Chapter 1

An Introduction to Neurological Rehabilitation

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1.1 Introduction

Advances in diagnosis and therapeutics have resulted in better survival of subjects with neurological disorders [1]. However, they are often left with permanent impairments which in turn result in limitations in daily activities and difficulty performing social roles [1, 2]. These changes in function may be classified using the World Health Organization (WHO) International Classification of Function (ICF). Using this framework, impairment is any loss or abnormality of psychological, physiological or anatomical structure or function [3]. Common neurological impairments include aphasia, weakness, involuntary movements, ataxia, loss of sensations, and loss of vision. Activity limitation is any restriction or lack of ability to perform an activity in a manner or within the range considered normal. Restriction in participation is any disadvantage for a given individual resulting from an impairment or disability that limits or prevents the fulfilment of a role that is normal for that individual [4]. The relationship between impairment, activity limitation, and participation is not linear. It is moderated by environmental and personal factors which are also captured in the ICF framework. Relatively minor impairments can lead to significant difficulties maintaining social roles; for example, loss of dexterity in the left hand may not have a significant impact on many roles but may be devastating to a professional musician.

The aim of neurological rehabilitation is restoration of the individual to the highest feasible functional level. The process of neurological rehabilitation involves assessment, goal planning, and interventions (Figure 1.1).

1.2 Assessments

Assessments in neurological rehabilitation include identification, measurement, and recording of impairment, activity limitation, participation, and the identification of patients' goals. The advantage of the ICF framework is that it allows a shared language for people from different disciplines to describe an individual's abilities and disabilities and to design interventions which are tailored to an individual's social roles based on their impairments, and sensitive to their environment and personal factors, including their values and beliefs. Multidisciplinary assessment results in a more accurate assessment of the underlying impairments and allows rehabilitation planning, which can be complex as the individual may have multiple interacting problems [5].

For example, an individual with multiple sclerosis may present with poor work performance because of a combination of fatigue, anxiety, and cognitive impairment. Anxiety aggravates fatigue, fatigue aggravates cognitive errors, cognitive errors aggravate impairment. The fatigue may be due to workload, domestic commitments, medication, poor physical fitness, and the multiple sclerosis itself. Analysing this complex situation requires skilled assessment from a multidisciplinary team. Designing a rehabilitation intervention also depends on a clear understanding of the individual's wants. In this case, they may be 55, and want to retire because their partner has already retired. If this is their primary driver, then any intervention to improve work performance, which is not the individual's preferred outcome, may fail.

1.3 Goal Planning

A goal is the state or change in state that is hoped or intended for an intervention or course of action to achieve [6]. Goal setting is a process of discussion and negotiation in which the patient, family, and the treating team determine the key priorities for that individual and agree on the performance level to be attained by the patient for defined activities within a specified time frame. It involves assessment of current functional status, identification of potential for

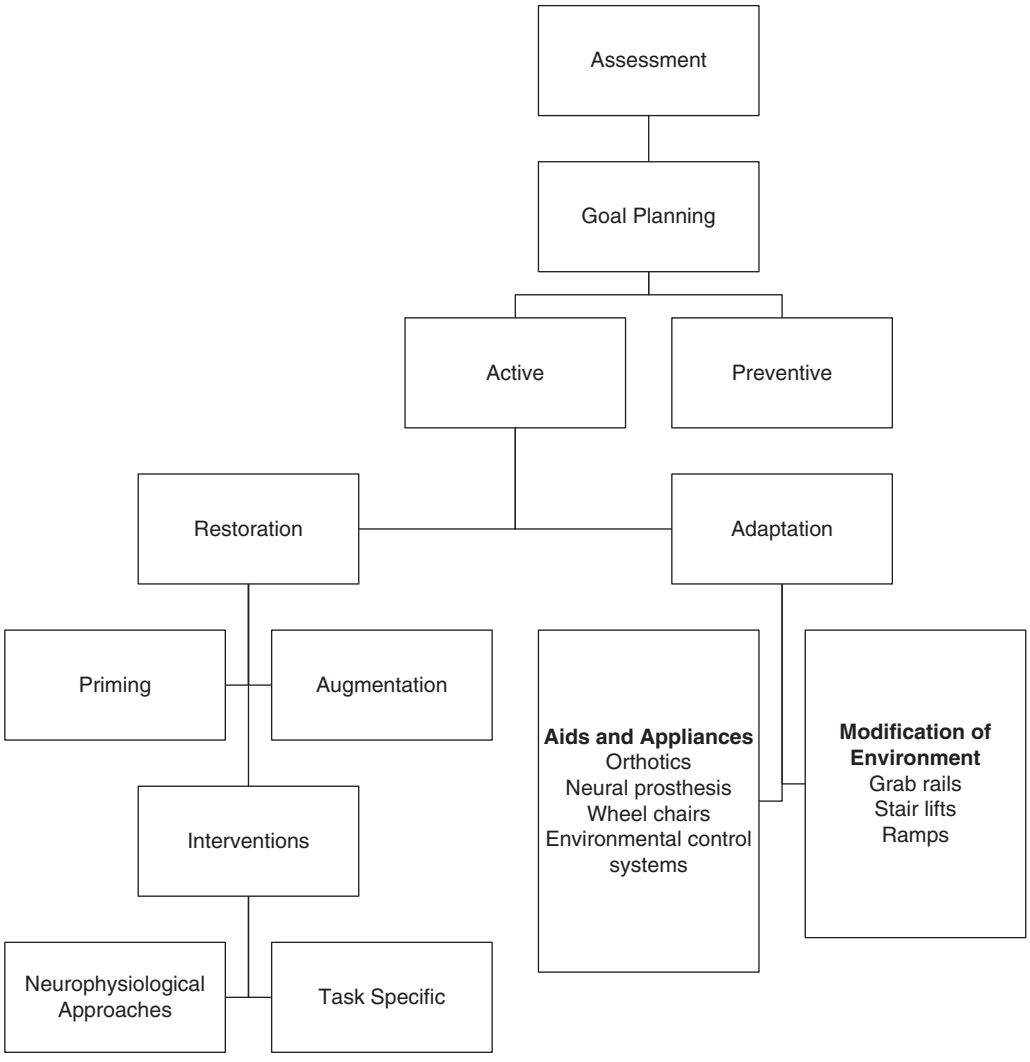

Figure 1.1 Neurological rehabilitation: The process

improvement, and setting short-, medium-, and long-term goals [6]. There are two elements to this definition. First is the process of discussion and negotiation.

Negotiation takes place between equals. Many studies demonstrate that in conversations between clinicians and patients, clinicians dominate the conversation. Recognition is increasing of the importance of shared decision-making in medicine. This is particularly important when individual preference informs the decision, which is true of many rehabilitation interventions. The steps in shared decision-making have been articulated by a number of authors but may be summarized as [7]:

A. Building trust and empathy
B. Negotiated agenda setting and prioritizing
C. Information sharing
D. Communicating and managing risk
E. Supporting deliberation
F. Summarizing and making the decision.

These steps are facilitated by the use of clear goal-setting processes and goal-setting materials. Steps may include a clear explanation of the rehabilitation process, the role of the multidisciplinary team, and the approach to goal setting, followed by an invitation to consider how their injury/disease has impacted different aspects of their lives.

Life goals are desired states that people seek to obtain, maintain, or avoid [8]. These goals take shape in childhood and adolescence as an idealized

self-image and are influenced by age, gender, personality, experiences, and society and environment. Pursuit and attainment of life goals affect sense of well-being. Life goals are accessible to conscious awareness and can be identified. Several questionnaires are available for assessment of life goals [8]. Impairments and activity limitations interfere with goal striving and result in emotional distress. Motivation to participate in a rehabilitation programme depends on concurrence between patient's life goals and treatment goals.

Having identified the key goal domains, the patient needs to prioritize the areas that are most important, and then work with the rehabilitation team to identify potential solutions. It is at this point that clinicians can describe any knowledge about the diagnosis, nature and extent of impairment, activity limitation and restrictions in participation, available interventions, and information about the patient's environment and how that individual has responded to interventions undertaken so far. The team can identify the most likely outcomes and the reasoning behind that prediction.

During this negotiation stage, the rehabilitation team need to support patient self-efficacy [9, 10] by highlighting progress that has already been made, providing vicarious experience which models success by describing similar patients who have improved using a particular approach (often during inpatient rehabilitation patients will provide this support to other patients), verbal persuasion, and emotional support. Patients then need to write goals down in their own words. There is no point in the only record of the goals being in the clinical notes where patients cannot see them or share them with their families. Finally, goals need to be reviewed, so progress is monitored. During this review stage, it is helpful to identify what worked for an individual and what did not.

The second part of the goal-setting definition stated that patient and staff agree on the performance level to be attained by the patient for defined activities within a specified time frame. This is making goals 'SMART' (specific, measurable, achievable, relevant, and timely). These concepts originally derived from the organizational psychology literature of the 1970s, which aimed to increase workplace productivity [11, 12]. This work featured three key findings. First, challenging goals lead to better performance [11, 12]. Second, participative goals tend to be more demanding than assigned goals [13–16], and, third, goal setting is more effective when goals are specific [12]. The goals should be clearly defined in terms of both purpose and duration. It is of interest that it was never stated that goals have to be achievable, and recent consensus conferences have highlighted they should, at least, be 'possible'. This confusion over the need for SMART goals lies in the fact that two types of goals are being set. Good practice dictates that the patients have both short-term goals which are reviewed every two to three weeks, and long-term goals. However, the long-term goals often contain elements which are not the patient's goal but an organizational goal around discharge from hospital. It is important that the rehabilitation team communicate clearly the planned discharge, including the date of discharge and the destination, but this is not a patient-centred goal. Organizational goals need to be achievable within the resources available. Patient goals merely need to be 'possible'. There is concern that patients can be demoralized by the failure to achieve goals. Patients are able to cope with setbacks, and an important part of the goal-setting process is the development of 'coping' or 'contingency' plans which will operate if barriers to goal achievement occur [10].

Goal setting has many other advantages. Subjects with neurological disorders often have multiple deficits and require input from different professionals. A major risk of this team approach is that individual professionals work independently without coordination, often with conflicting goals [17]. A process of goal planning is essential to ensure cooperation and coordination between different team members.

Despite the fact that goal setting in rehabilitation practice has been established for many years, the evidence base is very limited. A recent Cochrane review suggested that there is some very low-quality evidence that goal setting may improve some outcomes for adults receiving rehabilitation for acquired disability, with the best of this evidence appearing to favour positive effects for psychosocial outcomes (i.e., health-related quality of life, emotional status, and self-efficacy) rather than physical ones [18].

Family and carers should also be involved throughout the rehabilitation process, including goal setting, if that is acceptable to the patient. People with neurological disability often depend on their family members for emotional and physical support. Family members have to support a patient with disabilities in spheres of locomotion, self-care, communication, cognition, and depression and personality changes.

Factors associated with high degrees of depression in caregivers are disability in spouses, lack of social support, the presence of physical problems in caregivers, and the presence of depression, cognitive impairment, and abnormal behaviour in the patient. It is essential to take family and carers' views into account while planning for long-term care of people with severe permanent disabilities.

1.4 Outcome Measurement

In some cases, assessments using outcome measures help in communication between team members, evaluating effectiveness of interventions, and discharge planning. Assessment tools must be valid, reliable, sensitive to changes, simple, short, and applicable by all members of the rehabilitation team. Traditional psychometric approaches measure validity, reliability, and responsiveness [19, 20].

Validity measures the extent to which the scale measures what it is designed to measure. There are different ways to consider validity. Face validity is the most basic approach and asks whether the items in the measure appear to measure what they are meant to. For example, in a questionnaire about mobility, a question about whether an individual is able to leave the house when he wants to may measure mobility, but may also capture agoraphobia or fatigue. Only if it specifies 'does your mobility prevent you leaving the house when you want to?' would the item have face validity. Other forms of validity include content validity, which identifies whether the scale covers the range of relevant content. A scale aimed at capturing the mobility of a wheelchair user might differ from a scale aimed at capturing the mobility of an elite athlete with a prosthetic limb. Construct validity refers to the extent to which the scale measures the construct in relationship to other measures. This includes convergent validity, which occurs when two scales which aim to measure the same thing correlate. For example, the Barthel Index [21, 22], a measure of dependency, should correlate with the Functional Independence Measure [23], which also measures dependence, but not with the Hospital Anxiety and Depression Scale [4]. Discriminant validity measures the extent to which the measure is not associated with things that differ from the construct. Known groups validity measures the extent to which a measure can discriminate between two groups who are known to differ on the construct in question. For example, one would anticipate that the scores for people with schizophrenia differ on the Barthel Index from the scores for those with stroke.

Reliability is how consistent a measure is of the construct over a period of time, and between different users. Test-retest reliability occurs when the measure obtains the same test score on two different occasions when the patient has not changed clinically. Inter-rater reliability occurs when two or more individuals obtain comparable ratings on the same patient [19]. Responsiveness captures whether the patient has changed with time [19].

Item response theory (IRT) was first proposed in the field of psychometrics for the purpose of ability assessment. Most measures capture ordinal but not interval data [20, 21]. This theory allows the calibration of items in tests and the scoring of subjects on the domain being measured. The likelihood of an item being endorsed is dependent on the difficulty of the item and the 'ability' of the person. Many measures in rehabilitation have been developed or subject to Rasch analysis [20], which is one approach to item response theory, and this allows the ranking of patients depending on the extent of their ability, or otherwise, in the domain under question, attitudes, or other latent traits.

A wide range of scales is in use in rehabilitation. Various scales measure different impairments like motor power, tone, sensations, language, cognition, range of motion, visual fields, and ataxia. Commonly used impairment scales include the Medical Research Council (MRC) grading of motor power, the National Institutes of Health stroke scale, the Glasgow coma scale, and the Modified Ashworth scale for spasticity. Assessments of limitation activity include activities of daily living (ADL), social functioning, intellectual functioning, perception, speech, mobility, gait, and arm functions [2]. Scales used in the assessment of activities include the Barthel Index [21], the Functional Independence Measure [22], and the Spinal Cord Independence Measure. Scales to measure participation include the Ghent Participation Scale [24], the WHO Handicap Scale [2], and the Impact on Participation and Autonomy Questionnaire [25].

1.5 Interventions

Rehabilitation interventions are typically delivered by a team including physicians, nurses, physiotherapists, occupational therapists, speech and language

Table 1.1 Neurological rehabilitation: The team

Team member	Role
Rehabilitation physician	Medical assessment and interventions, prognostication
Rehabilitation nurse	Skin care, bowel and bladder management, liaison with family and carers, coordinates the team
Physiotherapist	Strengthening of muscles, improve endurance, optimize functional movements
Occupational therapist	Training in activities of daily living assessment and remediation of impact of cognition on functional activities
Speech therapist	Assessment and treatment of communication issues, swallowing issues, and salivary control
Neuropsychologist	Assessment and management of cognitive issues, coping with loss of function, management of mood and behaviour
Social worker	Identification of community resources, help with benefits, housing, and home modifications, reintegration into community
Orthotist	Assessment, fabrication, and maintenance of orthoses and prostheses
Dietician	Nutritional assessment and advice, home enteral feeding, parenteral nutrition
Activity coordinator	Coordinate social and recreational activities like sports, arts and crafts, community reintegration, provide psychological support
Biomedical engineer	Maintenance and provision of devices like environmental controls, wheelchairs, and functional electrical stimulation systems

therapists, psychologists, rehabilitation engineers, orthotists, dieticians, and social workers (Table 1.1).

Rehabilitation teams tend to follow one of three models: multidisciplinary, interdisciplinary, and transdisciplinary [5]. Multidisciplinary rehabilitation involves members from different disciplines working individually with the patient towards separate goals. Interdisciplinary rehabilitation refers to the activities of a group of rehabilitation professionals who work towards common goals. The objectives are set jointly by the members of the team and may require joint therapy sessions. In transdisciplinary rehabilitation, a single team member acts as a primary therapist with other members providing information and advice [5]. This approach is cost-effective and useful in delivering rehabilitation services at patients' homes and for patients with cognitive behavioural issues who may find it difficult to deal with different therapists.

Rehabilitation interventions can be grouped as 'active' and 'preventive' processes. Active rehabilitation includes a process to facilitate recovery from impairments and adaptive strategies to cope with limitations in activities. People with neurological disabilities are prone to develop complications secondary to impairments and activity limitations like pressure ulcers, pain, and contractures. The interventions to maintain function and prevent these complications are grouped here as preventative rehabilitation.

1.5.1 Active Rehabilitation

Potential for recovery is maximal early on after injury. During the early phases emphasis should be on restoration of functions. Recovery from neurological disorders is often incomplete. Later in the course the rate of recovery slows and reaches a plateau. As the time from the injury lapses, the emphasis should shift from restoration to adaptation.

1.5.1.1 Restorative Interventions

Restorative interventions aim to rectify neurological impairments by facilitating recovery through modification of the neural networks. These can be divided into priming techniques, augmenting techniques, and specific interventions (Table 1.2) [26].

1.5.1.2 Priming Interventions

Priming interventions try to make the nervous system more receptive to rehabilitation interventions. For example, imagery is used to 'rehearse' the motor, sensory, and visual consequences of movement [27]. When a patient mentally rehearses a specific task, the motor areas associated with the planning,

Table 1.2 Interventions to promote recovery

Priming interventions	Augmenting interventions	Specific interventions
Motor and visual imagery	**Robotics**	**Neurophysiological approaches**
Tactile stimulation	**Biofeedback**	
Passive movements	**Treadmill with body weight support**	Bobath's neurodevelopmental approach
Action observation and mirror therapy	**Constraint-induced movement therapy**	
Transcranial magnetic stimulation		Brunnstrom's technique
Transcranial direct current stimulation		Proprioceptive neuromuscular facilitatory approach
		Task-specific training

preparation, and execution of the movement get activated. Repeated imagination strengthens the cortical movement templates and facilitates the effects of interventions. Tactile stimulation and passive movements provide sensory input that may act by improving attention and prime the neural circuits for the desired movement. Action observation and mirror therapy use visual input for priming. The patient observes specific movements of their non-affected limb reflected in a mirror placed at the body's midline. This activates the frontal and parietal circuits involved in the movements and may facilitate recovery [28]. Repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS) are non-invasive techniques for priming the brain. Using these techniques, it is feasible to improve or reduce the excitability of the specific cortical neural circuits. Five sessions of rTMS could improve upper limb dysfunction following stroke [29].

1.5.1.3 Augmentative Interventions

Augmentative interventions are used to augment the effects of rehabilitation interventions. Robot-assisted therapy is using robots to deliver therapy [30]. This is a less expensive way of accurately delivering multiple repetitions of standard therapy exercises. Some of these devices can also vary torque and provide feedback. Functional electrical stimulation activates the muscles to produce the desired movement. This can be used to augment the weak muscles and can be combined with the robot-assisted therapy to enhance limb movements [31]. Biofeedback provides the patient with visual and auditory feedback about the timing, accuracy, and strength of the movements [32]. This can help the patient to identify errors and learn the correct movement patterns. Constraint-induced movement therapy (CIMT) aims to reduce the inhibition of the affected cortex from the non-affected side by restricting the activity of the non-paretic arm. This involves wearing a mitten to constrain the normal arm with high-intensity task-specific training of the paretic arm. Several studies, including randomized controlled trials, validate this approach in rehabilitation of upper limb function in people with stroke [32]. Treadmill training with body weight support involves walking on a treadmill with a harness to support part or all of the body weight. The proportion of the body weight supported is incrementally reduced. This can increase the amount of walking practice and has been tried to improve gait in people with stroke [32].

1.5.1.4 Specific Interventions

Specific interventions seek to facilitate recovery from impairments. They are broadly divided into neurophysiological approaches and task-specific practice.

Neurophysiological Approaches

These techniques are based on neurophysiological principles of motor control and recovery. The basic principles of neurophysiological approaches are: (a) application of sensory stimuli to facilitate or inhibit an activity; (b) patient evaluation and treatment plans based on milestones of developments; (c) utilization of reflexes to facilitate or inhibit any motor activity; (d) utilization of concepts of motor relearning such as repetition; (e) focus on the patient as a whole; and (f) close interaction between the therapist and the patient. These approaches stress enhancement of the

natural recovery process. Neurophysiological approaches include the proprioceptive neuromuscular facilitation technique (PNF), Bobath's neurodevelopmental approach, Brunnstrom's technique, and Rood's approach.

Task-Specific Practice

Repeated performance of a specific task facilitates learning and improves performance. Task-specific practice can induce experience-dependent plasticity in the cortex. Task-specific training includes breaking down of the meaningful task into simple individual components. The training starts with the patient performing multiple repetitions of a small component of a specific task. It gives the brain opportunities to identify errors and correct them. As the patient masters this step, further components are added, leading to the performance of the complex task. A meta-analysis showed that task-specific training may have a positive effect on the hand function after stroke [32]. None of these therapies have any proven superiority over others. Each of these techniques try to facilitate recovery of motor control through different strategies. They can be integrated and used based on the requirements of the patient, experience of the rehabilitation team and stage of motor recovery.

1.5.1.5 Adaptive Interventions

Adaptive strategies facilitate recovery of function through training, use of aids and appliances, or modification of environment. One of the major objectives of rehabilitation is to regain functional independence. Patients can be taught dressing techniques with adapted clothing like Velcro closures, pullovers, and front-buttoning clothing. Similarly, self-feeding can be helped with the use of friction plates, rocker knives, and other modified utensils. For grooming also different techniques and assistive devices are available. An occupational therapist can train the patient in ADL and the use of various assistive devices.

Orthotic devices like ankle or foot orthoses help to facilitate movement or to maintain alignment of joints and relieve pain. Neural prostheses are devices that substitute or augment functions lost due to neurological injury. Commonly used neural prosthesis include cochlear implants and the functional electrical stimulation systems for upper and lower limb movements. Environmental control systems, also known as electronic aids to daily living, enable people with neurological disabilities to access everyday electronic devices in their environment such as navigating through television channels, operating remote-controlled doors, and using mobile phones and computers. Environmental control systems are devices that help a person with a limitation in an activity to control his or her surroundings. Some individuals may also require environmental adaptations like stair lifts and ramps to facilitate functional independence.

1.5.2 Preventive Rehabilitation

Around 56–95% of patients undergoing inpatient rehabilitation develop medical complications [33]. These complications adversely affect outcome and prolong hospital stays. These complications include pressure sores, deep venous system thrombosis, shoulder pain, and contractures. Most of these complications are preventable. Techniques like proper positioning of the limbs and passive exercises may help to prevent complications. Protocols for prevention, early detection, and treatment of common medical complications should be an integral part of any rehabilitation programme.

Traditional exercise programmes are interventions to prevent complications from immobilization and can be divided into a passive range of motion exercises and active joint-by-joint exercises. In the passive range of motion exercises, the therapist or the caregiver moves various joints passively through their entire range of motion. This helps in preventing disuse atrophy, contractures, and development of abnormal postures. In active exercises, the patient actively moves the joints. These may be either isotonic or isometric exercises. Initially, the patient attempts simple movements, and subsequently complex movements and actions are tried.

1.6 Outcome

Rehabilitation helps in promoting natural recovery, preventing complications due to disabilities and adapting to disabilities. A well-planned coordinated strategy towards rehabilitation is bound to yield good results. Factors favouring a good outcome are good family support and financial status, higher social and educational levels, early initiation of a rehabilitation programme, and the expertise of the centre. Patients with low motivation, confusion and disoriented thinking, withdrawn and apathetic behaviour, previous medical illness, gross perceptual deficits, low

levels of education, old age, and prolonged unconsciousness do not improve with rehabilitation programmes. However, currently, it is not possible to predict the outcome of an individual patient and therefore all patients should be given a trial of rehabilitation.

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Chapter 2

Management of Disorders of Cognition in Neurorehabilitation

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2.1 Introduction

Impaired cognitive functioning is a hallmark consequence of acquired/traumatic brain injuries, leading to potential disruptions in all aspects of life functioning. Many factors impact cognitive functioning following brain injuries and illnesses, including pre-morbid intellectual functioning, nature and severity of injury or illness, and biopsychosocial factors impacting cognitive functioning and the recovery process. Thus, planning effective neurorehabilitation interventions first relies on a comprehensive evaluation of cognitive functioning status, biopsychosocial barriers to cognitive functioning, and therapeutic engagement, as well as patient-specific goals for community reintegration. In an interdisciplinary model of neurorehabilitation, various providers work within their expertise but with collaborative goals of improving cognitive functioning and promoting functional independence.

Neurorehabilitation is conceptualized here as a collaborative, interdisciplinary, rehabilitation model of care to serve those with acquired brain injuries, which not only addresses specific areas of cognitive dysfunction but also helps improve associated barriers to cognitive functioning and establish goals to maximize functional independence. A key component of neurorehabilitation is cognitive rehabilitation. The Cognitive Rehabilitation Task Force of the Brain Injury Interdisciplinary Special Interest Group (BI-ISIG) of the American Congress of Rehabilitation Medicine (ACRM) has developed evidence-based clinical guidelines for cognitive rehabilitation [1, 2, 3]. Cognitive rehabilitation interventions are intended to facilitate progress towards maximizing safety, independence, daily functioning, and overall quality of life through targeted approaches for ameliorating neurocognitive deficits [4]. Cognitive rehabilitation can be carried out by various trained rehabilitation specialists, including occupational therapists (OT), speech-language pathologists (SLP), and rehabilitation neuropsychologists.

Comprehensive neuropsychological rehabilitation interventions, in conjunction with cognitive rehabilitation interventions, facilitate therapy engagement, provide targeted interventions to reduce the impacts of emotional, behavioural, interpersonal, and injury-related difficulties (e.g., sleep, fatigue, pain) on cognitive status and functional independence, and assist in navigating reintegration into appropriate community settings.

This chapter reviews evidence-based cognitive rehabilitation interventions for specific areas of neurocognitive impairments. Furthermore, neuropsychological rehabilitation considerations and interventions are described as they relate to impacts on cognitive functioning and disability status.

2.2 Treatment: Evidence-Based Cognitive Rehabilitation

Evidence-based cognitive rehabilitation practice recommendations have been established by the BI-ISIG Cognitive Rehabilitation Task Force of the ACRM [1, 2, 3]. Systematic reviews of the cognitive rehabilitation literature have informed empirically supported cognitive rehabilitation treatment strategies primarily for stroke and traumatic brain injury (TBI) populations [1, 2, 3]. Recommendations are categorized as 'Practice Standard' if shown to have 'substantive evidence of effectiveness', 'Practice Guideline' if shown to have 'probable effectiveness', and 'Practice Option' for strategies that are thought to have 'possible effectiveness' but require further investigation [2]. The *Cognitive Rehabilitation Manual: Translating Evidence-Based Recommendations into Practice* was developed based on the empirical evidence from these systematic reviews to provide clinicians with specific evidence-based interventions for addressing specific neurocognitive deficits [4].

Cognitive rehabilitation intervention initially relies on formal evaluation, such as a comprehensive neuropsychological evaluation to identify cognitive and neurobehavioral impairments impacting daily functioning, as well as relative strengths to utilize in the rehabilitation intervention process [4]. Neuropsychological assessment can also help identify cognitive barriers to rehabilitation and help prioritize treatment recommendations. The neuropsychological evaluation also takes into account patient-specific factors that may impact rehabilitation outcomes (e.g., psychological distress, sleep disturbance, pain, fatigue, social support).

Following a comprehensive evaluation to identify goals and priorities, treatment planning takes place and emphasizes cognitive interventions that are relevant to patients' life goals and addresses specific underlying cognitive impairments. Cognitive rehabilitation intervention is ideally carried out in three hierarchical stages [5]. The acquisition stage involves bringing awareness to the patients about their cognitive impairments and the need for intervention, establishing collaborative short- and long-term meaningful goals, and teaching the treatment model for cognitive rehabilitation interventions. In the application stage, patients initially work closely with therapists to apply strategies to simple tasks, typically within the therapeutic setting. Early in this stage, strategies are usually external or compensatory (e.g., use of planners, calendars, technology aids) and are structured by the therapist, who provides consistent cues and supervision. With therapist cues and feedback, the goal is for increased patient internalization of strategies (i.e., increased automaticity of practised strategies with improved independence through consistent use of compensatory strategies). This is achieved by providing ample practice of strategies with gradual removal of external cues to promote internal or self-generated cues for strategy use. For individuals with more pronounced cognitive impairments, the therapy goal is procedural learning through structure, practice, and repetition. Finally, in the adaptation stage, patients learn to apply strategies to more complex, functional, and non-structured tasks outside of the therapeutic environment. Generalization is promoted and refers to the process of applying learned skills across a variety of settings. Again, not all patients are able to generalize, given the severity of their cognitive deficits, and thus the use of external cues for these individuals is necessary long term.

The following sections review evidence-based cognitive rehabilitation interventions across the cognitive domains of attention, memory, executive functioning, visuospatial skills, and language. For comprehensive systematic reviews of the cognitive rehabilitation literature, refer to Cicerone et al. [1, 2, 3], and for comprehensive clinical guidance for evidence-based cognitive rehabilitation protocols, refer to the *Cognitive Rehabilitation Manual: Translating Evidence-Based Recommendations into Practice* [4].

2.2.1 Executive Functioning

Executive functions determine goal-directed and purposeful behaviours and include abilities to formulate goals, problem-solve, think abstractly, think flexibly, plan and organize, initiate behaviours, anticipate consequences of behaviours and actions, and self-monitor and adjust behaviours according to the situation and environment [4].

Executive dysfunction is a common outcome of brain injury and can manifest in disruptions of cognitive functioning as well as emotional and behavioural regulation. Cognitive impairments in executive functioning can result in problems with awareness, difficulties planning out and organizing daily activities, being able to problem-solve effectively in new situations, anticipating and analysing situations, and self-monitoring responses to tasks at hand. Impairments in awareness after brain injury are multifactorial and can involve right hemispheric or parietal damage, frontal injury, diffuse brain injury, and impairments in executive functions, as well as contributing causes of psychological or emotional readiness and social-environmental factors impacting the opportunity for meaningful learning about brain injury [6].

Emotional dysregulation after brain injury can range from non-reactivity (apathy) and lability in emotional reactivity, to over-reactivity with heightened emotional responsiveness. Behavioural manifestations of executive dysfunction can be characterized by 'positive symptoms' or behaviours overly influenced by the environment (e.g., impulsivity, disinhibition, stimulus-bound behaviours), or 'negative symptoms' such as abulia, poor initiation, task impersistence, or lack of spontaneity [4].

Cognitive rehabilitation interventions for executive functioning. Practice Standard recommendations for evidence-based cognitive rehabilitation of

executive functioning deficits include training of metacognitive strategies after TBI to help with emotional dysregulation and as a component of cognitive interventions for attention, neglect, and memory [3]. During post-acute rehabilitation after TBI, problem-solving strategies to help with dealing with everyday situations and functional activities are recommended as Practice Guidelines. Group-based interventions can also be considered as a Practice Option to help with remediation of executive and problem-solving impairments after TBI.

Studies show that strategies focused on enhancing metacognitive skills are beneficial for improved self-awareness after moderate to severe TBI, and can facilitate treatment of attention, memory, language deficits, and social skills impaired in those with TBI or stroke [3]. Metacognition is defined as 'thinking about thinking' with metacognitive knowledge representing awareness about cognitive abilities, and metacognitive control representing self-monitoring and adaptive change to environmental demands [7]. Metacognitive training goals involve helping the patient enhance and internalize awareness to then exert greater behavioural and emotional control through a process of learning self-monitoring and self-control through education, feedback and cuing, modelling, external directions, and instructional aids [4].

Problem-solving strategies in cognitive rehabilitation aim to teach individuals to apply consistent, general strategies to each new problem across situations through a framework of identifying the problem, goal-setting, planning a solution, executing the solution, then monitoring feedback to make appropriate changes [4]. Practice and repetition are implemented to help with internalizing problem-solving strategies so that individuals can generalize the use of strategies across situations with less external cues, though external cuing remains optimal for those who cannot demonstrate internalization [4].

2.2.2 Memory

Several cognitive functions are required for memory processes. Attention, encoding, storage, and retrieval are all involved in memory functioning [5]. Attention is required to attend to and process the information to be encoded and stored into long-term memory, usually through repetition and association for later retrieval or acquisition of stored information [4]. Long-term memory is conceptualized as declarative or non-declarative. Declarative or episodic memory refers to conscious and intentional recall of episodic (i.e., autobiographical) and semantic memory (concept-based knowledge) [8]. Non-declarative or implicit memory refers to recall of information learned through repeated performance without conscious effort and is often seen in motor learning (e.g., brushing teeth, riding a bike) [8].

Memory functions can easily be disrupted by brain injury given the reliance on the complex network of brain pathways involved in memory functioning. Memory retrieval is thought to involve the frontal lobes and subcortical regions, impacting free recall but with benefit from the provision of cues. Subcortical damage (e.g., hippocampus, amygdala, or striatum) may impact declarative memory. Procedural memory can be disrupted with damage to the cerebellum or basal ganglia, though it is less commonly seen in TBI [4].

Cognitive rehabilitation interventions for memory. Based on Cicerone et al.'s [3] evidence-based cognitive rehabilitation review, the Practice Standard recommendation for remediation of memory deficits involves both internalized and external memory compensatory strategies for mild memory impairments following TBI. External memory compensatory strategies are recommended for individuals with severe memory deficits following TBI or stroke as a Practice Guideline. Practice Options include errorless learning for specific skill/knowledge learning (but not for novel tasks or functional memory problems in TBI-related severe memory impairments), as well as group interventions for remediation of memory deficits after TBI.

The severity of injury impacts practice recommendations given that severe memory impairments and/or limitations in self-awareness impact the utility of internalized memory strategies. Rather, for severe impairments, external compensatory strategies or the use of external devices to aid in memory is recommended. Given that executive functioning impacts learning and the utility of external memory strategies, executive functioning difficulties must also be addressed in the treatment of memory disorders. External memory aids may include a Memory Notebook (e.g., written notebook or planner, electronic planner, smartphone). Orientation Books are beneficial to those with very severe memory impairments, including during post-traumatic amnesia, and help