stretching scores of the following measures: resistance, range of movement, Modified Ashworth Scale and level of discomfort. The within-subjects factor of time had two levels (baseline assessment, 8 week assessment) and the between-subjects factor of group had two levels (control group, experimental group). The non-parametrical equivalents of these tests have been performed as well but did not show any different results from the parametrical tests. Only the F-tests are reported here because they are known to be robust statistical tests. The significance level for all tests was set at, $p<0.05$. Where the assumptions were not met the appropriate test solution was adopted. A complete case analysis was performed using the statistical software package SPSS v 12.0 (SPSS inc, Chicago, USA).

RESULTS

Table 4 presents participant characteristics and group allocation. No significant differences between the groups were found for these variables. Six participants were allocated to the Motor Imagery group and five to the Progressive Muscle Relaxation group. One participant (nr. 1) was not able to complete both assessments due to communication problems. No data were fitted in this case.

Table 4. Participant characteristics and group allocation.

Group Allocation	**Case Number**	**Sex** (Male/ Female)	**Age** (years)	**Diagnosis**	**Diagnosis Onset** (Months)
Progressive Muscle Relaxation	1	F	40	MS	255.5
	3	M	33	Stroke	1.7
	6	M	59	Stroke	233.0
	7	M	35	Brain Injury	4.5
	11	F	62	Stroke	16.3
	Mean (SD)		45.8 (13.7)		102.2 (130.0)
Motor Imagery	2	F	54	MS	365.0
	4	M	73	Stroke	5.7
	5	F	69	Stroke	2.5
	8	M	21	Brain Injury	4.1
	9	F	63	MS	292.0
	10	F	36	MS	36.5
	Mean (SD)		52.7 (20.3)		117.6 (165.4)
Total	Mean (SD)		49.5 (17.2)		110.6 (143.2)

Legend: F, Female; M, Male; MS, multiple sclerosis.

Baseline scores on the Barthel Index, the SOMCT, the Rivermead Mobility Index, the Motricity Index and the Modified Ashworth Scale are presented in table 5. The substantial difference between the control and experimental group on the mean Motricity Index scores (which reached significance) suggests that the Progressive Muscle Relaxation group had better general motor function at baseline than the Motor Imagery group.

Table 5. Descriptive data of the participants at baseline on the Barthel Index, the Short Orientation-Memory-Concentration Test, the Rivermead Mobility Index, the Motricity Index and the Modified Ashworth Scale.

Group Allocation	Case Number	Barthel Index	Short Orientation-Memory-Concentration Test	Rivermead Mobility Index	Motricity Index	Modified Ashworth Scale
Progressive Muscle Relaxation	1	0	-	0	17	1+
	3	19	22	14	73	1
	6	15	28	10	59	2
	7	6	13	2	75	1
	11	20	28	14	40	1
	Median	*15*	*25*	*10*	*50**	*1*
	Range	*0-20*	*13-28*	*0-14*	*17-76*	*1-3*
	(IQR)	*(17)*	*(13)*	*(13)*	*(46)*	*(2)*
Motor Imagery	2	7	25	3	19	1
	4	12	22	6	14	0
	5	5	14	1	11	1
	8	3	0	3	11	1+
	9	1	26	0	0	1
	10	20	28	13	64	1
	Median	*5*	*23.5*	*3*	*13**	*1*
	Range	*1-20*	*0-28*	*0-13*	*0-64*	*0-2*
	(IQR)	*(12)*	*(16)*	*(7)*	*(22)*	*(1)*
Total	*Median*	*7*	*23.5*	*3*	*20*	*1*
	Range	*0-20*	*0-28*	*0-14*	*0-76*	*0-3*
	(IQR)	*(17)*	*(14)*	*(12)*	*(53)*	*(1)*

Legend: IQR, Inter-quartile Range; *, significant difference on between-groups ANOVA ($F_{(1,9)}$ = 5.394, P=.045).

The pre-stretching data and the difference scores are presented in tables 6 and 7, respectively. For the pre-stretching data the main effect of time on the imagery questionnaire was significant ($F_{(1,8)}$ = 8.891, P=.018). No significant difference was found on any of the difference scores.

Table 6. Pre-stretching data on the resistance during the Modified Ashworth Scale, the electro-goniometer, the Imagery ability questionnaire, the Modified Ashworth Scale and discomfort level at baseline (T0) and at 8 weeks (T1).

		Progressive Muscle Relaxation group		Motor Imagery group	
		T0	**T1**	**T0**	**T1**
Resistance	*Mean*	5.16	5.51	4.33	3.88
	(SD)	*(3.33)*	*(1.10)*	*(1.93)*	*(1.03)*
Electro-Goniometer	*Mean*	118.69	119.30	129.90	112.65
	(SD)	*(17.04)*	*(21.80)*	*(12.05)*	*(19.97)*
Imagery Ability*	*Median*	19	19	18.5	22.5
	(Range)	*(13,25)*	*(14,28)*	*(10,19)*	*(18,26)*
MAS	*Median*	1	2	1	2
	(Range)	*(1,3)*	*(1,4)*	*(0,2)*	*(1,3)*
Discomfort	*Median*	0	0	3	1
	(Range)	*(0,6)*	*(0,5)*	*(0,6)*	*(0,2)*

Legend: SD, standard deviation; MAS, Modified Ashworth Scale; T0, baseline assessment; T1, assessment at 8 weeks; *, significant difference on ANOVA between T0 and T1 ($F_{(1,8)}$ = 8.891, P=.018). Range of movement is represented in degrees and resistance in kilograms.

Table 7. Difference scores between pre-stretching and post-stretching data on the resistance during the Modified Ashworth Scale and the electro-goniometer on the Modified Ashworth Scale and discomfort level at baseline (T0) and at 8 weeks (T1).

		Progressive Muscle Relaxation group		Motor Imagery group	
		T0	**T1**	**T0**	**T1**
Resistance	*Mean*	-.71	-.32	-.64	-.35
	(SD)	*(1.03)*	*(1.38)*	*(.85)*	*(1.89)*
Electro-Goniometer	*Mean*	-5.71	1.37	3.09	4.13
	(SD)	*(20.34)*	*(14.59)*	*(17.91)*	*(19.24)*
MAS	*Median*	0	0	0	-1
	(Range)	*(0-0)*	*(0-1)*	*(0-1)*	*(0-1)*
Discomfort	*Median*	0	0	-0.50	0
	(Range)	*(0,5)*	*(0,1)*	*(-1,3)*	*(-5,1)*

Legend: SD, standard deviation; MAS, Modified Ashworth Scale; T0, baseline assessment; T1, assessment at 8 weeks. Range of movement is represented in degrees and resistance in kilograms. Difference value = post-stretching value – pre-stretching value.

Sample size calculation

Because resistance to passive movement is the construct measured according to the definition of spasticity[166] and because it can easily be measured in the clinical setting it was chosen in this study as the outcome measure to calculate the post-hoc sample size. The power and level of significance were chosen by convention, generally 80% (β=0.20) and 5% (α=0.05), respectively. The mean value (SD) for resistance to passive movement at baseline in this pilot study was 4.70 (1.73). A change of 20% on resistance to passive movement was considered as clinically significant resulting in $\mu1$= 0.94 and σ=1.73. The sample size calculation formula used for measuring the difference between two unpaired samples is:

$$N1 = N2 = (z_{1-\beta} + z_{1-\alpha/2})^2 * ((\sigma_1^2 + \sigma_2^2) / (\mu_1 - \mu_2)^2)$$

$$(0.85 + 1.96)^2 * ((1.73^2 + 1.73^2) / (0.94 - 0.0)^2) = 54$$

This suggests that we should have at least 54 patients in each group, experimental and control group, to show a significant difference on the resistance to passive movement measure.

Feasibility

Informal post-intervention interviews revealed that there was a large variety in the delivery and amount of the intervention. In some cases the therapist, carer or even the patient self performed the intervention. They all found that they could give the instructions, or in the case of the self-stretch, do the motor imagery practice, easily, while doing the stretching exercises. Some patients received stretches daily, usually from their carers, while others received stretches only once a week thus dose varied between 8 and 56 sessions. Compliance was hard to determine and control.

DISCUSSION

In this pilot trial, motor imagery therapeutic stretching in individuals with spasticity was investigated. Motor imagery during stretching was well tolerated by all participants, including those with cognitive and physical deficits, and easily incorporated into stretching by their therapists and carers. Motor imagery appears to be a feasible technique for use during stretching exercises in individuals with spasticity. This study found a positive trend and a post-hoc sample size calculation suggests that a future study would need to recruit 54 participants per group to show a significant effect of imagery during stretching. Our findings support future research examining the use of motor imagery during stretching interventions in people with neurological conditions.

The research population varied considerably regarding age, diagnosis, stage of the disease, functional level, cognition, general motor function and spasticity level. The significant difference that was found between the Progressive Muscle Relaxation and Motor Imagery group on the Motricity Index suggests that the Progressive Muscle Relaxation group had better general motor function. However, it is unlikely this has affected our primary results.

There were no drop outs but some data were missing. Therefore a complete case analysis, rather than an intention-to-treat analysis, was performed.

The diverse population does suggest that motor imagery can be easily used by a variety of people. It remains unclear, however, who benefits most (if anyone) from performing motor imagery during their stretches and this could be explored in future research.

It has been suggested that there is not one single measure that quantifies spasticity appropriately and that a combination of measures should be used.[165] However, resistance to passive movement has been used regularly in studies to measure spasticity[165-167]; it is an objective outcome measure compared to the MAS; and it directly measures the resistance to a passive movement which is the construct of the definition of spasticity (muscle tightness and stiffness which is velocity-dependent and associated with increased resistance to passive muscle stretch). Due to the lack of a better outcome measure resistance to passive movement was chosen in this study to calculate the post-hoc sample size. In this study we also measured the subject's level of discomfort when performing the Modified Ashworth Scale. Vergeer et al.[168] have also measured the subject's level of discomfort on the stretching exercises in healthy subjects. It seemed to be a valuable outcome measure and should be considered in future research.

Vergeer and colleagues[168] have examined the effect of motor imagery during stretching on flexibility in healthy subjects. They found that the psychological effects of the imagery were stronger than the physiological effects, i.e. there was no difference between groups in range of movement but the level of comfort was better in the group that performed motor imagery. Motor imagery has proven to be effective in the management of pain.[169, 170] Because stretching exercises, particularly in subjects with spasticity, cause discomfort in many cases, motor imagery could be a very useful technique for the individual with spasticity, who often just has to endure the pain. Moreover, less discomfort/ pain during stretching exercises could lead to more effective stretches which could improve range of movement and/ or spasticity.

In informal interviews, during and after the intervention period, the participants, therapists and carers reported that motor imagery during routine stretches was easy to learn and could easily be incorporated in a normal stretching routine. The subjects who were using motor imagery appeared to increase their imagery ability. Participants reported the motor imagery as pleasant, easy to use and used the technique outside stretching sessions. Particularly, individuals enjoyed actively participating in their treatment by focusing on their stretched limb using the imagery technique instead of being handled passively. Higher level participants reported boredom with the intervention, with some individuals struggling to maintain concentration.

Although there was no significant change in the outcome measures a decrease in resistance and discomfort in the Motor Imagery group can be observed (table 3). Interestingly, at baseline only one person decreased 1 point on the Modified Ashworth Scale. At 8 weeks, five participants decreased one point on the Modified Ashworth Scale, of which four were from the Motor Imagery group. There is a trend visible in favour of motor imagery.

Implications for this thesis

Two major results from this pilot study directed the development of this thesis. First it was the need for an outcome measure that could be utilised for any patient. Characteristics of patients with neurological damage or disease vary widely and there is not one outcome measure that can evaluate these characteristics. Most standardised measures have: floor and/or ceiling effects; lack sensitivity, and/or; they do not measure parameters important to the patient.[171] This means that these measures are only suitable for a select group and will probably not pick up relevant changes. Chapters 4 and 5 of this thesis address some of these issues by assessing the use of goal attainment scaling in neurological rehabilitation.

Another central observation was the importance of a standardised intervention protocol for motor imagery as people reported performing the intervention slightly differently. Motor imagery is a complex intervention and it has been recommended that all complex interventions need a framework and a standardised protocol.[14, 135] A complex intervention needs a theoretical foundation and should be standardised in order for it to be repeated and developed into guidelines.[35]

There is currently no protocol for using motor imagery in neurological populations. A protocol should include a theoretical framework and should define standard procedures and the course of action when using motor imagery; however, it should allow room to:

- be applied to a wide range of patients, as patients with different levels of physical and cognitive functioning will have to use it;
- be applied to almost any activity, as patients have different aims and goals; and

- be adapted to the patient's progression, as patients get better over time and with therapy.

The protocol should also be easy to use by clinicians as well as patients and should be easy to implement in current practice. Chapter 6 of this thesis discusses the development of a motor imagery protocol to improve motor function in neurological rehabilitation. The actual protocol is presented in appendix 2.

Chapter 7 of this thesis is where these two issues come together and are employed in a randomised controlled trial.

Chapter 4

Goal Attainment Scaling: Method Development

Publications relevant to this chapter:

- Bovend'Eerdt TJH, Botell RE, Wade DT. Writing SMART Rehabilitation Goals and Achieving Goal Attainment Scaling; a Practical Guide. Clin Rehabil 2009:23(4);352-361

SUMMARY

Goal setting in rehabilitation and particularly the writing of 'good' goals is reported to be a difficult, time-consuming and unwieldy process. One definition of a 'good' goal is one that is specific, measurable, achievable, realistic/ relevant and timed (SMART). This chapter describes a method for writing SMART goals for goal attainment scaling. This method may make it easier to set and write good goals and also standardises the method of goal attainment scaling, a way of setting individual goals that nonetheless can be compared between patients or groups of patients.

INTRODUCTION

Many patients attending rehabilitation services have multi-factorial, complex problems that often require several or many different interventions to be given by different people, frequently in a specific sequence. Rehabilitation is the archetypical 'complex intervention' comprising a multitude of complicated activities and actions. It is a problem-solving process delivered by a multi-professional team and standard, single treatment packages are rarely, if ever, appropriate.[172] In this context a goal-planning process should be used to ensure that all the people involved, especially the patient, agree on the goals of rehabilitation, on the methods to be used to achieve these goals, and on each person's role in this process.[173]

It is also well recognised that goal setting is an effective way of achieving behavioural change in people.[174, 175] Some of the characteristics of goals that effectively alter behaviour are that the goals: should be relevant to the person concerned, should be challenging but realistic and achievable, and should be specific (in order to measure them).[176] These characteristics are often abbreviated with the acronym SMART (Specific, Measurable, Achievable, Realistic, Timed).[177]

Every patient has different aims and goals; some would like to be able to walk again whereas others would like to become independent in toilet use. Most outcome measures investigate only one domain, for example, mobility. Goal attainment scaling offers one outcome measure to investigate any domain.

Goal attainment scaling is a method for evaluating the attainment of goals. It is particularly dependent on defining goals that are measurable,[177] which is not always easy because each goal requires several different levels to be defined. Yip and colleagues[178] developed standardised goal attainment scaling menus to address the difficulties associated with writing multiple goals. However, these menus may be at the cost of some of the advantages of goal attainment scaling, such as its client-centred and individual approach.

For the randomised controlled trial investigating motor imagery (chapter 7) individualised specific goals were needed for the primary outcome measure (i.e. goal attainment scaling). For this trial goals must:

- be individualised to a particular patient;
- be written without too much effort, time or specific training;
- allow accurate, unambiguous determination of goal achievement;
- be flexible enough to cover most situations.

The method described in this chapter for writing SMART goals can be used to write better goals for Goal Attainment Scaling.

Background assumptions

This method is based on four assumptions set by the researcher. Firstly, it will consider rehabilitation as taking place within the pre-eminent (biopsychosocial) model of illness used in rehabilitation, namely an expanded version of the World Health Organisation's International Classification of Functioning, Disability and Health (WHO ICF) model, described in chapter 1.[20]

It then assumes that rehabilitation goals will usually be set around observed behaviours at the ICF level of activities. This does not deny the importance of other goals concerning the patient's personal experiences or the patient's context (personal, physical or social). Indeed it should be possible to use or adapt this method for goals in those realms. However, the method described here focuses on activities because they are most easily defined, and they are of most concern to the patient and to this research.

Third, the description assumes that preliminary work with the patient (and relevant other parties) has already established necessary background information: the patient's wishes and expectations, and all the additional information needed. Goals are set in the realms that are of interest to the patient and to the context of this thesis. It is also important to know sufficient other information to ensure that the goal is potentially achievable and to identify the actions needed to achieve the goal. In other words, this method is only a part of the complete rehabilitation process.

Thus, finally, this method assumes that the therapists will only set goals that are attainable and realistic for the patient to achieve.

Goal attainment scaling - introduction

Goal attainment scaling is the term used to describe a simple method of scoring (quantifying) the achievement of goals. Rather than simply stating that a goal has or has not been achieved, attainment scaling recognises that sometimes achievement exceeds expectation, whereas at other times achievement is less than expected but nonetheless there is some progress towards the goal, and (rarely) there may be no progress towards goals set, or even deterioration.[171, 179]

Goal attainment scaling is a structured approach to recording goal achievement and was first introduced in the 1960s by Kiresuk and Sherman[179] within a mental health service. The approach is based on predicting the expected goal to be achieved, accompanied by two states above the expected outcome and two states below, one of which is usually the current (or 'baseline') state.

The process of goal attainment scaling was chosen here because it is already reasonably well researched with evidence that it is at least as sensitive as a measure of change as other standardised scales.[180] Furthermore the scoring system can be adapted to take into account variables such as the difficulty of achieving a goal and the patient's priority, and the scoring system can encompass more than one goal but still give a single outcome value which makes it very useful for this thesis.

Process of method development

It is not necessarily easy to write good goals and it has been reported to be a time-consuming and unwieldy process.[178] The additional challenge when using goal attainment scaling in particular is to write a series of five well-defined potential states.

A meeting was convened with clinicians from each discipline (consultant, nurse, physiotherapist, occupational therapist, speech and language therapist, psychologist) and the researcher. The researcher had previously performed an inventory of recently developed physiotherapy goals (184 goals from 22 patients). The aim of the meeting was to develop a menu of goals, similar to the paper by Yip and colleagues[178], specifically for the research population at the Oxford Centre for Enablement. A start was made to create this menu and the goals were categorised into obvious recurring functions and activities, for example transfers, posture, ambulation, stairs, arm function, pain and range of movement. Table 8 shows an example of this for the functions/ activities: transfers, posture and arm function.

Table 8. Example of initial goal menu.

Transfers	Posture	Arm function
For X to perform (frequency) sit-stands from a (height) plinth weight-bearing through both legs.	For X to tolerate standing in a (equipment) (level of independence) (method) whilst performing UL activities for (duration).	For X to be able to increase arm function to (level of outcome measure).
For X to be confident and safe in sitting-standing (standing-sitting) with(out) (equipment) (level of independence).	For X to tolerate forward lean sitting in (posture; e.g. nose above knees) as preparation and progression of sit-stand for (duration) (level of independence).	For X to improve the dexterity in (side) hand measured with the nine hole peg test within (duration).
For X to be able to do step-around transfer to transfer from wc to other surfaces in (direction) (level of independence).	For X to improve standing balance so that he/she is able to stand for (duration) (equipment) (level of independence) (method; e.g. feet together).	For X to drink from a glass of water held in (side) hand (method).
...	...	...

This categorising allowed us to compare different kinds of goals and gave us insight into what constitutes a SMART goal or a not very SMART goal. We were able to identify goal domains that were common to many patients and would be recurring, for example perform a sit-stand transfer. We also identified domains that would be highly individual, for example; the number of times to perform the activity (e.g. frequency).

The initial aim was to develop a large database of goals to select from for the RCT described in chapter 7. However, because there were recurring domains within a goal, defining these domains and combining them to make a SMART goal would allow us to create an infinite number of goals, specified to the patient. The final method was adapted so that it could be used in Goal Attainment Scaling. This method is described below.

Goal Attainment Scaling method

The process of goal attainment scaling includes 5 steps.[171] Steps 1 to 3 of our method are illustrated in figure 4.

STEP 1 – Defining the expected goals

The key innovation described in this chapter is a structured approach to specifying a goal and its different levels, and this is the important characteristic in goal attainment scaling. Even if goal attainment scaling is not used, this method allows one to write a SMART goal. The method involves 'building up' an expected goal using four parts:

I. specifying the target activity (a behaviour);
II. specifying the support needed;
III. quantifying the performance; and
IV. specifying the time period to achieve the desired state.

Part I. Specify the target activity

Rehabilitation is, ultimately, concerned with altering behaviour whether that behaviour is (a) observed activities, such as dressing or working, (b) the reporting by a person of their internal experiences (such as pain), or (c) the report of a person about their interpretation of activities and experiences (such as their own assessment of quality of life, or satisfaction, or social role performance).

In the context of setting specific and measurable goals it is easiest to focus upon target behaviours concerned with activity. Common examples include mobility and the many activities of daily living (personal, domestic, community, vocational etc). The method described here can extend to the reporting of experience and perception, but this chapter will not consider these aspects in any detail.

This first part has the largest number of possibilities and identifies the functional purpose of the goal.

The behaviour should be specified as clearly and explicitly as possible: 'walking indoors' rather than 'mobilising', and 'cooking a three course meal' rather than 'preparing food'. Phrases such as 'using left hand in functional tasks' are too vague and need more detail such as 'brushing teeth using left hand'.

In rehabilitation some activities are commonly targeted, and one might use a list such as the Rehabilitation Activities Profile[181] or the ICF core sets for stroke[182] as a check-list both to ensure that all relevant activities have been considered when setting goals and to standardise the behavioural descriptions used, to an extent.

Part II. Specify specific support

Behaviour is a (goal-directed) interaction with the environment, whether objects or other people. In rehabilitation it is often necessary to modify or provide additional environmental factors for the behaviour to succeed. There are several environmental supports to consider, and thus this part is divided into three subparts.

The first subpart concerns support given by *people* in the environment:

- hands-on, practical or physical assistance (such as assisting in a transfer, cutting food, doing up shoe laces); or
- emotional and stand-by support to increase self-confidence; or
- cognitive, structural support such as prompting and reminding.

The second subpart concerns specific *objects* in the environment – extra aids, or particular adaptations to objects – that need to be present. It covers the field of physical equipment, for example:

- specific items that can be moved around (such as a walking stick, wheelchair, or hoist); or
- adaptation to personal items (such as clothing or cutlery); or
- an adapted fixed environment (such as a ramp, or a stair rail).

The third subpart of support concerns the way that items in the environment can be set up to provide *informational* support encoded or present within the environment; it is the *meaning* or *involuntary consequence* associated with the object that is important. Examples include lists to prompt the person to sequence actions, sign posting for orientation, and barriers that remind the person not to go somewhere.

Part III. Quantify performance

Activities can be described both qualitatively, using judgement, and quantitatively in terms of some measurable aspect of the behaviour. The patient's perception of quality (and, to a lesser extent, the judgement of other people) is of importance but it is not easily standardised. Thus qualitative descriptions have been left out in this method although an assessment of quality could be used as an option if quantification is not possible.

Performance can be quantified in three ways:

- by the time taken to achieve a set quantity of the activity; and/or
- by the quantity of a continuous activity performed (e.g. distance) in a set time; and/or
- by the quantity of a discrete activity occurring in a period of time (i.e. its frequency).

Any activity that has a reasonably clear start and finish can be *timed*, and timing allows a reasonably accurate and sensitive (to change) method of quantification that, incidentally, will often also be associated with the quality of performance. Timing should be widely used. Examples include time to walk to the post office, time taken to get up and dressed, and time to complete a shopping trip successfully. Generally (but not inevitably) time will be shortened as performance improves.

Distance or amount is commonly used to quantify activities, for example the distance walked in two minutes, or the number of words typed in five minutes. It could also be the distance walked before being stopped by pain, or the amount of time elapsing before fatigue supervenes.

Any activity that occurs repeatedly can also be *counted*. If the activity is a desired activity then an increase will usually be specified (e.g. number of letters filed successfully) but counting can also apply to unwanted activities (such as falling, swearing, forgetting, needing prompts or dropping objects) when a decrease will usually be the desired change.

Part IV. Specify time period to achieve the desired state

The last part is to specify the time period over which (or date when) the target state is to be achieved. This time will vary depending on the rehabilitation setting (post-acute or longer term) and the goal set (most commonly short or medium term goals).

This method (step 1), consisting of combining the four parts described above, allows the clinician to specify a goal accurately. On page 96 an example is presented of how a goal is formed with these four parts.

STEP 2 – Weighting the Goal

Traditionally in goal attainment scaling, each goal is weighted for importance and difficulty. The *importance* and the *difficulty* are determined by the therapist in conjunction with the patient. Both importance and difficulty are ranked on a 3-point scale, ranging from 1 (a little importance/difficult) to 3 (very important/difficult). If weighting is used, it needs to be used consistently and uniformly for all goals and in all patients if any comparison is being undertaken. If wanted, each goal can be weighted for importance and/or difficulty. However, it is possible not to score importance and difficulty and simply assign a weight of 1 to the goal.

STEP 3 – Scaling the Goal

In the goal attainment scaling process, once the initial goal has been set in terms of the performance level expected at a specified time (which is defined as the level scoring '0'), four more performance levels need to be specified: two that are better than and two that are worse than the goal.

The particular advantage of the structured approach to defining a goal outlined above (step 1) is that it allows easy definition of better than expected and worse than expected states. These states are achieved by adding, deleting and/or varying one or more of the parts or subparts from step 1.

Thus, states that indicate exceeding the goal will involve one or more of:

- succeeding with less support from people;
- succeeding with a less supportive physical environment;
- succeeding with a less supportive 'cognitive' environment;
- being faster (usually);
- an increase in quantity (e.g. distance); and/or

- doing the activity more or less frequently.

And states that indicate underachievement will be the reverse.

Step 3 allows the clinician to easily adjust the specifications of a goal in order to set different levels of success for a particular goal.

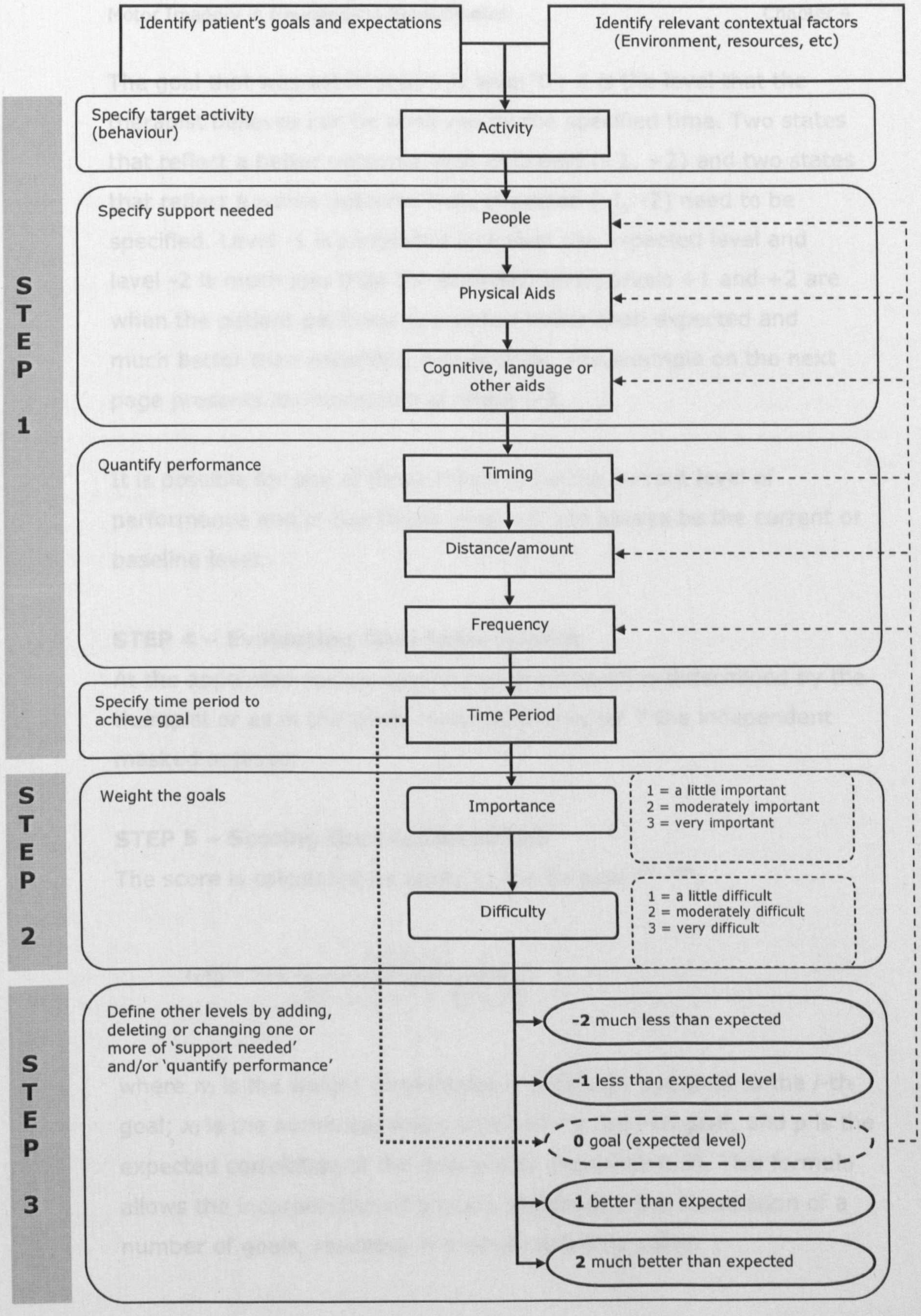

Figure 4. Flowchart for writing goals in Goal Attainment Scaling.

The goal that was set in step 1 is level '0'; it is the level that the therapist believes can be achieved by the specified time. Two states that reflect a better outcome than expected (+1, +2) and two states that reflect a worse outcome than expected (-1, -2) need to be specified. Level -1 is somewhat less than the expected level and level -2 is much less than the expected level; levels +1 and +2 are when the patient performs somewhat better than expected and much better than expected, respectively. The example on the next page presents an illustration of steps 1-3.

It is possible for one of these levels to be the current level of performance and in this thesis level '−1' will always be the current or baseline level.

STEP 4 – Evaluating Goal Achievement

At the appointed review date the level achieved is determined by the therapist or as in the study reported in chapter 7 the independent masked assessor.

STEP 5 – Scoring Goal Achievement

The score is calculated by applying the formula[183, 184]:

$$GAS = 50 + \frac{10\Sigma(w_i x_i)}{\sqrt{\left((1-\rho)\Sigma w_i^2 + \rho(\Sigma w_i)^2\right)}}$$

where w_i is the weight (*importance x difficulty*) assigned to the *i*-th goal; x_i is the numerical value achieved for the *i*-th goal; and ρ is the expected correlation of the goal scales (normally 0.3). This formula allows the incorporation of a goal's weight and the summation of a number of goals, resulting in a single outcome value.

Example. An illustration employing steps 1-3.

Mr R, 73 years old, had a stroke 2 months ago. He used to live independently in an apartment with an adapted shower. The stroke has left him with slightly reduced balance and some apraxia. He has expressed the desire to be able to wash himself in the shower on his own. It is anticipated that at the time of discharge Mr R will need a small care package to provide some help at home. The interdisciplinary team will need to write a SMART goal for Mr R to work towards washing himself in the shower on his own.

STEP 1. Defining the goal
By selecting possibilities from each (sub) part a SMART goal is created. The occupational therapist suggests that Mr R needs verbal prompting (support by people) to perform this activity and would be safe doing this if he had a long-handled sponge (support by objects). The psychologist suggests using a checklist (cognitive, structural, communication support) to increase his independence. He should be able to do it within 15 minutes (quantifying by timing) on a daily basis (quantifying by frequency) within 4 weeks time (time period to achieve state). So the result is the SMART goal: To wash in the shower with verbal prompting using a long-handled sponge in 15 minutes on a daily basis using a checklist within 4 weeks.

This goal is clear for Mr R as well as for the interdisciplinary team. The psychologist will have to teach him the strategy of checklists. The occupational therapist will have to practice the activity with Mr R and will have to supply the long-handled sponge. The physiotherapist will have to practice activity related balance and the nursing staff will have to implement the techniques in his daily routine.

STEP 2. Weighting the goals
A weight for importance and difficulty is assigned to the goal. For Mr R the goal is very important (score 3) and it is moderately difficult (score 2). The weight for this goal is importance x difficulty; 3 x 2 = 6.

STEP 3. Defining other levels
The goal is: To wash in the shower with verbal prompting using a long-handled sponge in 15 minutes on a daily basis using a checklist within 4 weeks (level 0). The other levels are defined by adding, removing or changing one or more of the (sub)part (from II and III) that are specific for Mr R.
Level -1 is the current level: To wash in the shower with physical assistance of 1 person on a shower chair within 4 weeks.
Level -2 is less than current: To wash in the shower with physical assistance of 1 person on a shower wheelchair within 4 weeks.
Level 1 is somewhat better than expected: To wash in the shower with a long-handled sponge in 15 minutes on a daily basis within 4 weeks.
Level 2 is much better than expected: To independently wash in the shower in 15 minutes on a daily basis within 4 weeks.

GAS formula

The formula used to calculate the GAS score was developed by Kiresuk and Sherman.[179] In the following section the formula is explained.

The GAS formula incorporates the weight of each goal (w_i) and the numeric value of the attained level of the goal (x_i). The weight that is given to the goal is the product of the rated importance of that goal and its difficulty (formula 1). In the method used in this thesis the score range of both importance and difficulty is 1 to 3 (1= a little important/ difficult; 2= moderately important/ difficult; 3= very important/ difficult). However, it is possible not to score importance and difficulty and simply assign a weight of 1 to the goal, which has been used in recent methods.[171]

$$w_i = \text{Importance} * \text{Difficulty} \qquad (1)$$

The numeric value corresponding to the goal level attained is scored from -2 to +2. By converting the attainment levels to T-scores an overall score is produced that is an average of a varying number of outcome scores adjusted for the relative weight of the scores and the expected inter-correlation among the goal scales. The expected inter-correlation of the goal scales (ρ) is set at 0.3 resulting in formula 2. The transformation results in a standardised measure with a mean of 50 and standard deviation of 10. By standardising the attainment scores one can easily interpret the scores (how different the score is from the mean score) and use parametric statistical techniques compared to non-parametric statistical techniques that would be needed for the levels –2, -1, 0, 1 and 2.

$$GAS = 50 + \frac{10\sum(w_i x_i)}{\sqrt{(0.7\sum w_i^2 + 0.3(\sum w_i)^2)}} \quad (2)$$

DISCUSSION

This chapter describes a new, structured method for writing goals that are SMART without too much effort. More detailed information on goal attainment scaling in general is available elsewhere[179, 180, 183, 185].

The method described here allows a clinician or researcher to specify a goal accurately and to easily adjust the specifications of a goal to set different levels of success. Besides saving time and effort, the method described in this chapter may well improve goal setting through careful standardisation. Scoring goal attainment, however, has been performed in several different ways; by a clinician familiar with the patient[186, 187], by consensus between clinical staff[188, 189] and by telephone calls.[190] GAS has been proven to be a useful tool but there is not much information regarding its use in research.

If GAS is to be used in randomised clinical trials with masked assessors, the scoring method will be different from the method used clinically. In the next chapter (chapter 5) an investigation into the agreement of goal attainment scoring between the patient's therapist and the masked independent assessor is presented to investigate its viability in research.

Note, the current and the next chapter refer to different 'method components' of goal attainment scaling. This deserves clarification; this chapter focuses on the methods of steps one and three of goal attainment scaling (see page 88-95). These methods are concerned with; (a) a method to specify a goal accurately (step 1) and (b) a method to adjust specifications of a goal to set the levels of success (step 3). The method referred to in the next chapter applies to step 4 of goal attainment scaling, namely the scoring of the attained level. The treating clinician has a different scoring method than the masked independent assessor. These 'method components' are parts of the overall 'goal attainment scaling method.'

Chapter 5

Scoring Goal Attainment: Agreement of Two Scoring Methods

Publications relevant to this chapter:

- Bovend'Eerdt TJH, Dawes H, Izadi H, Wade DT. Scoring goal attainment: agreement of two scoring methods. (submitted)

SUMMARY

In the previous chapter a novel method of writing goals that facilitates goal attainment scaling was presented. This method is used with goal attainment scaling as the primary outcome measure in the randomised controlled trial presented in chapter 7. In this randomised trial a masked independent assessor scores the goal attainment, whereas in most other studies and in clinical practice the goal attainment scoring is performed by the clinician. This chapter investigates the agreement between the scoring by the independent assessor and the treating clinician. This is important to investigate whether the methods can be used interchangeably.

INTRODUCTION

Goal attainment scaling (GAS) individualises the outcome measured for each patient, in contrast to conventional measures which comprise of a standard set of items rated in a standard way. The validity and inter-rater reliability of goal attainment scaling in various clinical populations has been reported as good.[186-189, 191, 192]

Goal attainment scaling is an attractive outcome measure for measuring the effectiveness of interventions in randomised controlled trials (RCTs) because it should be sensitive to change and appropriate for evaluating complex interventions.[185] In RCTs an independent assessor who is masked for the subject's allocation should measure outcome, to ensure unbiased measurements.

If, however, the assessor is to stay masked and remain independent, the assessor will necessarily be unfamiliar with the subject and cannot draw on information known to treating staff. In this case the assessor has to assess the goal attainment directly or explore the score from the patient (or clinicians) through interview, resulting in a different scoring method from scoring by clinical staff. Different methods are bound to have some lack of agreement and it is important to know how much the methods differ in order to find out if the difference causes problems in clinical interpretation and whether the two methods can be used interchangeably.

Two measures that are regularly used in clinical practice are the Barthel Index[158, 193] and the Rivermead Mobility Index[161, 193] (appendix 1). Correlations between the Barthel Index and the Rivermead Mobility Index with goal attainment scaling are a measure of construct validity.[194] If both correlations (i.e. Barthel Index versus GAS and Rivermead Mobility Index versus GAS) are good, the instruments measure the same construct (e.g. mobility is the construct of the Rivermead Mobility Index). If the patient's therapist and the independent masked assessor score goal attainment differently, the construct validity is likely to be different as well.

This chapter investigates the reliability and agreement[195] of goal attainment scoring by the patient's therapist and by an independent masked assessor. Comparison of the construct validity between the patient's therapist and the independent assessor is used as an additional illustration of the quality of the goal attainment scores.

METHODS

This analysis is based on data collected from the RCT discussed in chapter 7. The RCT investigated the effectiveness of a six week programme of motor imagery in neurological rehabilitation.

Goal attainment scaling method

At admission to the rehabilitation centre, each member of the multidisciplinary team assessed the new patient and discussed goals and expectations with the patient; relevant contextual factors were identified. After mapping the patient, the multidisciplinary team would meet at a goal planning meeting to set out (interdisciplinary) goals together with the patient.

Shortly after admission the researcher met the patient for a screening (see chapter 7) and to discuss participation in the research study. The patient's physiotherapist and occupational therapist were asked to write two current goals each, for patients that gave informed consent, resulting in up to four individualised goals for each patient. The minimum number of goals for a patient to be included was two. Each goal was weighted by the therapist, considering the importance and difficulty of each goal for the patient, after which the other goal levels were defined (i.e. two levels better than the expected outcome and two levels worse than the expected outcome). These goals and the levels were usually written based on the physiotherapist's and occupational therapist's assessments and were part of the goals set at the goal planning meeting but specific to the therapist's input. The researcher helped with writing the goals when necessary. The time specified for the goals was six weeks, or less if the patient would be discharged within that period.

The methods for writing objective goals[196] and of goal attainment scaling (GAS)[171, 179] have been described in chapter 4. Therapists were taught this method in a one hour workshop. Briefly, after listing the patient's wishes, expectations and the patient's situation and before the baseline assessment the therapists set valued and achievable goals using the following four parts:

I. specify the target activity;
II. specify support needed;
III. quantify performance, and;
IV. specify the time period to achieve the desired state.

Combining information from these four parts results in a measurable goal. Each goal was then weighted both for importance and difficulty which were ranked on a 3-point scale, ranging from 1 (a little importance/difficult) to 3 (very important/difficult).

Once the goal was set in terms of the performance level expected at a specified time (i.e. the '0' scoring level), four more performance levels were specified at the specified time: two that were better and two that were worse than the goal. The current level was always set at level -1. Defining the other levels was easily done by varying one or more of the parts discussed above.

Scoring goal attainment

At baseline the patient's physiotherapist and occupational therapist created two individualised goals each (resulting in up to four goals per patient), as described above. At the assessment (i.e. usually six weeks unless discharged earlier), each of the two treating therapists marked the two goals that they had set, and the masked assessor scored the goal attainment on all goals, and each did this without knowledge of the other's rating.

The therapists usually treated the patients weekly or even daily and could therefore score the goal achievement without much trouble. The therapists were simply asked to complete the rating of the patient at that moment. If the therapist was unable to score the goal attained immediately, the therapist was allowed to score after the next session with the patient. This allowed the therapist to test or ask the patient what their performance level was.

The assessors were trained to score the goal attainment by either assessing the activity directly or by interviewing the patient. Direct assessment simply involved asking the patient to perform the activity.

In the interview method the independent assessor had to establish the patient's actual level of attainment as accurately as possible. This was done by consulting the patient. To avoid bias the assessor was not allowed to consult the patient's therapist or any other clinical staff.

The interview was performed using a semi-structured interview with the patient involving the following three steps:

1. Ask an open question to let the patient describe how he/she executes the task (e.g. *Can you describe to me how you transfer from your wheelchair to the toilet?*).
2. Ask open questions during the patient's explanation to get the patient to elaborate on certain points (e.g. *How and where do you park your wheelchair?*).
3. Ask more specific questions to get detailed information on the domains.
Special effort was put into trying to 'measure' ambiguous terms (e.g. walk outdoors safely). This was done by asking specific task-related questions (e.g. "D*o you cross the street on your own?*" or "Do *you need help stepping down or up curbs?*").

The score was calculated by applying the usual formula,[171, 179] as described in chapter 4:

$$GAS = 50 + \frac{10\Sigma(w_i x_i)}{\sqrt{\left(0.7\Sigma w_i^2 + 0.3(\Sigma w_i)^2\right)}}$$

w_i = the weight (*importance x difficulty*) assigned to the *i*-th goal
x_i = the numerical value achieved for the *i*-th goal

The independent assessor also measured the Barthel Index and the Rivermead Mobility Index (see chapter 7) at baseline and after six weeks.

Analysis

The Rehabilitation Activities Profile (RAP)[197] is a tool consisting of 21 activities covering the domains communication, mobility, personal care, occupation and relationships. The activities covered in this instrument were used to categorise the goals from this study as an illustration of the kind of goals that had been generated.

One summary GAS score was calculated for each patient, contributed to by up to four goals.[171, 179] The same weights were used in calculating the GAS score from both the therapist and the masked assessor scoring. Consequently, differences in GAS scores are all attributable to differences in the actual ratings of the goals.

Reproducibility involves the degree to which repeated measurements provide similar results. De Vet et al.[195] distinguish between reliability and agreement parameters to report reproducibility. Agreement parameters assess how close the results of the measurements are by estimating the measurement error, for example, when one person is measured on several occasions there can be some variation in the measurements (within-person measurement error). When this variation between the measurements, within that person, is high, the agreement of low (i.e. the repeated measurements poorly agree with each other). Reliability parameters assess whether the results can be distinguished from each other, thus the measurement error is related to the variability between persons. This tells us how well the persons can be distinguished from each other. In this study reliability was investigated using a mixed model intra-class correlation coefficient ($ICC_{(A,k)}$) (two-way mixed model with absolute agreement).[198] The limits of agreement (LoA = mean ± 1.96 sd)[199, 200] were used to illustrate the agreement between the two scoring methods. Normality of the data, absence of systematic bias and homoscedasticity were checked (and confirmed).

Pearson correlation coefficients were calculated between the change scores on GAS (for both the therapist and the masked assessor), the Barthel Index and the Rivermead Mobility Index. Statistical Package for the Social Sciences (SPSS) software version 17.0 was used for analyses.

RESULTS

Goals

Thirty patients participated in the RCT. One patient was lost to follow-up due to infection control and thus had no outcome goals measured; two patients only had three goals each and one patient only had two goals resulting in a total of 112 goals. Data from the 112 goals from 29 patients has been used in this analysis.

Table 9 presents some descriptive data of the 29 patients included in this study at baseline. Two patients could not complete the Short Orientation Memory Concentration Test due to communication problems.[159] The mean (SD) GAS scores by the therapist and the assessor at six weeks are also presented.

Table 9. Descriptive data of the research population at baseline and the GAS score after six weeks.

Variable	**Result** (mean (SD))
Gender	11 female/ 18 male
Diagnosis	- stroke (n=27) - traumatic brain injury (n=1) - multiple sclerosis (n=1)
Age (years)	50.28 (13.88)
Short Orientation Memory Concentration Test (n=27)	22 (4.77)
Motricity Index (n=29)	57.19 (25.45)
Barthel Index (n=29)	12.17 (6.62)
Rivermead Mobility Index (n=29)	6.38 (5.40)
GAS score (n=29)	
- **therapist**	51.99 (11.01)
- **assessor**	53.51 (10.29)

Note: the motricity index presents data of the treated side (i.e. usually the most affected side but in some cases, where both sides are seriously affected and where the prognosis of the most affected side is poor, the less affected side was measured (n=2)).

Table 10 presents the goal areas covered, based on the Rehabilitation Activities Profile[197] with two additional domains specific to arm and leg activities not covered by the Rehabilitation Activities Profile but evident from the goals. A wide variety of goals were used with mobility and personal care being the largest domains, 42 and 38 goals respectively.

Table 10. Goal areas according to the activities from the Rehabilitation Activities Profile plus two categories specific to upper and lower limb activities.

Category	**Sub-category**	**Number of goals**
Communication (n=5)	Expressing	5
Mobility (n=42)	Maintaining posture	4
	Changing posture	11
	Walking	20
	Using wheelchair	1
	Climbing stairs	6
Personal care (n=38)	Eating and drinking	17
	Washing and grooming	9
	Dressing	11
	Maintaining continence	1
Occupation (7)	Providing for meals	3
	Professional activities	1
	Leisure activities	3
Upper limb specific activities		18
Lower limb specific activities		2
	Total	**112**

Reliability and agreement

The mixed model $ICC_{(A,k)}$ between the therapist and the masked assessor scoring methods is 0.478 (95%CI -0.122 to 0.756); this is not significantly different from zero.

Figure 5 shows a Bland-Altman plot[200] of the difference between the measurements (therapist - assessor) by the two methods for each patient against their mean, including the Limits of Agreement (LoA) (-1.52 ± 24.54). Normal distribution of the differences and absence of systematic bias and heteroscedasticity were confirmed.

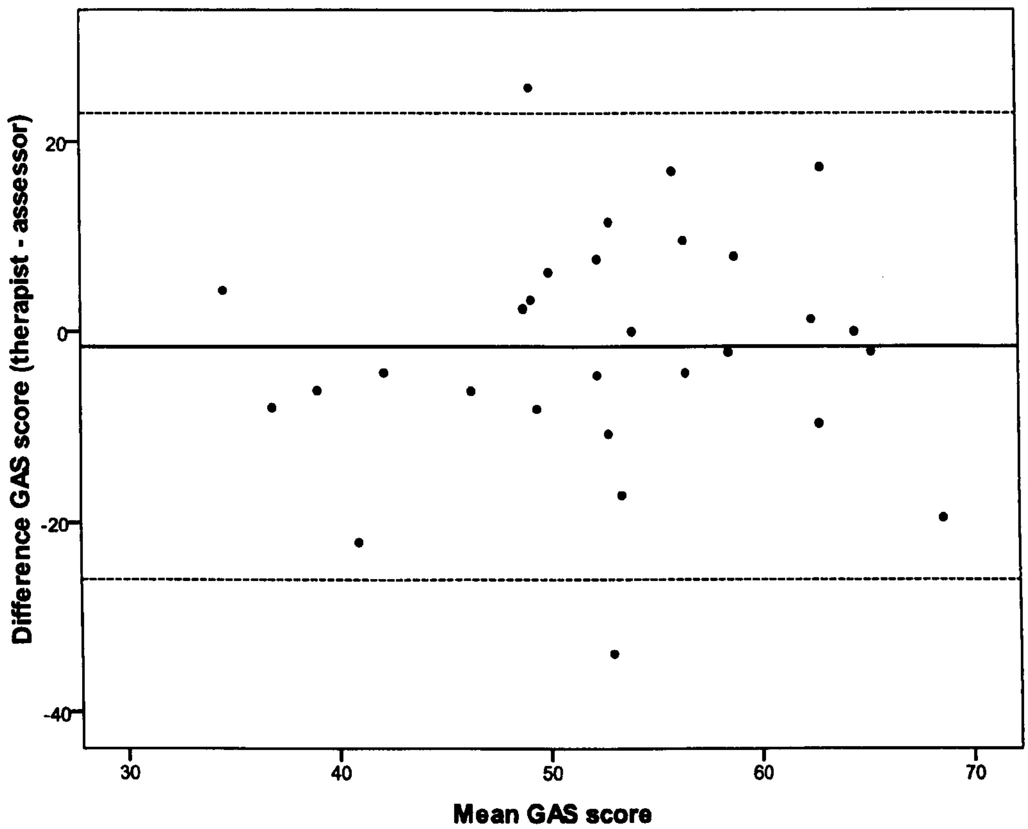

Figure 5. Bland-Altman plot of the GAS score (n=29). Difference in GAS score between therapist and assessor against mean GAS score. Limits of Agreement: -1.52 ± 24.54.

Correlations

Table 11 shows the Pearson correlation coefficients of the change scores between the GAS scores and the Barthel Index and Rivermead Mobility Index. The GAS scores of the assessor show significant correlations with both the Barthel Index and the

Rivermead Mobility Index, whereas the GAS scores of the therapist only shows a significant correlation with the Rivermead Mobility Index.

Table 11. Pearson correlations of change scores between the goal attainment scores scored by the assessor and the therapist with the Barthel Index and the Rivermead Mobility Index.

	Barthel Index	**Rivermead Mobility Index**
GAS assessor	r=0.36*	r=0.41*
	P=0.049	P=0.025
GAS therapist	r=0.29	r=0.39*
	P=0.118	P=0.035

* Correlation is significant at the 0.05 level (2-tailed).

DISCUSSION

This study found that goal attainment scored by a treating therapist has low agreement with attainment scored by an independent assessor. If GAS scores are to be compared between patients or groups in an RCT, more reliable scoring needs to be achieved before using different assessors to score different patients or patients at different times.

The intraclass correlation coefficient in this study show poor reliability. There was a large measurement error, but it was not systematic (i.e. the group means were similar). The difference in scoring between the treating therapist and the independent assessor lies between -26.06 and 23.02 (figure 5) suggesting poor agreement.

It is unclear which score is the 'true' score, if either. The therapists scoring the goals were usually the authors of the goals and the treating therapist, which may have lead to biased scores. For the independent assessor activities that were safe to assess and required no or easy accessible equipment (e.g. write name) were directly assessed. However, it was seldom possible to assess goals directly because: (1) goals involved activities that could have compromised the safety of the patient and/or the assessor (e.g. climbing stairs or making a hot drink); (2) goals required equipment not readily available (e.g. a kettle for boiling water); and (3) goals involved observing behaviour in particular situations or settings (e.g. communicate with partner using alphabet chart).

Consequently, the assessor usually depended upon asking the patient how he/she performed an activity. This was particularly prone to error in patients with aphasia and/or with cognitive deficits (e.g. insight problems) and was also probably generally less accurate.

The RCT, from which this data comes, included a wide range of patients with different levels of physical and cognitive functioning and with a large variety of goals (see table 10). Future research may wish to focus on investigating the reproducibility in particular populations or of particular goals. For example, in the current study the assessor largely relied on the patient's information to score the goals. This may have been biased, especially in patients with cognitive deficits. Also particular goals (e.g. walk 10 meters) may be more reliably scored than other less specific goals (e.g. grocery shopping).

Other studies have scored goal attainment through consensus within the clinical team.[188, 189] This may be viewed as the true score but would be an inappropriate method in blinded RCTs. Another study used a telephone interview method with the patient to score the goals which should be interpreted with caution as the current study shows that agreement between different scoring methods is low.[190]

The data presented above is a cross-section of a study (described in chapter 7) in which, besides GAS, also the Barthel Index and the Rivermead Mobility Index were measured concurrently, allowing establishment of concurrent validity. In a previous study concurrent validity of GAS was already established in frail elderly with the Barthel Index (r=0.59), the Functional Independence Measure (r=0.45) and the Katz Activities of Daily Living Index (r=0.49).[188] Table 11 shows significant correlations in the current study between the GAS scores and the Barthel Index and Rivermead Mobility Index, particularly when scored by the assessor. This suggests that changes on the Barthel Index and Rivermead Mobility Index are picked up by GAS. The correlations are relatively low but this can be explained by the wider variety of the goals in the GAS method (see table 10) compared to the relatively narrow construct of the Barthel Index (i.e. generic ADL) and the Rivermead Mobility Index (i.e. mobility).

There are several limitations to this study. First of all, data from an RCT were used to investigate the agreement between two scoring methods. The goal of the RCT was to measure the effectiveness of an intervention (i.e. motor imagery), thereby creating two groups. However, in this study the agreement is calculated from the total group which may create a bias when the agreement differs between the two groups. Future research into the agreement of different scoring methods should employ a design more adequate for this purpose. Also, the score of the independent assessor was compared to the aggregate of the two therapists' scores. This may have biased the results if one of the two therapists scored particularly poorly. Finally, using construct validity is not an appropriate method to compare the quality of the therapists' and the independent assessor's score (note that it is only intended as an illustration); especially when it was the same independent assessor scoring GAS as well as the Barthel Index and Rivermead Mobility Index.

In conclusion, caution is needed when comparing goal attainment ratings obtained from a patient in different ways but changes in GAS show positive correlations with changes in the Barthel Index and the Rivermead Mobility Index suggesting some concurrent validity of GAS and as such GAS may provide information alongside other measures within a trial. Methods for collecting outcome data relating to a wide variety of goals in a consistent and reproducible way need to be developed.

The next chapter (chapter 6) will present a motor imagery strategy that was developed for neurological rehabilitation. This strategy is then investigated in the randomised clinical trial presented in chapter 7 using goal attainment scaling as its primary outcome measure.

Chapter 6

A Comprehensive Strategy for Motor Imagery Practice in Neurological Rehabilitation

Publications relevant to this chapter:

- Bovend'Eerdt TJH, Sackley C, Dawes H, Wade DT. Motor Imagery Practice in Neurological Rehabilitation: a Comprehensive Strategy (submitted)

SUMMARY

The MRC guidance for complex interventions suggests that during the development of a complex intervention it is important to:[14, 35]

- identify the evidence base;
- identify or develop theory, and;
- model the process and outcomes.

Chapter 2 of this thesis was largely concerned with the identification of the evidence base and theories of motor imagery. It described the large diversity in motor imagery interventions, the limited information on the content of motor imagery as well as the lack of a framework. Chapter 2 concluded that motor imagery interventions used in neurological rehabilitation are most likely sub-optimal as they make only limited use of the evidence from sports psychology and fundamental research. The current chapter is largely committed to the other MRC components for the development of complex interventions, namely, developing theory and modelling processes and outcomes. It describes an intervention strategy for motor imagery use in neurological rehabilitation. This strategy was developed as a result of the review described in chapter 2 and experiences from the pilot study (chapter 3).

INTRODUCTION

Motor imagery is a particularly attractive technique because it can be embedded in usual therapy and combined with physical practice; it is potentially cost effective; it is probably safe and it does not require expensive equipment.[47, 118] Motor imagery can virtually be used at any time of the day, within and outside therapy sessions. Another advantage of motor imagery could be its ease of use; one can imagine almost anywhere (i.e. bedroom, gym, between points of travel), at any time of day (i.e. during therapy, while lying in bed), for any amount of time (from seconds to tens of minutes), with minimal physical fatigue (although it can cause mental fatigue), however, there is no evidence yet supporting this in neurological populations. After the patient has acquired the basic skills he/she can use the technique(s) on his/her own.

During the spontaneous recovery in patients with neurological conditions and with rehabilitation, motor learning mechanisms are active and interact.[137] It is suggested that new therapies should adhere to these motor learning principles.[137, 201] In this chapter a strategy for motor imagery interventions is developed and described, as has been recommended by the MRC for all complex interventions.[35, 135] Because there is no specific strategy available for motor imagery in neurological rehabilitation and because the concept of motor learning has been successfully used in increasing performance through physical practice,[107, 108, 136, 137] the motor learning concept is used here as the framework for the motor imagery strategy.

In this chapter a comprehensive strategy for motor imagery use in neurological rehabilitation is set out, based on chapters 2 and 3 of this thesis and the available literature on motor learning. The first part of this chapter sets out the concepts that serve as the foundation for the strategy, and the second part of this chapter will describe the practical strategy for employing motor imagery in neurological rehabilitation.

The aim of this chapter was to develop a motor imagery strategy that:

- could be used by a wide variety of patients;
- is easy to learn by patients and health professionals;
- is practical to use by patients and health professionals;
- could be used for any motor task, and;
- has a sound theoretical basis.

I. THE CONCEPTS

In this first part the concepts of *motor learning* and *information processing* will briefly be discussed. These concepts serve as foundations for the actual motor imagery strategy described in the second part of this chapter. Motor learning is used as the general framework on which the motor imagery intervention is based. These motor learning principles will not be further discussed in part II as they serve as general principles, however, in this part some examples are provided to illustrate how these principles apply to motor imagery. The concept of information processing is useful in creating the actual imagery script and will be applied as a method for creating scripts in part II.

Motor learning

Motor learning is defined as, the changes in behaviour arising as a result of practice or experience and taking place when the skill is retained and resulting in a relatively permanent change in behaviour (e.g. motor skill), as opposed to an impermanent short-lived change in behaviour. The behaviour that is observed here is motor performance.[107, 108, 136, 137]

In motor learning as elsewhere there is an increasing interest in translating basic research into treatment concepts for rehabilitation disciplines.[127, 136, 137] For the (re)learning of motor skills in neurological populations principles from motor learning are increasingly implemented because elements affecting motor learning in healthy populations are generally considered similar to elements affecting motor (re)learning in neurological populations. This assumption is supported by results from neuro-imaging studies that show similar cortical changes.[202, 203] Cortical changes after motor imagery are similar to changes after physical practice[204-206] and similar cortical networks are activated during motor imagery and physical practice.[94-96]

This suggests that motor learning principles could be used as the base of the motor imagery strategy. This first part will briefly discuss how the following components of motor learning might influence motor imagery:

- stages of learning;
- types of tasks;
- feedback;
- practice, and;
- environment.

For more detailed information the appropriate literature should be consulted.[107, 108, 136, 137]

Stages of learning

When one performs a movement for the first time it looks stiff and inaccurate, it requires a lot of attention, the movements are inconsistent and much feedback is required.[107, 108] With practice the movements become more accurate and automatic, the speed of actions increase and feedback processing becomes less important.

High skill performance is usually characterised by: a maximum likelihood of achieving the goal; minimum energy expenditure; and minimum movement time.[107, 108]

When learning, improvements in the early phase are usually more rapid than during later practice.[107, 108] Different authors suggest different stages of learning but usually 3-4 stages are identified.[108, 138] Similarities between the authors are that the early stages are characterised as being mainly cognitively involved, whereas the later stages involve more automatic processes. For example; Schmidt and Wrisberg[108] describe the following structure: 1. verbal-cognitive stage; 2. motor stage; 3. autonomous stage.

During the verbal-cognitive stage the learner gets a general idea of the movement.[108] The learner 'talks' about what he/she is trying to do and is discovering strategies. The cognitive demand is high and words, demonstrations, visual feedback and physical guidance can be used to conceptualise the movement. Improvements in performance are large and occur fast.[108]

During the motor stage the movements are refined to attain more effective movement patterns.[108] This stage is characterised by smoother and more consistent movements.[108]

In the autonomous stage the skill is performed more or less automatically with little attention.[108] The confidence in performance is high and errors are usually detected by the performer.

When learning new skills or relearning old skills the patient passes through these stages in a cyclic manner, and the same probably applies in motor imagery.[207] When translating the above evidence from motor learning through physical practice to motor learning through motor imagery practice, it suggests that initially the performer will need a lot of *guidance* for the motor imagery and demonstrations and visual information (e.g. picture cards, video) may be necessary to conceptualise the movement. When moving through these phases the motor imagery performer will need less guidance and the imagined movements should be refined and more effective movement patterns should develop over time. In the final stage the motor imagery performer should not need guidance anymore and the amount of errors should decrease.

Types of tasks

Skills can be categorised in many different ways and usually consist of a continuum between extremes. Examples of classifications are:

- motor versus cognitive skills;
- discrete, serial and continuous skills, and;
- closed versus open skills.

The literature suggests larger benefits from motor imagery for skills with relatively large cognitive elements.[57, 58] In this thesis the use of more closed skills for motor imagery is suggested (e.g. walk from the kitchen to the living room) instead of open skills (e.g. go shopping). It is easier to describe closed skills where the environment is stable and predictable and the skill usually has a clear start and end; as opposed to an open skill where the environment is variable and unpredictable.

Feedback

Feedback is the information the patient receives as a result of the movement and is necessary to learn.[107, 108] It is possible to distinguish between intrinsic and extrinsic feedback.[107, 108] Intrinsic feedback is the sensory information the patient receives as a natural result of the movement. During motor imagery similar neural networks are activated as during movement execution, but without the overt movement; the motor system is said to be activated 'offline' in contrast to movement execution when the motor system is 'online'. De Vries and Mulder[98] suggest that during motor imagery feedback is acquired 'offline'.

Extrinsic feedback is information provided to the patient by an outside source and consists of knowledge of results (KR) and knowledge of performance (KP).[107, 108] Knowledge of results is feedback on the **outcome** of a movement in terms of the environmental goal. Knowledge of performance is feedback information about the **process** (quality) of the movement.[107, 108]

During normal motor learning the therapist and/ or the patient have this knowledge and they can both give feedback.[107, 108] However, during motor imagery the patient is the only person who has this knowledge. This is why I suggests that evaluation should form an essential part of the motor imagery intervention. In this case the therapist has to try and find out how the task was imagined. Only after gathering enough information on the performance and the result of the movement, can the therapist give suitable feedback and instructions to proceed.

Practice

Practicing is purposefully repeating a skill with the intention of improving one's skill, to maximize the goal achievement and increase efficiency and effectiveness.[107, 108] It is generally known that more practice results in better performance.[107, 108] The best learning experiences result from those experiences that resemble the movements and environmental conditions of the skill most. This is known as the *specificity of learning*.[107, 108] However, to achieve transferable learning one should repeat the experiences with slightly altered movements and environments. This concept is also known as *variability of practice*.[107, 108]

In motor imagery *variability of practice* can be used as a method to enhance generalisation. By varying the imagined task slightly it may be possible to transfer the skills learned to similar tasks. Variation can be applied in the task (e.g. altering the cup to a mug), the situation (e.g. lifting the cup standing), and/or the environment (when the patient has mastered imagined walking in the gym the therapist could ask the patient to imagine walking in the garden). This can be an important way to identify problems the patient may encounter when the task is slightly altered and to enhance transfer of skills.

Environment

The importance of incorporating context and environment in practice is well known[107, 108] and is closely related to the previous paragraph (variability of practice). Motor learning does not involve learning sequential contractions of isolated muscles, but the learning of how to reach goals in the environment. It is not the movement that counts but the action in which the movement is embedded. This concept is also known as the *linkage to the site of application* where one should aim to link the practice to the environment and context that is important and understandable to the patient.[107, 108]

Similar to variability of practice, *linkage to the site of application* can be used as a technique through giving clear instructions.[107, 108] This aspect is closely related to the *orientation stage* of the imagery script (see below). It is necessary to vary situations and environments, but these situations and environments should also be applicable to the patient.[107, 108] This can offer an important way of identifying problems that may be encountered when performing the task in another environment or it could facilitate the patient's ability to recall and to rehearse the task.[81]

Information processing

According to the concept of information processing an action can be conceptualised as being composed of three consecutive phases[208, 209]:

- Orientation phase;
- Execution phase;
- Control phase.

The *orientation phase* is the first phase in human movement and consists of the preparation for the task to be performed. The patient orientates him/ herself to the situation, the environment, the task and his/ her own abilities. With the sensory information the patient receives he/she can make a judgment on the situation and its significance. This phase is closely linked to the *environment* element of motor learning (see earlier).

On the basis of this phase and on memories an internal concept should be developed on how to perform the task in that particular situation. This internal concept is an action plan held in working memory and is based on the planning of object usage, environment and movements.

The second phase is the actual movement, the execution of the action plan. There is a start and an end to this. Fluency of movement, speed and timing of movement are usually observed. The execution phase relies largely on the orientation phase.

During the execution phase the patient will verify his/her situation constantly (e.g. control phase). The patient checks whether his/her action and the created situation still comply with the internal concept. According to this control the internal concept can be adjusted.

This concept of information processing creates a loop (figure 6). During the control phase the patient orientates him/herself on the task and adjusts the execution phase appropriately, going through the phases again. This concept has been successfully implemented in a treatment strategy for patients with apraxia.[210, 211]

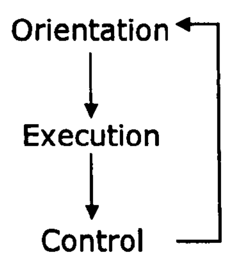

Figure 6. Illustration of the loop for information processing.

II. THE MOTOR IMAGERY STRATEGY

The second part of this chapter describes the motor imagery strategy for clinicians for which the concepts have been set out in part I. As mentioned before, this intervention strategy is designed to offer clinicians a structure to deliver subject-specific motor imagery. It is not designed to provide set rules but rather to provide support to tailor the imagery to the patient's level and goals. The strategy presumes some common sense by the therapists and will not go into the fundamentals of how to treat a patient.

This second part will start with a description of how to create a motor imagery script by using the concept of information processing after which the importance of imagery ability is discussed as well as a brief note on progression. Finally, an illustration is provided and the strategy will be summarised in a flowchart.

Creating a motor imagery script

To create a script I suggest using a combination of the concept of information processing (see part I)[208] and a method from a sports guide on motor imagery.[212] The method from the sports guide suggests telling the basic story of the task first. This involves outlining the basic content of the task including all actions that occur in the correct sequence. The basic story can then be refined to focus on particular aspects or details of the task. This method can be applied to any type of task.

Initially the basic story is given by describing the environment, then the components of the task (execution phase) and finally the control elements of the task. After the basic story the instructions can be refined repeatedly. In this way a script of a task always starts with the description of the situation and the environment, followed by the sequence of the movement and finally ending with verification of the action plan and correction if necessary.

Motor Imagery Ability

The ability to imagine movements varies between people and between tasks.[126] Several authors[48, 57, 123] have shown that motor imagery is more effective in people who are good at it, so it makes commonsense to optimise a person's imagery ability to reach a maximum effect on physical performance. However, in patients with cortical damage imagery ability may be impaired.[98, 213] A person's ability to perform motor imagery can be segregated in *intensity* and *control*.[47, 106, 214]

Motor imagery is different from visualisation in that during motor imagery all senses are used.[44, 47] The ability to imagine these senses 'as in reality' is, in this thesis, defined by the term intensity. This not only includes the visual aspect, like colours and shapes, but also the quality of all the other sensations. The aim is to imagine these sensations as really as possible. Other definitions of this concept may include the terms clarity or vividness.[80, 156, 215] In this thesis the term intensity is used because of its multi-sensory nature, compared to clarity and vividness which suggest visual sensation only.

Control, in this thesis, is defined as the ability to manipulate the content of imagery. This is a very important feature in rehabilitation where patients often see themselves performing the task incorrectly.[80, 216]

Having the ability to change between internal (imagery from a first person perspective) and external (imagery from a spectator perspective) imagery is a form of control. Good control over imagery enables the patient to imagine themselves doing the task correctly, which is essential for correct overt movement.[114, 120]

Several methods are available to test and monitor a patient's motor imagery ability. For example, the Kinaesthetic and Visual Imagery Questionnaire (KVIQ-20)[125, 215] has been used to measure the kinaesthetic and visual qualities of motor imagery in persons with physical disabilities. Chronometry is a method based on the observation that the time to imagine a movement is similar to the time to execute the movement.[80, 128] By using these methods and by interviewing the patient it is possible to reduce subjectivity of the patient's motor imagery ability.[80] The methods described here are used as an illustration, as an in depth review of available methods to examine motor imagery ability is outside the scope of this chapter.

For more information about methods to examine a person's motor imagery ability and for some examples of methods I refer to the appropriate literature.[80, 103, 125, 215, 217]

Motor imagery content

When a movement is executed incorrectly this can lead to inaccurate learning, similarly an incorrect imagined movement can lead to inaccurate learning, including all temporal and spatial aspects.[114, 117] People with neurological conditions, who have deficits in performing a movement correctly, should particularly focus on the correct content of motor imagery. They should aim to imagine the task successfully in order to learn the correct movement instead of mentally practicing an incorrect movement. This success is relative but should be realistic above all. Success in this population can mean walking with a rollator and does not necessarily mean regaining one's previous walking ability.

Developing motor imagery skills

Motor learning theory suggests that physically repeating a task leads to improved performance,[107, 108] so in this thesis it is suggested that the ability to perform motor imagery needs to be practiced too. Note the distinction made here between learning to do motor imagery and using motor imagery to learn a task.

It is suggested that motor imagery is more effective in people who are good at it[47, 48, 123, 126] (i.e. they have good intensity and control). This implies that it is worth first practicing the skill of motor imagery. When the patient has reached a certain level at motor imagery, one can use it as a technique to practice tasks. The motor imagery ability can still be practiced to attain a higher level of motor imagery ability. To practice the ability to imagine movements, one can focus on certain aspects of the imagery, such as developing the senses during imagery (i.e. intensity) or developing the perspective of imagery (i.e. control) or the way (e.g. temporal aspects such as speed) a task is imagined (i.e. control). According to the progression in one's imagery ability, the tasks practiced may change. For example; it may be necessary to practice sit-to-stand before practicing walking.

Adaptation

From experience it was noted that when using motor imagery implemented in therapy sessions the instructions or the script are never the same twice. Depending on the feedback from the patient the script can be adapted. It is possible that the patient can not imagine the task performance or the sensation appropriately. The therapist can then pick out the specific elements that need more attention (e.g. part of a movement or a sensation). Or maybe the patient can imagine the task correctly and the therapist can proceed to the next (part of the) task. This is much the same as the therapist would do during usual clinical practice. In this way a loop is created that can be adjusted to the individual's need.

Illustration

Figure 7 is an illustration of the motor imagery strategy. The strategy is described in 5 steps. Numbers 1, 2 and 3 involve the creation of the script; number 4 is the evaluation and number 5 is the modification of the intervention by applying different techniques. The task used in this example is wiping the table surface.

1. The script starts by describing the environment and context.
"You sit in a chair with the table in front of you.
The cloth is lying in front of you."

2. This is followed by a description of the movement sequence.

"You lift your right hand.
Reach forward.
Grab the cloth and wipe the table."

3. In the control phase the action plan is verified and adjusted if necessary.
"Your hand is flat and is slightly pushing on the cloth.
You wipe the entire table."

4. The evaluation consists of three types of questions.

- *"Could you imagine that?"* Refers to the ability to use motor imagery.
- *"Could you imagine the movement/task successfully?"* Refers to Knowledge of Results.
- *"How did you perform the movement/task?"* Refers to Knowledge of Performance.

The aims of the evaluation are to find out if the patient has the ability to imagine (referring to intensity and control); if the patient achieved his/her goal (Knowledge of Results); and if the patient imagined the movement correctly (Knowledge of Performance). The therapist should use open as well as closed questions to check for these elements.

In our example these questions could be:
"Could you 'feel' the cloth in your hand?" (Imagery ability)
"Could you reach all four corners of the table?" (Knowledge of Results)
"Was your hand flat and your elbow straight?" (Knowledge of Performance and Control)
"Can you describe how you performed the task?" (Knowledge of Performance)

This evaluation process can continue until the therapist has enough information to act on.

5. Depending on the results from the evaluation (4) the script is adapted and the process starts from 1 again. Some examples are:

- If the result is that the patient can imagine the task perfectly and correctly one can introduce variability of practice (e.g. performing the task in standing, focusing on a dirty patch on the table), increase the speed of the task, practice the task physically, etc.
- If the result is that the patient cannot 'feel' the cloth one can give a cloth to the patient and focus on its texture, colour, temperature, wetness and transfer it to the imagery by using more response proposition, etc.
- If the patient cannot 'see' him/herself extending the elbow one can; focus on exercises to increase imagery control, use response propositions, imagine the task with the unaffected side and transfer the image to the affected side, etc.

In our example the patient could not complete the task successfully so response propositions and a refined description were used.

1 *"You're sitting in the chair with the table in front of you. You can wipe the complete surface from this position. The cloth is yellow, wet and cold and is lying in front of you on the table.*
You lift your right hand and feel your hand opening up. Feel your hand is open and straighten your elbow while you feel the tension at the front of your shoulder increase. Your hand touches the cold wet cloth. Feel the cold wet cloth and push it against the table. Then move the cloth to the upper left corner and with long fluent moves from right to left wipe the table down."

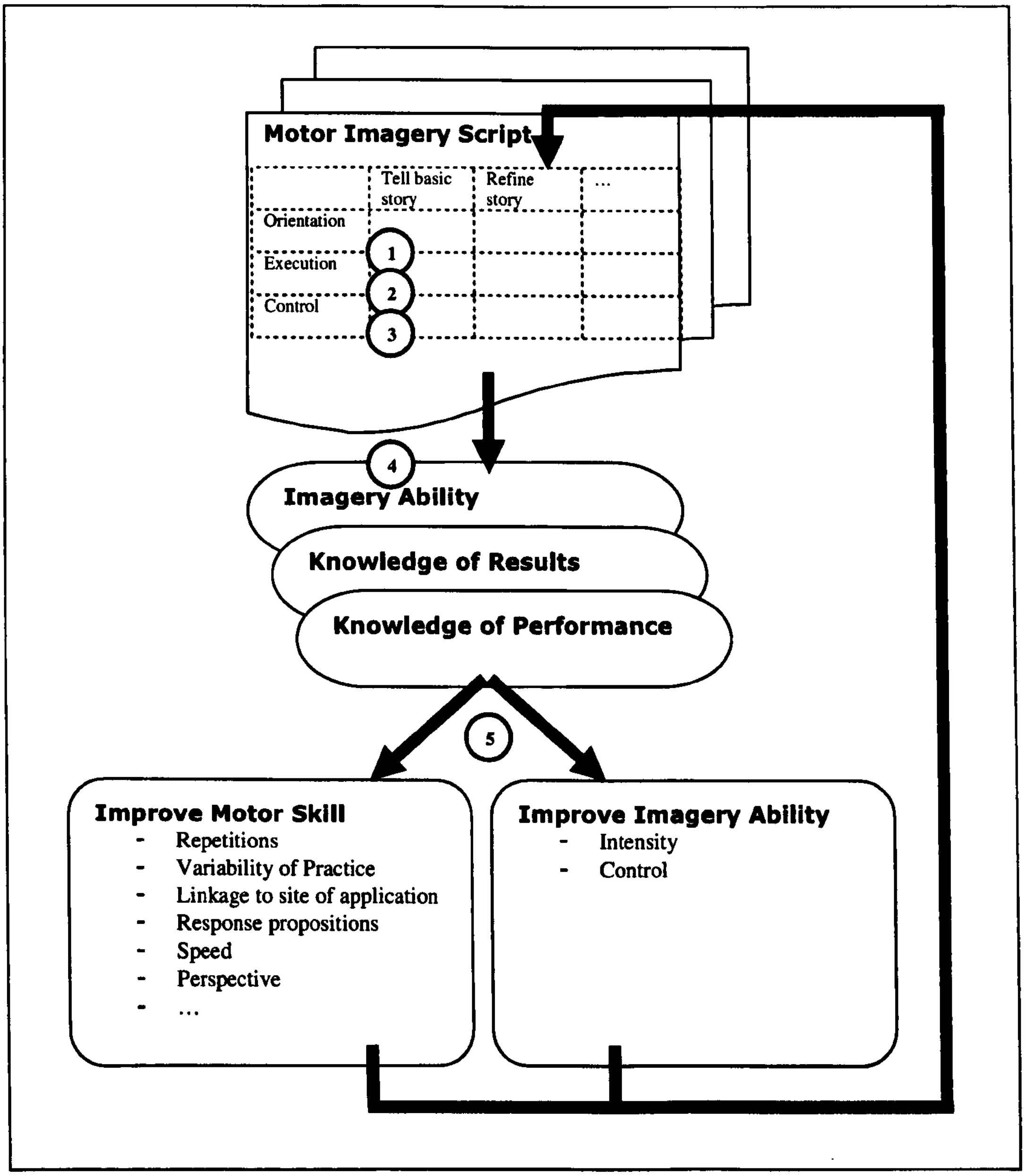

Figure 7. Illustration of the motor imagery strategy.

DISCUSSION

This strategy was developed in an attempt to optimise the theoretical potential of motor imagery and in order to standardise and operationalise the intervention. The strategy is based on evidence but clinical experience was also used. It should be noted that motor imagery should be viewed as complementary to and not as a substitute for physical exercise.

Figure 8 shows a flowchart of the total strategy. Motor learning is used as the base of the framework and it assumes some basic understanding and an introduction for the patient on motor imagery. It should be clear from this flowchart that it is a cyclic process with an important role for evaluating the imagined and subsequently modifying or adapting the intervention. Some techniques that can be used during motor imagery are mentioned. This list may not be complete but allows expansion with evidence-based techniques. This strategy is designed so that some patients can ultimately use motor imagery without guidance.

This strategy was designed for health professionals, especially with physiotherapists and occupational therapists in mind, but could also be used by nurses, psychologists and speech and language therapists. The strategy focuses on motor imagery with the aim to improve a patient's motor performance, but it may also indirectly affect control of arousal, control of anxiety, improve decision making, improve relaxation, build self-confidence or improve concentration. This strategy offers the therapists structure to deliver subject-specific imagery. It does not provide set rules but is designed to tailor the imagery to the patient's level and goals.

For clinical practice this means that it is impossible to advice on the exact duration and repetitions of motor imagery, as they should be graded to the patient and the level of difficulty. However, the review in chapter 2 suggests that 10 to 15 minutes of motor imagery is generally acceptable. Alternating between physical practice and motor imagery is suggested, however, future research should investigate the best proportion.

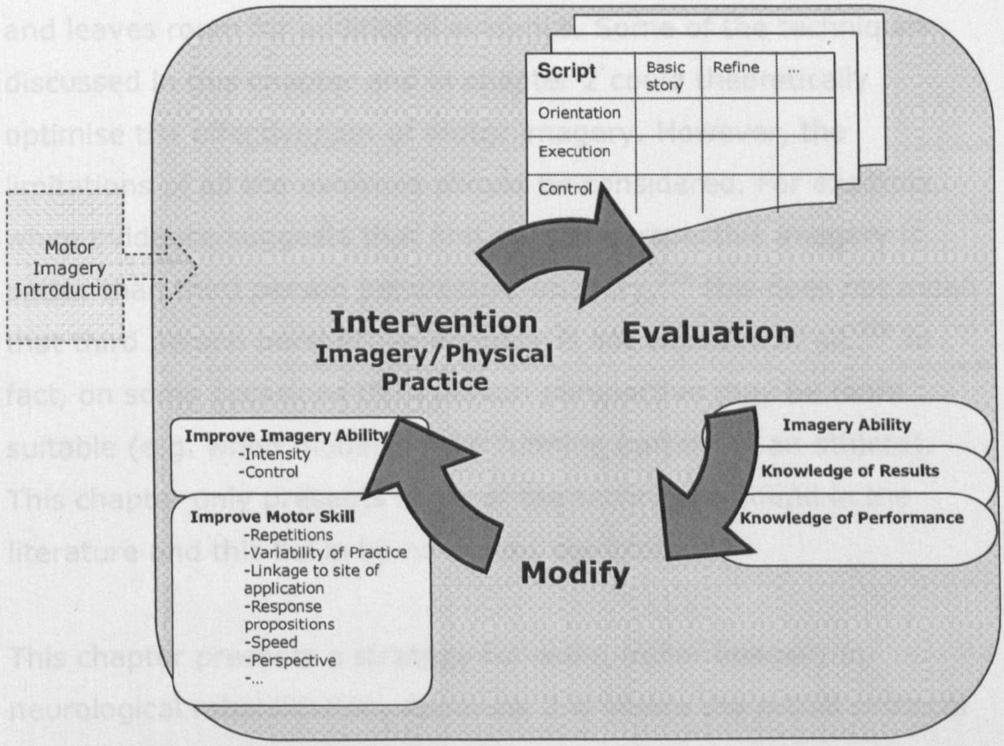

Figure 8. Flowchart of the motor imagery strategy.

This protocol should not be interpreted rigidly; it is not a cookbook and leaves room for additional evidence. Some of the techniques discussed in this chapter and in chapter 2 could theoretically optimise the effectiveness of motor imagery. However, the limitations of all the evidence should be considered. For example, when evidence suggests that first person perspective imagery is better than third person perspective imagery,[218] this does not mean that third person perspective imagery is not effective at all.[219] In fact, on some occasions third person perspective may be more suitable (e.g. when modelling the running pattern of an athlete). This chapter only presents some of the techniques found in the literature and this list is by no means complete.

This chapter presents a strategy for using motor imagery in neurological rehabilitation. Appendix 2 is where the actual protocol for the therapists is described.

So far this thesis has described the development of goal attainment scaling for use as a primary outcome measure in chapters 4 and 5; it has reviewed the literature on the content of motor imagery interventions (chapter 2), it has described a pilot study on using motor imagery in the treatment of spasticity (chapter 3) and as a result of these two chapters it has presented a motor imagery strategy (chapter 7). The next chapter of this thesis presents a randomised controlled trial where the goal attainment scaling technique is used as the primary outcome measure and the motor imagery strategy as the independent variable.

Chapter 7

An Integrated Motor Imagery Strategy for Neurological Rehabilitation: a Single-Blind Randomised Controlled Trial

Publications relevant to this chapter:

- Bovend'Eerdt TJH, Dawes H, Sackley C, Izadi H, Wade DT. An integrated motor imagery program to improve functional task performance in neurorehabilitation – a single-blind randomized clinical trial. Arch Phys Med Rehab

SUMMARY

This chapter presents a parallel group, assessor-blinded randomised controlled trial comparing motor imagery embedded in usual therapy (i.e. the strategy presented in chapter 6) with usual therapy only. Inpatients as well as outpatients at a neurological rehabilitation centre diagnosed with stroke, brain injury or multiple sclerosis were recruited and assessed at baseline, after 6 weeks (post-intervention) and after 12 weeks (follow-up). Goal attainment scaling was used as the primary outcome measure. The results show that there is no significant difference in outcome between the two groups even though the amount of physical practice was less in the motor imagery group; it was not less effective. The motor imagery protocol developed for this study proved to be easy to use in a variety of patients and for any task. Future research into the clinical use of motor imagery should focus on the effective components of motor imagery, which tasks and who benefits most from motor imagery and when in the rehabilitation process motor imagery is (most) effective.

INTRODUCTION

For individuals with neurological damage or disease, such as after a stroke, brain injury or in multiple sclerosis, rehabilitation by a multi-disciplinary team is effective.[2, 25, 30, 33, 220] Some evidence, from stroke populations in particular, shows that being involved in a coordinated neurological rehabilitation programme is effective for improving recovery[220] and reducing mortality.[32] There is some evidence that 'more is better,'[6] but otherwise there is less evidence to support specific techniques or components of the overall rehabilitation bundle. Using motor imagery to practice complex skills could potentially be used to deliver more rehabilitation within the current services but it is not clear whether using motor imagery in routine services is practical or effective.

A recent systematic review[8] has suggested that motor imagery practice may improve physical recovery in patients after stroke but there was a lack of studies investigating the effectiveness of service-delivered motor imagery and the motor imagery interventions were generally described poorly. Several recent studies[64, 66, 109, 134] suggest that motor imagery should not be used alone but should be implemented in therapy sessions, linking physical activities with motor imagery.

If motor imagery is effective in the recovery of patients with neurological conditions, such as stroke, brain injury and multiple sclerosis, it would be a useful additional intervention that could be performed by nearly everyone and possibly only with minimum guidance.

For this study a motor imagery strategy has been developed that can be integrated in usual therapy (i.e. clinical practice), can be tailored to individual goals and can be used for any activity (chapter

6).

The main question to be answered in this trial:

- Is physiotherapy and occupational therapy incorporating motor imagery more effective than standard physiotherapy and occupational therapy consisting of physical practice in people with neurological disease or damage?

METHODS

A Phase II exploratory Randomised Controlled Trial (RCT) with masked assessment and two parallel groups was performed. Both groups received task specific physiotherapy and occupational therapy given by their own therapists, as usual. Patients in the experimental group were additionally taught how to incorporate motor imagery into usual therapy and into activities practiced outside therapy. Patients in the control group received information on task-specific practice and on how to undertake it outside therapy. All rehabilitation therapy was delivered by the patients' own physiotherapist and occupational therapist. An independent assessor performed masked assessments. The study was approved by the Oxfordshire Ethics Committee (07/H0605/84) and the trial was registered on the internet (www.clinicaltrials.gov; identifier NCT00618085).

Randomisation and allocation concealment

A series of sequentially numbered opaque envelopes were filled with a card determining the treatment group, the allocation being determined randomly using a computer. To ensure an even study entry a block randomisation sequence using blocks of two, four and six was used. Patients were stratified into one of three groups; inpatients with onset between 2 weeks and 3 months prior to randomisation, inpatients with onset more than 3 months prior to randomisation or outpatients. The envelope, indicating the patient's group, was opened by the study manager after the baseline assessment.

Participants

Each patient that was admitted as an inpatient to the rehabilitation unit was initially screened by a consultant. Possible candidates were then screened by the study manager. Patients expressing an interest were given written information after which they were contacted in person by the study manager to answer any questions and discuss procedures. Patients were encouraged to discuss the study with family and/or friends before consenting. Outpatients at the rehabilitation centre (Centre for Enablement, Oxford, UK) were recruited through referrals from consultants, physiotherapists or occupational therapists.

Patients were eligible for this study if they:

1. Were participating in a rehabilitation program for problems arising from a recent event or change in disability, secondary to disease or damage affecting the central nervous system (e.g. stroke, traumatic brain injury, relapse in multiple sclerosis).
2. Were over 18 years of age.
3. Had sufficient language skills to undertake the intervention. Operationally this was defined as those able to score positive on the first three items (appendix 3) of the Sheffield screening test for acquired language disorders[221] (i.e. able to understand, remember and execute simple commands).
4. Had no co-morbidity that would interfere with the ability to perform imagery as judged by the clinician or from the medical notes (for example; schizophrenia, pre-existing

dementia).

Interventions

All patients received standard physiotherapy and occupational therapy care, and the amount (time) and content (other than adding motor imagery in the experimental group) of interventions was not specifically changed. Standard therapy was client-centred and aimed at functional restoration and independence enhancement. The imagery group was encouraged to use motor imagery in physiotherapy and occupational therapy sessions and elsewhere. The control group was encouraged to practice tasks outside therapy sessions. The suggested motor imagery schedule is shown in table 12.

Table 12. Suggested motor imagery intervention schedule.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Study manager	2 introduction films (20 + 15 min)	Sit in on 1 physiotherapy and 1 occupational therapy session (15 min)	*Optional additional session for motor imagery*	*Optional additional session for motor imagery*		
Physiotherapist		At least 3 sessions (3x15 min)	At least 3 sessions (3x15 min)	At least 3 sessions (3x15 min)	At least 2 sessions (2x15 min)	At least 2 sessions (2x15 min)
Occupational therapist		At least 3 sessions (3x15 min)	At least 3 sessions (3x15 min)	At least 3 sessions (3x15 min)	At least 2 sessions (2x15 min)	At least 2 sessions (2x15 min)
Participant			Practice tasks from therapy sessions (5x5min)	Practice tasks from therapy sessions (5x5min)	Practice tasks from therapy sessions (5x5min)	Practice tasks from therapy sessions (5x5min)

After randomisation each patient was shown two films on separate occasions. Initially scripts were written for the films and comments and suggestions were given on these scripts by another researcher. A patient, not involved in this trial, provided useful feedback on the first versions of the films resulting in the current final versions.

The films were shown on a desktop or a laptop computer with the participants either seated or lying supine in front of the screen with headphones on. There were two versions of each film, either for the control group (physical practice films) or the motor imagery group (motor imagery films). The films consisted of still pictures, commands, instructions and exercises spoken by a male person.

The films consisted of the following elements:

Physical practice film 1 (20 minutes)

- Information about stroke, brain injury and multiple sclerosis;
- Information on the brain;
- Information on impairments after brain damage;
- Information on rehabilitation and various disciplines.

Physical practice film 2 (15 minutes)

- Information on motor learning principles;

- Progressive muscle relaxation exercise;
- Phases of information processing (orientation, execution and control).

Motor imagery film 1 (20 minutes)

- Introduction to motor imagery (definition and multi-sensory nature of motor imagery);
- Two introductory exercises (exercise 1. picturing the face of a person; exercise 2. moving through the person's house);
- Background information (use of motor imagery by athletes and evidence from imaging studies showing similar brain activation during motor imagery as when actually performing movement);
- Two body awareness exercises (exercise 3. recognising if hand shown is left or right; exercise 4. imagining moving own hand in the same position as pictured);
- Information on the two perspectives (internal and external) and on the intensity, clarity and vividness of motor imagery;
- Exercise (nr. 5) on quality of the images;
- Progressive muscle relaxation exercise (nr. 6).

Motor imagery film 2 (15 minutes)

- Recapitulation of previous film;
- Instructions and exercise (nr. 7) to imagine success not impairment;
- Instructions and exercise (nr. 8) on imagining the environment;
- Instructions on when to do motor imagery;
- Instructions on 3 steps to develop a motor imagery script (1. tell the basic story. 2. add details to the story. 3. refine the story).

All the therapists received 2 training sessions of 1 hour each by the study manager. Therapists were taught how to implement motor imagery in their therapy sessions. The therapists received a printed version of the motor imagery strategy (appendix 2). The strategy was written by the author of this thesis and had undergone several rounds of feedback and comments from a physiotherapist, three researchers and a psychologist before resulting in the final version. The study manager (who was also a physiotherapist) sat in on the first therapy session with the patient to help the therapist deliver motor imagery in a standardised fashion and to support the therapist with the techniques. If therapists felt they needed more support with using imagery in their sessions the study manager sat in on more sessions. The study manager also sat in on the first session of the control group to control for attention. All interventions took place on the institution's ward, in the treatment rooms or the gym.

Table 12 shows the suggested dose of motor imagery during the six week period. The therapists would perform motor imagery with the patients at least three times per week for the first three weeks and at least two times per week for the last two weeks. The total amount spent on motor imagery during therapy sessions with the therapists was suggested to be approximately 6.5 hours. The control group received standard therapy, and both groups received a comparable amount of therapy.

In weeks 3 to 6 the patients in both groups were encouraged to practice tasks being taught in their therapy sessions for at least 5 minutes each day outside their therapy sessions. The motor imagery group would use motor imagery and the control group would use physical practice. Safe tasks were chosen to practice.

Measures

An independent assessor performed assessments at baseline, post-intervention (6 weeks) and follow-up (12 weeks). The assessments were performed in the most convenient setting for the patient and assessor, which included inpatient, outpatient and domiciliary settings.

Baseline measures

The Short-Orientation-Memory-Concentration test (SOMCT) and the Motricity Index were performed at baseline as descriptive measures (see appendix 1 for more information on these measures). The SOMCT[159] is a short questionnaire to assess aspects of cognitive function, including orientation in time and space, concentration and memory. The test comprises 6 questions with a total score range from 0 (worst) to 28 (best) and takes less than 5 minutes to administer. The Motricity Index [222] is an index of voluntary limb movement aiming to measure general motor impairment. Three movements for each limb (i.e. arm and leg) are assessed based on the MRC strength grades and weighted. The side score is the sum of the arm and leg score, divided by two. The minimum score is 0 and the maximum score is 100. The higher the score the less motor impaired.

Primary outcome measure

The primary outcome measure was goal attainment scaling in which two goals (at activity level) were identified by the physiotherapist and another two by the occupational therapist. Goals were chosen and set before the patient was allocated to a group for a period of six weeks and the methods are discussed in detail in chapter 4. Goal attainment was scored by the independent assessor post-treatment and at follow-up. The same goals were used for both post-treatment and follow-up assessment. The assessor received the goals and their levels at the assessment and was asked to indicate the level the patient was currently at. The goals were scored independently from each other.

Secondary outcome measures

The standardised secondary outcome measures are shown below. All outcome measures, except for the imagery questionnaire, are simple and widely used in clinical practice and research, and several are used routinely in local services (see appendix 1 for more information on these outcome measures).

Barthel Index [158, 223]

This is a staff-completed 10-item generic activities of daily living (ADL) assessment. Values are assigned to each item based on amount of physical assistance required to perform the activity. The minimum score is 0 and the maximum score is 20; the higher the score the greater the independence.

Rivermead Mobility Index [161]

This is a staff-completed questionnaire first developed to measure mobility disability after head injury and stroke, but now widely used in many conditions.[224-226] It comprises 14 questions (activities scored range from turning over in bed to running) and 1 direct observation of standing for 10 seconds. Each answer is scored 'Yes' (1) or 'No' (0). The minimum score is 0 and the maximum score is 15; the higher the score the better the mobility.

Timed Up & Go (TUG) [227]

The TUG measures the time it takes a patient to: stand up from a chair, walk 3 meters, turn, walk back to the chair and sit down again. Aids can be used if necessary and will be recorded, however, physical support from the assessor is not allowed. This test is practical and easy to execute.

Action Research Arm Test (ARAT) [228]

The ARAT is a 19-item staff-completed measurement of arm motor function divided in 4 categories (grasping, gripping, pinching and gross movement). Each item is scored on a 4-point ordinal scale (0= can perform no part of test; 1= performs test partially; 2= completes test but takes abnormally long time or has great difficulty; 3= performs test normally) with a score range between 0 and 57. The ARAT has high intrarater (r=0.99) and retest (r=0.98) reliability and validity.

Nottingham Extended ADL Index [193, 229, 230]

This simple extended ADL index consists of four sections (mobility, kitchen use, domestic tasks, and leisure activities) with a total of 21 items and can be filled in by the patient. It has proven to be a valid and useful outcome measure of mainly activity level in patients after stroke.[229]

Motor imagery Questionnaire

This questionnaire is a custom designed test investigating the self-efficacy and perceived effort to imagine up to four individualised skills. Each subject has up to four individualised goals which are generated by the physiotherapist and occupational therapist (from goal attainment scaling). The patient was asked to imagine performing the particular task (e.g. goal) in his/her mind's eye after which the patient was asked how confident he/she was in imagining the task, thus investigating the patient's perceived self-efficacy in performing motor imagery. Patients were asked to score their confidence on a numerical scale between '0' (not at all confident) and '10' (totally confident) for each goal. The perceived effort to imagine the task was investigated by asking the patient how much effort it cost him/her to imagine the particular task. The perceived effort was scored on a numerical scale between '0' (no effort at all) and '10' (maximum effort).

Subjective evaluation

The therapists (at T2; post-intervention) and the patients (at T3; follow-up) who had used motor imagery were asked to answer some simple questions from the researcher regarding compliance with using motor imagery and the perceived benefits from it (appendix 4). The therapists were asked: if they had spent the proposed amount of time (see table 12) on motor imagery over the past 6 weeks; if, in their opinion, the patient spent the proposed amount of time (see table 12) on motor imagery outside the therapy sessions; and if, in their opinion, the patient had benefited from using motor imagery.

The patients were asked: if they had used motor imagery over the past 6 weeks (e.g. between the post-intervention and follow-up assessment); and if they thought they had benefited from using motor imagery.

Both the therapists and the patients were given the opportunity to comment on the motor imagery intervention.

Analysis

GAS scores were calculated for each patient according to the method described in chapter 4.

Independent samples t-tests were performed on the demographic data and on the descriptive measures (e.g. Short Orientation Memory Concentration Test and the Motricity Index) to investigate whether there were differences between the control group and experimental group at baseline.

A 3*2 (Time*Group) repeated measures ANOVA was used to analyse the primary and secondary outcome measures. The within-subject factor Time had three levels (e.g. baseline, post-intervention and follow-up) and the between-subject factor Group had two levels (e.g. control group and experimental group). The significance level for all tests was set at $P<0.05$ and analysis were performed with the statistical software package SPSS v 17.0 (SPSS inc, Chicago, USA).

An intention-to-treat analysis was performed and missing data were imputed with the last observed response carried forward for all measures except for the timed up and go. Many patients were not able to perform the timed up and go (e.g. time to stand up from chair, walk 3 meters, turn, walk back to the chair and sit) at baseline and repeated measures ANOVA can not handle missing data. This means that only the patients that could perform the timed up and go at baseline were used in this analysis. A complete-case analysis and a subgroup analysis employed the same repeated measures ANOVA.

The success of the masked assessments was investigated by employing a chi-square test, comparing the random allocation and the masked assessor's guesses.

Where the assumptions for parametric testing were violated, the non-parametric equivalent was performed. Because the F-test (e.g. repeated measures ANOVA) is usually more robust than the non-parametric equivalent and because the tests did not show different results in this chapter, only parametric results are presented here.

RESULTS

Patients were recruited from the Oxford Centre for Enablement between February 14th 2008 and January 15th 2009. Figure 9 presents the CONSORT flowchart for this study. Of the 77 admitted patients, seven refused to participate, one was uncooperative, 34 patients did not fulfil the criteria (14 on the grounds of diagnosis, 17 could not complete the Sheffield screening test, 2 did not speak English and 1 was younger than 18 years). Seven patients were only admitted for a short stay, one patient was readmitted to hospital before being screened and another patient was readmitted to the rehabilitation unit with another stroke but had already been included in the trial.

Twenty-six patients provided informed consent and were randomised either to the experimental (n=13) or the control (n=13) group. Four outpatients attending for out-patient therapy at the Oxford Centre for Enablement were also included resulting in a total of 30 patients in this study; 15 patients in each group. Many patients are treated as outpatients at the Oxford Centre for Enablement but the actual number is unknown. One patient was lost to follow-up after the baseline assessment due to infection control (patient developed C Diff diarrhoea) and the researcher was unable to contact another patient for the final assessment. The average duration (mean (SD)) of the intervention period was 5.3 weeks (1.5) and 5.7 weeks (1.2) for the follow-up period.

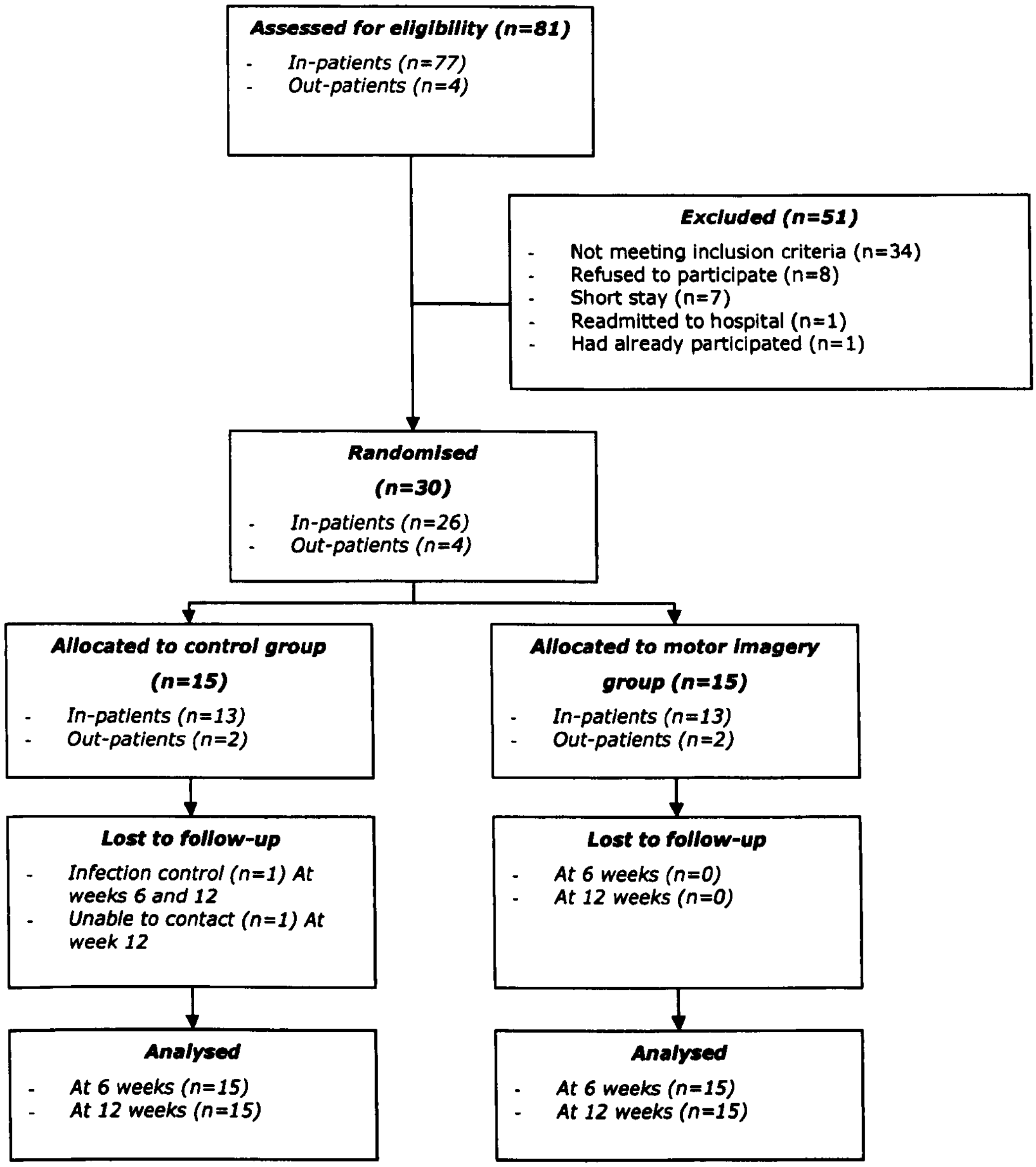

Figure 9. Consort flow diagram. Note that an intention-to-treat analysis was performed, hence the analysed numbers are n=30, despite the lost to follow-up.

Baseline characteristics for each group and for the total sample are presented in table 13. The control group and the experimental group show similar characteristics and no significant differences between the two groups were found.

Table 13. Patient characteristics per group and for the total sample (mean (SD)).

	Control	Experimental	Total
Gender (female/male)	5/10	6/9	11/19
Age (yrs)	50.6 (16.48)	51.2 (11.75)	50.3 (13.88)
Diagnosis			
▪ Stroke	n=14	n=14	n=28
▪ TBI	n=1	n=0	n=1
▪ MS	n=0	n=1	n=1
Time since onset (wks) n=29	21.8 (15.17)	15.9 (17.25)	18.9 (16.20)
SOMCT	21.1 (8.14) n=15	21.9 (3.39) n=13	21.4 (6.29) n=28
Motricity Index			
▪ UL	60.3 (27.75)	58.1 (35.19)	59.2 (31.16)
▪ LL	54.8 (29.97)	53.5 (26.18)	54.1 (27.66)
▪ Total	57.5 (21.65)	55.8 (29.02)	56.7 (25.17)

Notes: the MS-patient was excluded from the calculation of the time since onset because this was an outlier (10 years); two patients randomised to the experimental group were unable to complete the Short-Orientation-Memory-Concentration Test.
Legend: TBI, traumatic brain injury; MS, multiple sclerosis; yrs, years; wks, weeks; SOMCT, Short Orientation-Memory-Concentration Test; UL, upper limb; LL, lower limb; *, significant independent sample t-test, $P<0.05$.

Primary and secondary outcome measures

Table 14 presents group and combined sample data of the three assessments for Goal Attainment Scaling, the Barthel Index, the Rivermead Mobility Index, the Nottingham Extended ADL Index and the Action Research Arm Test.

For the primary outcome measure (i.e. GAS scores) the multivariate approach was used (Pilliai's Trace). The main effect of the within-subject factor Time was significant: $F(2, 27) = 45.159$, $P<.001$. The group by time effect was not significant: $F(2, 27) = 0.085$, $P=.919$. The main effect of Group was not significant: $F(1, 28) = 0.039$, $P=.845$. Pairwise comparisons show that the difference over time is significantly different between each assessment (i.e. baseline versus post-intervention, post-intervention versus follow-up and baseline versus follow-up).

A separate analysis using the covariates; age, SOMCT score, imagery confidence score or imagery effort score, presents similar results, that is; the within-subject factor Time is significant and the interaction factor (i.e. Time*Group) and the between-subject factor Group are not significant.

Figure 10 shows a bar graph for the control and experimental group of the primary outcome measure (GAS scores). The figure illustrates a similar increase in GAS score over time for both groups.

Multivariate analyses of the Barthel Index, Rivermead Mobility Index, Nottingham Extended ADL Index and Action Research Arm Test show an improvement in both groups over time; the within-subject factor Time (baseline, post-intervention, follow-up) is significant for all outcome measures. Analyses do not show significance for the interaction factor (Time*Group) and the between-subject factor

Group (control group, experimental group) suggesting that there is no difference in outcome between the control and experimental group. A complete case analysis presents the same results.

Table 14. Results of the primary and secondary outcome measures (mean (SD)) on the three assessments; baseline (T1), post-intervention (T2) and follow-up (T3).

		T1	T2	T3
GAS*	CO	35.8 (0.33)	52.9 (13.31)	57.9 (14.49)
	EXP	35.9 (0.54)	53.0 (7.53)	59.3 (11.48)
	TOT	35.9 (0.45)	52.9 (10.63)	58.6 (12.86)
Barthel Index*	CO	12.0 (6.72)	13.5 (6.98)	13.9 (6.44)
	EXP	11.9 (6.72)	13.5 (6.00)	15.1 (6.24)
	TOT	12.0 (6.61)	13.5 (6.39)	14.5 (6.26)
RMI*	CO	6.1 (5.54)	7.7 (5.63)	8.4 (5.19)
	EXP	6.3 (5.38)	8.2 (5.43)	8.9 (5.51)
	TOT	6.2 (5.37)	7.9 (5.44)	8.7 (5.27)
NEADL*	CO	18.3 (15.99)	23.3 (17.22)	28.2 (20.05)
	EXP	20.3 (14.26)	24.4 (16.72)	27.8 (17.70)
	TOT	19.3 (14.92)	23.9 (16.69)	28.0 (18.59)
ARAT*	CO	26.4 (22.69)	30.7 (23.38)	31.5 (22.05)
	EXP	26.9 (24.52)	31.7 (24.97)	32.9 (25.60)
	TOT	26.6 (23.2)	31.2 (23.78)	32.2 (23.49)

Legend: *, significant within-subject factor of time, $P<0.05$ but no significant between-subject factor of group or interaction time*group, $P>0.05$; CO, control group; EXP, experimental group; TOT, total sample; GAS, Goal Attainment Scaling; RMI, Rivermead Mobility Index; NEADL, Nottingham Extended ADL Index; ARAT, Action Research Arm Test.

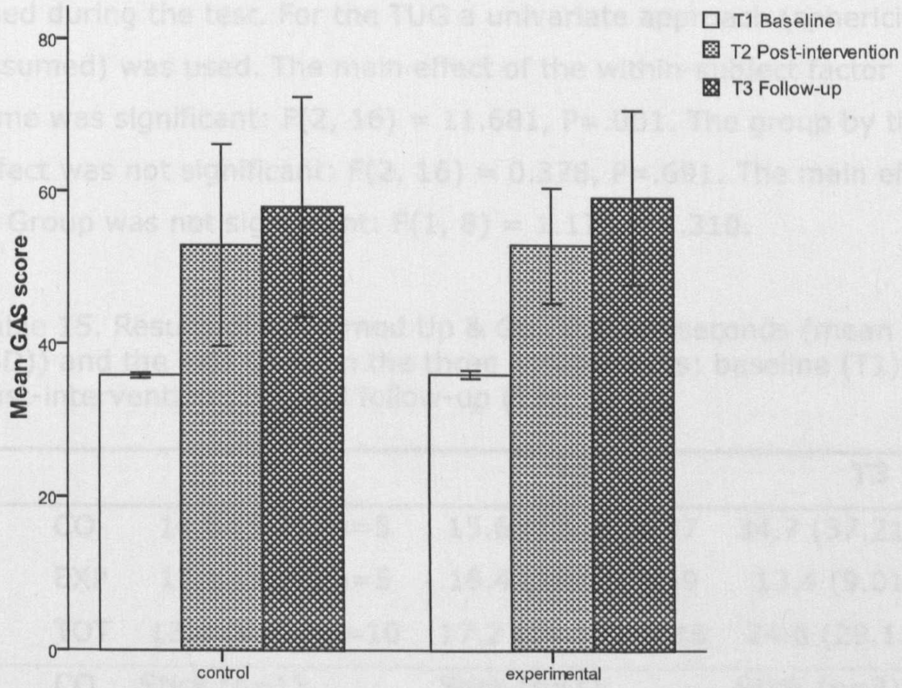

Figure 10. Bar graph of the GAS scores for the control and experimental group over time; baseline (T1), post-intervention (T2) and follow-up (T3). Error bars: +/- 1 SD.

Table 15 presents the results for the TUG as well as the walking aids used during the test. For the TUG a univariate approach (sphericity assumed) was used. The main effect of the within-subject factor Time was significant: $F(2, 16) = 11.681$, $P=.001$. The group by time effect was not significant: $F(2, 16) = 0.378$, $P=.691$. The main effect of Group was not significant: $F(1, 8) = 1.175$, $P=.310$.

Table 15. Results of the Timed Up & Go (TUG) in seconds (mean (SD)) and the aids used on the three assessments; baseline (T1), post-intervention (T2) and follow-up (T3).

		T1	T2	T3
TUG*	CO	14.8 (5.21) n=5	15.6 (12.15) n=7	34.7 (37.21) n=10
	EXP	12.1 (3.87) n=5	18.4 (16.07) n=9	13.4 (9.01) n=9
	TOT	13.4 (4.56) n=10	17.2 (14.10) n=16	24.6 (29.11) n=9
Aids	CO	Stick (n=1)	Stick (n=1) 3-rollator (n=1)	Stick (n=2) Quad stick (n=1) 4-rollator (n=1)
	EXP	4-rollator (n=1)	Stick (n=2) 4-rollator (n=1) Frame (n=1)	Frame (n=1)

Notes: repeated measures ANOVA of the TUG is only performed on the patients able to perform the test at baseline (n=10) but the table shows the mean time in seconds (SD) of all patients completing the TUG over the three assessments. Legend: *, significant within-subject factor of time, $P<0.05$ but no significant between-subject factor of group or interaction time*group, $p>0.05$; CO, control group; EXP, experimental group; TOT, total sample; TUG, Timed Up & Go; 3-rollator, 3-wheeled rollator; 4-rollator, 4-wheeled rollator; frame, walking frame.

Table 16 presents group and total sample data of the three assessments for the confidence and effort components of the Imagery Questionnaire and has similar results as the other outcome measures. The within-subject factor Time is significant but the interaction term Time*Group and the between-subject factor Group are not.

Table 16. Results of the Imagery Questionnaire (mean (SD)) on the confidence and effort components on the three assessments; baseline (T1), post-intervention (T2) and follow-up (T3).

		T1	T2	T3
Confidence*	CO	8.1 (1.87)	8.6 (1.59)	9.0 (1.06)
	EXP	8.0 (1.79)	7.8 (2.26)	8.7 (0.98)
	TOT	8.1 (1.80)	8.2 (1.96)	8.9 (1.01)
Effort*	CO	4.1 (2.51)	2.7 (2.73)	2.5 (2.33)
	EXP	3.8 (2.28)	3.1 (1.77)	3.1 (2.35)
	TOT	3.9 (2.36)	2.9 (2.27)	2.8 (2.32)

Legend: *, significant within-subject factor of time, $P<0.05$ but no significant between-subject factor of group or interaction time*group, $P>0.05$; CO, control group; EXP, experimental group; TOT, total sample.

Masking

The success of the masked assessments was investigated after each assessment and the reasons of unmasking were recorded. Of the 29 post-intervention assessments (T2) the assessor was unmasked in three of the assessments (10.3%). Of the 28 follow-up assessments (T3) the assessor was unmasked in seven of them (25%). The reasons of unmasking were:

- patient reveals the allocation unintentionally;
- staff reveal the allocation unintentionally;
- assessor remembered the unmasking from the previous assessment.

When the assessor was asked to guess the patient's allocation (for the patients that were not unmasked), 57.7% of the guesses were correct for the post-intervention assessment (T2) (50% correct guesses for the experimental group), being not significantly different from chance (X^2 = 0.62, P=.433). At the follow-up assessment (T3) 47.6% of the guesses were correct for the (36.4% correct guesses for the experimental group), which is not significantly different from chance (X^2 = 1.19, P=.275).

Compliance

Table 17 presents the answers on the compliance questions by the therapists (at T2) and the patients (at T3). It is obvious that the therapists used less than the proposed amount of time on motor imagery and that patients did not use it as much outside their therapy sessions as suggested.

The reasons the therapists had not used as much motor imagery during the sessions can be categorised in practical and patient-specific considerations.

Practical reasons for not delivering the proposed amount of motor imagery were: the patient was being seen by an assistant or a student who was not trained in using motor imagery; outpatients received less therapy sessions; therapists were on holiday or they simply forgot to deliver the motor imagery.

Patient-specific reasons were: the therapists felt motor imagery was inappropriate for a patient because of cognitive problems (e.g. attention, concentration and memory problems); some activities were felt to be inappropriate to practice with motor imagery; some patients were uncooperative and others were unwell.

The main limiting factor why the therapists thought the patients did not spent the proposed amount of time on motor imagery outside the sessions was inadequate cognitive capabilities to practice independently such as attention, concentration and memory deficits.

Table 17. Compliance questions for the treating therapists (physiotherapist and occupational therapist) and the patients.

Question	Therapist/patient	Answer
Have you spent the proposed amount of time on motor imagery over the past 6 weeks?	Occupational therapist (n=13)	Yes (n=1) No, less time (n=12)
	Physiotherapist (n=14)	Yes (n=3) No, less time (n=11)
In your opinion, has the patient spent the proposed amount of time on motor imagery outside the therapy sessions?	Occupational therapist (n=8)	Yes (n=1) No, less time (n=6) No, more time (n=1)
	Physiotherapist (n=14)	Yes (n=3) No, less time (n=10) No, more time (n=1)
Have you used motor imagery over the past 6 weeks?	Patient (n=12)	Yes, daily (n=2) Yes, weekly (n=3) Yes, sporadically (n=5) No (n=2)

Subgroup analysis

Five patients reported to have used motor imagery at least once a week (see table 17) suggesting good to fair compliance. This subgroup (n=5) was compared to the control group (n=15) and table 18 presents the data for the primary outcome measure Goal Attainment Scaling.

Table 18 shows that the changes over time in the motor imagery subgroup are higher than the changes in the control group. This is illustrated in figure 11 which shows curves for the control group (n=15), the complete motor imagery group (n=15) and the motor imagery subgroup (n=5). A multivariate subgroup analysis (3*2

(Time*Group) repeated measures ANOVA) for Goal Attainment Scaling demonstrated the following: the main effect of the within-subject factor Time was significant: $F(2, 17) = 29.845$, $P<.001$; the group by time effect was not significant: $F(2, 17) = 1.498$, $P=.252$ and the main effect of Group was not significant: $F(1, 18) = 2.255$, $P=.151$.

Analyses do still not show significant differences between the motor imagery subgroup and control group. This is the case for the other outcome measures (i.e. Barthel Index, Rivermead Mobility Index, Nottingham Extended ADL Index, Action Research Arm Test) as well (presented in appendix 5). However, there is a visible trend (see figure 11) in favour of the motor imagery group in all outcome measures (see appendix 5) with generally larger increases over time compared to the control group.

Table 18. Results of the motor imagery subgroup (n=5) and the complete control group (n=15) for Goal Attainment Scaling (mean (SD)) on the three assessments; baseline (T1), post-intervention (T2) and follow-up (T3).

		T1	T2	T3
GAS*	CO	35.8 (0.33)	52.9 (13.31)	57.9 (14.49)
	EXP	35.9 (0.34)	59.4 (5.79)	70.1 (10.43)
	TOT	35.8 (0.33)	54.5 (12.08)	60.9 (14.38)

Legend: *, significant within-subject factor of time, P<0.05 but no significant between-subject factor of group or interaction time*group, P>0.05; CO, control group; EXP, experimental group; TOT, total sample; GAS, Goal Attainment Scaling.

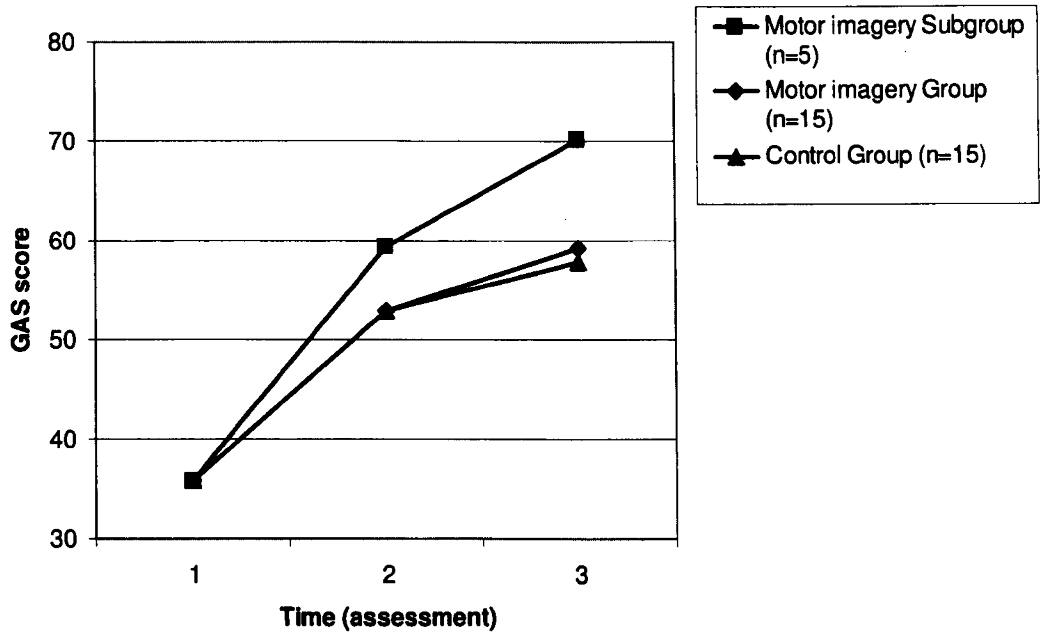

Figure 11. Average values of the Goal Attainment Scaling (GAS) score on the three assessments. The motor imagery subgroup (n=5), the complete motor imagery group (n=15) and the complete control group (n=15) are presented.

Perceived benefits

The therapists and patients were asked if they thought motor imagery had had a beneficial effect. The physiotherapists reported benefits in 12 cases and no benefits in only 1 case (2 unanswered) and the occupational therapists reported benefits in 4 cases and no benefits in 2 cases (9 unanswered). Eleven of the patients thought motor imagery had benefited them and only 1 case did not think it benefited him (3 unanswered).

The reasons the therapists gave for motor imagery not being of benefit were that patients were too cognitively impaired to benefit or that patients were too sceptical of the technique. The reasons given for a beneficial effect were: the patient was quicker in correcting errors and took more effortful attempts in performing the activity; the patient was very disabled and there were limited treatment options available but motor imagery filled that gap; it helped the patient concentrate; it improved the patient's insight into her own problems and it was beneficial to think through the movements before actually performing them.

According to the patients they benefited from motor imagery because: it actually made them think about the movements and put their mind to it; it gave them more confidence; it motivated them; going through the movements and actions helped; it prepared them for action and it gave a better idea of what needed to be done.

DISCUSSION

The phase II RCT presented here shows that motor imagery integrated in usual therapy (i.e. occupational therapy and physiotherapy) is not more effective than not using motor imagery during therapy sessions. This suggests that there is no additional effect of using motor imagery during therapy sessions.

Although no statistically significant additional effect of motor imagery was found it should be noted that even while the amount of physical practice in the motor imagery group was probably lower than in the control group, the motor imagery group did not perform worse but stayed at the same level as the control group. This suggests that motor imagery embedded in usual therapy in this RCT is just as effective as physical practice which could be useful in clinical practice when sessions with the therapists drop out or when the therapist is on holidays. Motor imagery can in such cases still offer a method of practicing the tasks and with continuation of the program.

It should be noted that Kwakkel et al.[4] showed in a meta-analysis that at least 16 hours of augmented exercise therapy is needed to find a beneficial effect. In the present study the difference in exercise therapy amount is less than 16 hours. Another study[231] showed that more motor imagery is required to find a similar effect from physical practice. The amount of motor imagery in the present study was similar to the amount used in other studies but probably more motor imagery is required in clinical practice.

A subgroup analysis of patients (n=5) who reported using motor imagery more than one session per week showed a positive trend exceeding the improvement of the physical practice group but the difference was not statistically significant. This finding warrants further research in which special attention should be paid to increase compliance or patients should be screened for compliance.

Limitations of the study

Complex interventions are commonly used in health services but the evaluation of these complex interventions presents various problems.[14] Not finding a statistically significant effect of a complex intervention does not mean that it is not clinically effective.[4, 14] Not being able to show a significant effect of motor imagery in this RCT can be due to:

- methodological quality of the RCT;
- patient selection;
- amount of contrast between interventions;
- type, focus and timing of the interventions;
- outcome measures, and;
- inadequate statistical power (small number of patients).

Although in this RCT the random allocation was successful, the masking was adequate and the overall methodological quality was good, the follow-up period (6 weeks) was particularly short. Ideally the follow-up period would have been at least 3-6 months to measure the long-term effects of motor imagery. Unfortunately, it is usually impossible to mask the patient and/or the therapist to the interventions in rehabilitation studies but the masking of the assessor has been fairly successful in this RCT. It is sometimes possible to generate equally expectations for each therapy, but we did not measure this.

The population included in this RCT was particularly heterogeneous, making it difficult to demonstrate a difference between the groups, especially when the treatment effects are relatively small compared to the nature of recovery and with a relatively small population.[39]

Cognitive deficits may negatively affect the patient's ability to engage in rehabilitation.[25] By using the Sheffield screening test we selected patients that could follow simple instructions and had some basic cognitive abilities. The SOMCT is a brief test measuring orientation, memory and concentration and is not a very specific measure of cognition. This resulted in a research population with a wide range of cognitive abilities which may have affected the results of this study negatively. Future studies should investigate the effect of cognition on motor imagery further.

The aim was to use at least 6.5 hours of motor imagery during the 6 weeks intervention period, however, compliance was poor; reducing the amount of motor imagery. This has probably contributed to the failure to show additional benefit. Future studies should consider increasing the compliance by employing therapists to deliver the intervention, by reminding the patient frequently about the intervention, but also by increasing the amount of the intervention.

In this RCT a clinical client-centred approach was employed for measurement of outcome, resulting in a wide range of tasks usually at the activity level. Interventions have different effect sizes for different tasks,[6] for example; treadmill training has a summary effect size of 0.70, whereas improving the symmetry when moving from sitting to standing has a summary effect size of 0.92.[6] The variety of the tasks in this RCT, ranging from walking to manipulating food, has added to the heterogeneity and may have made it harder to find significant differences. Goal attainment scaling is supposed to counter this problem but the relatively high standard deviations of GAS found on T2 and T3, 10.63 and 12.86 respectively, suggest otherwise. Goals are not necessarily weighted in recent methods[171, 232] anymore, but instead a weight of 1 is assigned to the goal. Using a weight of 1 in our analyses did not alter our results.

Although the standard outcome measures (i.e. other than goal attainment scaling) used in this RCT are valid and reliable, they may not have been responsive enough and may have inadequately covered the tasks from the interventions. The outcome measures mostly covered the ICF activity domain for which it is more difficult to measure changes than on the ICF function domain.[233] Because a wide variety of tasks was practiced in this RCT, not all of the tasks may have been covered by the standard outcome measures used; for example, a patient could have had mainly arm function problems which would have been covered by the action research arm test. However, the timed up & go was also assessed in this patient which would have been an inadequate outcome measure because mobility would not have been targeted in the intervention of this patient. Goal attainment scaling is supposed to counter this problem but it too may not have been responsive enough.

The sample in this RCT was small resulting in low statistical power and a possible type II error (i.e. failure to reject the null hypothesis when the null hypothesis is false). A post-hoc sample size calculation suggests that 18 patient would be needed per group to find a significant difference of 20% on the GAS ($\alpha=0.05$).

The lack of statistical power coupled with the great heterogeneity of patients are the most probable reasons that no differences were found (other than the possibility that motor imagery actually has no additional benefit).

Compliance

Compliance of the patients using motor imagery or physical practice outside therapy sessions was investigated by having patients keep a logbook. Only 9 of the 30 patients were able to keep a logbook. Reasons for not being able to keep a logbook were cognitive problems (i.e. memory deficits, unable to write due to arm function deficits or due to expressive aphasia). Even then, not all patients who could keep a logbook actually did this. The result was that only two logbooks gave an accurate overview of the 6 weeks intervention period; one from the control group and the other from the experimental group. It can be concluded that compliance varied largely and was probably similar in both groups. Although logbooks are a useful way of investigating compliance[234] it should be recognised that not all patients are able to keep logbooks and that even fewer will do so. Consequently more effort should be made to keep logbooks simple (e.g. ticking boxes instead of writing) and to increase the compliance of keeping a logbook (e.g. by frequent reminders). This issue stresses the difficulty of measuring a person's compliance with motor imagery.

Analysis of compliant patients

On the compliance questionnaire five patients reported to have used motor imagery at least on a weekly basis. Nevertheless, a subgroup analysis did not show a significant benefit for the motor imagery subgroup. However, it should be noted that on most of the outcome measures there were larger increases over time for the motor imagery subgroup (see figure 11 above and appendix 5), suggesting that this subgroup improved more than the control group, although not significantly. This subgroup was chosen because it was observed that there was a wide variety in motivation to perform motor imagery which may have lead to the wide variety in compliance to the technique. This comparison is merely intended as an illustration because the groups are not comparable and the advantages of the randomised controlled design are nullified.

It can be argued whether the favourable effect of the subgroup is the result of motor imagery practice. It may be that the patients in the subgroup were simply more motivated than the other patients from the motor imagery group. Although they reported to have used motor imagery more often than the rest of the motor imagery group, this increased motivation may have resulted in an increased use of any available practice technique, so also physical practice. Another explanation for their greater improvement may be their initial level. Figures 1, 2 and 4 from appendix 5 (Barthel Index, Rivermead Mobility Index and Action Research Arm Test) show that the subgroup has higher initial values (not significant) than the other patients. Future research should attempt to identify subgroups that benefit the most from motor imagery.

Relation to other studies

Previous randomised controlled studies using motor imagery in neurological rehabilitation have reported significant positive effects of motor imagery.[62, 63, 66, 67, 134] The main difference with the current study is that the current study embedded the motor imagery intervention in usual therapy, whereas other studies recruited patients who were not actually receiving therapy anymore, where the patients received motor imagery as a separate addition to physical therapy and where therapists were employed to deliver the motor imagery or motor imagery was delivered by tape. The novelty of this study compared to the other motor imagery studies, but also to many other studies in neurological rehabilitation, is the clinical client-centred approach making the study directly relate to actual clinical practice, which is questionable in most other studies. The current study is underpowered but it provides valuable information on how motor imagery can actually be applied in clinical practice.

Future clinical research should establish the effectiveness of the motor imagery strategy presented in this thesis and should try to distinguish which tasks and when in the rehabilitation process motor imagery is most beneficial and who benefits most from motor imagery.

Chapter 8

Epilogue

SUMMARY

This chapter is a synopsis of the body of work contained in this thesis. The chapter title epilogue, instead of general discussion, is used because this chapter is not intended to repeat all the discussions of the previous chapters but instead to bring this thesis to a close by discussing some specific issues arising from the whole study. First discussed is the position of this thesis in the general research literature; this is followed by a discussion on motor imagery interventions in clinical research and the use of goal attainment scaling as an outcome measure in research.

POSITION OF THESIS

It has been recognised that past intensive research efforts have failed to translate into rigorous novel therapeutic strategies;[105, 235-237] therefore various initiatives have been established to boost this translational research.[105, 235] Various definitions of translational research exist but the definition used here is by the Dutch advisory council on health research:[235] "*translational research is a phase in the knowledge chain comprising all steps, from the identification of possible leads (in patients or patient material) for diagnostics, prevention or treatment, up and including early application in clinical practice. Research questions may originate from clinical practice as well as from the laboratory. What we want is generalisation and transfer of treatment effects.*"

Reasons for the failure to translate fundamental research successfully to clinical practice are usually complex and inter-linked.[105, 235, 238, 239] There are a large number of unsuccessful neurological rehabilitation trials[201] and the research foundations for neurological rehabilitation are only partially studied. The general consensus is that more rehabilitation is better but there is no preference for a specific technique.[201] Despite extensive preclinical studies examining the effect of specific interventions, the bridge between fundamental and clinical research is often missing. The fact that neurological populations usually have multidimensional problems (e.g. physical, cognitive, emotional etc) possibly makes this translation even more difficult.

This thesis presents some examples of effective translational research. First, in chapter 3 a question generated in the clinic was investigated by using a pilot study; an example of bedside to bench research (i.e. the carer who reported that stretching could be more comfortably and effectively delivered if performed whilst simultaneously imagining the movement). Whether motor imagery can be effectively used in the treatment of spasticity should be further explored; initially at least by using more fundamental research methods. Second, translational research from bench to bedside was performed by developing a motor imagery strategy for neurological rehabilitation based on fundamental research from other disciplines such as sports psychology and motor learning; using the MRC guidance on developing and evaluating complex interventions. The fundamental research was then linked by employing the intervention strategy in a service-delivered trial in neurological patients.

This thesis illustrates how challenging translational research can be. Some of the challenges are more practical (e.g. getting therapists to deliver the intervention) and others more methodological (e.g. finding adequate outcome measures). Nevertheless, there is an unmistakable need for translational research in neurological rehabilitation and efforts should be made to develop a structure to guide future translational research in neurological rehabilitation.

A prerequisite for translational research is first of all a (better) collaboration between research disciplines and between researchers and clinicians. Researchers should also move along the continuum from fundamental to clinical research (i.e. from animal studies to computational models to skill acquisition in humans) in order for new interventions to succeed. I was lucky enough to work in a setting where clinical and fundamental research and researchers are closely linked.

MOTOR IMAGERY

There is a body of research signifying that motor imagery is effective in enhancing performance, in both healthy[48, 57, 58] and patient populations.[8, 96, 170] However, motor imagery is a complex intervention, as illustrated by chapter 2, and a variety of motor imagery intervention protocols have been employed in stroke populations.[8]

Chapter 7 presents an RCT where the motor imagery strategy was embedded in usual therapy and was delivered by the patient's usual therapists, translating more fundamental research into clinical practice. The RCT showed that it was possible to employ motor imagery in a variety of patients for a variety of tasks and that it could be tailored to the patient. This is an important finding if motor imagery is to be used in clinical practice. However, transfer of research findings into practice is a difficult and slow process with many barriers.[240] In order to investigate the strategy's effectiveness when embedded in clinical practice, future research should try and change established practice first.[240, 241] To increase the amount of rehabilitation by using motor imagery not only the clinician's behaviour but also the patient's behaviour should be changed.[241] Motor imagery allows patients to increase the amount of practice without continuous therapists' time and without causing physical fatigue but compliance will have to be optimised first. The subgroup analysis presented in chapter 7 suggests a beneficial effect in the more compliant patients, although not statistically significant. Beside the poor general compliance, a lack of power (type II error), the heterogeneous population and the wide variety in tasks are probably the most important reasons for not finding a positive effect of motor imagery in the RCT.

In the RCT (chapter 7) short-term effects of motor imagery were investigated in sub-acute and chronic patients. Future research should address what the long-term effects of motor imagery practice are and when motor imagery is most effective (e.g. is this in the sub-acute stage after stroke when patients are physically limited the most or is this in the chronic stage). The motor imagery strategy (chapter 6) consists of a combination of techniques and components and future research should investigate what the most effective components of motor imagery are and how compliance by the therapists as well as the patients can be adequately monitored.

Neurological patients usually present with multiple problems and they are characterised by their heterogeneity. The motor imagery strategy developed in this thesis (chapter 6) allows motor imagery to be used by a wide variety of patients and for any motor task. A pragmatic approach to the motor imagery strategy was used in order to give therapists and patients a structure so that they can easily make use of motor imagery in clinical practice. The strategy allows accumulation of new evidence to be integrated in the future but it does not go into detail. More research will be required in the future to specify elements of the strategy, such as the optimal dose, but these elements should always be matched to the task and the patient.

Mediating factors of motor imagery should also be considered in the future and deserve further investigation. For example: what is the location and the extent of the brain damage, as this may affect the patient's imagery ability[213, 242] and, what other deficits does the patient have that may impact on the effectiveness of motor imagery (e.g. apraxia, neglect, etc). These factors refer to the ability of the patient to engage in motor imagery, which, in the clinic, can be established with questionnaires (e.g. Kinaesthetic and Visual Imagery Questionnaire)[125, 215] or mental chronometry.[80] A discussion of methods to investigate motor imagery ability fell outside the scope of this thesis.

Another potential benefit of motor imagery is that it may promote generalisation. Most therapeutic interventions are task-specific; the effect is usually limited to the task trained and does not generalise to other related tasks that are not trained.[201] However, a recent study by Liu et al.[243] showed that motor imagery promotes generalisation and improved patients' ability on performing the tasks they did not mentally practice and in places different from the practice environments. The strategy presented in chapter 6 may provide useful guidance to improve generalisation but requires further investigation.

GOAL ATTAINMENT SCALING

The evaluation of neurological rehabilitation programmes is challenging because of the heterogeneous population and the multidimensionality of the problems.[7, 33, 244] The result is a range of services and interventions that are often delivered in multidisciplinary teams.[25, 30, 33] Although the interventions are manifold, the evaluation usually focuses on a limited number of set outcomes. Compared to standard measures (e.g. Barthel Index, Action Research Arm Test, etc), goal attainment scaling allows measurement of multiple domains[185, 245] (e.g. ADL, mobility, cognition etc) that are individualised to each patient but still results in one outcome that can be used in analyses.

The responsiveness of goal attainment scaling is believed to arise from the fact that GAS covers more domains than standard measures while remaining focused on the target of the intervention.[185] Goal attainment scaling may be a useful tool in neurological rehabilitation but its use as an outcome measure in research is questionable. The goal attainment method presented in chapter 4 reinforces the viability of the instrument and the standardisation of GAS in clinical practice. However, the low agreement in scoring and the lack of familiarity of the assessor with the patient, which makes the scoring of the goals very difficult, make its usefulness in research problematic. The ideology of GAS is good and may work in clinical practice but this thesis illustrates that further evaluation in a neurological population is required before it can be successfully employed as a primary outcome measure in research. Especially the purported responsiveness of goal attainment scaling in research should be scrutinised.

In this thesis a wide variety of goals were used and future research should investigate whether a distinction between goals can be made (e.g. do ADL goals have better clinimetric properties than cognitive goals), and if so, which goals are better (i.e. more reliable and responsive) for goal attainment scaling in research. This leads to the question what actually defines good goals and how many goals should be used to get an adequate score for use in research.

CONCLUSIONS

Previous research has suggested that motor imagery is a beneficial intervention in neurological rehabilitation. However, motor imagery is a complex intervention and evidence has not been effectively translated to clinical practice. In this thesis a comprehensive motor imagery strategy and a standardisation of the goal attainment scaling method were developed and tested. Although the intervention did not demonstrate significant positive benefits, it also did not show a negative effect, whereas the patients in the motor imagery group employed less physical practice. This thesis does show that the goal attainment scaling method can be used as a client-centred outcome measure in clinical practice and that the motor imagery strategy is client-tailored and can be service-delivered.

Appendices

Appendix 1. MEASURES

This appendix briefly describes the measures used in chapter 3 and 7 of this thesis and presents forms at the end of this appendix.

Short Orientation-Memory-Concentration Test (SOMCT)[159, 246]

The SOMCT is a short questionnaire to provide a quantitative assessment of cognitive function (ICF body functions category), including orientation in time and space, concentration and memory. It is derived from the Blessed scale[247] and comprises 6 questions with a score range of 0-28, with a higher score being higher cognitive ability. The SOMCT is moderately reliable[159] and correlates well with the paragraph recall subtest of the Rivermead Behavioural Memory Test (r=0.74)[159] and a test of phonological fluency (r=0.63).[248] Reliability and validity have been established in a population with a variety of neurological diseases.

Motricity Index[222, 246]

The Motricity Index is a short and simple measure of general motor function (ICF body functions category). Six movements are examined: pinch grip, elbow flexion, shoulder abduction, ankle dorsiflexion, knee extension and hip flexion. The grading is similar to the Medical Research Council (MRC) grading. The weighting for the first item (i.e. pinch grip) is: 0 for no movement, 11 for beginnings of prehension, 19 for grips cube but unable to hold against gravity, 22 for grips cube, holds against gravity but not against weak pull, 26 for grips cube against pull but weaker than other side and 33 for normal pinch grip; the weighting for the other 5 items is: 0 for no movement, 9 for palpable movement, 14 for movement seen, 19 for full range against gravity, 25 for movement against resistance and 33 for normal movement. Scores can be calculated for the arm and leg separately or as an average total score. If the sum of the arm score is 99, an extra point is added to make 100; creating a score range of 0-100. The same method is applied to the leg score. The total score is the average of the sum of the arm and leg score ((arm + leg) / 2). The higher the score the better general motor function is. Collen et al.[222] demonstrated that the leg score of the Motricity Index was reliable and Collin and Wade[160] confirmed that the whole test was reliable and valid.

Barthel Index [158, 223, 246]

The Barthel Index is a 10-item generic activities of daily living (ADL) assessment of independence (ICF activity category). Items are scored on level of independence on a 2, 3 or 4-point scale, resulting in a score range of 0-20. The higher the score the greater the independence.

Test-retest reliability was reported to be very good as Green et al.[193] reported an agreement of more than 75% and Wolfe et al.[249] reported a kappa of 0.98, both in stroke populations. The Barthel Index has been found to have high inter-rater reliability with a kappa of 0.88 and higher[249] and correlation coefficients between 0.71 and 0.99.[250] Construct validity between the Barthel Index and the Functional Independence Measure was found to be strong[251] and concurrent validity with the Katz ADL Index reported high correlations (k=0.77).[250]

Rivermead Mobility Index (RMI)[161, 246]

The RMI investigates mobility and consists of 14 questions (activities scored range from turning over in bed to running) and 1 direct observation (standing for 10 seconds) (ICF activity category). It specifically reflects patients' ability to move themselves without aids or assistance from another person. Each answer is scored 'Yes' (1) or 'No' (0) resulting in a score range of 0-15. Items are arranged in hierarchical order and high scores represent high level of mobility.

Inter-rater reliability in head injured and stroke patients has been reported to be high with no more than 2 points difference between the raters.[161] Test-retest reliability was shown to be good in stroke patients with a small random error coefficient of 2.2 (out of 15).[193] A review[252] of the RMI concluded it being a reliable and responsive measure. Concurrent validity of the RMI with gait speed, gait endurance and standing balance was shown to be good[161] and its reliability, validity and responsiveness have also proven to be good in other populations than stroke such as people with multiple sclerosis.[253]

Timed Up & Go (TUG) [227]

The TUG is a measure of basic mobility and balance manoeuvres investigating the ability to stand up, walk 3 meters, turn around, walk back to the chair and sit down again without physical support (ICF activity category). It is administered through direct observation and the time to perform this task is recorded as well as the aid(s) used. A standardised chair type (45-47 cm high) without arm rests was used.

Test-retest reliability was shown to be good to very good in Parkinson's patients and frail elderly: Morris et al.[254] reported correlations between $r=0.73-0.99$ and Podsiadlo and Richardson[255] reported an ICC of 0.99. Inter-rater reliability was reported as being high[255] (ICC = 0.99) and was better in experienced than inexperienced raters.[256] More recently, the TUG also showed very good reliability[257, 258] in chronic stroke patients with ICC>0.95 and good correlations with ankle plantar flexors strength ($rho=-0.86$, $p<0.01$), gait parameters ($rho>0.62$, $p<0.05$) and walking endurance ($rho=-0.96$, $p<0.01$).[258]

Action Research Arm Test (ARAT) [228, 259]

The ARAT consists of four sub-tests of arm function, namely: grasp, grip, pinch and gross movement (ICF activity category). It has a total of 19 items; each can be scored on a 4-point scale (0-3), resulting in a score range of 0-58, with higher scores representing a higher level of arm function. Each sub-test is arranged in such a way that a score of 3 on the first item of a sub-test results in a full score for that sub-test (reasoning: if the subject can perform the most difficult item of the sub-test first, there is no need to test the rest, less difficult, of the sub-test items). If the subject scores a 0 on both the first and the second item of the sub-test, a sub-test score of 0 is assigned (reasoning: if the subject can not perform the easiest item of the sub-test, there is no need to test the rest, more difficult, of the sub-test items). In any other situation all sub-test items need to be completed.

The ARAT has high inter-rater and test-retest reliability in a stroke, multiple sclerosis and traumatic brain injury population, r=0.99 and r=0.98 respectively.[228] Van der Lee et al.[260] showed correlations higher than 0.98 for the intra and inter-rater reliability in chronic stroke patients. The validity is high and the test is responsive to changes in chronic stroke patients, more so than the arm section of the Fugl-Meyer Assessment.[261]

Nottingham Extended ADL Scale [229]

This extended ADL index consists of four sections; mobility, in the kitchen, domestic tasks and leisure activities. It has a total of 21 items (ICF activity category) and was originally developed as a postal measure for stroke patients. Each item is scored on a 4-point scale; not at all (0), with help (1), alone with difficulty (2) and alone easily (3) resulting in a score range of 0-63. The index examines what the subject currently does (*"do you..."*) at the time of assessment and not if the subject could do it.

The scale shows high inter-rater correspondence[230] and it is able to discriminate between patients in institutions and at home. The scores correlated with the Barthel Index, the patient's age, previous mobility, time spent in hospital, the abbreviated mental test and whether the patient was living alone or not.[229]

Motor Imagery Questionnaire

This questionnaire is a custom designed test investigating the self-efficacy and perceived effort to imagine up to four individualised skills (ICF activity category). In the study presented in chapter 7 each subject has up to four individualised goals which are generated by the physiotherapist and occupational therapist. The advantage of this is that each skill is tailored to the level of the subject in comparison to other questionnaires with set tasks which can include inappropriate skills for a neurological population such as jumping.[162, 214] Moreover, by using the goals to assess the subject's imagery ability we assess skills that are important to the subject and that can't be performed by the subject yet at baseline. This is in contrast to most questionnaires that can include unimportant skills and some skills that can and others that cannot be performed by the subject. People find it easier to imagine a skill that they can physically perform then imagining a skill that they cannot physically perform.[156, 215, 262] In questionnaires with set tasks this can possibly lead to bias (i.e. patient 1 can physically perform 1 of the 10 tasks; patient 2 can physically perform 9 of the 10 tasks).

Self-efficacy is a construct developed and evaluated by Bandura.[263] It is a belief or conviction that one has the capability to successfully engage in a course of action. Self-efficacy is not so much dependent on a person's skills but more on the person's judgement about performing that skill. This questionnaire is based on the patients' goals defined for goal attainment scaling. The patient was asked to imagine performing the particular task (e.g. goal) in his/her mind's eye after which the patient was asked how confident he/she was in imagining the task, thus investigating the patient's perceived self-efficacy in performing motor imagery. Patients were asked to score their confidence on a numerical scale between '0' (not at all confident) and '10' (totally confident) for each goal.

The other construct used in this questionnaire was based on a person's perceptual responses. This concept is well described and researched by Borg[264] who in particular investigated the scaling of perceived exertion and perceived pain. The concept is based on ratings of subjective intensity as perceived by the subject resulting in an individualised direct measure. This perceptual continuum plays a fundamental role in a person's behaviour and how he/she adapts to a situation. In this thesis this concept was used to estimate the perceptual intensity of mentally performing a task. The patient was asked how much effort it cost him/her to imagine the particular task. The perceived effort was scored on a numerical scale between '0' (no effort at all) and '10' (maximum effort).

Appendix 2. Motor Imagery Strategy

This appendix presents the motor imagery strategy taught to the therapists. Note that the chapter references in this appendix refer to the chapters of this appendix (the motor imagery strategy), not the thesis chapters.

SECTION 1 BACKGROUND

Chapter 1

Introduction

This is a guideline for the use of imagery in adults with neurological disease or damage. It is designed for health professionals, especially physiotherapists and occupational therapists, but could also be used by nurses and speech and language therapists. This guideline is part of a research project in which the effectiveness of imagery in the treatment of stroke subjects will be examined. The imagery technique in this guideline focuses on motor or action-based imagery. The aim is to increase the patient's skills and performance, but it may also indirectly affect control of arousal, control of anxiety, improve decision making, improve relaxation, build self-confidence or improve concentration, for which usually other imagery techniques are used.

This guideline offers the therapist structure and a strategy to deliver subject-specific imagery. It does not provide set rules but is designed to tailor the imagery to the subject's level.

Three major frameworks were used for the development of this guideline. One of these frameworks comes from The National Coaching Foundation who has developed an imagery training guide for sports coaches and performers [212]. The second framework comes from a base of evidence in the motor learning literature [265, 266]. The third framework is based on a phased process of human movement. The principles on motor learning and on phased motor behaviour will be known to most health professionals such as physiotherapists and occupational therapists. Background information on motor learning and phased motor behaviour can be found in appendix 1 and 2. This provides a base of knowledge and the framework on imagery training from the National Coaching Foundation is implemented and interwoven in this guideline. The actual application of motor imagery will be is presented in section 2.

Chapter 2

What is imagery?

Imagery is referred to by many different names. A few of the terms most often used are: mental practice, mental rehearsal, mental imagery, guided imagery, motor imagery and action-based imagery. This technique can be used for many different purposes but because the main aim of this technique here is to enhance performance of skills the terms 'motor imagery,' 'action-based imagery' and simply 'imagery' will be used in this guideline. However, this does not exclude overlap with other imagery techniques, for example to improve relaxation.

Motor imagery is best explained as a method of using all the senses to create or re-create an experience in the mind; it is nothing more than the person imagining him- or herself performing the task without actually doing the movement. So there is no overt movement, but instead the movement occurs in the person's 'mind's eye'. Studies, especially in the fields of sports and music, have shown the benefits of this technique. Indeed not only have studies shown an improvement in performance but they have also revealed that the same brain areas are activated both when imagining and when overtly performing a skill. Visualisation is only one aspect of imagery and it is essential to incorporate as many senses (auditory, olfactory, tactile, kinaesthetic, etc.) as possible when imagining.

Recently it has been suggested that imagery may have a role in the rehabilitation of stroke patients. A systematic review [8] of studies in stroke subjects indicates that imagery might be an effective technique but at present this is not certain. More importantly this review demonstrated that little is known about the content of the imagery interventions and how practical and applicable it is to subjects with neurological disabilities.

This document is an attempt to create a guideline for imagery in the rehabilitation of neurological people, based on evidence from motor learning and motor behaviour, from a variety of levels for health professionals.

Chapter 3

Why is imagery used?

Imagery can be performed for many different purposes. Below follows a brief overview of the sports literature that identifies five categories of imagery. These are:

1. **Motivational-specific** (MS) - This involves seeing yourself winning an event, receiving a trophy or medal and being congratulated by other athletes. MS imagery may boost motivation and effort during training and facilitate goal setting, but is unlikely on its own to lead directly to performance benefits.
2. **Motivational general-mastery** (MG-M) - This is based on seeing yourself coping in difficult circumstances and mastering challenging situations. It might include maintaining a positive focus while behind, and then coming back to win. MG-M

imagery appears to be important in developing expectations of success and self-confidence.

3. **Motivational general-arousal** (MG-A) - This is imagery that reflects feelings of relaxation, stress, anxiety or arousal in relation to sports competitions. There is good evidence to suggest that MG-A imagery can influence heart rate - one index of arousal - and can be employed as a 'psyche-up' strategy, to increase ones arousal before performance.
4. **Cognitive specific** (CS) - This involves seeing yourself perform specific skills, such as a tennis serve, golf putt or triple-toe-loop in figure skating. If learning and performance are the desired outcomes, evidence suggests that CS imagery will be the most effective choice.
5. **Cognitive general** (CG) - This involves images of strategy and game plans related to a competitive event. Examples could include employing a serve-and-volley strategy in tennis or a quick-break play in basketball.

The main goals of physiotherapy and occupational therapy in rehabilitation after stroke are the (re)-learning of skills so that lost but previously undertaken tasks can be undertaken again or so that new tasks can be learned (one-handed lace tying).

From the categories mentioned above, cognitive specific imagery suits this aim best. This does not mean that there is no overlap possible between the categories or that the other categories are not suitable in the rehabilitation after stroke. However, in this workbook we will only focus on the cognitive specific category, which is mainly aimed at skill learning and performance, because this category is most applicable to the physiotherapist and occupational therapist. In this workbook the general term 'imagery' will be used for this. Thus, the purpose of imagery here is <u>to enhance performance</u>.

SECTION 2 **IMAGERY**

Chapter 4

Motor (re)-learning, phased action and motor imagery

There is no 'cook book' on how to provide imagery to a population with neurological disease or damage. Previous studies have used a variety of techniques but most do not describe clearly what the intervention contained. Because of this lack of information and a lack of consensus we have used a combination of resources to define the intervention. Many of our techniques and exercises are based on a strategy used in athletes [217]. However, it was felt that a framework was needed to relate imagery to the treatment of a neurological population and that would give therapists a guideline on the technique.

Motor (re)-learning and motor imagery

Motor learning has been a subject of investigation for several decades. The key elements have been described in Appendix 1 (knowledge of results, knowledge of performance, variability of practice and linkage to the site of application). These terms may not be the most suitable terms for use in imagery but from a more abstract point of view one could recognise these aspects in imagery. For example; in terms of motor learning in physical performance the therapist and subject can usually observe the movement and have direct 'knowledge of results.' In imagery, however, it is only the subject who has 'direct' 'knowledge of performance and results.' Then again, the subject could communicate this to the therapist. In this example the term 'knowledge of performance and results' may not be entirely correct, however, in this guideline we will utilise these terms from motor learning but they will be used within the confines of an imagery intervention as detailed below.

Knowledge of results and *knowledge of performance* are both needed to provide feedback. In normal motor learning the therapist and/ or the subject have this knowledge and they can both give feedback on it. However, in imagery the subject is the only person who has this knowledge. This is why evaluation of the imagery (see chapter 8) is of such great importance. In this case the therapist has to try and find out how the skill was imagined. Only after gathering enough information on the performance and the result of the movement, can the therapist give suitable feedback and instructions.

This is a cyclic process in which the subject learns how to perform a skill. For example: when the skill is to drink from a mug (subject with weakness in shoulder) the therapist may ask if he/she succeeded (result). The therapist could then ask the subject to describe the components of the skill (performance). If this is described correctly the therapist can ask specific questions such as: "Was your shoulder elevated?" It is likely that the subject needs to perform the image again to focus on this aspect. This process can continue until the skill is imagined correctly.

Generally, the evaluation is used to gain exact information on knowledge of results and performance. This information is used to tackle problems that arise. Problems that arise could be in the result of the movement, the performance of the movement, the process of the movement or in the image quality or control.

Variability of practice should be added by the therapist to enhance generalisation. The therapist should vary the task slightly (altering the cup to a mug) the situation (lifting the cup standing) and/ or the environment (when the subject has mastered imagined walking in the gym the therapist could ask the subject to imagine walking in the garden).

Similar to variability of practice, *linkage to the site of application* should be added by the therapist through giving clear instructions. It is necessary to vary situations and environments, but these situations and environments should also be applicable to the subject. For example: the subject usually consumes a drink when sitting at his kitchen table, so the imagined environment and situation should be situated in the subject's kitchen.

Once the subject can perform the imagery correctly on his/ her own the subject should be given homework. The therapist can easily ask the subject to imagine the same tasks that have been practiced; however, these homework exercises are ideal to apply 'variability of practice' and 'linkage to the site of application' to. This means that the therapist should suggest that the subject practices the specific task, for example, in the subject's home.

Phased action and motor imagery
The three consecutive phases of orientation, execution and control can be distinguished in human movement and could also be implemented in motor imagery. Again, evaluation is of key importance in this process.

When implementing these phases in imagery the *orientation phase* is needed for the subject to prepare for the imagined task. The subject should first imagine the situation and the environment and plan the task strategy (dressing; are the clothes there and in what order should they be put on) before imagining the task. After this preparation the subject can develop an internal concept for the task.

When using imagery the preparation is largely provided by the therapist. The therapist should provide clear instructions and should be specific about the situation, the environment and the task (wipe table with cloth: What colour is the cloth? Is it wet? Where is the table? What position is the subject in? etc). This enhances the quality of the imagery. Initially the subject will need a lot of guidance on this but as the subject progresses and starts practicing outside the sessions the subject should create the orientation phase on their own. An important aspect in this phase is linking the patient to an appropriate situation applicable to them.

The next phase, the *execution phase*, relies largely on the orientation phase (if there is no cloth it is impossible to clean the table). The actual task is imagined, the action plan is executed. The start and end of the task should be clearly defined in the previous phase (when walking, how far or how many steps is the walk?). The subject should initially be guided through this phase. Once the subject has progressed less or even no guidance through this phase is necessary. Through thorough evaluation the therapist should find out how the movement was performed.

During the imagined task the subject will verify his/her situation constantly, which is the *control phase*. The subject checks whether his/her action and the imagined action still comply with the internal concept. The execution can be changed accordingly. Again through evaluation the therapist should find out if the movement was executed as planned. If not, what did the subject do to adjust? For example: when imagining walking the subject notices that the cadence he/she imagines is asymmetric so he/she imagines a drum beat to adjust the walking pattern.

This process is cyclic with feedback and consideration of both performance and results. Through the continuous succession of these phases one learns. The therapist can intervene during these phases. Generally one can say that the intervention during the orientation phase is 'instructions,' during the execution phase the intervention is 'guidance' and in the verification phase the intervention is 'feedback' [208].

Chapter 5

When is imagery used?

Imagery can be used at any time of the day. Imagery can be used within and outside therapy sessions. One of the great advantages is its ease of use. You can imagine almost anywhere (bedroom, gym, between points, etc.), at any time of day (during therapy, while lying in bed, etc.), for any amount of time (from seconds to tens of minutes), with minimal physical fatigue (although it can cause mental fatigue). Below we describe some specific situations when imagery can be used in the rehabilitation after stroke. A preview is an advance image of a skill, which is used to practice the skill, whereas a review is a repeated imagined view of a prior performed skill.

When	Preview/ Review	Purpose
- Spare time	Preview	Rehearsal
- Before therapy	Preview	Orientation
- During therapy	Instant preview	Preparation
	Instant review	Evaluate
- During skill execution	Instant preview	Planning
- After therapy	Review	Retention

Imagery can be performed in the subject's own time, before the therapy session, during the therapy session, after the therapy session but also during the execution of a skill. The main purposes for each situation are mentioned but there obviously is overlap between these purposes for each situation. For each situation the subjects can have their own routines. A few examples follow:

- Spare time imagery. When the subject is performing imagery on his/her own there is no therapist to guide him/her. This is completely different from when the therapist is there. The subject chooses the location, the position and the exercise. These exercises are usually based on previous therapy sessions. The subject could practice a specific skill that he/she is learning, or the subject could practice the clarity of the images (colour, senses, etc.) to improve the quality of the imagery.
- Before therapy imagery. While the subject is being wheeled to the gym he/she can prepare for the skill to be practiced (walking), recall, plan and orientate on the skill by using imagery.
- During therapy imagery. The therapist and the subject can prepare for a skill that will be practiced and rehearse it before the actual performance. After the actual execution imagery can be used to evaluate the performance.
- During skill execution imagery. While the subject is performing a skill he/she can rehearse the skill and events before they actually occur and plan the movements.
- After therapy imagery. While the subject is being wheeled back to his/her room he/she can perform imagery of the skills just performed to attain retention of the skill.

It is key to maximise a subject's potential for recovery through using imagery to obtain maximal result. Like (re)-learning any physical skill it is important to follow a daily routine. Pre and post therapy imagery should be encouraged and spare imagery time slotted into patients timetables.

Chapter 6

Conditions and general principles

The following are guidelines for the imagery intervention. Many of these techniques come from the motor learning theory (see chapter 4).

- The intervention should be performed WHEN and WHERE the subject can easily concentrate.
- The imagery should be implemented in normal therapy where the imagery and overt movement should be used alternately.
- The subject should imagine a successful action. When impaired subjects often imagine the movement at their current ability. For example: a subject with shoulder weakness may find it difficult to imagine reaching for a mug successfully because of the impairment. The imagery should be successful even if in reality it would not be. This improves control of imagery.
- Skills should be practiced that are significant to the subject.
- Imagery should be used in each session.
- When performing imagery the subject should be relaxed. If need be the subject should be instructed to relax (using breathing exercises and/or progressive muscle relaxation).
- As many senses as possible should be incorporated in the imagery to increase intensity of the imagining.
- The patient should be encouraged to use the technique throughout the day, outside therapy sessions.
- Research suggests that visualising may be more effective in influencing the more cognitive aspects of a movement, for example; the movement sequence. Whereas kinaesthetic imagery is more important in improving movement performance.
- Facilitation techniques that can be used include:
    - Cues. While the therapist guides the subject through the imagery cues can be used to facilitate the action(s) in

the imagery. For example: when imagining walking cues could be; 'left' 'right,' or when reaching for an object and the hand needs to be opened; 'open.'

- Passive/ assisted movement. To facilitate the movement/ task the therapist could perform the movement/ task passively on the subject prior to performing imagery. For example: when drinking from a cup the therapist could assist the subject's affected arm and perform the movements required for this task.
- Exteroceptive, proprioceptive, auditory input. To facilitate the intensity of the imagery the therapist could provide different sorts of input before and/ or during the imagery. For example: when the subject practices cleaning the table with a cloth; show the cloth to the subject, let the subject touch the cloth to feel its texture and wet the cloth so the subject can feel the temperature and wetness of the cloth. Or when imagining walking the therapist taps on the floor to demonstrate the speed.
- Description (oral). Either the subject or the therapist could do this. The movement/ task could be described step-by-step.
- Action observation. Prior to performing the imagery the therapist could show the movement/ task to the subject first to facilitate the correct execution of the movement/ task.
- Imagine ideal performance. Before trying the movement, either physically or imagined, the subject can imagine how the movement should ideally be performed. This can be done by imagining an athlete or an animal performing the movement and 'analysing' its performance [130].

- Equipment. Different equipment can be used to facilitate the intensity of the imagery. For example: the subject can observe his/ her movements in the mirror prior to the imagery.
- Alternate between imagery and for example passive movement, or between imagery and observation.

Chapter 7

Creating a script

An imagery script is created, either by the therapist or the subject him/herself, to describe the skill to be imagined. This is done through 3 basic steps. Continuous evaluation is necessary to add or change details and for refinement of the imagery. In this way a script develops. Scripts can be written down but this is not necessary.

The 3 basic steps to create a script are:

1. Basic picture. The basic content of the action is outlined. If the performer is creating the script it should be in the first person (I). When the therapist is creating the script is should be in the third person (you). Describe all the (sub)-actions and describe them in the correct sequence.
2. Add details. Add descriptors, such as sensations (tactile), features (context), qualities (speed of movement) and responses (fatiguing) to the original script. The words that are added should imply action, such as verbs and adverbs and should clearly describe the details.
3. Refine script. Try the script and evaluate it. Does it actually feel as if the action is being performed? What is missing? What word is a better descriptor? In this step one can add allegories to the script (light as a feather).

Depending on the evaluation the intervention is adjusted accordingly.

A sample script is detailed in the following table. Therapists should encourage focus during imagery on evaluation of performance and results. This will be discussed in chapter 8.

Wiping table surface	Step 1 **Telling the basic story** Normal sequence	Step 2 **Adding the details** Descriptors	Step 3 **Refinement of script** (Allegories)
Orientation	Own location	I'm sitting in my chair in front of the table. I can hear the music from the radio	
	Cloth location	The cloth is yellow and wet and is lying in front of me on the table	
	Table location	I'm sitting behind the table and can wipe the complete surface from this position	
Execution	Lift hand	I lift my right hand and feel my hand opening up. My left hand I put on the surface of the cold table	Arm is as light as a feather
	Reach forward	I feel my hand is open and is reaching toward the cloth, my shoulder muscle tensing and my shirt pulling	
	Grab cloth	My hand touches the cold wet cloth and I feel that it is sufficiently wet to wipe the table	
	Wipe table	I feel the wet cold cloth and I push it against the table. Then move the cloth to the left upper corner and with long fluent moves from left to right I wipe the table down	Like a waving movement
Evaluation	Concentrate on dirty area	On a certain part of the table I feel the resistance increase and see a sticky dirt patch on the table. I push harder and wipe a few more times over this specific area	Feel hand and shoulder tensing up
	Use other side of cloth	I can feel and see the dirty patch clean again, I turn over the cloth and continue cleaning the table	

Chapter 8

Evaluation

Evaluation is of key importance when using imagery. In imagery the therapist can evaluate the subject's performance but also the performer him/ her self can do the evaluation on his/ her own. In this chapter we discuss what the key points are in this evaluation. Another chapter will discuss what to actually do with this.

Two major aspects can be distinguished in an image: the actual performance of the imagined movement and the quality of the image. During overt movement the therapist and/or the patient him/ her self have direct feedback about the quality of the movement (visually, either with equipment such as video or mirror). Obviously during imagery this is not possible. In that situation the therapist has to rely on the subject's description of the image. This implies that the subject gives an accurate description of the image but also has to be conscious/ has to have the knowledge of the movements and of its sequence. The second aspect is the quality of the image (sensations, emotions, colours, etc.), which depends on the performer's ability to imagine.

Evidence suggests that imagery is most effective when the images are as clear as possible. So it is essential to create the ideal conditions, optimum clarity, when performing imagery. In reality these two aspects (imagined performance and image quality) are practiced alternately and parallel but the general aim is to create as clear images as possible to make the imagery most effective. These two aspects will be discussed in more detail below. In the chapter 'Progression' exercises are described to improve both these aspects.

Imagined performance

Instead of the therapist observing the skill performed by the subject, the therapist has to find out from the subject how the skill was performed in the image. The questions below are suggestions for the therapist to ask the subject.

There is an order in the sequence of the questions, from general to more specific.

How did it go?

What did you do?

Could you talk me through the stages of the movement?

Could you cut the stages in smaller piece and describe it again (maybe after doing imagery in slow motion first)?

Were you successful (did you walk the 10 meters)?

Did you perform the movement <u>symmetrically</u>?

What was the position of your (feet) (affected foot pointing out)?

What did your unaffected (arm) do (swing?)?

At what <u>speed</u> did you perform the movement?

In which <u>order</u> did you perform that movement (heel strike before foot rock)?

Image quality

The quality of an image is important in the effectiveness of imagery. This is why one should try to improve the quality of the images. Chapter 9 suggests exercises to increase the quality of the images. Below are suggested questions for the subject regarding the image quality.

From which perspective did you see yourself (1st or 3rd person)?

Did you see yourself or did you see another person?

How clear was your image?

Which sense did you find easiest (sight/sound/smell/touch/taste)?

Which did you find most difficult?

Could you feel yourself moving? How well?
Did you feel the fabric of the cloth?
Were the colours clear?
Did you hear anything?

So the idea is to incorporate all the senses in the image. For the quality of these senses the term 'clarity' is used. Clarity does not only refer to the visual aspect, like colours and shapes, but also to all the other senses and to emotions. The other senses are: auditory, vestibular, kinaesthetic, olfactory and tactile.

Control of the image could be seen as separate category. With this is meant the ability to manipulate ones images. This is a very important feature in rehabilitation where patients often see themselves performing the skill incorrectly. Good control over the imagery enables the subject to imagine themselves doing the skill correctly, which is essential for correct overt movement.

Obviously, where problems arise, one should try to solve these. This can be through practice of exercises and through instructions. For example, if the subject can not describe the sequence of movements, the skill should be analysed first. Or if the subject sees another person's arm when imagining, one should first try to create a correct body image. This is a continuous process of evaluation and optimising the intervention.

How do you know if the subject is really imagining?
Generally one can get a good idea from the evaluation if the subject is actually imagining or not. Usually, the more accurate the descriptions of the images are, the better the ability to imagine. However, if in doubt about the subject's involvement in the therapy one could test this with the techniques below.

1. While the subject is performing imagery, stop him/her, and ask where (environment) and/or at what stage of the movement the subject currently is at.
2. Time the physical execution of the movement and the time it takes the subject to imagine the movement. These times should be similar.

Chapter 9

Improving the quality of imagery

Similar to physically learning a skill, imagery needs to be practiced too. In both techniques this process is cyclic. According to progress the practiced may change. To improve progression in imagery it is important to master the technique. In imagery this means that the intensity of the image needs to be optimal and the subject needs good control over the imagined. To practice this one can focus on certain aspects of the imagery, such as: developing the senses during imagery (intensity) or develop the perspective of imagery (control) or the way (speed, duration) a skill is imagined (control). This is all to improve the quality of the imagery and should be practiced when necessary. Below are some exercises that can be used to improve progression.

- Improve 'visual' image intensity (clarity, vividness). Select a piece of equipment and closely examine it, noting all details (colours, designs, insignias, logo, shape). It can be useful to reintroduce the object and alternate between visual inspection and imagery.
- Improve 'tactile' image intensity. Select a piece of equipment but now focus on the feel and texture. It can be useful to reintroduce the object and alternate between tactile inspection and imagery.

- Improve 'auditory' image intensity. Chose an environment, first visualise the environment and later focus on the sounds, for example a patient's kitchen where the radio is always on.
- Improve 'kinaesthetic' image intensity. Choose a relatively simple skill and focus on kinaesthetic imagery, 'feel your movement.' Again, it can be useful to reintroduce the movement and alternate between moving and imagery.
- Improve image intensity and control. Observe a simple skill being performed. From an internal view first visualise the movement then feel the movement and last see and feel the movement.
- Improving image control. Observe a demonstration of a skill or physically perform a skill and visualise the skill. First only visualise components of the movement and then proceed to the whole action. After visualising the whole movement start with components of the movement again but now focussing on the feelings. Also proceed to the whole movement.
- Improving image control (speed and duration). Choose a relatively easy and closed skill (with clear beginning and end). Focus on speed and duration of skill, use stopwatch and compare to physical performance if necessary. The aim is natural timing. Vary the speeds of imagined performance; at slower speed than normal and at faster speed.
- Improve image control (perspective). Choose a relatively simple skill. First let the patient observe their movement, then imagine the movement from the same view. Change perspective to third-person view.

Chapter 10

Progression

With practice subjects are likely to improve, in imagery ability and (we hope) in physical performance. Techniques have to be adjusted accordingly and this will be done by the therapist and maybe at a later stage by the patient him/herself. The therapist's expertise will determine when and what changes will be made. Some of these progression changes have been described earlier but below is an enumeration of some techniques.

It is noteworthy that these processes are guiding principles. They can be used in a cyclic process, are best used mingled and the best format should be chosen for each individual.

- **From guided imagery to cues to self performance.** A subject may need a lot of guidance at the start. Instructions can be very specific in the beginning and could grow out to just using some cues. When the subject has mastered the technique it is even possible that no instructions or cues are necessary any more. For example: in the beginning the subject may need a detailed description of his/her kitchen when performing the imagery (wooden table, 4 chairs, linoleum floor, radio on, etc), after some practice the subject may only need a prompt ("imagine your kitchen"), and finally the subject can practice the task in the kitchen outside the therapy sessions.
- **From visualising to incorporating all senses.** Visualising is often perceived as relatively easy. It may take some practice to incorporate other senses but sessions should also focus on the development of these other senses to create a high quality 'film.' For example: one can first focus on the visual image after which one can focus on the kinaesthetic feeling and later on the auditory sensations of walking in the gym. After these can used solely one can progress to using all three these sensations at the same time.
- **From an easy to a difficult task.** The progression of a task should be practiced in steps, as is done during normal therapy.

For example: before learning how to walk one should be able to transfer the weight between legs.

Chapter 11

Imagery in practice

Figure 1 shows a flowchart of using imagery in clinical practice based on the frameworks. The chart shows a cyclic process. The start is towards the upper left where the subject receives an introduction on motor imagery and where a goal is chosen. For this goal the therapist, and later the patient him/her self, can create a basic script (chapter 7) which will be refined in the process. After each imagined performance evaluation (chapter 8) is highly important. This evaluation should incorporate both the image quality and the imagined performance and principles from the framework should be used here.

For instance; the motor learning theory provides evidence on how to evaluate best and the use of *Knowledge of Results* and *Knowledge of Performance*. But also, in a process of diagnosis and intervention one should use the principles of phased movement during the evaluation of the imagery. In which phase(s) do problems occur?

Based on the evaluation the imagery intervention may change to tackle the image quality and/or the imagined performance. To enhance generalisation motor learning principles should be applied (*Variability of Practice* and *Linkage to the site of Application*) and the phases of movement should again be clearly identified. This will lead to a refinement of the imagery script and another cycle.

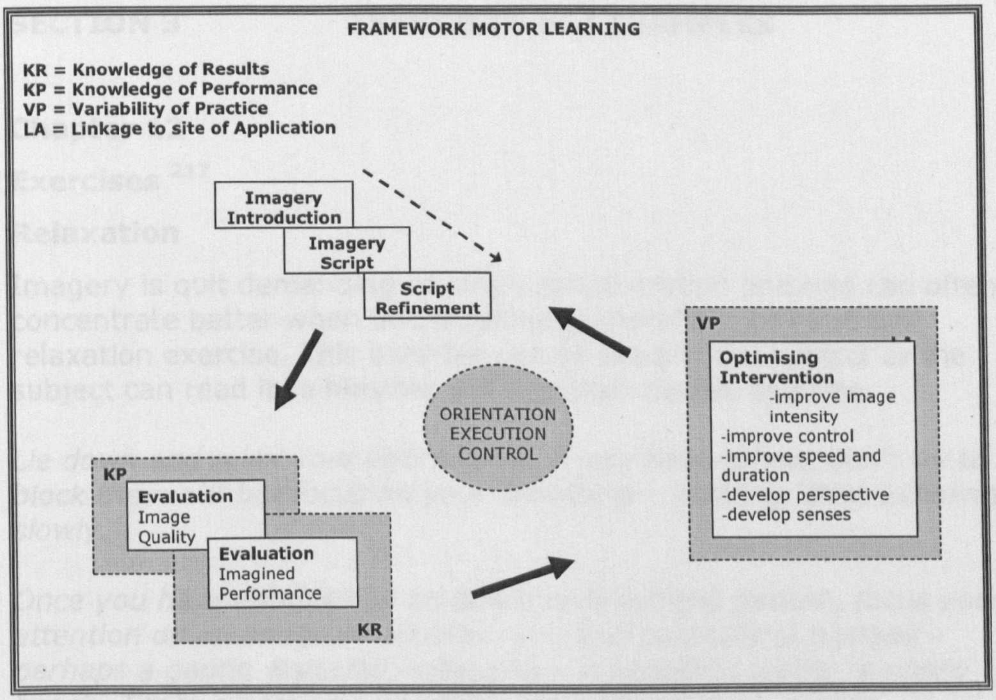

Figure 1. Flowchart of frameworks for motor imagery.

SECTION 3 EXERCISES and EXAMPLES

Chapter 12

Exercises [217]

Relaxation

Imagery is quit demanding on one's concentration and one can often concentrate better when one is relaxed. Therefore we have this relaxation exercise. This exercise can be read to the subject or the subject can read it to him/her self and then do the exercise.

Lie down and relax your entire body. If you hear noises, don't try to block them out but focus on your breathing - inhaling, then exhaling slowly.

Once you have established an effective breathing pattern, focus your attention on an image or situation you find particularly tranquil - perhaps a gentle waterfall, rolling hills, a beautiful sunset, a sunny beach. Try to create a vivid image - see the shapes, colours, textures, people - all in as much detail as possible.

Note any sounds - perhaps of water, birds, voices. Notice any smells - of the sea air, sun, cream, flowers. Try to feel any sensation - the breeze on your face, the wind in your hair, the sand between your toes, the water on your feet. Are there any tastes - the salt air, ice cream, a cool drink?

Don't worry if you find yourself wandering from one image to another - it is useful to experiment to find the ideal image that elicits the most relaxed response. Continue this exercise until you are easily able to hold the images effortlessly.

When you wish to return to a higher level of consciousness, count upwards from one to seven, counting on each exhalation, gradually experiencing greater alertness and awareness of the external environment. When you reach seven, you should feel fully awake, relaxed and refreshed.

Imagery introduction

This exercise can be read to the subject or the subject can read it to him/her self and then do the exercise. It is an introduction to imagery.

Imagine yourself picking up an orange from a fruit bowl. Note the colours of the rest of the fruit in the bowl – the yellow of the bananas, the green and red of the apples, the black of the grapes and the orange of the oranges and satsumas.

Feel the surface of the orange in your fingers and note its smell.

See the zest spring from the orange as you dig your fingernails into the skin.

Be aware of the smell of the orange, as you continue to peel the skin away.

Note the noise as you peel the orange and split it into segments.

Feel the sticky zest and juice on your fingers.
Experience the taste of the orange and the feel of it in your mouth and on your teeth as you bite into a segment and chew it.

Profile imagery skills

After using imagery several times try to profile your own imagery skills to determine strengths and weaknesses. Score each item on a 0-10 scale; where 0 means 'can not imagine,' and 10 means 'can easily imagine.' Score (some of) the characteristics below:

- internal
- external
- relaxed
- clarity
- control
- speed
- duration
- outcome
- perspective
- visual
- kinaesthetic
- auditory
- touch
- smell
- taste

Exercise for motor imagery

Select a basic skill and imagine the performance.

Imagine you are inside your body and about to picture yourself executing (a particular skill) successfully. Try to visualise from an internal perspective (i.e. through your own eyes), feel the kinaesthetic sensation of your movements and experience as many senses as you can. Imagine what it feels like to perform the skill perfectly and see the successful end result.

Appendix 4. Therapist and participant evaluation

THERAPIST EVALUATION

Name:

Have you spent the proposed amount of time (see table) on motor imagery over the past 6 weeks?

NO

- I have spent <u>more</u> time using motor imagery, namely...
- I have spent <u>less</u> time using motor imagery because...

YES

In your opinion, has the participant spent the proposed amount of time (see table) on motor imagery practice outside the therapy sessions?

NO

- He/she has spent <u>more</u> time using motor imagery
- He/she has spent <u>less</u> time using motor imagery because...

YES

In your opinion, has the participant benefited from using motor imagery?

NO

YES

Comments or Suggestions (why do you think there was a benefit or why not?)

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Therapist		At least 3 sessions (3x15 min)	At least 3 sessions (3x15 min)	At least 3 sessions (3x15 min)	At least 2 sessions (2x15 min)	At least 2 sessions (2x15 min)
Participant			Practice tasks from therapy sessions (5x5min)	Practice tasks from therapy sessions (5x5min)	Practice tasks from therapy sessions (5x5min)	Practice tasks from therapy sessions (5x5min)

PARTICIPANT EVALUATION

Name:

Have you used motor imagery over the past 6 weeks?

NO
YES

- O I have used it almost daily
- O I have used it weekly
- O I have used it sporadically

In your opinion, have you benefited from using motor imagery?

NO

YES In what way?

Do you have any comments or suggestions on using motor imagery?

Appendix 5. Subgroup analysis

This appendix illustrates the comparison of the motor imagery subgroup (see chapter 7) (n=5) and the control group (n=15) on the Barthel Index, Rivermead Mobility Index, Nottingham Extended ADL index and Action Research Arm Test. For illustration purposes the complete motor imagery group is also presented in the figures 1-4.

Table 1. Results of the motor imagery subgroup (n=5) and the complete control group (n=15) for the secondary outcome measures (mean (SD)) Barthel Index, Rivermead Mobility Index, Nottingham Extended ADL index and Action Research Arm Test on the three assessments; baseline (T1), post-intervention (T2) and follow-up (T3).

		T1	**T2**	**T3**
Barthel Index	CO	12.0 (6.72)	13.5 (6.98)	13.9 (6.44)
	EXP	14.0 (6.52)	16.8 (4.55)	17.2 (4.66)
	TOT	12.5 (6.56)	14.4 (6.51)	14.8 (6.10)
RMI*	CO	6.1 (5.54)	7.7 (5.63)	8.4 (5.19)
	EXP	7.8 (6.02)	11.0 (5.39)	11.2 (4.76)
	TOT	6.6 (5.55)	8.5 (5.62)	9.1 (5.12)
NEADL	CO	18.3 (15.99)	23.3 (17.22)	28.2 (20.05)
	EXP	28.4 (15.44)	32.2 (15.24)	35.8 (17.04)
	TOT	20.9 (16.08)	25.6 (16.82)	30.1 (19.21)
ARAT	CO	26.4 (22.69)	30.7 (23.38)	31.5 (22.05)
	EXP	33.4 (29.28)	40.4 (24.99)	42.4 (22.82)
	TOT	28.2 (23.87)	33.2 (23.51)	34.2 (22.17)

Legend: *, significant within-subject factor of time, $p<0.05$ but no significant between-subject factor of group, $p>0.05$; CO, control group; EXP, experimental group; TOT, total sample; RMI, Rivermead Mobility Index; NEADL, Nottingham Extended ADL Index; ARAT, Action Research Arm Test.

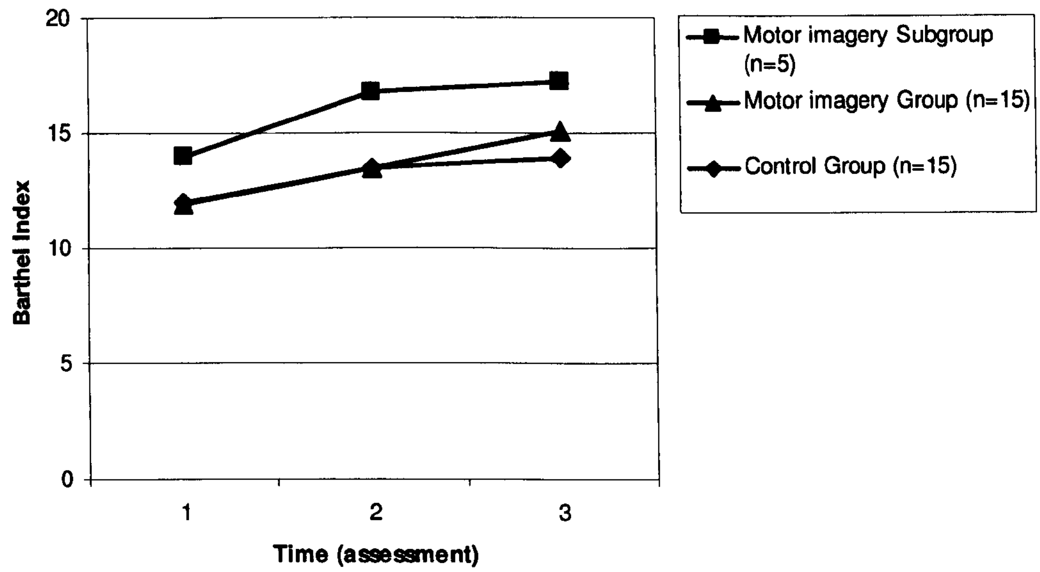

Figure 1. Average values of the Barthel Index on the three assessments. The motor imagery subgroup (n=5), the complete motor imagery group (n=15) and the complete control group (n=15) are presented.

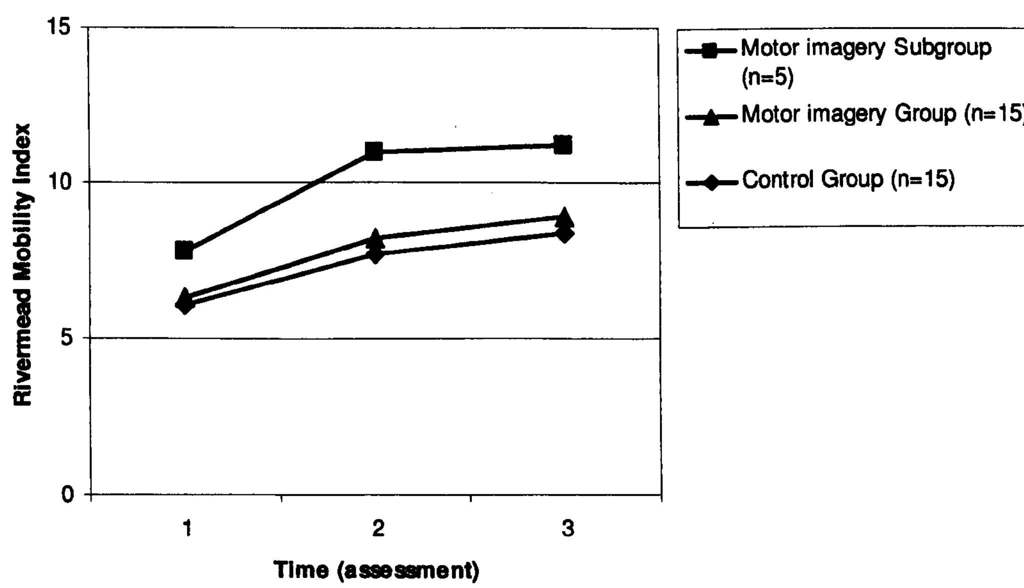

Figure 2. Average values of the Rivermead Mobility Index on the three assessments. The motor imagery subgroup (n=5), the complete motor imagery group (n=15) and the complete control group (n=15) are presented.

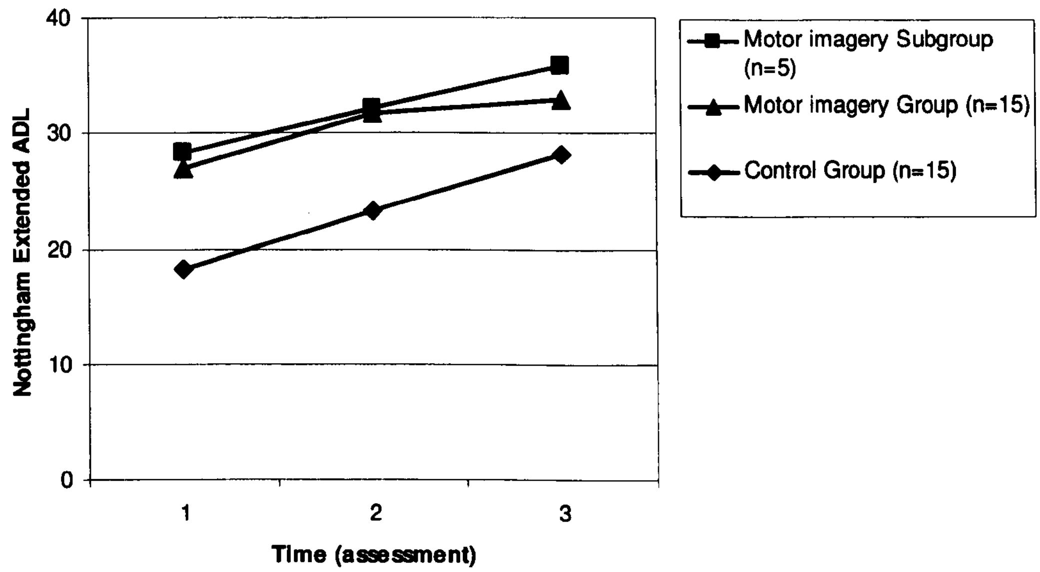

Figure 3. Average values of the Nottingham Extended ADL index on the three assessments. The motor imagery subgroup (n=5), the complete motor imagery group (n=15) and the complete control group (n=15) are represented.

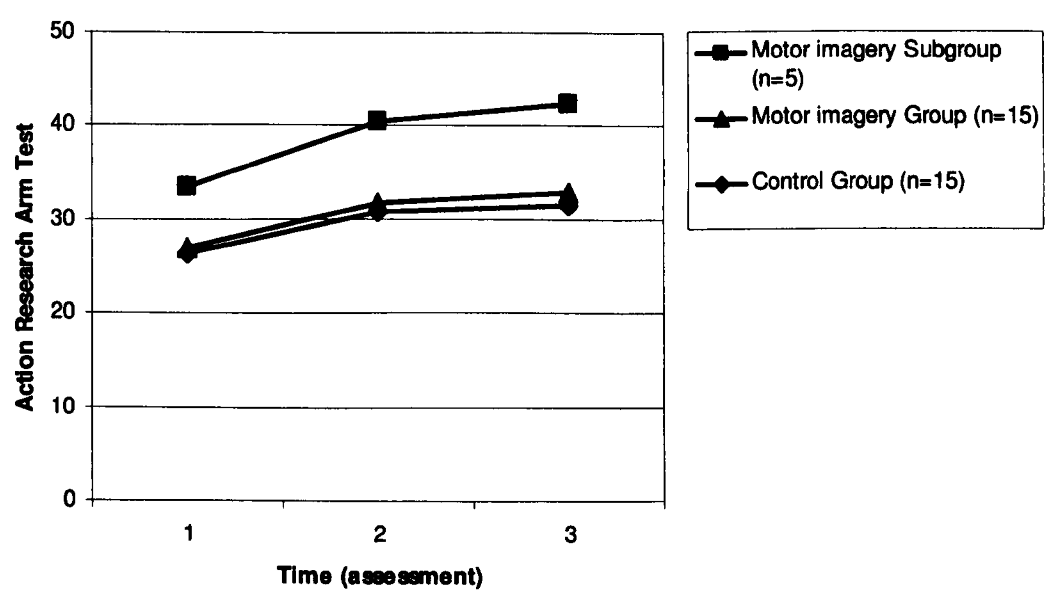

Figure 4. Average values of the Action Research Arm Test on the three assessments. The motor imagery subgroup (n=5), the complete motor imagery group (n=15) and the complete control group (n=15) are represented.

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