Learning after acquired brain injury
Learning the hard way

Hileen Boosman

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Learning after acquired brain injury
Learning the hard way

Leren na niet-aangeboren hersenletsel
Het is niet vanzelfsprekend

(met een samenvatting in het Nederlands)

Proefschrift

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Hiltje Boosman

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Promotoren: Prof.dr. J.M.A. Visser-Meily

Prof.dr. C.M. van Heugten

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Contents

CHAPTER 1

General introduction

Acquired brain injury

Acquired brain injury (ABI) is a major cause of death and disability worldwide with an estimated number of 160,000 cases annually in the Netherlands.[1] ABI refers to a sudden-onset neurological condition which is not of congenital, hereditary, or degenerative nature nor induced by birth trauma.[2] It is an umbrella term that includes traumatic and non-traumatic brain injury. Traumatic brain injury occurs when an external force injures the brain, such as a car accident or a blow to the head. Non-traumatic brain injury is caused by internal events such as a stroke or a brain tumour. Both traumatic and non-traumatic brain injury can cause enduring physical deficits such as paralysis and impaired coordination.[3] There are also many 'hidden' consequences of ABI that can affect patients' neuropsychological functioning.[4] Neuropsychological problems frequently faced by patients with ABI are depression, poor self-awareness and impairments in memory and attention.[4] Patients with ABI are often referred to a neuropsychological rehabilitation program to learn how to manage such 'hidden' deficits.[4]

Neuropsychological rehabilitation

Neuropsychological rehabilitation is specifically concerned with the management of emotional, behavioural and cognitive problems following brain injury.[4] The ultimate goal of rehabilitation is to optimize patients' social participation and quality of life.[5] Rehabilitation generally involves a four-step process: assessment, goal setting, intervention, and reassessment.[5] First, the patient's needs and problems are identified. Second, realistic and attainable short- and long-term goals are set. Third, the planned interventions are executed. Fourth, the effects of the interventions are evaluated against the goals set.

The focus of rehabilitation treatments is on learning. Learning is commonly defined as "any relatively permanent change in behaviour that occurs as a direct result of experience".[6] This ranges from learning or relearning practical (e.g., learning how to use an agenda as an external memory aid) to psychosocial skills (e.g., learning how to cope with fear of recurrence). A measurable, observable or inferred change in knowledge, skill or attitude suggests that learning has occurred. Obviously, when the organ that is responsible for learning – the brain – has suffered damage, the learning process can be considerably disturbed. Brain damage can influence *what* is learned, but also *how* learning takes place.

Learning: what?

What patients can learn is often discussed by clinicians in terms of learning ability. Despite the lack of a thorough scientific basis, a patient's degree of learning ability is often mentioned as an important prerequisite for treatment success. For example, a patient with substantial memory impairments but low learning ability and poor self-monitoring skills may not profit from being taught memory strategies.[7] In clinical practice, neuropsychologists are frequently consulted to estimate patients' degree of learning ability.[8] A comprehensive neuropsychological assessment can give valuable information about impairments that may hamper or facilitate the learning process and consequently about the feasibility and type of treatment required.[9] Relatively intact executive functions are, for example, required to generalise learned behavior to other tasks and situations.[10] Although several cognitive tests have been suggested for the assessment of learning ability,[9,11] it is not yet known whether psychologists actually use specific cognitive tests or assessment tools to assess patients' learning ability.

Each cognitive tests basically measures one specific aspect of learning ability. Neuropsychologists can obtain further information about patients' cognitive abilities by going beyond the standard instructions of the test for instance by using a testing-the-limits procedure.[11] When the patient's limits are tested, extended time or attempts are allowed in order to evaluate the patient's maximum abilities on the test at hand.[12] This provides additional information about a patient's "approach to the task and ability to accurately complete the test if given enough leeway".[12]

Testing-the-limits is an example of a dynamic testing procedure.[13] The aim of dynamic testing procedures is to investigate performance change brought about by deliberate and often standardized intervention by the examiner.[14] The degree of change in cognitive performance is generally used to indicate patients' degree of 'cognitive learning potential'.[15] Dynamic testing procedures, such as testing-the-limits, can be applied to basically all conventional cognitive tests.[11] Dynamic testing procedures are intended to supplement and enrich conventional cognitive tests to deepen insight into patients' cognitive functioning particularly in the domain of learning. Despite the potential merit of such procedures in assessing patients' abilities, particularly with regard to learning, most studies on dynamic testing were performed in educational settings. To date, relatively little is known about dynamic cognitive testing procedures in patients with cognitive impairments such as ABI.

Learning: how?

Learning is commonly viewed as a 'black box' as it is mostly examined in terms of input and output without specific knowledge of its specific underlying processes. When attempting to maximize patients' learning output, information about learning processes is paramount. Such information can be used to tailor treatment to patients' strengths, weaknesses and preferences in the process of learning. Currently, rehabilitation treatments are commonly based on a 'learning by doing' approach.[16] In the process of learning or relearning skills after ABI, mere practice does not necessarily suffice. What is needed is an optimum learning environment to overcome learning barriers, facilitate learning, and maximize the maintenance and generalisation of learned skills. In an optimum learning environment, teaching strategies are tailored to best suit individual needs. Clinicians can, for instance, be more or less directive and persuasive depending on patient characteristics and the treatment target of interest.[17]

The concept of learning style was introduced based on the premise that adapting instructions and teaching strategies to a person's learning style may facilitate the learning process ('matching theory').[18] Learning style is the way a person prefers to approach or choose a learning situation.[19] Imagine a patient who learns how to use an electric wheelchair. Some patients will prefer to learn by hands-on experience, in a trial-and-error manner, whereas other patients prefer to learn by observing others and thinking about it first. More than 71 learning style models have been described of which most were developed for healthy individuals in educational or vocational settings.[18] Although the term 'styles' seems to imply a fixed trait which is stable over time, several models consider learning style as flexible, context-specific or even task-specific.[18,19] Also, the extent to which learning style models pay attention to personal and environmental factors varies widely.[18,19] One of the most influential learning style models is Kolb's experiential learning theory (ELT)[20] which regards learning as a continuous and interactive process. According to Kolb's ELT, learning preferences are relatively flexible and can change slightly from situation to situation.[18,20] In the year 2000, Kolb's ELT was already applied in over 1000 studies in several fields (e.g., management, computer studies, education).[18] To date, Kolb's ELT has not yet been examined in ABI rehabilitation.

The role of learning in predicting rehabilitation outcomes

Besides assessing patients' abilities and preferences in the area of learning, it is of interest to determine whether such information contributes to predicting patients' functioning on the long term. Given the high inter-individual variability in rehabilitation outcomes, prognostic indicators are required to provide a more accurate prognosis and to stratify patients for the risk of poor outcome.

Rehabilitation outcomes are commonly expressed in terms of activities limitations and participation restrictions.[21] These concepts are derived from the widely used 'International Classification of Functioning, Disability and Health' (ICF) conceptual framework of the World Health Organisation.[22] Activity limitations are problems a patient may experience when executing certain activities.[22] Participation restrictions are difficulties patients may have that influence their involvement in life situations.[22] A patient may, for example, be unable to remember appointments (activity limitation) which causes difficulties with work or the patient's engagement in leisure activities (participation restrictions).[4] In the ICF activities and participation domain, learning occupies a prominent position. The first chapter within activities and participation is 'learning and applying knowledge'. This chapter includes purposeful sensory experiences (e.g., watching, listening), basic learning (e.g., learning to read, acquiring skills), and applying knowledge (e.g., focusing attention, solving problems). Due to learning impairments or specific learning preferences, patients may not be capable of acquiring the skills necessary for successful participation in daily life. Since learning is a key ingredient of rehabilitation, a relation between learning and rehabilitation outcomes seems plausible. However, the role of learning, as compared to other neuropsychological factors, in predicting participation has not yet been examined.

Aims of this thesis

In an era of evidence-based practice, it becomes increasingly important to translate clinical practice into research questions as well as translating research findings into clinical practice. This can help strengthen the link between research and practice. The concepts of learning ability and learning style are already applied in Dutch current clinical practice. Therefore, in recognition of the potential significance of these concepts for neuropsychological rehabilitation, a 'quick-result project' was conducted in an effort to expand our knowledge of learning ability and learning styles following ABI. This project was funded by the National Initiative Brain and Cognition (NIBC) and embedded in the pillar 'The Healthy brain, Program Cognitive Rehabilitation'. The general objective of this thesis was to explore the concepts of learning ability and learning style in patients with ABI. This thesis had the following aims:
(a) examining methods of measuring learning ability in patients with ABI; (b) examining methods of measuring learning style in patients with ABI; and (c) determining the role of learning ability and learning style in predicting outcomes in ABI rehabilitation.

Outline of this thesis

Chapter 2 focuses on clinicians' views on learning in brain injury rehabilitation. In an online survey, it was evaluated which factors can influence a patient's learning ability and which methods clinicians use to assess patients' learning ability. In a systematic review in **chapter 3**, a comprehensive overview is given about the methodology and predictive validity of dynamic testing procedures in cognitively impaired patient populations. In **chapter 4,** the validity of a dynamic cognitive test was studied prospectively in patients with ABI in inpatient rehabilitation. Chapter 5 and chapter 6 focus on learning style in two retrospective studies in patients with ABI. In **chapter 5**, it was explored whether there is an association between learning style and cognitive impairments. In **chapter 6** the psychometric properties of a learning style instrument were examined. In **chapter 7**, the predictive value of learning and other neuropsychological factors for rehabilitation outcomes was examined in inpatients with ABI in a prospective, longitudinal cohort study. Finally, **chapter 8**, summarizes the main findings of this thesis and discusses the results in terms of lessons learned and implications for clinical practice. This is followed by methodological considerations and directions for future research. The chapter finishes with main conclusions.

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CHAPTER 2

Clinicians' views on learning in brain injury rehabilitation

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Boosman H, Visser-Meily JMA, Winkens I, van Heugten CM. Clinicians' views on learning in brain injury rehabilitation. *Brain inj.* 2013;27:685-688.

Abstract

Primary objective: To determine clinicians' views on learning ability in brain injury rehabilitation.

Research design: Online survey.

Methods and procedures: An online survey was sent to physicians, psychologists and therapists of three Dutch organizations for neuropsychology or rehabilitation. The survey enquired (1) whether clinicians take learning ability into account; (2) about factors influencing learning ability; and (3) about assessment tools used to assess learning ability.

Main outcomes and results: Thirty-seven physicians, 83 psychologists and 43 therapists completed the online survey. In total, 93% of respondents reported that they take learning ability into account when making a prognosis. The most frequently mentioned factors influencing learning ability were cognition, awareness of deficits and motivation. Learning ability was mainly determined by means of cognitive and memory tests and observations during therapy.

Conclusions: This study demonstrates that a patient's learning ability may be influenced by not only cognition but also by motivation and awareness of deficits. Structured and standardized assessment of these factors may be suggested for standard use in clinical practice. More research is needed about the influence these factors have on the learning process.

Introduction

Rehabilitation can be described as an educational, problem-solving process.[1] Obviously, the objective of education is learning which is defined as the acquisition of new infomation.[2] During rehabilitation, patients re-learn old skills and learn new skills in order to optimize social participation and well-being.[1] The rate of learning influences the time needed to accomplish rehabilitation goals. This in turn affects the costs of care.[3] Although patients' learning ability is frequently discussed in brain injury rehabilitation practice, the current scientific literature provides little insight into this complex concept.

A patient's learning ability may be affected by brain injury sequelae. A factor that is commonly associated with learning ability is cognitive functioning and in particular memory functioning.[2,4] For instance, when using a verbal learning task, the presence of a learning curve with adequate delayed recall is said to reflect learning ability and consequently the potential to profit from rehabilitation.[2,4] Solely considering the patient's cognitive or memory profile when estimating the ability to learn raises the question as to whether it is fair to state that all patients with poor cognitive functioning have poor ability to learn during rehabilitation. In contrast, does the absence of (severe) cognitive impairments automatically imply adequate learning ability? Other factors may also influence the rehabilitation process. A previous study[5] suggested that the frequently observed cognitive, physical and emotional impairments after traumatic brain injury (TBI) may substantially impact the learning process of patients with TBI. One could for instance think of a lack of motivation to pursue goals,[6] impaired awareness of deficits that impedes participation in rehabilitation[7] or passive coping which hampers active involvement in therapy.[8]

The identification of potential barriers for learning would aid clinicians to explore and target these factors in order to facilitate learning in patients with brain injury. This knowledge can provide a starting point for the development of an assessment tool to determine a patient's degree of learning ability. Such a tool may be useful for referring patients to the level of rehabilitation care that best fits their needs and capabilities.

To gain more knowledge about barriers for learning, it is believed it is important to start with exploring clinicians' views and current clinical practice. Therefore, the objectives of this study were to (1) determine whether clinicians take learning ability into account when making a prognosis; (2) evaluate clinicians' views on factors influencing learning ability; and (3) determine what assessment tools clinicians currently use to assess a patient's learning ability.

Methods

Participants and survey

This study aimed to include the primary disciplines working in brain injury rehabilitation. Therefore, an online survey was sent to members of three major organizations in the

Netherlands: (1) Netherlands Institute of Psychologists (NIP) section rehabilitation psychology (200 members) and section neuropsychology (482 members); (2) Dutch Working Group of Rehabilitation Physicians for Stroke (40 members); and (3) National platform for Cognitive Rehabilitation (112 members).

The survey enquired whether clinicians take learning ability into account when making a prognosis. Furthermore, the survey included open-ended questions about factors that can influence a patient's learning ability and about assessment tools respondents use to assess a patient's level of learning ability. In addition, respondents were asked about their age and professional details (profession, years of working experience, type of organization, main patient population).

Statistical analysis

Mann Whitney *U*-tests were applied to determine differences between disciplines regarding age and years of working experience. Furthermore, reported assessment tools were categorized into one of the following diagnostic assessment methods: conversation (e.g., intake, anamnesis), observation (standardized and non-standardized), cognitive test(s) or questionnaire(s). Data were analyzed using SPSS version 18.0. To adjust for a Type 1 error a Bonferroni correction was applied, alpha was set at 0.05/3 (disciplines)=0.017.

Results

Participants

In total, 174 rehabilitation professionals replied. The response rate was not calculated given the possibility that some respondents were members of more than one of the three organizations and consequently received the survey more than once. In addition, members of the Netherlands Institute of Psychologists do not necessarily work in a rehabilitation setting, which led them to disregard this survey.

Not all respondents answered all questions. Duplicates (n = 1) as well as respondents who did not indicate their profession (n = 10) were excluded, leaving a total of 163 respondents. Among these were 37 physicians (36 physiatrists, one psychiatrist), 83 psychologists and 43 therapists (24 occupational therapists, 15 cognitive trainers/therapists, three physical therapists, one psychological assistant). The mean number of years of working experience was 9.0 years (*SD* 6.9 years; range 0–29 years). The mean age of the professionals was 39.4 years (*SD* 9.9 years; range 22–65 years) (Table 2.1).

A Mann-Whitney *U*-test with Bonferroni correction revealed that the physicians were significantly older than the psychologists (U = 798.5, z = -4.19, $p < 0.0001$) and the therapists (U = 466.5, z = -3.05, $p = 0.002$). There were no significant differences regarding the number of years of working experience. For the total group, 95.7% (n = 156) spent more than 30% of their time on neurological patients.

Table 2.1 Sample characteristics (*n* = 163)

Mean age (*SD*; range) (*n* = 162)	39.4 (9.9; 22-65)
Profession, *%* (*n*)	
Physician	22.7 (37)
Psychologist	50.9 (83)
Therapist	26.4 (43)
Mean years of experience (*SD*; range) (*n* = 147)	9.0 (6.9; 0-29)
Type of organization, *%* (*n*) (*n* = 162)[a]	
Rehabilitation centre	73.4 (119)
Hospital	19.8 (32)
Nursing home	4.9 (8)
Primary care	3.7 (6)
Mental healthcare	2.5 (4)
Main patient population, *%* (*n*)	
Adults	81.6 (120)
Adults and elderly	10.9 (16)
Children and adults	4.1 (6)
Children	3.4 (5)

[a] More than one answer was possible.

Learning ability and prognosis

In total, 94.6% (*n* = 35) of physicians, 91.6% (*n* = 76) of psychologists and 93% (*n* = 40) of therapists indicated that they take learning ability into account when making a prognosis. Reasons for not taking learning ability into account were: there is no clear definition of learning ability (*n* = 2); everyone has learning ability (*n* = 1); learning ability is part of a patient's cognitive functioning (*n* = 1); according to the literature, learning ability is not important (*n* = 1); more environmental adjustments are needed when learning ability is impaired (*n* = 1); not involved in making a diagnosis or prognosis (*n* = 1); and five persons did not specify their answer.

Factors influencing learning ability

Respondents reported a wide variety of factors influencing learning ability. Thirteen different factors were mentioned by at least five respondents in the total group. Among these were eight psychological factors. Across disciplines, the most frequently mentioned factors were cognition (79.4%, *n* = 123), awareness of deficits (56.1%, *n* = 87) and motivation (29.0%, *n* = 45). Furthermore, a considerable number of respondents mentioned injury characteristics (10.3%, *n* = 16), pre-morbid functioning (10.3%, *n* = 16), personality (10.3%, *n* = 16) and coping style (9.7%, *n* = 15) (Table 2.2).

Table 2.2 Clinicians' views on factors influencing learning ability[a]

	Total (*n* = 155) % (*n*)	Physician (*n* = 34) % (*n*)	Psychologist (*n* = 81) % (*n*)	Therapist (*n* = 40) % (*n*)
Cognition	79.4 (123)	76.5 (26)	81.5 (66)	77.5 (31)
Awareness of deficits	56.1 (87)	55.9 (19)	54.3 (44)	60.0 (24)
Motivation	29.0 (45)	32.4 (11)	29.6 (24)	25.0 (10)
Injury characteristics	10.3 (16)	8.8 (3)	6.2 (5)	20.0 (8)
Pre-morbid functioning	10.3 (16)	14.7 (5)	8.6 (7)	10.0 (4)
Personality	10.3 (16)	5.9 (2)	14.8 (12)	5.0 (2)
Coping style	9.7 (15)	11.8 (4)	12.3 (10)	2.5 (1)
Social environment	5.8 (9)	0	7.4 (6)	7.5 (3)
Ability to generalize acquired skills	4.5 (7)	2.9 (1)	3.7 (3)	7.5 (3)
Demographic characteristics	3.9 (6)	0	4.9 (4)	5.0 (2)
Intelligence	3.9 (6)	5.9 (2)	3.7 (3)	2.5 (1)
Acceptance	3.2 (5)	2.9 (1)	2.5 (2)	5.0 (2)
Co-operation	3.2 (5)	2.9 (1)	3.7 (3)	2.5 (1)

[a] Only factors that were mentioned by at least five respondents are reported in the total group.

Table 2.3 Assessment methods of learning ability

Assessment method[a]	Physician (*n* = 6)[b]	Psychologist (*n* = 54)[b]	Therapist (*n* = 17)[b]
Conversation, % (*n*)	0	5.6 (3)	0
Observation, % (*n*)	0	20.4 (11)	64.7 (11)
Cognitive test(s), % (*n*)	83.3 (5)	94.4 (51)	23.5 (4)
Questionnaire, % (*n*)	0	5.6 (3)	11.8 (2)
Other, % (*n*)	16.7 (1)	3.7 (2)	29.4 (5)

[a] More than one answer was possible.
[b] Number of respondents that indicated the method of assessment.

Assessment of learning ability

Table 2.3 shows that physicians (five out of six) and psychologists (51 out of 54) mainly reported to use cognitive tests to determine learning ability, whereas therapists mainly reported to use observational data (11 out of 17). Within these categories, 20 psychologists and nine therapists mentioned specific tests to assess learning ability. The following cognitive tests were mentioned by at least three psychologists: the Rey-Auditory Verbal Learning Test (R-AVLT)[9] (*n* = 14), the Rivermead Behavioural Memory Test (RBMT)[10] (*n* = 6), the Visual Association Test (VAT)[11] (*n* = 6), the Amsterdam Dementia Screening Test

6 (ADS-6): eight word test[12] (*n* = 4) and the Verbal Learning and Memory Test (VLGT).[13] Therapists mentioned the R-AVLT (*n* = 1) and VLGT (*n* = 1) as well. These five cognitive tests are generally used to assess memory functioning.

Therapists also reported several observational instruments: the Allen Cognitive Level Screen (ACLS)[14] (*n* = 4), the Assessment of Motor and Process Skills (AMPS)[15] (*n* = 3) and the Perceive, Recall, Plan and Perform System (PRPP)[16] (*n* = 1). The AMPS is used to measure instrumental ADL performance, whereas the ACLS and PRPP focus on functional task performance.

Discussion

The vast majority of respondents take learning ability into account when making a prognosis. The most frequently mentioned barriers for learning were cognition, awareness of deficits and motivation. Learning ability was primarily determined by means of cognitive and memory tests and observations during therapy.

Respondents mentioned cognitive functioning, awareness of deficits and motivation as the primary factors influencing a patient's learning ability. Previous studies have also mentioned cognition as an important factor for learning.[2,4] One can imagine that relatively intact cognitive functions are essential to grasp and follow instructions and to remember what one has learned. The second factor, awareness of deficits, is important since decreased awareness can reduce the motivation to learn and rehabilitate.[17] In addition, previous studies showed that patients with poor awareness have worse cognitive functioning than patients with good awareness.[18,19] The third potential barrier to learning is motivation. A patient who is not motivated is unlikely to exert any effort in therapy and in applying the learned skills in daily life.[6] Besides cognition, awareness and motivation, several other factors may indirectly influence learning ability. For example, depression can influence cognitive functioning and motivation[2] and is, thus, indirectly linked to a patient's learning ability.

Ideally, all major potential barriers for learning should be taken into account. However, respondents mainly reported to use cognitive and memory tests and observations during therapy. Regarding the other two potential barriers for learning, motivation and awareness of deficits, no specific tools were mentioned. It is, however, possible that respondents use their observations to estimate a patient's degree of awareness of deficits and motivation. More research is needed to determine whether the mentioned tests are appropriate indicators of learning ability in patients with brain injury.

Several limitations of this study should be noted. Not all respondents answered all questions, which resulted in small group sizes for the question about assessment tools. Furthermore, it is unknown whether the answer 'cognitive tests' refers to the interpretation of test scores for specific cognitive tests or, for example, the observation during the completion of a cognitive test. In addition, for the total group, the years of experience ranged from 0–29 years and is, therefore, a potential confounder in the analysis. Respondents with limited clinical experience may have insufficient knowledge about learning barriers and assessment methods. However, 73% of respondents (*n* = 119) had at least 3 years of experience and solely including these patients yielded similar results. A last limitation is that the sample was collected in the Netherlands. Generalizability to other countries may be limited due to differences in healthcare. However, cognitive and physical sequele after ABI are similar across countries and, therefore, it is believed that this sample is representative.

In conclusion, the current study is one of the first studies to 'open the black box of learning in rehabilitation and demonstrates that a patient's learning ability may be influenced by not only cognition but also by motivation and awareness of deficits. Structured and standardized assessment of these factors may be suggested for standard use in clinical practice. More research is needed about the specific influence these factors have on the learning process.

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CHAPTER 3

Dynamic testing of learning potential in adults with cognitive impairments: A systematic review of methodology and predictive value

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Abstract

Dynamic testing includes procedures that examine the effects of brief training on test performance where pre- to post-training change reflects patients' learning potential. The objective of this systematic review was to provide clinicians and researchers insight into the concept and methodology of dynamic testing and to explore its predictive validity in adult patients with cognitive impairments. The following electronic databases were searched: PubMed, PsychINFO, and Embase/Medline. Of 1141 potentially relevant articles, 24 studies met the inclusion criteria. The mean methodological quality score was 4.6 of 8. Eleven different dynamic tests were used. The majority of studies used dynamic versions of the Wisconsin Card Sorting Test. The training mostly consisted of a combination of performance feedback, reinforcement, expanded instruction or strategy training. Learning potential was quantified using numerical (post-test score, difference score, gain score, regression residuals) and categorical (groups) indices. In five of six longitudinal studies, learning potential significantly predicted rehabilitation outcome. Three of four studies supported the added value of dynamic testing over conventional testing in predicting rehabilitation outcome. This review provides preliminary support that dynamic tests can provide a valuable addition to conventional tests to assess patients' abilities. Although promising, there was a large variability in methods used for dynamic testing and, therefore, it remains unclear which dynamic testing methods are most appropriate for patients with cognitive impairments. More research is warranted to further evaluate and refine dynamic testing methodology and to further elucidate its predictive validity concerning rehabilitation outcomes relative to other cognitive and functional status indices.

Introduction

Cognitive impairments are commonly described in sudden onset conditions such as stroke and traumatic brain injury as well as in evolving conditions such as dementia and schizophrenia.[1-4] In a rehabilitation setting, these patients are generally referred to a neuropsychologist for comprehensive cognitive assessment. Conventional cognitive tests provide information about a patient's baseline performance from which treatment decisions can be made and progress can be monitored.[5] Neuropsychologists can obtain additional information about patients' abilities by going beyond the standard administration procedures of a cognitive test.[5] This can be done by employing a dynamic testing procedure to assess patients' potential to improve cognitive performance.

Dynamic testing is an umbrella term for procedures that examine the effects of a brief training on a person's test performance.[6] A commonly used dynamic testing procedure to target cognitive abilities is a one-session pre-test – train – post-test paradigm where a test is administered before and after a brief training.[7] During the brief training, the experimenter can, for instance, provide additional instructions or explain compensational strategies. The degree of change between pre- to post-training performance represents a patient's learning potential.

Generally, it is proposed that dynamic tests provide unique information about a person's abilities in addition to the information that is provided by conventional tests.[7] It is important to note that dynamic tests were designed to supplement conventional testing procedures rather than replacing them.[7] Conventional tests provide valuable information about cognitive deficits that may hamper or facilitate learning, whereas dynamic tests more specifically evaluate patients' potential to learn and improve cognitive performance. Taken together, they can provide a more comprehensive picture of a patient's abilities.

Besides providing additional information about patients' abilities, dynamic tests may also contribute to accurately predicting rehabilitation outcome. Accurate prediction of future achievement is important as it could guide treatment programs and identify patients who are in need of individually tailored treatment. The dynamic testing approach has already shown evidence of predictive validity in a review that focused on the use of dynamic testing in academic settings.[8] The authors concluded that dynamic tests provided unique information about students' abilities that was not captured by conventional tests; information that contributed to accurately predicting students' future achievement.

The concept of dynamic testing is relatively new for adults with cognitive impairments. Therefore, the objective of this systematic review was to provide clinicians and researchers insight into the concept and methodology of dynamic testing and to explore its added and predictive value in adult patients with cognitive impairments. The following questions were answered:

1) Which one-session dynamic tests are currently used in adults with cognitive impairments?
2) Which brief training methods are incorporated into these dynamic tests?
3) Which computational methods are applied to quantify learning potential?
4) What is the predictive validity of learning potential concerning rehabilitation outcome?
5) What is the added value of dynamic tests over conventional tests in predicting rehabilitation outcome?

Methods

Data sources and study selection

The following three electronic databases were searched between January 1990 and May 2014: PubMed, PsychINFO and Embase/Medline. Search terms were adapted from a previous review on the predictive value of dynamic testing concerning student achievement,[8] and a study on the main features and history of dynamic testing.[7] Search terms included dynamic testing, dynamic assessment, learning potential, testing the limits, cognitive plasticity, cognitive modifiability, interactive assessment, mediated learning, mediated assessment, or learntest. Only English language, peer-reviewed journal articles of one-session dynamic tests that include a training phase and target cognitive abilities in adults with acquired cognitive impairments were included. Reviews, dissertations, books, case studies, columns, qualitative studies, neuroimaging studies, psychometric, and methodological evaluations were excluded. Reference lists of full text eligible articles were screened for relevant articles.

Data extraction

Two authors (HB and TB) independently assessed all studies for inclusion based on the title and abstract. A third author (CvH) was consulted when agreement between the two reviewers was not reached. For all eligible studies, details about the dynamic test, training methods and learning potential indices were extracted. For longitudinal studies that measured rehabilitation outcome on the level of activities and participation, we extracted information about the predictive value of learning potential and the added value of dynamic tests over conventional tests in outcome prediction.

The methodological quality of the included studies was assessed independently by the same two researchers. An 8-point checklist, the Methodological Quality Assessment List,[9] was used that yields a total score between 0 (low quality) to 8 (high quality). This checklist was originally used in spinal cord research. Therefore, item 3 ‘type of lesion’ (paraplegia/tetraplegia) was changed into ‘diagnosis’. Studies with a methodological quality score below 3 were excluded from this review. No review protocol was published.

Results

Study selection

In Figure 3.1, a flow diagram of the search process is presented. The initial search resulted in 1,141 articles. In total, 411 references were duplicates and 695 were excluded based on subject matter. The reference lists of the remaining 35 articles were screened for relevant articles. This yielded three additional articles. The same authors (HB and TB) reviewed the remaining 38 full-text articles and selected studies that were in agreement with the inclusion criteria. The study population characteristics were identical in two articles of the same research group.[10,11] The study with the lower methodological quality was excluded for further review.[11] Two other studies also used the same study population.[12,13] Because those studies used different learning potential indices and partially different outcome measures, they were retained for review. The search process resulted in a total of 24 articles, which were included for review.

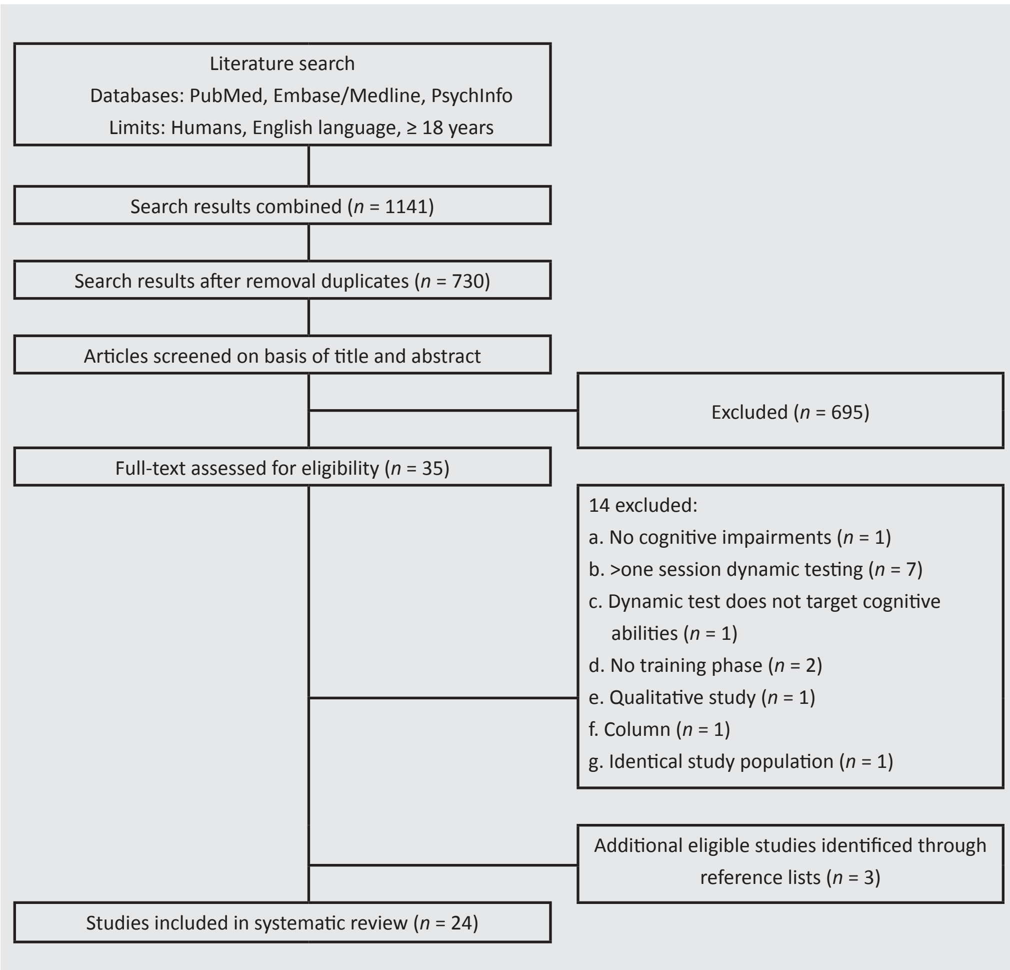

Figure 3.1 Literature review results flowchart

Study characteristics

Sixteen studies had a cross-sectional design and eight studies had a longitudinal design (Table 3.1). The methodological quality assessment revealed that on an 8-point scale, the average score was 4.6 (range 3-6). The quality score for 12 out of 24 articles was 5 or 6. The majority of studies included patients with cognitive impairments due to a psychiatric diagnosis (*n* = 16). The remaining studies included patients with a neurodegenerative disease (*n* = 4), acquired brain injury (*n* = 2) or a combination of patients with a psychiatric or a neurodegenerative disease (*n* = 2). The included studies determined learning potential for descriptive, diagnostic, or predictive purposes. A descriptive purpose was, for example, to explore the association between learning potential and cognitive functioning.[14] A diagnostic objective was used only in studies including patients with a neurodegenerative disease. These studies, for example, evaluated whether learning potential can discriminate healthy persons from patients with mild cognitive impairment and Alzheimer's disease.[10] Other studies used learning potential to predict a patient's long-term functioning (e.g., community integration).[15]

Six of eight longitudinal studies measured patients' rehabilitation outcome in terms of activities or participation after a treatment programme. The outcome measures were classified in three domains: community functioning, vocational functioning, or social functioning. The treatment programs varied from specific skills training (e.g., grocery shopping skills[16]), to a comprehensive 8 or 12 months rehabilitation programme.[12,17]

Measures

Dynamic versions of 11 cognitive tests were employed in the reviewed articles. In Table 3.2 an overview of all dynamic cognitive tests with their training method and learning potential index is presented. In two studies, dynamic versions of two different cognitive tests were used to assess patients' learning potential.[18,19] In the majority of studies (*n* = 16) dynamic versions of the conventional or modified Wisconsin Card Sorting Test (WCST; M-WCST)[20,21] were used. Also, all longitudinal studies that evaluated the predictive validity of learning potential used dynamic versions of the WCST[12,13,16,22,23] or M-WCST.[17] The results for the WCST and M-WCST were combined as these two measures are similar.

Dynamic versions of memory tests were used in seven studies; Auditory Verbal Learning Test (AVLT),[24] Auditory Verbal learning Test of Learning Potential (AVLT-LP),[25] Buschke Selective Reminding Test (BSRT),[26] California Verbal Learning Test – II (CVLT-II),[27] Little Mister Jakob Drawings (LMJD),[28] Wechsler Memory Scale Revised Visual Paired Associates (WMS-R),[29] and Rey-Osterrieth Complex Figure Test (ROCFT).[30] In one study, a dynamic version of a reasoning task was applied; Adaptive Figure Series Learning Test (ADAFI).[31] Two studies used the Battery of Learning Potential for Assessing Dementia (BEPAD)[10,31] which includes multiple cognitive domains, namely perception, memory, executive functioning, and language.

Training methods

Training methods that were used most frequently during the brief training were a combination of performance feedback, reinforcement, expanded instruction, or strategy training.

Performance feedback

Eight dynamic tests incorporated performance feedback in the brief training. On the ADAFI, error-specific help was given after an incorrect response.[33] For list-learning tests (AVLT, AVLT-LP, BEPAD Verbal Memory Learning Potential Test, BSRT, CVLT-II), feedback mostly consisted of telling the patient the number of words recalled correctly or reminding the patient of words not recalled.[18,19,25,32] For the ROCFT, patients were corrected after each mistake before continuing with the test and, when needed, patients were given cues for the design elements and organizational sequence during recall.[30] Feedback on the WCST included telling the patient why their choice was correct or incorrect after each card sort (e.g., "This was wrong, we don't sort for color, but for form or number"). In contrast, Uprichard *et al.*[15] provided feedback on the WCST according to an errorless learning approach. After each card sort, patients were asked to say out loud which rule they were using and their count of correct responses. Before starting a new rule, the examiner reminded the patient of the completed and new card sorting rule.

Reinforcement

Four dynamic tests incorporated reinforcement into the brief training. The BEPAD subtests included verbal reinforcement on the patient's performance (e.g., "you did very well!").[32] The M-WCST included a monetary reinforcement. Patients received five cents after each correct card sort.[17] The type of reinforcement that was used for the AVLT[19] and AVLT-LP[25] was not described.

Expanded instruction

Expanded instruction was given during the brief training of three dynamic tests. The extended, standardized instruction of the AVLT was approximately four times longer than the standard instruction and focused on motivating the patient and ensuring adequate attention (e.g., "Don't let yourself be distracted by noise or other things").[19] During the M-WCST training, the examiner gave card-by-card instructions and told the patient of the category shift after ten correct card sorts.[17] During the WCST training the sorting rules were explained (e.g., "There are 3 possible ways to match the cards: you can match the card by color, by number of the objects, or by shape") and the patient was informed of the rule change after ten consecutively correctly sorted cards (e.g., "After you get 10 correct in a row, the rule changes; you are no longer matching to color, you must be matching to the number of objects or to the shape").[12-14,16,19,22,34-39]

Table 3.1 Study and participant characteristics

Ref	Test(s)	Population (*n*) [a]	Mean age (*SD*/range)	% men	Ethnicity, % Caucasian	Treatment programme
Cross-sectional studies						
10	BEPAD	Healthy controls (100) Mild Cognitive Impairment (50) Alzheimer's disease (50)	73.1 (NR) 74.9 (NR) 75.1 (NR)	49% 40% 28%	NR NR NR	NA
31	BEPAD	Healthy controls 55-89 years (601) Healthy controls >90 years (188) Mild Cognitive Impairment (57) Alzheimer's disease (98)	68.8 (6.6) 92.9 (2.5) 76.1 (5.2) 78.2 (5.1)	42% 36% 49% 58%	NR NR NR NR	NA
41	CVLT-II	Schizophrenia (40), schizoaffective disorder (10)	42.4 (10.1)	78%	62%	NA
34	WCST	Schizophrenia (10), schizoaffective disorder (10)	43.5 (NR)	45%	20%	NA
18	BSRT, WMS-R VPA	Experiment 2: Head injury (64) Experiment 3: Head injury (26)	NR (18-55) NR (18-55)	80% 80%	NR NR	NA
35	WCST	Schizophrenia, schizoaffective disorder (54)	IEF: 32.7 (10.8) GL: 33.8 (10.1) PL: 36.6 (11.9)	72%	NR	NA
36	WCST	Schizophrenia, schizoaffective disorder (48)	34.7 (12.2)	1%	NR	NA
14	WCST	Bipolar disorder (22), unipolar (major) depression (17), schizophrenia or schizoaffective disorder (21)	43 (10.2)	32%	80%	NA
30	ROCFT	Schizophrenia (45), schizoaffective disorder (36)	41.7 (8.6)	51%	37%	NA
33	ADAFI	Healthy controls (12) Mild Cognitive Impairment (10)	67.8 (8.3) 70.2 (7.1)	33% 30%	NR NR	NA
15	WCST	Closed head trauma (58), stroke (8), anoxic damage (6), cerebral infection (2), missing (3)	30.8 (11.3)	75%	NR	NA
28	LMJD	Healthy controls (11) Major depression (11) Alzheimer's disease or at risk (19)	Median 65 (57-85) Median 65 (48-73) Median 72 (49-88)	36% 45% 47%	NR NR NR	NA
37	WCST	Schizophrenia (26)	32.3 ± 9.3	65%	NR	NA
38	WCST	Schizophrenia (30)	31.5 (9.6)	67%	100%	NA
39	WCST	Schizophrenia (23)	29.2 (5.2)	52%	NR	NA
40	WCST	Schizophrenia or schizoaffective disorder (49)	HS: 29.5 (4.3) L: 33.6 (8.1) NL: 34.9 (7.4)	NR	NR	NA

Table 3.1 (*continued*)

Ref	Test(s)	Population (*n*) [a]	Mean age (*SD*/range)	% men	Ethnicity, % Caucasian	Treatment program
Longitudinal studies						
25	AVLT-LP	Healthy controls (101), Mild Cognitive Impairment (102)	74.7 (8.6)	46%	NR	NA
16	WCST	Schizophrenia, schizoaffective disorder (9), unipolar (major) depression (8), bipolar disorder (8)	43.8 (NR)	34%	84%	9-session grocery shopping skills training
22	WCST	Schizophrenia (40), schizoaffective disorder (17)	CIG: 41.4 (10.6) ELG: 41.5 (10.0)	61% 83%	NR NR	1-hour work skills training
23	WCST	Schizophrenia (49), schizoaffective disorder (7)	49.4 (6.2)	93%	38%	8-session social skills training
12, 13	WCST	Schizophrenia, schizoaffective disorder (41)	27.2 (7.4)	61%	NR	1-year vocational rehabilitation programme
19	AVLT, WCST	Sample I: Schizophrenia (29) Sample II: Schizophrenia (33) Elderly with dementia (50), elderly without dementia (37)	30.4 (5.7) 34.9 (16.5) 74.8 (8.0)	NR NR 48%	NR NR NR	NA
17	M-WCST	Healthy controls (79) Schizophrenia (44)	32.7 (7.8) 30.7 (8.2)	58% 86%	NR NR	NA 8-month rehabilitation programme

Notes. ADAFI = Adaptive Figure Series Learning Test; AVLT = Auditory Verbal Learning Test; AVLT-LP = Auditory Verbal Learning Test of Learning Potential; BEPAD PLPt, VFt, HTPLt, VLMPt = Battery of Learning Potential for Assessing Dementia subtests Position Learning Potential test, Verbal Fluency test, Hanoi Tower Potential Learning test, Verbal Memory Learning Potential test; BSRT = Buschke Selective Reminding test; CVLT-II = California Verbal Learning Test; LMJD = Little mister Jakob drawings; ROCFT = Rey-Osterrieth Complex Figure Test; M-WCST = Modified Wisconsin Card Sorting Test; WCST = Wisconsin Card Sorting Test; WMR-R VPA = Wechsler Memory Scale-Revised Visual Paired Associates.
CIG = conventional instruction group; ELG = errorless learning group; GL = good learner; HS = high scorers; IEF = intact executive-function; L = learners; NL = non-learners; PL = poor learner; NR = Not reported; NA = Not applicable.

[a] Number of participants who completed the dynamic cognitive test.

Table 3.2 Dynamic cognitive tests with their training method(s), and learning potential index

Ref	Cognitive test(s)	Training method(s)					Learning potential index
		Performance feedback	Rein-forcement	Expanded instruction	Strategy training	Other	
25	AVLT-LP	*	*			*[a]	Groups
10	BEPAD PLPt BEPAD VFt BEPAD VMLPt BEPAD HTPLt	* * *	* *		*		Post-test score, difference score
32	BEPAD VMLPt	*	*		*		Post-test score, difference score
41	CVLT-II	*			*		Groups
34	WCST	*		*			Groups
18	BSRT WMS-R VPA	*			 *		Groups Groups
35	WCST	*		*			Groups
36	WCST	*		*			Gain score
14	WCST	*		*			Groups
16	WCST	*		*			Difference score
30	ROCFT	*			*		Groups
33	ADAFI	*				*[a]	Post-test score, difference score
22	WCST	*		*			Gain score, groups
23	WCST	*			*	*[b]	Regression residuals
15	WCST	*		*		*[c]	Groups
28	LMJD				*		Post-test score
37	WCST	*		*			Gain score
38	WCST	*		*			Gain score, groups
12	WCST	*		*			Groups
13	WCST	*		*			Post-test score
39	WCST	*		*			Groups
19	AVLT WCST	*	*	*			Post-test score Post-test score
40	WCST	*		*			Groups
17	M-WCST	*	*	*			Post-test score, groups, difference score

Notes. ADAFI = Adaptive Figure Series Learning Test; AVLT = Auditory Verbal Learning Test; AVLT-LP = Auditory Verbal Learning Test of Learning Potential; BEPAD PLPt, VFt, HTPLt, VMLPt = Battery of Learning Potential for Assessing Dementia subtests Position Learning Potential test, Verbal Fluency test, Hanoi Tower Potential Learning test, Verbal Memory Learning Potential test; BSRT = Buschke Selective Reminding test; CVLT-II = California Verbal Learning Test; LMJD = Little mister Jakob drawings; ROCFT = Rey-Osterrieth Complex Figure Test; M-WCST = Modified Wisconsin Card Sorting Test; WCST = Wisconsin Card Sorting Test; WMR-R VPA = Wechsler Memory Scale-Revised Visual Paired Associates.

[a] Verbalizations aimed at focusing attention on the task; [b] Increasing difficulty; [c] Guidance; [d] Errorless learning.

Strategy training

Six dynamic tests incorporated strategy training in the brief training. The BEPAD Position Learning Potential test incorporated verbal and visual strategies separately in order to detect the effect of these different strategies on performance.[10] The BEPAD Verbal Memory Learning Potential test included a cognitive strategy (e.g., "Perhaps you can group the words").[32] For the CVLT-II a semantic memory strategy training was used.[41] During that training patients were demonstrated that semantic grouping of words increases recall. Patients were given specific instructions on how to group words semantically and were asked to say aloud the semantic groups after recall. The LMJD training included action verbalization.[28] The patient was asked to say out loud what was happening on the target pictures. During administration of the WMS-R Visual Paired Associates subtest the patient was instructed to use verbal labeling.[18] In other words, the patients were asked to attach a verbal label to each line drawing. One study incorporated a problem-solving mnemonic in the WCST.[23] The mnemonic included the following steps: (1) identify the problem, (2) identify and select a potential strategy for solving the problem, (3) assess the success of the chosen strategy, and (4) continue to use a successful strategy or revise if the chosen strategy was unsuccessful. For the ROCFT, an organizational strategy was taught. Patients were directed to construct the complex figure in three sequential steps from large structural elements to filling in smaller details. After completion of the drawing, patients were instructed to observe the components and organizational features of the figure.[30]

Computational methods to quantify learning potential

Learning potential was conveyed as a numerical (post-test score, difference score, gain score, regression residuals) or categorical index (groups, e.g., poor learner, strong learner, high-achiever). The computational methods are described below. Six studies used multiple learning potential indices: post-test score and difference score;[10,32,33] gain score and groups;[22] and post-test score, difference score, and groups.[17]

Post-test score

The post-test score represents the maximum performance a patient can achieve on a cognitive test. A higher post-test score indicates better learning potential. A post-test score was used in seven studies.[10,13,17,19,28,32,33]

Difference score

A difference score can be calculated by subtracting the pre-test score from the post-test score. A higher difference score indicates a greater difference between the pre- and post-test. Five studies used a difference score.[10,16,17,32,33]

Gain score

Gain scores are ratios calculated by dividing actual performance change (i.e., difference score) by potential performance change.[22] The lower the score the lower the learning potential. For example, on the CVLT-II the maximum score a patient can achieve for each trial is 16. This yields the following gain score formula: (trial 5 score – trial 1 score) / (16 – trial 1 score). Thus the gain score represents the relative change score. Gain scores were calculated in four studies.[22,36-38]

Regression residuals

This score was calculated by performing a regression analysis in which the pre-test scores was used as a predictor of the post-test scores. The residual scores were used as a measure of learning potential. The higher the score, the greater the difference between the observed and predicted post-test score. One study used regression residuals for the WCST.[23]

Groups

In total, 14 studies divided patients into groups. The following methods were used to do so:

Raw test scores

Patients with a significant increase in the number of words recalled on the BSRT between trials 1 and 4 were classified in a 'learn only' group. Patients who showed an increase in organizational score from trials 4 to 5 on the BSRT, and demonstrated use of a labeling strategy on WMS Visual Paired Associates were classified in a 'learn and benefit group'. Patients who showed adequate scores for semantic labeling strategy were classified in a 'learn, benefit and transfer group'. This method was used in one study.[18]

Median split

In one study, a median split of the change in pre-to post-test T-scores on the WCST was used to classify patients as 'poor learner' or 'strong learner'.[35] Another study used a median split of the gain score (described above) to classify patients in a 'high learning potential' or 'low learning potential' group.[22]

Rasch maps

The difficulty for the different WCST measures (pre- and post-test; e.g., learning to learn, failure to maintain set) was displayed on a 0-100 scale. Patients who scored below the cut-off value for all measures were considered 'non-learners'. Patients who passed some measures were split into 'spontaneous learners' and 'guided learners' based on a midpoint split of 50 on the scale. This method was used in one study.[15]

Algorithm of Schöttke, Bartram, and Wiedl[42]

Linear regression was used to predict the post-test score and a confidence interval was calculated based on the standard error of prediction. The confidence interval was used to determine whether or not the post-test score could be attributed to chance. A post-test score above the confidence interval reflected true change. Patients scoring below the upper limit of the confidence interval were classified as 'poor learners' (also called 'non-retainers' or 'non-learners'). Patients with a post-test score outside the upper limit were considered 'strong learners' (also called 'learners'). Patients with a high pre- and post-test score were classified as 'high achievers' (also called 'high scorers'). Another study used the algorithm to categorize patients in two groups: persons with plasticity or persons without plasticity. This method was used in 10 studies.[12,14,17,25,30,34,38,39,40,41]

The predictive and added value of learning potential on rehabilitation outcome

Six of eight longitudinal studies evaluated whether learning potential can predict rehabilitation outcome after a treatment program. These studies focused on predicting community functioning, vocational, or social functioning. The results are presented in Table 3.3.

Two studies measured outcome on the level of community functioning.[12,16] Compared to the conventional WCST, the dynamic WCST explained an additional 32% of the variance in shopping skills after a 9-session grocery shopping skills training.[16] Three months after a one-year vocational rehabilitation program, non-learners had significantly poorer community functioning compared to learners and high scorers. There were no significant differences between learners and high scorers.[12]

Two studies measured outcome on the level of social functioning.[17,23] In one study,[23] the dynamic WCST was not associated with the change in social functioning between baseline and after an 8-session social skills training. In the other study,[17] it was reported that the conventional M-WCST, and not the dynamic M-WCST, showed a significant, positive association with the change in social functioning between baseline and after an 8-month rehabilitation program. When patients were divided into learner groups, it showed that non-retainers and learners significantly improved to a similar degree, but non-retainers demonstrated significantly lower social functioning compared to learners after the rehabilitation program.[17]

Three studies measured outcome in terms of vocational functioning.[12,13,22] In one study,[22] the authors evaluated the predictive value of the conventional WCST and the dynamic WCST on work skill accuracy and performance three months after a one-hour work skills training. The conventional WCST was a significant predictor of work skill accuracy, whereas the dynamic WCST additionally predicted work skill performance. The conventional WCST explained 6%, and the dynamic WCST explained an additional 13% of

Table 3.3 Longitudinal associations between learning potential and rehabilitation outcome

Ref	Predictor variable	Outcome variable			Main results	Results in words
		Measure	Domain	Assessment time		
12	WCST group	O-AFP	Vocational functioning	a. After 26 weeks b. Post-treatment	a. NL < HS**, L < HS* b. NL < L,HS*	Compared to learners and/or high achievers, non-learners had lower vocational functioning after 26 weeks, directly after and 3 months after a 1-year vocational rehabilitation program.
		5-level ordinal scale	Vocational functioning	3 months post-treatment	NL < HS***	
		LFS	Community functioning	3 months post-treatment	NL < H, HS*	Non-learners had poorer community functioning compared to learners and high scorers 3 months after a 1-year vocational rehabilitation program.
16	1. WCST pre-test score 2. WCST difference score	TOGSS	Community functioning	Post-treatment	1. $R^2 = 0.27$ 2. $\Delta R^2 = 0.32$***	The conventional WCST explained 27%, and the dynamic WCST difference score explained an additional 32% of the variance in community functioning after a 9-session grocery shopping skills training.
17	1. M-WCST pre-test score 2. M-WCST post-test score 3. M-WCST difference score	REHAB-GB[a]	Social functioning	Pre- to post-treatment change	1. r = 0.34* 2. r = 0.09 3. r = 0.26	The pre-test score, and not the post-test and difference score, was significantly associated with the change in community functioning between baseline and after an 8-month rehabilitation program.
	4. M-WCST group			Post-treatment	4. NR < L*	Compared to learners, non-retainers showed lower community functioning after the program.

Table 3.3 *(Continued)*

Ref	Predictor variable	Outcome variable			Main results	Results in words
		Measure	Domain	Assessment time		
13	1. WCST pre-test score 2. WCST post-test score	O-AFP	Vocational functioning	a. After 6 months b. Post-treatment	1a. β = 0.312 1b. β = 0.096 2a. β = 0.310* 2b. β = 0.148	The dWCST post-test score, and not the pre-test score, was a significant predictor of vocational functioning 6 months after a 1-year vocational rehabilitation programme and not directly after the treatment programme.
	1. WCST pre-test score 2. WCST post-test score	5-level ordinal scale	Vocational functioning	3 months post-treatment	B = 0.050 B = 0.100**	The post-test score, and not the pre-test score, was a significant predictor of vocational functioning three months after a 1-year vocational rehabilitation program.
22	1. WCST pre-test score 2. WCST gain score	Work skill accuracy	Vocational functioning	3 months post-treatment	1. F(1, 52) = 6.87* R^2 = 0.06 2. F(1, 52) = 9.69***, ΔR^2 = 0.13**	The WCST pre-test and gain score were significant predictors of work skill accuracy 3 months after a 1-hour work skills training, where the gain score explained an additional 13% of variance beyond the pre-test score.
23	WCST regression residuals	MASC	Social functioning	Pre- to post-treatment change	r = -0.11 to 0.07	The WCST regression residuals were not associated with the change in social functioning between baseline and after an 8-session social skills training.

Notes. LFS = Level of Functioning Scale; MASC = Maryland Assessment of Social Competence; M-WCST = Modified Wisconsin Card Sorting Test; O-AFP = Osnabrueck Ability to Work Profile; REHAB-GB = Rehabilitation Evaluation Hall and Baker subscale General Behaviour; TOGSS = Test of Grocery Shopping Skills; WCST = Wisconsin Card Sorting Test; HS = high scorers; L = learners; NR = non-retainers.
[a] Higher scores reflects poorer functioning.
*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$

the variance in skill accuracy post-training.[22] The remaining two studies used the same patient population to evaluate work capabilities and vocational integration after a one-year vocational rehabilitation program.[12,13] One of these studies focused on the predictive value of the conventional WCST and the dynamic WCST on vocational outcomes.[13] The other study focused on between-group (non-learners, learners, high scorers) differences in vocational outcome.[12] The dynamic WCST, and not the conventional WCST, was a significant predictor of work capabilities after six months of programme attendance.[13] At that time, non-learners and learners demonstrated significantly lower work capabilities compared to high scorers. There were no significant differences between non-learners and learners.[12] More important, the dynamic WCST, and not the conventional WCST, significantly predicted patients' vocational integration.[13] Regarding learner groups, non-learners demonstrated significantly lower vocational integration compared to high scorers. No significant differences were reported between non-learners and learners, and between learners and high scorers.[12]

Discussion

We systematically collected the literature on one-session dynamic testing methods in adults with cognitive impairments and examined the relation between learning potential and rehabilitation outcome. In total, 24 studies were identified describing 11 different dynamic tests that were used to assess learning potential in patients with cognitive impairments. This review provides preliminary support that dynamic tests can provide a valuable addition to conventional tests to predicting rehabilitation outcome. There was, however, a large variability in the methods used for dynamic testing.

Measures

All tests in this review were adaptations of renowned conventional cognitive tests such as the WCST and CVLT-II. The dynamic WCST was used in the majority of studies and was the only test that was administered to patients in all three major diagnostic groups (i.e., acquired brain injury, psychiatric, or neurodegenerative disorders). Of the remaining ten tests, seven were memory tests which reinforces the view that memory is associated with learning.[5,43] Memory tests that include repeated administration of a word-list (e.g., CVLT-II) have previously been described as dynamic in nature.[36,44] However, solely using repetition is in fact unassisted assessment and therefore does not entirely comply with the assumptions of dynamic testing. Repetition of a cognitive test without adding a training phase seems to measure learning effects instead of learning potential.

The BEPAD was unique in the sense that it was the only multi-domain instrument. The BEPAD was developed to test whether learning potential can discriminate healthy persons from persons with Mild Cognitive Impairment and Alzheimer's Disease.[10] The BEPAD subtests were adaptations of existing cognitive tests which had the greatest discriminative power according to experts.

It is important to note that not all cognitive tests can be used for dynamic testing since tests differ in their sensitivity to repeated exposure. Repeated exposure to the same cognitive test may result in practice effects. In particular tests with a single solution are prone to practice effects such as the WCST.[5] WCST performance basically depends on discovery of the sort and shift principle. As soon as the sorting principle is discovered or explained, patients are likely to significantly improve their test performance during a second administration of the test.[5] The issue of practice effects may be less pronounced for list learning tests as alternative versions can be used.[5] Furthermore, some conventional cognitive test may no longer be administered reliably once the patient has performed an adapted dynamic version, especially when explicit instructions are given.

Training methods

Most dynamic tests used a combination of performance feedback, reinforcement, expanded instruction or strategy training. These training methods are commonly used as therapeutic interventions.[45] In contrast to clinical therapeutic interventions, the brief training during dynamic testing is not intended to provide the patient with information or strategies for use in subsequent rehabilitation or daily life. Dynamic tests merely assess patients' learning potential. The different training methods attempt to induce learning through distinct mechanisms. Providing constructive feedback on performance and giving positive reinforcement and extra instructions may promote learning by enhancing patient's motivation and attention during the task. One of the reviewed studies used a monetary incentive. Although this type of reinforcement may show beneficial effects, its clinical value is questionable in terms of feasibility and ethics. A limitation of providing extra instructions during the training is that the test in some cases becomes a 'one-shot' test depending on the type of instructions given. Strategy training aims at teaching ways to compensate for impairment. Pre- to post-training improvement reflects patients' ability to learn and apply strategies. Strategy training during dynamic testing may not be feasible for all patients. For instance, memory strategy training was dubbed effective in improving recall only in patients with mild memory impairments and not in patients with severe memory impairments.[46] Also, poor performance after strategy training may be the result of the type of strategy training used. There was only one study,[32] in which patients were taught two different strategies separately to detect the effect of these different strategies on test performance.

Learning potential indices

There was a large variability in the computational methods used to quantify learning potential. This variability reflects the discussions in the literature regarding the 'best' or 'preferred' method to quantify learning potential. Several studies have discussed the strengths and limitations of different learning potential indices.[47-49] The post-test score, regression residuals and learner groups have been favored because of their good stability and validity.[47,49] These learning potential indices were used in the majority of studies in this review. The difference and gain score were also applied in a number of studies, but mostly in conjunction with the post-test score or the group classification. Several drawbacks have been pointed out regarding the use of the difference and gain score to index learning potential. For example, a difference score of zero does not distinguish between a ceiling effect and non-responsiveness,[48] and gain scores can produce disproportionately high or low scores.[49] There are also some issues regarding the use of the post-test score, regression residuals and learner groups to index learning potential. Strictly speaking, the post-test score only measures a patient's maximum performance as it does not assess the amount of learning that has occurred.[47] Regression residuals do provide information about the magnitude of change, but are difficult to interpret and are therefore less feasible for use in clinical settings. The group classification provides a clear-cut classification of patients often based on reliable change[15,42] at the expense of within-group variation. Hence, the learning potential indices need to be interpreted together to provide a clearer picture of a patient's learning profile, i.e. a patient's initial performance, magnitude of change from training and their post-training performance. These scores can also be used to examine within-group variability when using the categorical approach. Any of the learning potential indices viewed in isolation could be misleading.

Learning potential and rehabilitation outcome

The predictive and added value of learning potential was only evaluated for dynamic versions of the WCST and M-WCST and mainly in patients with psychiatric diseases. The results suggest that learning potential can significantly predict rehabilitation outcome in terms of community and vocational functioning.[12,13,16,22] Also, support was found for the added value of the dynamic WCST compared to the conventional WCST in predicting community and vocational functioning.[13,16,22]

The predictive value of learning potential on social functioning was only partially supported. One study reported that learning potential was not a significant predictor of social functioning,[23] whereas another study found significant differences in social functioning between learner groups.[17] A possible explanation is that social functioning is less reliant on cognitive functioning and thus cognitive learning. Another possible explanation is the use of different learning potential indices. The first study was unique in the use of regression residuals to convey learning potential.[23] The latter study used three different learning potential indices: the post-test and difference score and a group classification (i.e., non-retainers, learners).[17] Only the group classification showed significant results. These findings are in line with a recent systematic review and meta-analysis of the dynamic WCST learner groups.[50] The authors of that systematic review reported that poor learning potential was highly predictive of poor response to a psychosocial intervention (OR = 26.44).

Strengths and limitations

One of the strengths of this systematic review is that most search terms were selected from two previous studies[7,8] and included both specific approaches to dynamic testing (e.g., testing the limits) and major concepts (e.g., cognitive modifiability). We did not limit our search to a specific dynamic testing approach. Furthermore, diagnoses included evolving conditions (neurodegenerative, psychiatric) as well as sudden onset conditions (acquired brain injury). These diagnostic groups are all commonly referred to a neuropsychologist for neuropsychological evaluation and, therefore, provide a good representation of current neuropsychological practice.

A limitation of the studies in this review is that none of the studies had high methodological quality. In particular the internal validity and control of patient drop-out was inadequate. None of the studies tested the validity and reliability of all measurements used, or referred to other studies, which determined the validity and reliability; and none of the studies did a non-response analysis to compare participants and non-participants. Second, between 2010 and 2012 only five studies were published which may indicate a waning interest in dynamic testing. Third, we only included studies in which the whole dynamic testing procedure including the training was done in a one-day session. This criterion was chosen to minimize the possibility that pre- to post-test improvement can be attributed to other factors than the brief training (e.g., recovery). Last, relatively few studies evaluated the predictive and added value of dynamic testing. For these studies, diagnoses mostly included schizophrenia and schizoaffective disorder. Only one study included patients with acquired brain injury. Interpretation of these results was difficult due to the use of different treatment programs and outcome measures.

Suggestions for potential clinical applications of dynamic testing

In patients with ABI or a neurodegenerative diseases, information about learning potential could be valuable in triage into groups for discharge destination such as in- or outpatient facilities and for the intensity of rehabilitation. For example, patients who are classified as poor learners may need a more intensive or context-dependent, inpatient rehabilitation programme than patients who are classified as high achievers. For the latter group, a less-intensive programme or an outpatient facility may suffice. Since most research was performed in psychiatric populations, more research is needed to evaluate the feasibility and predictive value of dynamic testing in patients with ABI or a neurodegenerative disease.

Although this review shows promising results regarding the relation between learning potential and rehabilitation outcome, more research is needed to further evaluate the added value of dynamic testing. It is particularly important to demonstrate that dynamic cognitive tests provide unique information that cannot be captured by conventional cognitive tests, information that can be used to predict individual outcome.

Conclusion

This review provides preliminary support that dynamic tests can provide a valuable addition to conventional tests to assess patients' abilities. Although promising, there was a large variability in methods used for dynamic testing and, therefore, it is unclear which dynamic testing methods are most appropriate for patients with cognitive impairments. More research is warranted to further evaluate and improve dynamic testing methodology and to further elucidate the relation between learning potential and rehabilitation outcome.

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CHAPTER 4

Validity of the dynamic Wisconsin Card Sorting Test for assessing learning potential in brain injury rehabilitation

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Abstract

The dynamic Wisconsin Card Sorting Test (dWCST) examines the effects of brief training on test performance where pre- to post-test change reflects learning potential. The objective was to examine the validity of the dWCST as a measure of learning potential in patients with acquired brain injury (ABI). A total of 104 patients with ABI completed the dWCST at rehabilitation admission. Performance of a subgroup (*n* = 63) was compared to patients (*n* = 28) who completed a repeated administration of the conventional WCST (rWCST). Furthermore, dWCST performance was compared between patients with ABI (*n* = 63) and healthy controls (*n* = 30) matched on gender, age, and education. Three learning potential indices were used: post-test score, gain score, and a group classification (decliners, poor learners, strong learners, high achievers). The median dWCST administration time was 30 min. The dWCST showed no floor or ceiling effects and the post-test and gain score were significantly intercorrelated. The pre-test score showed no significant associations with other neuropsychological tests. The learning potential indices were significantly associated with language and/or memory. In contrast to the dWCST group, the rWCST group showed no significant pre- to post-test improvement. There were significantly more poor learners in the rWCST group. Compared to controls, patients obtained similar gains, but significantly lower pre- and post-test scores for the dWCST. The ratio of poor learners between-groups was not significantly different. The results support the validity of the dWCST for assessing learning potential in patients with ABI. Further research is needed to investigate the predictive validity of the dWCST.

Introduction

During brain injury rehabilitation, patients re-learn old skills and learn new skills with the ultimate goal of optimizing social participation and well-being.[1] Although learning is essential for achieving rehabilitation gains, there is a lack of research-based guidelines on how best to assess learning potential in rehabilitation. A promising assessment method to evaluate learning potential that has been used in patients with acquired brain injury (ABI) and several other populations (e.g., schizophrenia, dementia), is dynamic testing.[2-6]

Dynamic testing is an umbrella term for procedures that examine the effects of brief training on test performance where pre- to post-test change reflects a patient's learning potential.[7] It is proposed that dynamic tests provide unique information about a person's abilities beyond the information that is provided by conventional tests.[8,9] Conventional tests provide information about cognitive deficits that may hamper or facilitate learning, whereas dynamic tests more specifically evaluate patients' potential to learn and improve cognitive performance. In patients with cognitive impairments due to ABI or a psychiatric or neurodegenerative disorder, several one-session dynamic tests have been applied that target cognitive abilities. The most frequently used is the dynamic Wisconsin Card Sorting Test (dWCST).[4,5,10-12] The WCST is a renowned measure of executive functioning that can be used to evaluate a patient's ability to form, maintain, and shift cognitive sets.[13] In contrast to the conventional WCST, the dWCST includes a brief training phase in which additional feedback and instructions are given about the sorting principle after the initial testing phase. The training is followed by a second test phase (i.e., test-train-test design). The degree of change in test performance in response to the training is proposed to represent a patient's learning potential or capacity to benefit from training.

The dWCST has already shown some evidence of validity in a number of longitudinal studies that included patients with ABI[5] and psychiatric disorders.[4,6,12,14,15] These studies found that dWCST learning potential was a significant predictor of rehabilitation outcome and provided unique information beyond the conventional WCST in predicting outcome.[15] Although promising, there are some issues that affect interpretation of these findings and hence the potential utility of the dWCST in clinical practice. First, adding a training phase may have consequences for the validity of the post-test. For instance, previous authors[16] administered the dWCST to patients with schizophrenia and reported that the training phase alters the cognitive abilities assessed by the post-test. Not surprisingly, both the pre- and post-test scores were associated with tests of executive functioning. The post-test score was, however, additionally associated with verbal memory tests. This suggest that the dWCST pre- and post-test scores reflect different cognitive constructs. These findings have not yet been confirmed by other researchers.

A second issue is that the role of practice effects on pre- to post-test improvement has not yet been examined. Improvements in test performance due to repeated exposure to the same test materials reflect practice effects, whereas pre- to post-test gains due to the brief training reflects learning potential. Just like the conventional WCST, the dWCST has a single solution and is therefore prone to practice effects.[17] Performance basically depends on discovery of the sort and shift principle. After the sorting principle is discovered or explained, patients are likely to improve their test performance during a second administration of the test.[17]

Further psychometric validation of the dWCST would provide researchers and clinicians with a better understanding of what the dWCST actually measures and how to interpret test results. Such research may also guide any necessary refinement of the dWCST for clinical use. Hence, the purpose of this study was to investigate the validity of the dWCST in patients with ABI by: (1) Examining the feasibility of administration and general psychometric properties of the dWCST in terms of score distributions, administration time, floor and ceiling effects, intercorrelations between different learning potential indices (i.e., post-test score, gain score), and associations between the post-test score and gain score and other neuropsychological tests. (2) Determining whether pre- to post-test improvement flects learning potential or practice effects. (3) Determining whether the dWCST can discriminate between patients and controls by comparing dWCST performance of patients with ABI and healthy controls matched on age, gender and education.

Hypotheses

We hypothesized that the distribution of the dWCST learning potential indices would demonstrate an absence of floor or ceiling effects and that the learning potential indices would be highly intercorrelated. We expected that the dWCST scores would be significantly associated with other measures of executive functioning at rehabilitation admission. Also, we hypothesized that patients and controls, would demonstrate a significant change in pre- to post-test scores for the dWCST, whereas patients who received a repeated assessment of the WCST (rWCST) would demonstrate no significant pre- to post-test change. Compared to the rWCST group, patients in the dWCST group would demonstrate similar pre-test scores, but significantly higher gain and post-test scores. Furthermore, we expected that, compared to healthy controls, patients would demonstrate significantly lower pre-test, post-test, and gain scores for the dWCST.

Mehods

Participants

Patients were recruited from five rehabilitation centers in The Netherlands. For all patients (i.e., the dWCST and rWCST group), the same in- and exclusion criteria were used. Inclusion criteria of this study were (1) diagnosis of traumatic or non-traumatic ABI based on medical records; (2) ≥ 18 years of age; (3) sufficient command of the Dutch language based on clinical judgment; and (4) completion of the dWCST at admission to rehabilitation. Exclusion criteria were: (1) severe aphasia based on a Dutch Aphasia Foundation (Stichting Afasie Nederland, SAN)[18] scale score less than 4 or clinical judgment; (2) premorbid psychiatric disorder and/or substance abuse for which hospital admission was necessary; (3) minimally conscious state or post-traumatic amnesia at the time of assessment; (4) degenerative or progressive brain disease; (5) active participation in another study to avoid participation burden; (6) no informed consent; and (7) completion of the conventional WCST during a neuropsychological assessment.

The control group consisted of volunteers who were recruited through personal contacts. Inclusion criteria were: (1) ≥ 18 years of age; (2) sufficient command of the Dutch language based on clinical judgment; and (3) written informed consent. Exclusion criteria were: (1) history of a neurological event or psychiatric disorder; and (2) cognitive impairments, indicated by a Montreal Cognitive Assessment (MoCA)[19] score below 24. The medical ethics committee of the University Medical Center Utrecht and the five participating rehabilitation centers approved the study protocol. All data was obtained in compliance with regulations of the participating rehabilitation centers. All participants gave informed consent.

Feasibility of administration and general psychometric properties

Data from patients who were participating in a longitudinal cohort study examining factors influencing outcome of ABI rehabilitation (dWCST group, see Appendix A) were examined. These patients were recruited from November 2012 to December 2013 from inpatient clinics of five rehabilitation centers in The Netherlands: Adelante Zorggroep, Hoensbroek; De Hoogstraat Rehabilitation, Utrecht; Reade Rehabilitation Center, Amsterdam; Rijndam Rehabilitation, Rotterdam; and Rehabilitation Center Tolbrug, 's-Hertogenbosch.

Learning potential versus practice effects

A subgroup of patients from the dWCST group was selected, namely all patients who were recruited at De Hoogstraat Rehabilitation (dWCST subgroup, see Appendix A). We only included patients from De Hoogstraat Rehabilitation to ensure uniformity of administration procedures from staff at the same clinic, and also achieve a large sample size for the main experimental condition. dWCST performance of these patients was compared to another group of patients (rWCST group, see appendix A). Patients in the rWCST group were recruited from July 2013 to December 2013 from the inpatient clinic of De Hoogstraat Rehabilitation. These patients were not eligible to participate in the dWCST group because they were admitted to one of the inpatient clinics in which the recruitment period had already ended.

Patients with ABI versus healthy controls

dWCST performance of the dWCST subgroup was compared to a group of healthy controls (control group, see appendix A) matched on age, gender, and education. The control group was recruited from October 2013 to December 2013 as a reference sample to compare performance of patients and healthy controls.

Measures

Wisconsin Card Sorting Test (WCST)

The participant was given two decks of 64 cards containing figures which differ in color (yellow, red, green, and blue), shape (star, square, circle, and cross) and number (one, two, three and four). The participant was instructed to place each card below one of four stimulus cards. The participant had to deduce the sorting principle from the experimenter's feedback ("right", "wrong").[13] The administration time of the conventional WCST is approximately 20 to 30 minutes.

Cognitive functioning

A nationally recommended core battery of cognitive tests[20] was administered by a psychological assistant. Verbal memory was assessed with the Rey Auditory Verbal Learning Test (R-AVLT)[21]. Attention was evaluated with the Trail Making Test parts A and B (TMT).[22] Part A is a measure of psychomotor speed and Part B is a measure of divided attention and executive functioning. Executive functioning was also evaluated with the letter fluency test (LFT).[23] Language performance was evaluated with the Boston Naming Test[24] short form and the Category Fluency Test (CFT).[25] The Star Cancellation Test (SCT)[26] was used to assess patients' visual perception and to screen for unilateral spatial neglect. In addition, premorbid intelligence was estimated with the Dutch version of the National Adult Reading Test (NART),[27] the 'Nederlandse Leestest voor Volwassenen' (NLV).[28] These tests are described in more detail elsewhere.[17]

Procedures

For all patients, the treating rehabilitation physician confirmed the eligibility criteria and obtained informed consent. After patients provided written informed consent, demographic and disease characteristics were obtained from their medical records. In the dWCST group (and thus the dWCST subgroup), the dWCST was administered within approximately two weeks of enrollment. Within approximately the same week, a cognitive screening was conducted by a psychological assistant as part of routine assessment procedures. In the rWCST group, the rWCST was administered within one week after informed consent was obtained. In the healthy control group, a home visit was scheduled. During the home visit, participants were checked for eligibility. If eligible, the dWCST was administered.

Administration procedures of the dWCST and rWCST

The dWCST and rWCST were administered in a quiet room by a trained clinician or trained neuropsychology student. Prior to commencement, patients and healthy controls were asked to give a detailed description of the four stimulus cards (one red triangle, two green stars, three yellow crosses, four blue circles) to assess potential visual (e.g., achromatopsia) or cognitive (e.g., visual form agnosia) problems that would interefere with patients' ability to complete the test. The test was not completed when such problems were considered to significantly influence performance.

During administration of the dWCST, a pre-test – train – post-test paradigm was used. The dWCST was administered according to the test protocol of Wiedl and Wienöbst[31] which was translated from German into Dutch. The dWCST pre- and post-test were administered according to standard WCST administration procedures.[13] The first deck of 64 cards was used for the pre-test as well as for the training, and the second deck of 64 cards was used for the post-test. The training phase consisted of three major elements: (1) explanation of the sorting rules (e.g., "There are three possible ways to match the cards: you can match the card by color, by number of the objects, or by shape"); (2) during the card sorting, the patient was told why a response was right or wrong after each card sort (e.g., "This was wrong, we don't sort for color"); and (3) how many consecutive correct responses the patient needed for the rule to change (e.g., "After ten consecutive correct sorts, the rule will change. You will then sort for color or number").

During administration of the rWCST, a test-test-test procedure was adopted. The deck of 64 cards was administered three times using standard WCST procedures.[13] The first deck of 64 cards was used for the first two administrations (i.e., pre-test and test without training) and the second deck of 64 cards was used for the third administration (i.e., post-test).

For both the dWCST and rWCST, the total number of correct responses was recorded for the pre-test and post-test. For both test phases, the score ranged from 0 to 64 with higher scores indicating better performance. The time needed to administer the dWCST and rWCST was recorded.

Statistical analyses

dWCST indices

For all patients and controls, the pre-test score and three different learning potential indices were calculated. The computational methods are described below. The learning potential indices were selected based on their use in prior studies to index learning potential[29,30] and their feasibility for use in clinical settings. For all indices, higher scores indicate better performance.

Pre-test score
Total correct after the pre-test.

Post-test score
Total correct after the training phase.

Gain score
Ratio calculated by dividing actual performance change (i.e., difference score) by potential performance change. The following formula was used: (post-test total correct – pre-test total correct) / (64 – pre-test total correct) in which 64 is represents the maximum total correct that can be achieved on the post-test.[30]

Groups
Previously established cut-off values were used based on Wiedl's[31] reliable change approach. Patients were categorized as "high achiever" (pre- and post-test ≥ 43 correct); "strong learner" (pre- to post-test improvement ≥ 15 points); "poor learner" (pre- to post-test improvement < 15 points); or "decliner" (pre- to post-test decline ≥ 15 points). The Reliable Change Generator[32] was used to determine whether these cut-off values were reliable[33] in our sample of patients with ABI. Based on the rWCST pre-test standard deviation (*SD* 12.1) and test-retest reliability ($r_{\text{pre-test, post-test}}$ = 0.81) a reliable change index of 15 was calculated. Thus, reliable change was considered present when the pre- and post-test differed by ≥15 points which is in agreement with the previously used cut-off values.

Feasibility of administration and general psychometric properties
The distribution of numerical learning potential scores was evaluated using Kolmogorov Smirnov, skewness and kurtosis tests. In case of a non-normal distribution, transformations were performed to improve normality. If these did not improve normality, non-parametric statistics were used. Feasibility of the dWCST was investigated by calculating the time needed to administer the dWCST. Floor and ceiling effects for the dWCST pre-test and numerical learning potential indices were examined. Floor or ceiling effects were considered present if more than 15% of all patients obtained the lowest (post-test score = 0; gain score = -64) or highest (post-test score = 64; gain score = 1) possible score.[34] Pearson or Spearman correlations were used to examine intercorrelations between the post-test score and gain score and their association with other neuropsychological tests. Associations between the dWCST pre- and post-test scores and between the pre-test score and other neuropsychological tests were also examined for comparison purposes. Between-group differences in neuropsychological test performance was evaluated using one-way between-groups ANOVAs and independent samples *t* tests or Kruskal-Wallis and Mann-Whitney *U* Tests.

Learning potential versus practice effects

First, independent samples *t* tests or Mann-Whitney *U* Tests, and χ^2 were used to examine differences between the dWCST subgroup and the rWCST group regarding age, gender, education, and functional independence. Between-group differences in dWCST and rWCST scores (pre-test score, post-test score, gain score) then were examined using independent samples *t* tests or Mann-Whitney *U* Tests. For both groups, paired samples *t* tests or Wilcoxon Signed-Rank tests were used to determine whether there was a significant change in pre- to post-test performance. Also, between-group differences in the number of poor learners and strong learners were examined using χ^2. Decliners and high achievers were not included in this analysis. A decline in performance indicates neither learning potential nor a practice effect, and high achievers do not require a training phase to perform adequately.

Patients with ABI versus healthy controls

First, independent samples *t* tests or Mann-Whitney *U* Tests, and χ^2 were used to examine whether the dWCST subgroup and the control group were adequately matched for age, gender, and education. Second, differences in dWCST scores (pre-test score, post-test score, and gain score) between the dWCST subgroup and the control group were evaluated using independent samples t-tests or Mann-Whitney *U* Tests. For both groups, paired samples *t* tests or Wilcoxon Signed-Rank tests were used to determine whether there was a significant change in pre- to post-test performance. Further, between-group differences in the number of patients with low performance (decliners and poor learners) *versus* adequate performance (strong learners and high achievers) between the dWCST subgroup and the control group were examined using χ^2.

For all analyses, Pearson or Spearman correlation coefficients between 0.30 and 0.49 were considered to be moderate and correlations exceeding 0.50 were interpreted as large.[35] Due to the large number of associations examined, alpha was set at 0.01. Data were analyzed using SPSS version 21.0.

Results

Participants

For the dWCST group, 125 patients with ABI were recruited from the five rehabilitation centers (response rate 78.1%). Of these, 21 patients were excluded for the following reasons: the conventional WCST was already administered during the routine neuropsychological assessment (*n* = 3); refusal to complete the dWCST (*n* = 2); withdrew from study (*n* = 4); dWCST was not administered due to early discharge (*n* = 4); dWCST was discontinued by the examiner because the test was perceived as too demanding for the patient (*n* = 7). A total of 104 patients were included in the dWCST group. Of these, 63 patients were recruited at De Hoogstraat Rehabilitation and thus were selected for the dWCST subgroup. For the rWCST group, 32 patients were recruited. Of these, the rWCST was discontinued by three patients during or after the pre-test, and for one patient the rWCST was discontinued by the examiner because the test was perceived as too demanding for the patient, leaving a total of 28 patients. Based on clinical judgment, all 28 patients in the rWCST group and all 104 patients in the dWCST group, showed sufficient visual and cognitive abilities to complete the test. For the control group, 30 healthy controls were recruited. The MoCA scores of the control participants ranged from 24 to 30 (mean 27.6, *SD* 1.73), indicating adequate cognitive functioning for all healthy controls.

There were no differences between patients in the dWCST subgroup and the rWCST group regarding age (U = 676.0, z = -1.77, p = 0.08, r = -0.19), gender (χ^2 = 1.90, p = 0.17, phi = -0.14), education (χ^2 = 0.68, p = 0.41, phi = -0.09), and functional independence (χ^2 = 2.16, p = 0.34, Cramer's V = 0.16). The dWCST subgroup was adequately matched with the control group for gender (χ^2 = 0.27, p = 0.61, phi = 0.05), age (U = 897.0, z = -0.40, p = 0.69, r = -0.04), and education (χ^2 = 0.63, p = 0.43, phi = 0.08). On average, the dWCST was administered significantly later than the rWCST (median, 27 *vs.* 11 days after admission, respectively; U = 435.5, z = -3.66, p < 0.001, r = 0.39). Table 4.1 shows the characteristics for all participants groups.

Score distributions and administration time

All learning potential indices showed a left-skewed, non-normal distribution (skewness -0.98 to -0.99). Data transformations did not improve normality. Therefore, non-parametric statistics were used. dWCST administration time varied from 10 to 55 minutes (median 30.0 minutes). In total, 86.5% of patients completed the dWCST in 40 minutes or less. In Table 4.2 an overview of the dWCST scores is presented. When classifying patients into groups, 34.9% were high achievers, 42.9% were strong learners, and 22.2% were poor learners. There were no decliners. Figure 4.1 shows the median dWCST scores for the pre-test, training and post-test for the three learner groups.

Floor and ceiling effects and intercorrelations

There were no floor or ceiling effects for the dWCST post-test score and gain score. In total, 11.1% of patients had ≥58 items correct and 1.0% had all 64 post-test items correct. The post-test score showed a large, significant association with the gain score (r = 0.62, p <0.001).

Associations with neuropsychological tests

In Table 4.3 the correlation coefficients are shown for the associations between the dWCST scores and the neuropsychological tests. The pre-test score correlations were presented for comparison. The pre-test score was not significantly associated with any of the cognitive tests. The post-test score and gain score showed significant, moderate associations with

Table 4.1 Characteristics of the participant groups

	dWCST group (*n* = 104)	dWCST subgroup (*n* = 63)	rWCST group (*n* = 28)	Control group (*n* = 30)
Gender, % male (*n*)	56.7% (59)	52.4% (33)	67.9% (19)	46.7% (14)
Mean age in years (*SD*)	54.0 (12.6)	54.1 (13.2)	59.4 (11.0)	54.6 (9.2)
Age range	22-78	22-78	27-73	32-80
High education (*n* = 90), % (*n*)[a]	43.3% (45)	41.3% (26)	32.1% (9)	50.0% (15)
Diagnosis, % (*n*)				
Cerebrovascular accident	62.5% (65)	68.3% (43)	67.9% (19)	-
Traumatic brain injury	22.1% (23)	15.9% (10)	17.9% (5)	-
Tumor	6.7% (7)	7.9% (5)	3.6% (1)	-
Post-anoxic brain damage	4.8% (5)	4.8% (3)	0% (0)	-
Neuro-inflammatory disease	3.8% (4)	3.2% (2)	7.1% (3)	-
Mean time post-injury in days (*SD*)	53.2 (34.5)	50.2 (34.3)	39.1 (40.9)	-
Mean BI at admission (*SD*)	15.2 (4.7)[b]	15.0 (4.7)	16.6 (4.3)[c]	-
Mean MOCA (*SD*)	-	-	-	27.6 (1.7)

Notes. BI = Barthel Index; MOCA=Montreal Cogitive Assessment.
[a] High education ≥ higher vocational education.
[b] *n* = 95
[c] *n* = 27

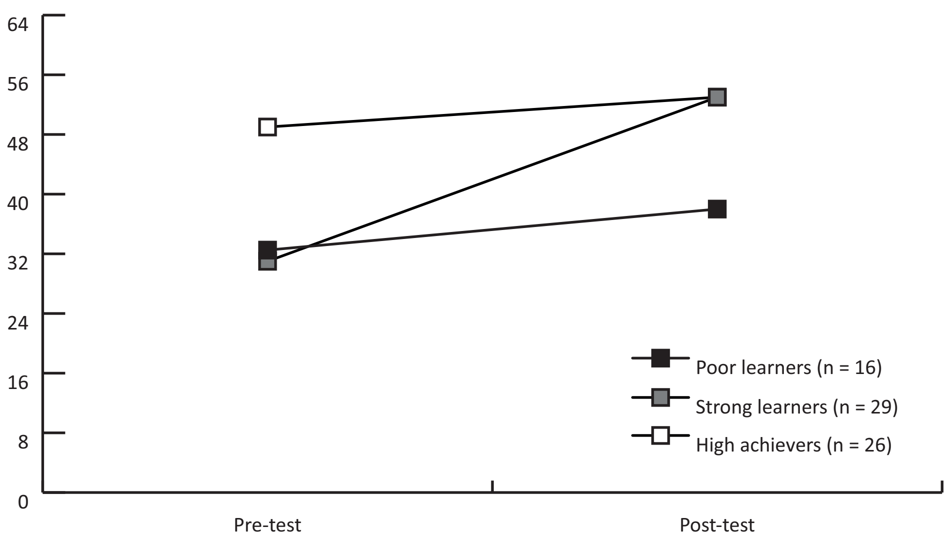

Figure 4.1 Median dynamic Wisconsin Card Sorting Test scores for the patient subgroup divided into poor learners, strong learners, and high achievers

Table 4.2 Descriptives, floor- and ceiling effects, and intercorrelations of dynamic Wisconsin Card Sorting Test scores of the dWCST group

								Spearman correlations (*p*-value)		
dWCST score	Min-max score	Median	IQR	Skewness	Kurtosis	% Lowest score	% Highest score	Pre-test score	Post-test score	Gain score
Pre-test score	12-57	39.0	17.8	-0.35	-0.77	0%	0%	1.00		
Post-test score	21-64	51.5	14.5	-0.99	0.30	0%	1%	0.50* (.00)	1.00	
Gain score	-0.9-1.0	0.4	0.5	-0.98	0.79	0%	1%	-0.32* (.00)	0.62 (.00)	1.00

Notes. IRQ = Interquartile range
* p ≤ 0.01

Table 4.3 Spearman correlations between the dynamic Wisconsin Card Sorting Test pre-test, post-test score and gain score, and neuropsychological tests of the dWCST group

			Correlation (*p*-value)		
Neuropsychological test (score used)	Cognitive domain	*n*[a]	Pre-test	Post-test	Gain score
Boston Naming Test (percentile)	Language	97	0.15 (0.15)	0.26** (0.01)	0.14 (0.16)
Category Fluency Test (percentile)	Language	99	0.23 (0.02)	0.26** (0.01)	0.08 (0.44)
National Adult Reading Test (IQ estimate)	Premorbid intelligence	98	0.11 (0.28)	0.13 (0.21)	0.01 (0.96)
Letter Fluency Test (percentile)	Executive functioning	99	0.13 (0.21)	0.04 (0.66)	-0.07 (0.48)
R-AVLT immediate recall (percentile)[b]	Short-term memory	102	0.21 (0.03)	0.32** (0.00)	0.15 (0.13)
R-AVLT delayed recall (percentile)[b]	Long-term memory	102	0.15 (0.53)	0.37** (0.00)	0.28** (0.01)
R-AVLT delayed recognition (raw)[b]	Recognition memory	102	0.06 (0.53)	0.37** (0.00)	0.31** (0.00)
Star Cancellation Test (total omissions)	Perception	98	-0.21 (0.04)	-0.15 (0.13)	0.04 (0.69)
Trail Making Test – Part A (percentile)	Psychomotor speed	98	0.12 (0.24)	0.23* (0.02)	0.11 (0.29)
Trail Making Test B-A (percentile)	Attention, executive functioning	92	0.25 (0.02)	0.23* (0.03)	-0.03 (0.77)
WCST-64 (total correct; pre-test only)	Executive functioning	104	-	0.50** (0.00)	-0.32** (0.00)

Notes. R-AVLT = Rey Auditory Verbal Learning Test; WCST-64 = Wisconsin Card Sorting Test -64.[45]
[a] Some patients could not complete all tests due to for instance reading or visual problems (*N* range 97-104); [b] Higher scores reflect worse performance.
** p ≤ 0.01; * p ≤ 0.05

long-term memory ($r_{post\text{-}test}$ = 0.37, p < 0.001; $r_{gain\ score}$ = 0.31, p = 0.001) and recognition memory ($r_{post\text{-}test}$ = 0.37, p < 0.001; $r_{gain\ score}$ = 0.34, p = 0.001). Further, the post-test score showed a moderate significant association with short-term memory (r = 0.32, p = 0.001) and a small, significant association with language (r = 0.26, p = 0.01; r = 0.26, p = 0.009). The dWCST pre- and post-test score showed a large, significant association (r = 0.50, p < 0.001).

Between-group differences in neuropsychological test performance are presented in Table 4.4. No significant between-group differences in neuropsychological test performance were observed at a 0.01 level. For two tests there was a trend toward significance. At a 0.05 level of significance, language scores were significantly lower for poor learners compared to high achievers (U = 320.0, z = -2.5, p = 0.01, r = -0.31), and poor and strong learners obtained lower scores for the measure of attention and executive functioning compared to high achievers (U_{poor} = 256.5, z = -2.4, p = 0.02, r = -0.31; U_{strong} = 437.5, z = -2.0, p = 0.04, r = -0.24) (Table 4.4).

Learning potential versus practice effects

Test scores of the dWCST subgroup were compared to test scores of the rWCST group. The median scores for both patient groups are presented in Table 4.5. There were no significant between-group differences in pre-test performance (U = 882.0, z = 0.000, p = 1.00). Compared to patients who were administered the dWCST, the rWCST group had lower scores for the post-test (U = 475.5, z = -3.50, p < 0.001, r = 0.37), and gain score (U = 416.0, z = -4.01, p < 0.001, r = -0.42). Furthermore, no significant change from pre- to post-test scores was found in the rWCST group (Z = -1.3, p = 0.182, r = -0.17). In the dWCST group, the pre- to post-test improvement was significant (Z = -6.10, p < 0.001, r = -0.54). There were significantly more strong learners in the dWCST group compared to the rWCST group (χ^2 = 17.3, p < 0.001, phi = -0.55, 42.9% *vs.* 3.6% respectively). In Figure 4.2, the median dWCST scores are displayed for the dWCST and rWCST group as well as the control group.

Patients with ABI versus healthy controls

Test scores of the dWCST subgroup were compared to the control group. The median dWCST scores for both groups are presented in Table 4.5. Compared to the dWCST subgroup, the control group had significantly higher scores for the pre-test (U = 599.0, z = -2.85, p = 0.004, r = -0.30), and post-test (U = 561.5, z = -3.16, p = 0.002, r = -0.33) (see Figure 4.2). There were no significant between-group differences for the gain score (U = 887.5, z = -0.47, p = 0.636, r = -0.05). Just like in the dWCST subgroup, the control group showed significant pre- to post-test improvement (Z = -3.9, p < 0.001, r = -0.50). Further, the difference in the number of poor learners between the dWCST subgroup and the control group was non-significant, but showed a trend toward significance (χ^2 = 5.22, p = 0.02, phi = 0.24, 65.1% *vs.* 40.0% respectively).

Table 4.4 Between-group differences in neuropsychological test performance

Neuropsychological test (score used)	1. Poor learners		2. Strong learners		3. High achievers		Between-group differences[a]			
	n^a	Median	n^a	Median	n^a	Median	1,2,3 χ^2	1,2 *U*	1,3 *U*	2,3 *U*
Boston Naming Test (percentile)	27	34.0	33	66.0	37	56.0	3.0	-	-	-
Category Fluency Test (percentile)	26	4.0	34	10.0	39	14.0	7.4*	343.5	320.0*	514.0
National Adult Reading Test (IQ estimate)	24	98.5	35	96.0	39	98.0	0.2	-	-	-
Letter Fluency Test (percentile)	26	12.0	34	8.0	39	5.0	0.2	-	-	-
R-AVLT immediate recall (percentile)	27	3.0	35	5.0	40	11.0	1.7	-	-	-
R-AVLT delayed recall (percentile)	27	2.0	35	8.0	40	8.5	3.8	-	-	-
R-AVLT delayed recognition (raw)	27	27.0	35	28.0	40	27.0	3.8	-	-	-
Star cancellation test (total omissions)[b]	26	0	33	0	39	0	3.2	-	-	-
Trail Making Test – Part A (percentile)	26	5.5	34	4.0	38	16.0	3.7	-	-	-
Trail Making Test B-A (percentile)	22	15.0	33	18.0	37	38.0	6.7*	256.5*	256.5*	437.5*

Notes. R-AVLT = Rey Auditory Verbal Learning Test; WCST-64 = Wisconsin Card Sorting Test -64.[45]
[a] Some patients could not complete all tests due to for instance reading or visual problems (*N* range 97-104).
[b] Higher scores reflect worse performance.
** $p \leq 0.01$; * $p \leq 0.05$

Table 4.5 Between-group comparisons of dynamic and repeated Wisconsin Card Sorting Test scores

	1. dWCST group (*n* = 63)	2. rWCST group (*n* = 28)	3. Control group (*n* = 30)	Group comparison *p*-value	
				1,2	1,3
Pre-test score, median (range)	37.0 (13-57)	37.5 (16-53)	46.0 (24-57)	NS	**
Post-test score, median (range)	51.0 (23-64)	36.5 (16-58)	55.0 (39-62)	**	**
Gain score, median (range)	0.5 (-0.6-1.0)	0.1 (-1.4-0.5)	0.5 (-0.5-0.9)	**	NS
Group, % (*n*)				**[a]	*[b]
Decliner	0%	3.6% (1)	0%		
Poor learner	22.2% (14)	57.1% (16)	10.0% (3)		
Strong learner	42.9% (27)	3.6% (1)	30.0% (9)		
High achiever	34.% (22)	35.7% (10)	60.0% (18)		

Notes. dWCST = dynamic Wisconsin Card Sorting Test (test-train-test); rWCST = repeated Wisconsin Card Sorting Test (test-test-test).
[a] Learning potential group (poor learners *vs.* strong learners) x participant group (dWCST subgroup, rWCST group).
[b] Learning potential group (poor learners *vs.* strong learners/high achievers) x participant group (dWCST subgroup, control group).
** $p \leq 0.01$; * $p \leq 0.05$; NS = Not significant

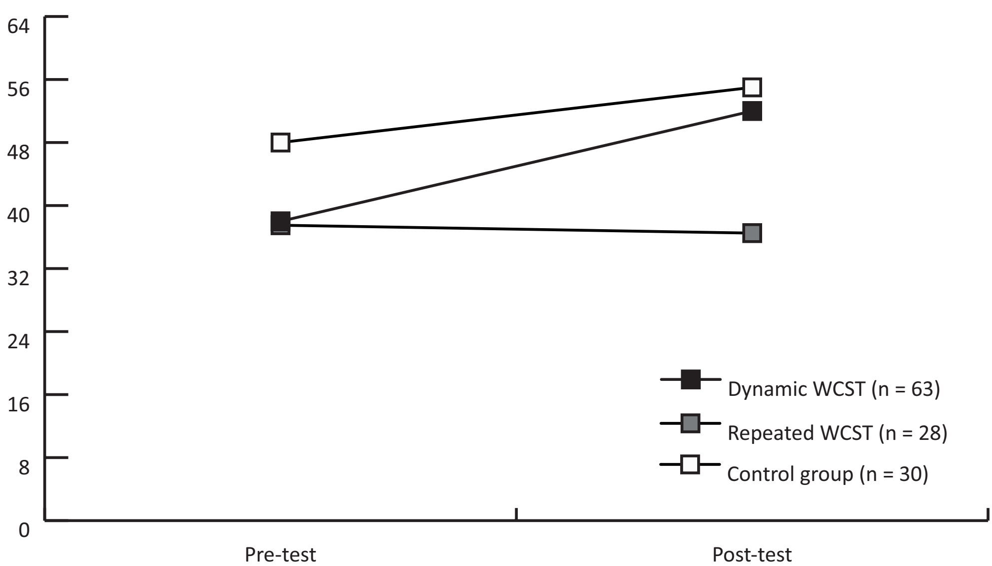

Figure 4.2 Median score for the dynamic Wisconsin Card Sorting Test subgroup, the repeated Wisconsin Card Sorting Test group, and the control group (Dynamic Wisconsin Card Sorting Test)

Discussion

This study investigated the validity of the dWCST for assessing learning potential in patients with ABI. The results showed that adding training to the WCST takes, on average, only about 10 minutes additional administration time. The dWCST showed no floor or ceiling effects, and a large intercorrelation between the two numerical learning potential indices. The pre-test score showed no significant associations with other neuropsychological tests, whereas the numerical learning potential indices were significantly associated with language and/or memory. The dWCST group had a similar pre-test score to that of the rWCST group, but a higher post-test and gain score. This is evidence that the dWCST measures learning potential opposed to practice effects. Compared to healthy controls, patients obtained similar gains but significantly lower pre- and post-test scores. The ratio of poor learners between-groups was not significantly different. This is partial support for the sensitivity of the dWCST to discriminate patients from controls.

Feasibility of administration and general psychometric properties

The dWCST showed good feasibility and adequate psychometric properties. As hypothesized, the learning potential indices on the dWCST were significantly associated with one another which is in line with previous findings.[30] This indicates that the learning potential indices measure a similar construct. The pattern of associations between the post-test score and gain score and memory performance is consistent with a previous study,[16] thus reinforcing the view that memory is associated with learning.[17,36] Effective performance requires patients to remember what they have learned during the brief training. Post-test scores were also significantly associated with language tests, which may be due to the verbal nature of the training. In contrast with our hypothesis, and the findings of a previous study,[16] the post-test was not significantly associated with tests of executive functioning. This may be explained by the use of different tests of executive functioning between the studies. Dissociations in performance among executive tests and low between-test correlations have been reported previously.[37] In the current study, the LFT and TMT were used as measures of executive functioning. Similar to the WCST, these tests measure inhibition.[37] However, the WCST measures several additional functions (i.e., rule detection, concept formation, set maintenance)[37] which may explain the lack of a significant association between the tests. In a previous study,[16] the Tower of Hanoi was used which requires patients to formulate and execute a strategy while complying with a set of rules, and thus may assess abilities more closely related to the dWCST.

The substantial memory component and verbal nature of the training may also explain why some patients with low pre-test performance showed a substantial improvement after training whereas others showed only a marginal shift in performance. In particular, it is possible that patients who have considerable verbal memory and/or language impairments, may benefit less from training on this particular task compared to patients with better language and verbal memory functioning. Although other authors have suggested distinct neuro-cognitive profiles between the three learner groups in psychiatric populations,[14,38-40] between-group differences in this study were only found at trend-level. Also, the learning potential indices were not significantly associated with demographic characteristics, level of functional independence, or diagnosis (traumatic *vs.* non-traumatic ABI). It is possible that a range of other injury-related, cognitive or psychological factors contributed to the observed differences in amount of learning (e.g., injury location, visual memory, motivation).[36]

Learning potential versus practice effects

The lack of significant pre- to post-test improvement on the rWCST suggests that training effects were apparent over and above practice effects. Although only one patient in the rWCST group showed significant gains (i.e., strong learner), several other patients did show some improvement in pre- to post-test performance (see Figure 4.2). These marginal gains may reflect test-specific improvement rather than learning potential. For the conventional WCST, improvements between the first and second deck of cards have been attributed to continued exposure and corrective feedback.[41] Differentiating test-specific gains from learning gains due to the training is a complex process. The lack of improvement on the rWCST may also be partly attributed to the demanding nature of the repeated administration condition in terms of the high number of trials and limited instructions and feedback provided by the experimenter. This may have influenced patients' motivation and attention during the task. These issues may have contributed to the significant decline in performance observed for one patient in the rWCST group. Such a decline in performance has also been observed between the first and second deck of the conventional WCST.[42]

Patients with ABI versus healthy controls

In line with the results of a previous study that compared dWCST performance of healthy controls and patients with schizophrenia,[43] patients obtained similar gains but lower pre- and post-test scores compared to healthy controls. This provides partial support for the sensitivity of the dWCST to discriminate patients from controls. The finding that patients and controls obtained similar gain scores may be explained by the fact that gain scores can produce disproportionately high or low scores.[30] Of note is that additional analyses revealed no significant differences in dWCST scores of healthy controls and patients classified as high achievers. This, along with the finding that there were no decliners, suggests that the dWCST has greatest utility for differentiating between poor and strong learners.

Learning potential indices

The learning potential indices can be used to interpret individual test performance. In this study, three different learning potential indices were used: the post-test score, gain score and group classification. Several studies have discussed the strengths and limitations of these and other indices in more detail.[29,44] Most importantly, the learning potential indices need to be interpreted together to provide a clearer picture of a patient's learning profile, that is a patient's initial performance, magnitude of change from training and their post-test performance. These scores can also be used to examine within-group variability when using the categorical approach. Any of the learning potential indices viewed in isolation could be misleading.

Limitations

Several limitations of this study should be noted. First, patients were not randomly allocated to the two assessment procedures (dWCST; rWCST). Although the groups did not differ in their level of functional independence and demographic characteristics, it is conceivable that between-group differences were confounded by other baseline differences between the two groups (e.g., cognition) and differences in the timing of assessment after admission to rehabilitation. The dWCST was administered significantly later than the rWCST. In the rWCST group, there were seven patients who were assessed in an early phase after ABI (< three weeks post-ABI) which may have negatively influenced their potential for gains. However, additional analyses, including only patients who were assessed at least three weeks post-ABI revealed a similar pattern of non-significant (i.e., pre-test score) and significant (i.e., post-test score and gain score) findings. A second limitation is the mixed etiology of our sample and the lack of injury specific analyses. However, clinical practice is also mixed. Third, although this study provides support for the validity of the dWCST, the clinical value of the dWCST for predicting rehabilitation outcomes was not established. Future studies could, for instance, examine the neuro-cognitive and psychological characteristics and long-term outcomes of poor and strong learners.

Conclusion

This study provides preliminary support for the validity of the dWCST as an instrument for assessing learning potential in patients with ABI. Evidence is provided for the absence of substantial practice effects as well as its ability to discriminate between patients with ABI and healthy controls. Further research is needed to investigate the predictive validity of the dWCST in comparison to other indices that are commonly used for prognostic purposes (e.g., functional independence).

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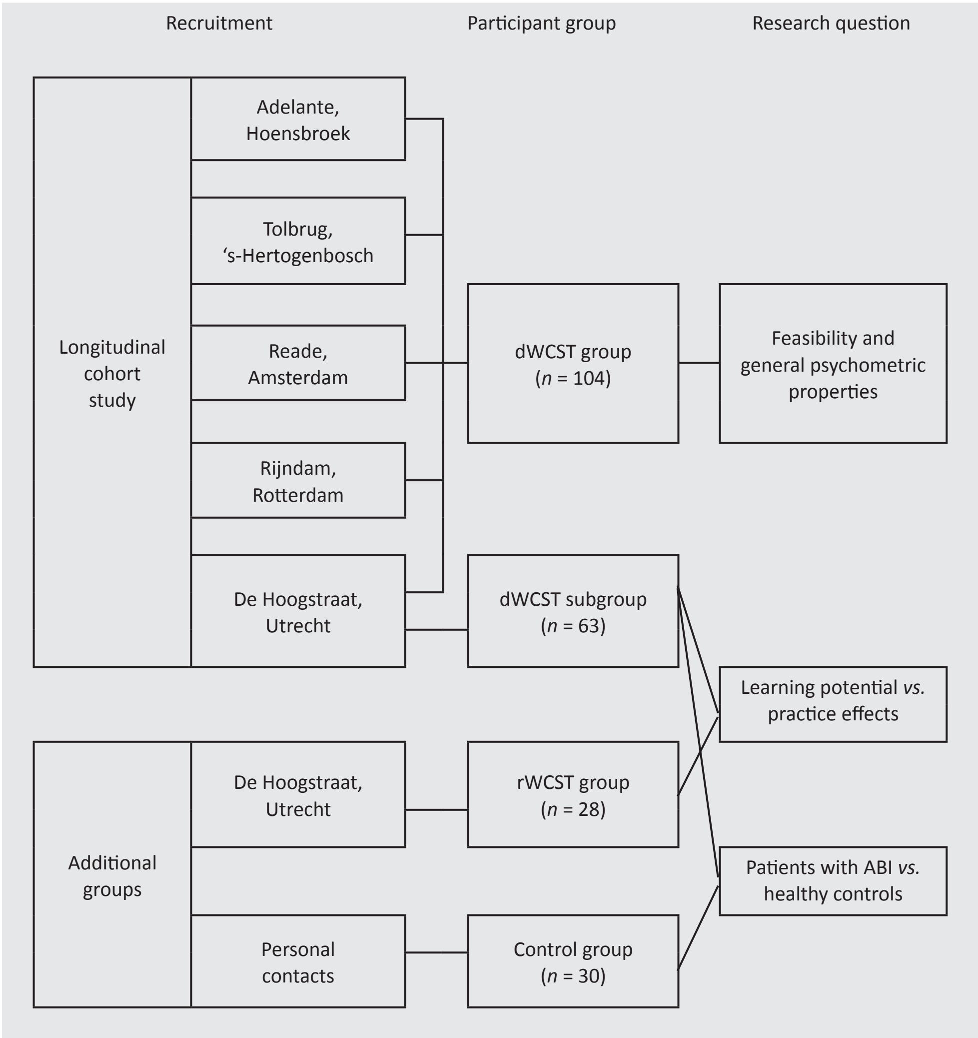
Appendix A The participant groups for each research question



CHAPTER 5

Exploring the relation between learning style and cognitive impairment in patients with acquired brain injury

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Abstract

The way a patient prefers to approach or choose a learning situation represents the patient's learning style. The objective of this chart review study was to explore the relation between learning style and cognitive impairment in patients with acquired brain injury (ABI). We used data from files of 92 adult patients with ABI referred to inpatient rehabilitation, who completed the Adapted Learning Style Inventory (A-LSI) and at least one of the following neuropsychological tests: Trail Making Test, Rey Auditory Verbal Learning Test, WAIS-III Digit Span, Rey-Osterrieth Complex Figure Test–Copy, Stroop Color-Word Test, or the Brixton Spatial Anticipation Test. The A-LSI yielded the following distribution of learning styles: 4 doers, 48 observers, 2 deciders and 38 thinkers. No significant correlation coefficients were found between the neuropsychological tests and the A-LSI. Furthermore, Chi-square tests revealed no significant associations between learning style (observer, thinker) and cognitive impairment. The results of this exploratory study suggest that learning style and cognitive impairment are independent in patients with ABI.

Introduction

Patients with acquired brain injury (ABI) frequently experience enduring cognitive impairments which can interfere with the process of rehabilitation and can negatively affect the patient's quality of life (QoL).[1] In response to these problems, cognitive rehabilitation has emerged as a method to remediate or alleviate cognitive impairments as well as behavioural, emotional and social disabilities, and to maximise the level of independence and QoL.[2,3] There is a large body of literature concerning cognitive interventions and their effectiveness,[4-11] in which three general approaches can be distinguished: substitution of intact functions, direct retraining, and teaching of compensatory strategies.[12] Whichever approach is used, it should be recognised that they all include aspects of (re)learning. In fact, the process of learning is important for all facets of rehabilitation.

Although learning is a fundamental component of rehabilitation, relatively little is known about learning processes after ABI. In clinical practice, neuropsychological measures can be used to detect cognitive impairments that might influence a patient's learning process during rehabilitation. For instance, impairments in memory, attention, and executive functioning, are likely to thwart the learning of new skills or strategies. However, neuropsychological measures mainly provide information about the limitations that a patient has, and does not give profound insight into a patient's learning strengths and preferences.

The way a person prefers to approach or choose a learning situation represents a person's 'learning style'.[13,14] Currently, little is known about learning styles of patients with ABI. The implementation of learning style in rehabilitation is still in its infancy and a validated learning style instrument for patients with ABI has not yet been developed.[13,14] The available learning style measures were developed for educational purposes, for instance within the field of health, management, and academic settings.[13] It is unknown whether these instruments are also feasible for patients with ABI.

One of the most influential learning style measures is Kolb's Learning Style Inventory (LSI).[15] The LSI is based on Kolb's Experiential Learning Theory (ELT)[15] which considers learning to be a continuous and interactive process. It has been suggested that the ELT is associated with certain brain structures.[16] For instance, active experimentation is said to be related to the motor brain, and abstract conceptualisation is said to involve the frontal integrative cortex. If indeed an association between learning style and brain structures exists, it becomes interesting to investigate what influence impairments in the brain may have on a person's learning style.

A previous study speculated that impairments in certain cognitive functions following brain injury can possibly cause difficulties in rehabilitation because of a decreased ability to learn in the preferred way.[17] This would imply that, for instance, an impairment regarding abstract reasoning would provide a greater barrier for a patient who has an abstract learning style than for a patient who learns through trial-and-error.[17] Previous authors[17] explored the association between Kolb's learning styles and cognitive skills in healthy individuals and reported an association between the decider and observer learning style and strong verbal reasoning.

After exploring the relationship between learning style and cognitive functions in healthy individuals, a next step would be to explore whether there is an association between learning style and cognitive impairment in patients with ABI. Therefore, the objective of this exploratory study was to determine whether learning style is associated with specific cognitive impairments in patients with ABI.

Methods

Participants

For this chart review study, we considered files of adult patients with ABI who were consecutively referred to inpatient rehabilitation in rehabilitation centre De Hoogstraat (The Netherlands) between February 2008 and January 2011. At De Hoogstraat, all patients are informed that their files can be used anonymously for research purposes, unless they object.

We included patients with ABI who completed the Adapted Learning Style Inventory (A-LSI) and a neuropsychological assessment (NPA) as part of routine assessment including at least one of the following neuropsychological tests: Trail Making Test, Rey

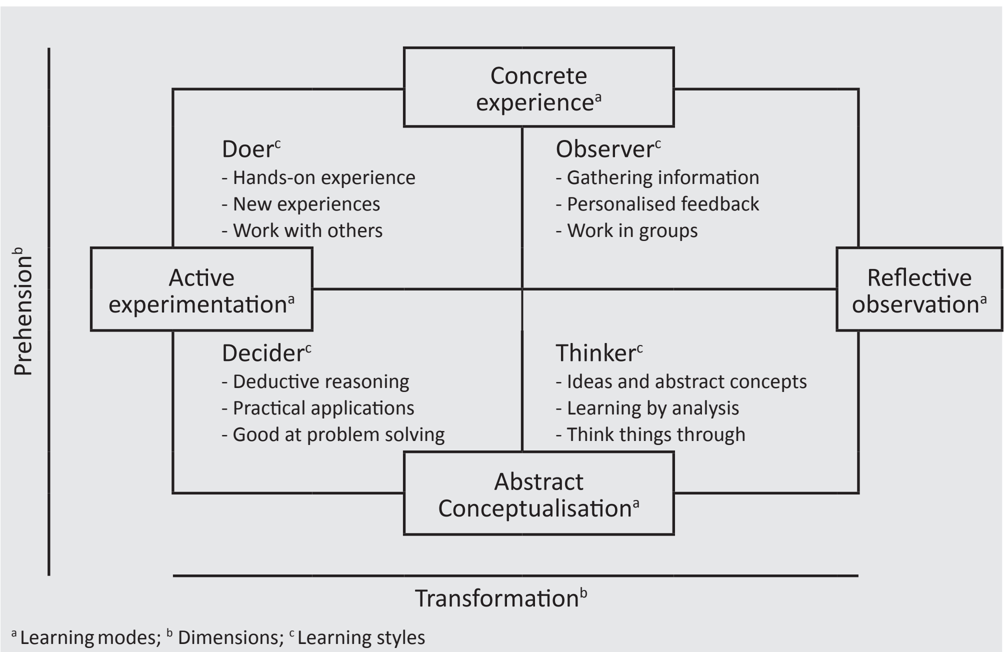

Figure 5.1 Learning styles and matching learning preference[15]

Auditory Verbal Learning Test, WAIS-III Digit Span, Rey-Osterrieth Complex Figure Test–Copy, Stroop Color-Word Test, or the Brixton Spatial Anticipation Test. Scores on the A-LSI and neuropsychological tests were collected from the files, as were demographic data, ABI characteristics and the Barthel Index[18] score at admission to the rehabilitation centre.

Procedure

The NPA and A-LSI were completed independently during the diagnostic phase, within approximately 6 weeks of admission. The Adapted Learning Style Inventory (A-LSI)[15] has already been used in clinical practice in our rehabilitation centre for several years. The cognition therapist completed and interpreted the A-LSI together with the patient within a one-hour session. The amount of assistance given while completing the A-LSI was dependent upon the patient's physical (e.g., fatigue, visual impairments) and cognitive functioning (e.g., neglect, attention deficits). The assistance could consist of, for example, clarifying the individual items, reading the questions aloud, or providing more structure by showing the answers one at a time on separate cards. In case of neglect, a perpendicular vertical line was drawn as a cue to the neglected side. The results were discussed with the patient after approximately one week. Based on the A-LSI result and observations during completion of the test, the cognition therapist wrote a report with individually tailored learning advice for all involved disciplines.

Measures

Disability

The Barthel Index is a measure of severity of disability. It has a 0-20 range for which a higher score reflects better functioning.

Learning style assessment

The A-LSI is a modified version of Kolb's Learning Style Inventory (LSI).[15] In contrast to Kolb's LSI, the modified version includes questions about concrete situations such as, for instance, learning how to sail a boat. The items of Kolb's LSI are stated more generally (e.g., I learn by: doing, watching, thinking, feeling). Therefore, the A-LSI seems more appropriate for use in brain injury rehabilitation than Kolb's LSI. Since the A-LSI version was originally developed for college students, items have been slightly changed into age-appropriate questions. The translated items are shown in Appendix A.

The A-LSI is based on Kolb's Experiential Learning Theory (ELT).[15] According to this model, effective learning depends on four learning modes (1) concrete experience (CE) – doing something and discovering its consequences, (2) reflective observation (RO) – watch what happens and think about it, (3) abstract conceptualisation (AC) – talk with others and apply existing knowledge, and (4) active experimentation (AE) – test theories and carry out plans.

The A-LSI contains nine items each with four answers corresponding to these four learning modes: CE, AC, AE, and RO. Participants were asked to rank the answers by giving 1, 2, 3 or 4 points in which 4 points represents the most suitable answer and 1 point the least suitable answer. The items belonging to the same mode are summed. For each mode, three items are not included in the sum-scores which leaves sum scores ranging from 6 to 24. These four scores can be used to calculate two dimensions of learning: prehension (AC minus CE) and transformation (AE minus RO). Prehension is the act of grasping information from experience (abstract *vs.* concrete) and transformation is the processing of this information (active *vs.* reflective). Relative positioning along these two dimensions defines a preference for one of the following four learning styles: doer, observer, decider, or thinker (Figure 5.1).

Neuropsychological assessment

From the routine neuropsychological assessment, we used neuropsychological tests for the following four major cognitive domains: attention, memory, perception and executive functioning. For the attention domain we chose the Trail Making Test (TMT)[20] parts A and B. Part A is a reaction-time measure of psychomotor speed and part B of divided attention. A higher score reflects a worse condition. To determine memory functions we chose the Rey Auditory Verbal Learning Test (R-AVLT)[21] and the Wechsler Adult Intelligence Scale (WAIS) – III Digit Span.[22] The R-AVLT is a verbal memory task that determines immediate recall on five consecutive learning trials (range 0-75), delayed recall (range 0-15) and delayed recognition (range 0-30). The WAIS-III Digit Span is a measure of working memory and attention with

Table 5.1 Characteristics of the study sample (*n* = 92)

Gender, % female (*n*)	37.0% (34)
Mean age in years (*SD*; range)	55.6 (14.6; 18-84)
High education (n=90), *%* (*n*)[a]	38.9% (35)
Diagnosis, *%* (*n*)	
Ischaemic stroke	55.4% (51)
Haemorrhagic stroke	16.3% (15)
Subarachoid haemorrhage	7.6% (7)
Post-anoxic brain damage	5.4% (5)
Traumatic brain injury	12.0% (11)
Brain abscess	1.1% (1)
Brain tumour	2.2% (2)
NPA: mean time post-admission in days (*SD*) (*n* = 89)	37.7 (38.8)
A-LSI: mean time post-admission in days (*SD*) (*n* = 67)	40.8 (42.8)
Barthel Index, mean (*SD*)	15.0 (4.7)

Notes. NPA = Neuropsychological assessment; A-LSI = Adapted Learning Style Inventory.
[a] High education ≥ finished high school; Low education < finished high school.

a 0-30 range. The Rey-Osterrieth Complex Figure Test–Copy (ROCFT)[23] was chosen for the perception domain. The ROCFT measures visuoconstruction, organisational ability and planning. The total score ranges from 0-36. For the executive domain, we chose the Stroop Color-Word Test[24] and the Brixton Spatial Anticipation Test.[25] The Stroop Color-Word Test is a measure of speed of information processing and response inhibition. The degree of interference was calculated with the following formula: StroopIII = ([StroopI + StroopII]/2). The Brixton measures rule detection and concept shifting. The number of errors are noted with a 0-55 range. In both the Stroop Color-Word Test and the Brixton a higher score reflects a worse condition. The tests are described in more detail elsewhere.[26] Dutch norms were used when available.

Statistical analysis

NPA and A-LSI data were first presented using descriptive statistics. The association between learning modes and dimensions and raw neuropsychological test scores were investigated by means of Spearman correlations with Bonferroni correction for multiple comparisons. Spearman correlations were considered significant when $p \leq 0.006$. Correlation coefficients between 0.30 and 0.50 were considered moderate and correlations exceeding 0.50 strong.[27] Next, neuropsychological test scores were dichotomised into impaired or not impaired. Scores were considered impaired when greater than or equal to the following cut-off values: 10th percentile, 1st decile, or 6th Wechsler Scale.[26] Chi-square tests with continuity correction were used to determine whether there is an association between the four learning styles and the dichotomous test scores. Alpha was set at 0.05. Data were analysed using SPSS version 18.0.

Results

Participants

In total, 92 patients with ABI were included. The majority of patients suffered a stroke (79.3%). At admission to the rehabilitation centre, the mean Barthel Index score was 15.0 (*SD* 4.7) indicating moderate disability. Table 5.1 presents the sample characteristics. The mean time between admission to the rehabilitation centre and administration of the A-LSI was 40.8 days (*SD* 42.8), and of the NPA 37.7 days (*SD* 38.8).

Learning style and cognitive impairment

In part of the files we could only trace back the total A-LSI score and not the scores for the individual items. Therefore, learning style classifications could be made for 92 patients and scores for the learning modes and dimensions were available for 63 patients. In total, 4 patients were doers, 48 were observers, 2 deciders, and 38 thinkers (Table 5.2). Cognitive impairments were most frequently observed for attention (40.8%–49.4%) and concept shifting (40.9%) (Table 5.3). Spearman correlations between the four learning modes and two dimensions with the nine raw neuropsychological test scores were calculated. No significant correlation coefficients were found. Furthermore, Chi-square tests indicated no significant association between the observer and thinker learning style and cognitive impairment (Table 5.4). Differences between the other learning styles were not assessed due to the small number of patients.

Table 5.2 Descriptive statistics A-LSI

	Range	Mean (*SD*)	Median	IQR
Modes (*n* = 63)				
Concrete experience	8-22	14.1 (3.3)	14.0	5.0
Reflective observation	11-21	16.0 (2.5)	16.0	4.0
Abstract conceptualization	10-22	16.6 (2.7)	16.0	4.0
Active experimentation	10-22	14.5 (2.3)	14.0	3.0
Dimensions (*n* = 63)				
Prehension AC – CE	-10-12	2.5 (4.7)	3.0	6.0
Transformation AE – RO	-10-10	-1.6 (4.0)	-1.0	-4.0
	Doer	Observer	Decider	Thinker
Learning style (*n* = 92)	4.3% (4)	52.2% (48)	2.2% (2)	41.3% (38)

Table 5.3 Descriptive statistics neuropsychological tests

	Raw scores					% impaired[c]
Neuropsychological test	*n*	Range	Mean (*SD*)	Median	IQR	
Trail Making Test - Part A[a]	79	18-322	76.1 (64.8)	50.0	53.0	49.4
Trail Making Test - Part B[a]	71	43-905	167.9 (144.2)	111.0	129.0	40.8
R-AVLT Immediate recall	82	4-70	36.0 (12.1)	35.0	14.5	23.2
R-AVLT Delayed recall	80	0-14	6.1 (3.8)	6.0	6.0	33.8
R-AVLT Recognition	80	15-30	26.7 (3.6)	28.0	5.0	[d]
WAIS-III Digit span	59	7-21	13.4 (3.1)	13.0	5.0	25.4
ROCFT Copy	45	20.5-36	32.6 (3.8)	34.0	3.0	20.0
Stroop Color-Word Test[a,b]	78	14-476	67.8 (61.2)	55.3	36.0	14.1
Brixton Spatial Anticipation Test[a]	22	4-45	19.4 (10.3)	17.0	13.8	40.9

Notes. R-AVLT = Rey Auditory Verbal Learning Test; WAIS-III = Wechsler Adult Intelligence Scale-III; ROCFT = Rey-Osterrieth Complex Figure Test.
[a] Higher score reflects worse condition.
[b] Stroop III = {[Stroop 1 + Stroop II] / 2).
[c] Impairment: score ≤ 10th percentile, 1st decile or 6th Wechsler Scale.
[d] No available cut-off point.

Table 5.4 Comparison of test scores for the observer and thinker learning style

	Observer		Thinker		
Neuropsychological test	*n*	% impaired (*n*)	*n*	% impaired (*n*)	*p*[a]
Trail Making Test - A	42	50.0 (21)	31	51.6 (16)	1.0
Trail Making Test - B	39	48.7 (19)	27	33.3 (9)	0.32
R-AVLT immediate recall	44	22.7 (10)	34	23.5 (8)	1.0
R-AVLT delayed recall	42	35.7 (15)	34	35.3 (12)	1.0
R-AVLT recognition[b]	42	-	34	-	-
WAIS-III digit span	33	27.3 (9)	24	20.8 (5)	0.81
ROCFT copy	25	28.0 (7)	18	11.1 (2)	0.34
Stroop Color-Word Test	41	9.8 (4)	32	18.8 (6)	0.44
Brixton Spatial Anticipation Test	14	35.7 (5)	8	50.0 (4)	0.84

Notes. R-AVLT = Rey Auditory Verbal Learning Test; ROCFT = Rey-Osterrieth Complex Figure Test WAIS-III = Wechsler Adult Intelligence Scale-III.
[a] Chi-square with continuity correction.
[b] No available cut-off point.

Discussion

In this retrospective, exploratory study we evaluated the extent to which cognitive impairment is related to learning style in patients with ABI. The majority of patients in our sample had an observer or thinker learning style. These two groups did not differ in terms of neuropsychological impairment. Furthermore, no associations were found between learning style and neuropsychological tests.

A previous study among healthy individuals[17] did report an association between Kolb's learning styles and cognitive functions. In our ABI population no such association was found. A possible explanation for the lack of an association in our study might be that we used different neuropsychological tests and an adapted version of Kolb's LSI. Use of other neuropsychological tests or another learning style instrument would possibly have produced different results. Another possibility could be that patients first need to experience their cognitive impairments before they are able to adopt a more efficient learning style. Therefore, it is possible that an association will be found in the long term when patients are no longer in inpatient rehabilitation. However, for clinical practice we believe that it is important to determine the patient's learning styles at the start of rehabilitation so that therapists can tailor rehabilitation to the individual.

A possible explanation for the uneven distribution of learning styles might be that learning styles change following ABI. Unfortunately, no studies have been executed in which the influence of ABI on learning styles was investigated. There is also no information regarding the distribution of learning styles in the general population, therefore it remains unclear whether the four learning styles are also unequally represented in the general population. Another possible explanation is that the A-LSI is not a valid measure to assess learning styles. Further studies are needed to determine the reliability and validity of the A-LSI in an ABI population.

Several limitations of this study should be noted. First, the A-LSI was originally developed for students; information concerning the development and validation of the A-LSI was not available. It remains to be seen whether it is possible and sensible to utilise an instrument in rehabilitation that was originally developed for use in education. However, given the exploratory nature of this study, we considered it important to start with evaluating an existing learning style instrument to gain familiarity and experience with learning style in rehabilitation before developing a model for rehabilitation.

Second, the question remains as to whether it is possible to use a self-assessment instrument in this population. Completing the A-LSI requires relatively intact cognitive functions and some degree of introspection. The A-LSI is not suitable for patients with severe aphasia.

Furthermore, due to the retrospective nature of this study, the content of the neuropsychological assessment varied as well as the frequency with which the different tests were used. In addition, it should be kept in mind that use of other neuropsychological tests or another learning style instrument would possibly have produced different results.

Further research into learning style is recommended to increase our understanding of learning style post-ABI and the added value for rehabilitation. Longitudinal studies are needed to, for instance, track potential changes in learning style following ABI.

In conclusion, the current exploratory study provides no support for the association between learning style and cognitive impairment. To our knowledge, this is the first study that attempts to explore the association between learning style and cognition in an ABI population. Therefore, caution should be taken in interpreting these preliminary findings. Further research into learning style and cognition is needed to verify these results and determine the added value of learning style assessment in ABI rehabilitation.

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CHAPTER 6

Validity and feasibility of a learning style instrument for brain injury rehabilitation

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Abstract

Purpose: Identifying learning styles of acquired brain injury (ABI) patients may aid the learning process by tailoring to the patient's learning needs and preferences. Currently, there is no learning style instrument for ABI patients. We therefore determined the validity and feasibility of the Adapted Learning Style Inventory (A-LSI) for patients with ABI.

Method: We included 99 patients with ABI and 42 healthy controls. Learning styles were determined and subgroups were used to evaluate the validity of the A-LSI. Furthermore, rehabilitation professionals' perceptions on learning style and the A-LSI were evaluated.

Results: In the patient group, the A-LSI yielded the following learning styles: 4 doers, 54 observers, 2 deciders and 39 thinkers. A similar distribution was found for the control group (3, 28, 0 and 11, respectively). Spearman correlations revealed moderate internal validity. Content validity of the A-LSI was also moderate; 11 out of 19 patients recognized themselves in their A-LSI learning style. Furthermore, 12 rehabilitation professionals reported positive and negative aspects of the A-LSI and suggestions for using learning style in rehabilitation.

Conclusions: Rehabilitation professionals were generally positive about using learning style in ABI rehabilitation. This study, however, raises doubts about the validity and feasibility of the A-LSI for this population.

Introduction

Patients with acquired brain injury (ABI) frequently experience enduring physical and cognitive impairments that require rehabilitation. In rehabilitation, these patients often follow a standard rehabilitation programme in which they relearn old skills and learn new skills in order to optimize social participation and well-being.[1] The fact that learning occupies a central position in the process of rehabilitation indicates the importance of increasing our knowledge about learning and the relevance and applicability of educational and didactic concepts in a rehabilitation setting.

There are numerous examples of learning situations in rehabilitation. For instance learning how to walk again, learning how to use compensatory strategies for deficits in memory and attention, or learning how to deal with limitations. There is, however, little knowledge about the way in which patients with ABI most efficiently and effectively learn such skills in rehabilitation. A closely related educational concept, that is currently emerging in the field of rehabilitation, is 'learning style'.[2] Learning style is the preferred way in which an individual approaches or chooses a learning situation and is associated with learning results.[3] Some individuals may, for instance, prefer to learn from hands-on experience, whereas others prefer to first think things through and reflect on their observations. The identification and implementation of a patient's learning style can possibly aid the learning process by tailoring to the patient's learning needs and preferences.[2] Recent studies have reported positive effects of matching learning style to cognitive-behaviour therapy technique in healthy persons[4] and of learning style tailored education materials in emergency room patients.[5]

Although several studies have addressed learning style in patients with ABI,[6-10] much remains to be explored. Currently, no specific instrument to assess learning style in this population has been developed. The available learning style measures were developed for educational purposes, for instance within the field of health, management, and academic settings.[3] It is unknown whether these instruments are also feasible and valid for patients with ABI since they frequently experience impairments regarding language, executive functioning, attention and slowed information processing.[11-13] Moreover, learning style assessment in rehabilitation would only be one of a large variety of measurement instruments that most patients need to complete during rehabilitation. Therefore, an assessment instrument has to be brief and easy to use. Unfortunately, the majority of existing instruments are quite lengthy and therefore less appropriate for use in rehabilitation.

Before developing a learning style instrument specifically for ABI rehabilitation, we believe it is important to start with evaluating an existing learning style instrument to gain familiarity and experience with learning style in rehabilitation. To this end, an existing learning style instrument, the Adapted Learning Style Inventory (A-LSI),[14] was implemented. The A-LSI is based on Kolb's experiential learning theory (ELT).[15] According to the ELT, effective learning is a continuous and interactive process depending on four learning modes, reflected by the four scales of the A-LSI: (1) concrete experience (CE) – doing something and discover its consequences; (2) reflective observation (RO) – watch what happens and think about it; (3) abstract conceptualization (AC) – talk with others and apply existing knowledge and (4) active experimentation (AE) – test theories and carry out plans. These four learning modes can be used to calculate two independent bipolar dimensions of learning: prehension (AC minus CE) and transformation (AE minus RO). Prehension is the act of grasping information from experience (abstract *vs.* concrete) and transformation is the processing of this information (active *vs.* reflective). The two dimensions are bipolar since it is, for example, impossible to simultaneously analyse the manual of an electric wheelchair (abstract) and drive the electric wheelchair (concrete).[16]

The objectives of this exploratory study were (1) to determine the distribution of learning styles in patients with ABI and healthy controls; (2) to evaluate the validity of the A-LSI in patients with ABI and (3) to evaluate rehabilitation professionals' perceptions on the A-LSI and learning style in general.

Methods

Participants

For this chart review study, we considered files of adult patients with ABI consecutively referred to inpatient rehabilitation at De Hoogstraat Rehabilitation (the Netherlands) between January 2008 and January 2011. At De Hoogstraat Rehabilitation, all patients are informed that their files can be used anonymously for research purposes, unless they object. The study was conducted according to the Code of Conduct for Medical Research of the Council of the Dutch Federation of Medical Scientific Societies. Since this study was based on secondary use of data, a review procedure by a medical ethics committee was not needed.

We included patients with ABI who completed the A-LSI as part of a routine assessment at the start of cognitive rehabilitation. Since the A-LSI is a written questionnaire, patients with severe aphasia or insufficient command of the Dutch language, were not assessed. A control group was recruited as a reference sample for the distribution of learning styles. The controls were volunteers who came to our attention by word of mouth. Inclusion criteria were age above 18, sufficient command of the Dutch language and written informed consent. Controls with cognitive impairments, indicated by a Mini Mental State Examination (MMSE)[17] score below 27, were excluded.

Measures

Demographic data and ABI characteristics were collected from the files. ADL dependence was assessed using the Barthel Index[18] score at admission to the rehabilitation centre. It has a 0-20 range for which a higher score reflects better functioning. In addition, the cognitive scale of the Utrecht Scale for Evaluation of Rehabilitation (USER)[19] was used to provide an indication of cognitive functioning. The USER is an observational instrument. The cognitive scale has 10 items each with a 0-5 range for which a higher score indicates better functioning. The total score range is 0-50.

Learning style was assessed with the A-LSI[14] which is a modified version of Kolb's LSI.[15] In contrast to Kolb's LSI, the A-LSI includes questions about concrete situations such as learning how to sail a boat. The items of Kolb's LSI are stated more generally (e.g., I learn by: doing, watching, thinking and feeling). Therefore, the A-LSI seemed more appropriate for use in ABI rehabilitation than Kolb's LSI. Since the A-LSI was originally developed for college students, items have been slightly changed into age-appropriate questions (see Appendix A). The A-LSI is based on Kolb's model of experiential learning[15] described above and contains nine items each with four answers corresponding to the four learning modes: CE, AC, AE and RO. Persons were asked to rank the answers by giving 1, 2, 3 and 4 points in which four points represents the most suitable answer and one point the least suitable answer. The items belonging to the same mode are summed. For each mode, three items are not included in the sum-scores which leaves sum scores ranging from 6 to 24. Consequently, two independent bipolar dimensions of learning are calculated: prehension (AC minus CE)

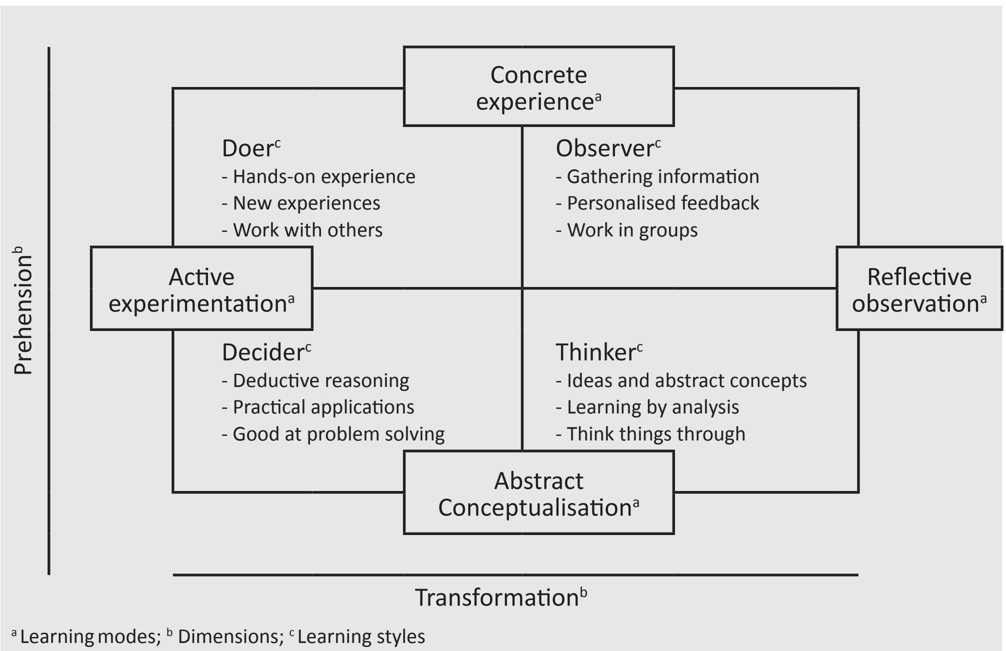

Figure 6.1 Learning styles and matching learning preference[18]

and transformation (AE minus RO). Relative positioning along these two bipolar dimensions defines a preference for one of the following four learning styles: doer, observer, decider or thinker (Figure 6.1).

Procedure

The cognition therapist completed and interpreted the A-LSI together with the patient within a one hour session. The amount of assistance given while completing the A-LSI was dependent upon the patient's physical (e.g., fatigue, visual impairments) and cognitive functioning (e.g., neglect, attention deficits). The assistance could consist of, for example, clarifying the individual items, reading the questions aloud or providing more structure by showing the answers one at a time on separate cards. In the case of neglect, a perpendicular vertical line was drawn as a cue to the neglected side. The results were discussed with the patient after approximately one week. Based on the A-LSI result and observations during completion of the test, the cognition therapist wrote a report with individually tailored learning advice for all involved disciplines.

According to the exploratory character of the study, a convenience sample was selected to do an additional task. To assess content validity of the A-LSI, 19 patients and 38 controls were asked whether they recognized themselves in the assessed learning style on a seven-point scale. The use of learning styles and the A-LSI in patients with ABI was qualitatively evaluated by interviewing three psychologists, three physical therapists, three occupational therapists and three cognition therapists of the rehabilitation teams who were all familiar with the concept of learning style. All interviewees have acquired basic knowledge of learning style through a one-day workshop at the rehabilitation centre. We asked them about the use of learning style in clinical practice, positive and negative aspects of the A-LSI, and potential suggestions for improvement

Statistical analysis

Learning style distributions were described for the patient group and the control group using descriptive statistics. Non-parametric statistics (Mann–Whitney *U* test and Chi squared test) were applied to determine differences between the patients and controls regarding gender, age, education, learning style and recognition of the assessed learning style. Furthermore, a Chi squared test was used to determine whether there was an association between learning style and education. Internal validity of the A-LSI was determined by calculating spearman correlations between learning modes and dimensions.[15] The following hypotheses were formulated to test the presence of two independent bipolar dimensions:

1. The two dimensions, prehension (AC – CE) and transformation (AE – RO) are independent:

   a. No significant association between the two dimensions.
   b. No significant association between the learning modes CE and AC and the dimension AE – RO.
   c. No significant association between the learning modes AE and RO and the dimension AC – CE.
2. The two dimensions are bipolar:
   a. A significant negative association for the within-dimension learning modes (AC and CE; AE and RO).
   b. The correlations between the cross-dimensional learning modes (CE and RO; AC and AE; CE and AE; and AC and RO) are lower than the within-dimension learning modes (AC and CE; AE and RO).

Content validity of the A-LSI was determined by asking patients and controls whether they recognized themselves in the assessed learning style. The score ranged from 1 (strongly disagree) to 7 (strongly agree). Scores exceeding 5 were considered a positive recognition. Data were analysed using SPSS version 18.0, *p* value was set at 0.05. In the case of multiple comparisons, a Bonferroni correction was applied.

Results

Participants

In total, 99 patients with ABI and 42 healthy controls were included in this study. The majority of patients suffered a stroke (77.8%, n = 77). At admission to the rehabilitation centre, the mean Barthel Index score was 14.8 (*SD* 4.9). In total, 58.5% (n = 58) of patients were ADL independent or mildly disabled and 41.4% were moderately to severely ADL disabled. The cognitive scale of the USER yielded a mean score of 40.1 (*SD* 8.9). The mean time between admission to the rehabilitation centre and administration of the A-LSI was 41.1 days (*SD* 40.9). Table 6.1 presents the sample characteristics.

A Mann–Whitney U test revealed no significant difference in age of the patients and controls (U = 1859.0, z = 0.992, p = 0.32). In addition, Chi squared tests indicated no significant difference between the patients and controls regarding gender (χ^2 = 0.014, p = 0.90) and education (χ^2 = 0.300, p = 0.58).

Learning style distribution

The A-LSI yielded the following distribution of learning styles: 4 doers, 54 observers, 2 deciders and 39 thinkers. A similar distribution was found for the control group (3, 28, 0 and 11, respectively). For the patient group, there was a significant association between learning style (observer, thinker) and education (low, high) (χ^2 = 9.75, p = 0.002) with a higher percentage of high educated patients in the thinker group (56.4%) than in the observer group (24%). This association was not found in the control group (χ^2 = 0.14, p = 0.71).

Table 6.1 Characteristics of the study sample

	ABI group (n = 99)	Control group (n = 42)
Gender, female, % (n)	39.4% (39)	40.5% (17)
Mean age in years (SD; range)	55.9 (14.2; 18-84)	54.5 (12.8; 30-85)
High education, % (n)[a]	37.9% (36)[b]	42.9% (18)
Diagnosis, % (n)		
Ischaemic stroke	53.5% (53)	
Haemorrhagic stroke	17.2% (17)	
Subarachoid haemorrhage	7.1% (7)	
Post-anoxic brain damage	5.1% (5)	
Traumatic brain injury	13.1% (13)	
Brain abscess	1.0% (1)	
Brain tumour	2.0% (2)	
Friedreich ataxia	1.0% (1)	
MMSE, mean (SD)		29.6 (0.7)
Barthel Index		
Independent (20), % (n)	19.2% (19)	
Mild disability (15-19), % (n)	39.3% (39)	
Moderate/severe disability (0-14), % (n)	41.4% (41)	
USER cognition, mean (SD)	40.1 (8.9)[c]	

Notes. MMSE = Mini Mental State Examination; USER = Utrecht Scale for Evaluation of Rehabilitation
[a] High education ≥ finished high school; Low education < finished high school.
[b] n = 95
[c] n = 80

Table 6.2 Spearman correlations between A-LSI modes and dimensions in the patient group (n = 70)

	Modes				Dimensions	
	1. CE	2. RO	3. AC	4. AE	5. AE-CE	6. AE-RO
Modes						
1. Concrete experience (CE)	1					
2. Reflective observation (RO)	0.04	1				
3. Abstract conceptualization (AC)	-0.23	0.05	1			
4. Active experimentation (AE)	-0.40*	-0.35*	-0.19	1		
Dimensions						
5. Prehension (AC – CE)	-0.83*	-0.01	0.70*	0.18	1	
6. Transformation (AE – RO)	-0.27	-0.84*	-0.14	0.78*	0.13	1

*Significant after Bonferroni correction ($p \leq 0.003$).

Internal validity of the A-LSI

Internal validity of the A-LSI was investigated by means of Spearman correlations between A-LSI learning modes and dimensions (Table 6.2). For 29 patients we could only trace back their overall learning style and not the scores for learning modes and dimensions. For the remaining 70 patients, scores for learning modes and dimensions were used to evaluate internal validity of the A-LSI. First, we evaluated whether the two dimensions, prehension and transformation, are independent. As hypothesized, there was no significant association between dimensions and cross-dimensional learning modes (CE, AC and AE – RO; AE, RO and AC – CE). These results provide support for two independent dimensions. Second, we determined whether the two dimensions are bipolar. In contrast to our hypothesis, the within-dimensions learning modes for the prehension dimension (AE and CE) were not significantly associated. The two learning modes belonging to the transformation dimension (AE and RO) did show a significant negative association (r = -0.35, p = 0.003). Furthermore, we hypothesized that the cross-dimensional learning modes were unrelated. One out of four correlations for cross-dimensional learning modes was significant (CE and AE: r = -0.40, p = 0.001). This correlation was comparable to the significant within-dimension learning modes (AE and RO: r = -0.35, p = 0.003). These results suggest that only the transformation dimension is bipolar.

Content validity of the A-LSI

Content validity of the A-LSI was assessed by asking patients and controls whether they recognized themselves in the assessed learning style. In total, 58% (11 out of 19) of patients recognized themselves in the assessed learning style. Eight patients did not recognize themselves in the assessed learning style of which one person strongly disagreed, two persons were neutral and five persons slightly agreed with the assessed learning style. For the control group, 71% (27 out of 38) of controls showed a positive recognition of their learning style as indicated by the A-LSI (Table 6.3). Of the remaining 11 healthy controls, two persons disagreed with the assessed learning style, one person was neutral and eight

Table 6.3 Recognition of the A-LSI learning style in a patient and control subgroup

	ABI patients (n = 19)		Controls (n = 38)	
Learning style	n	Positive recognition, n	n	Positive recognition, n
Doer	1	1	1	1
Observer	12	5	26	20
Decider	0	-	0	-
Thinker	6	5	11	6

persons slightly agreed with the A-LSI learning style. There was no significant difference between the two groups regarding the number of positive recognitions (χ^2 = 0.99, p = 0.32).

Feasibility of the A-LSI and learning style in general

We interviewed three psychologists, three physical therapists, three occupational therapists and three cognition therapists.

Implementing learning style in rehabilitation

All interviewees were generally positive about the implementation of learning style in rehabilitation; though, the majority considered it difficult to implement learning style into clinical practice. The physical and occupational therapists reported that they mainly rely on their experience and clinical observations during therapy when using the concept of learning style instead of using an instrument. An occupational and a physical therapist mentioned that it is hard to consciously integrate learning style during therapy; this requires additional preparation time and is therefore not always used consequently. Learning style is coming back into consideration when therapy stagnates or in the case of problems during therapy. Furthermore, some interviewees considered learning style to be a fixed trait that is more or less the same over tasks. Others suggested a situation-specific learning style and therefore make minimal use of the assessed learning style and accompanying advice.

Learning style and cognition

According to a psychologist, learning style should be put into perspective with the cognitive profile and personality of the patient. In the case of severe cognitive impairments, learning style is of less importance. An occupational therapist argued that it is possible to use learning style in these patients but on a lower level, for instance by giving more assistance. According to one of the psychologists, it is useful to evaluate difficulties from a learning style perspective. For instance, repetitive failing attempts at executing a certain task might be interpreted as impaired awareness of deficits while seen from a learning style perspective this could also have been caused by a trial-and-error learning approach.

Positive aspects of the A-LSI

Most consider the A-LSI a concise and easy to use instrument. The items are concrete and imaginable. According to one of the cognition therapists, the total of nine items is the maximum number of items that most individuals with ABI are able to complete. Another cognition therapist said that patients with ABI are generally positive about learning style assessment and consider it to be important. An occupational therapist, a psychologist and a cognition therapist mentioned that the A-LSI provides an explicit learning framework which can be used at the start of rehabilitation instead of having to discover the patient's learning preferences during treatment. According to one of the cognition therapists, the A-LSI makes it possible to adapt to the patient's preferences instead of the other way around which can consequently lead to a more unified, efficient approach of the entire rehabilitation team.

Negative aspects of the A-LSI

The majority of interviewees mentioned that completing the A-LSI requires a relatively high level of cognitive functioning (e.g., language comprehension, conceptualization and executive functioning) and is not suitable for patients with severe aphasia. According to two cognition therapists, most patients were able to rate the most and least favourite answer, but experience difficulties with rating their second and third choice. Concerning the items, the cognition therapists mentioned that these were not always well comprehended. Moreover, some questions caused reactions linked to the ongoing phase of acceptance. For instance, the question about learning how to sail a boat sometimes caused the individual's reaction ''I will never be able to learn how to sail anymore''. Two psychologists, an occupational therapist and a physical therapist expressed their doubts about the practical use in rehabilitation and since it was originally developed for educational purposes it might be inappropriate for use in rehabilitation. In addition, a physical and an occupational therapist mentioned that the learning style assessed with the A-LSI was not always in accordance with the learning style that was seen during observation. In contrast, two of the physical therapist mentioned that the reported learning style was always in accordance with the observed learning style.

Suggestions for improvement of the A-LSI and for using learning style in rehabilitation

Concerning the content of the items several suggestions were postulated. First, a psychologist and cognition therapist suggested using items that address general activities that are important for rehabilitation. For instance, ''during therapy you can choose the method of instruction, what do you choose?''. Every discipline could provide a certain skill that is important for their therapy. Second, an occupational therapist mentioned that items could focus more on the individual person which would consequently lead to a unique, personified A-LSI for each individual. Furthermore, there was a desire to make the A-LSI more accessible for patients with aphasia. A suggestion of a cognition therapist to this end was to use pictograms or to interview the primary caregiver of the patient. Several interviewees proposed that a patient's learning style cannot be based on a questionnaire alone. They suggested to add a practical task. Herein, it could be examined which learning style features can be seen during observation of that task. In addition, a physical therapist suggested that each discipline should observe learning style, these observations could be combined into one multidisciplinary advice. In addition, an occupational and a physical therapist suggested that the learning process of each patient should be evaluated more explicitly during multidisciplinary team meetings in order to exchange and increase knowledge about learning style.

Discussion

In this study we evaluated the validity and feasibility of a learning style instrument, the A-LSI, in inpatients in ABI rehabilitation. The results of this exploratory study indicated that rehabilitation professionals were generally positive about learning style assessment in rehabilitation. This study, however, raises doubts about the validity and feasibility of the A-LSI for this population.

A remarkable finding was that the vast majority of patients and controls had an observer or thinker learning style. This skewed distribution may be explained by the insufficient internal validity of the A-LSI. That is, the A-LSI contains two independent dimensions of learning but only the transformation dimension turned out to be bipolar.

Despite the insufficient internal validity of the A-LSI, the majority of patients and controls had some degree of recognition of the A-LSI learning style. In total, 84% of patients and 91% of healthy controls reported that they slightly agreed, agreed, or strongly agreed with the assessed learning style. This may be explained by the fact that most persons use all four modes of learning to some extent. For instance, a person with a thinker learning style cannot solely depend on reflection and observation when learning how to sail a boat. This person also needs to step into the sailboat and gain concrete experience with sailing. Hence, persons may recognize themselves in several aspects of each learning style.

The qualitative evaluation revealed that rehabilitation professionals mainly used learning style in the case of problems during therapy while, preferably, learning style should be used to prevent problems and to guide therapy. Therefore, learning style should be assessed directly at the start of rehabilitation as part of the diagnostic procedures. In our sample, the A-LSI was assessed, on average, 40 days after admission to the rehabilitation centre. Meanwhile, therapists have already developed their own teaching approach. To our knowledge, there is only one previous study that investigated perceptions on learning style assessment in individuals with a neurological condition.[20] That study investigated paediatric physical therapists and physical educators' perceptions on classifying learning styles in children and adolescents with cerebral palsy. In agreement with our study, the majority of interviewees were generally positive about learning style classification. Furthermore, the authors concluded that Kolb's LSI provided no useful basis for classifying learning styles for that population due to, among others, its difficult administration procedure and unsuitability in the case of low levels of cognition. This is in accordance with our results.

Several limitations of this study should be noted. The A-LSI was originally developed for students; information concerning the development of the A-LSI was not available. It remains to be seen whether it is possible and sensible to utilize an instrument that was originally developed for use in education. However, given the exploratory nature of this study, we considered it important to start with evaluating an existing learning style instrument to gain familiarity and experience with learning style in rehabilitation before developing a new instrument for rehabilitation.

The A-LSI relies on self-report while many patients with ABI have impaired awareness of deficits and difficulty with self-monitoring. Consequently, the validity of the responses can be doubted. A previous study that used different measures to assess learning style found no significant association between a self- report instrument and a performance-based instrument.[21] Future studies are needed to determine the validity of self-report measures of learning style.

Another limitation of this study is that we studied a convenience sample of patients with ABI which caused a rather heterogeneous group as regards diagnosis. However, for the current study we were interested in all patients with ABI, naturally occurring in a rehabilitation setting, irrespective of diagnosis. More research is needed to determine whether there is an association between learning style and diagnosis.

Further research into learning style is recommended to increase our understanding of learning style post-ABI and the added value for rehabilitation. Longitudinal studies are needed to, for instance, determine whether learning styles change during the rehabilitation process and to assess whether learning style is a predictor of rehabilitation outcome.

In conclusion, rehabilitation professionals considered learning style to be relevant for rehabilitation but found it difficult to implement in clinical practice. Even though the A-LSI might not be appropriate for an ABI population, this exploratory study provides a basis for further research into the concept of learning style. We recommend that future studies consider alternatives to self-report questionnaires such as behavioural observations or proxy questionnaires. We furthermore recommend that learning style should be assessed directly at the start of rehabilitation as part of the diagnostic procedures. For now, we believe it is important to acquaint rehabilitation professionals with the concept of learning style so that they are aware of the fact that their own learning style might not be the same as the patient they are treating and that they learn how to implement learning style into clinical practice.

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Appendix A Translated items of the A-LSI

Concrete experience	*Reflective observation*	*Abstract conceptualisation*	*Active experimentation*
1. You want to learn how to sail. What do you do?			
A. I would directly step into the boat and try to sail.	B. I would stay on the shore first, observing others.	C. I would first look up in a book how to sail.	D. I would ask someone to demonstrate it.
2. You get a new computer. You want to use it immediately. What do you do?			
A. I would first think about everything I can do with it.	B. I would first ask about all its functions and what I can do with it.	C. I would first read the manual.	D. I would try out everything immediately.
3. You put together a piece of furniture. What do you do?			
A. I would first verify what I have to do and determine the best way to do it.	B: I would read the manual completely and take a close look at the building plan.	C: I would first check what I can use the piece of furniture for.	D: I would immediately start putting the piece of furniture together.
4. You hear a story about an exciting event and you want to tell the story at home. What do you do?			
A: I would imagine that the exciting event is currently happening and that I'm present.	B: I love what I am hearing and I want to witness the exciting event for myself.	C: I first want to know whether the story is correct.	D: I would just repeat the story.
5. You are going on holiday. You choose out of two countries. What do you do?			
A: I would imagine what I could do in these countries. I find it hard to choose.	B: I would not think too long. You have to make the best of it.	C: I would try to get to know as much as possible about the countries. Afterwards I would decide.	D: I would consider what would be the best for me. I am a quick decider.
6. You are going to buy a new bicycle. What do you do?			
A: I would think about where I could go with the bicycle and how much fun it would be.	B: I would want to know exactly the specifications, which one is the best and the prices.	C: I would want to try the new bicycle immediately.	D: I would consider which bicycle is most suitable for me.
7. You have an exam. What do you do?			
A: I would only learn what I need to know for the exam.	B: I would try to understand the learning material.	C: I would write down the most important things.	D: I learn, just because I need to.
8. Someone offers you a new job. What do you do?			
A: I would try to imagine what it would be like for me to do the job.	B: I would first want to know exactly how hard I have to work and how much money I earn.	C: I would want to know exactly what someone has to do in the company and how the company works.	D: I would go to work and then experience whether I like it or not.
9. You are attending a course and you can decide about the way of teaching. What do you do?			
A: I would want the professor to tell stories.	B: I would want to work on projects.	C: I would want to receive concrete assignments.	D: I would like to know why I have to do certain assignments.

Note. The grey-coloured answers are not included in the sum-scores.

CHAPTER 7

Predictors of health-related quality of life and participation after brain injury rehabilitation: The role of neuropsychological factors

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Abstract

The aims of this longitudinal study were (1) to assess associations between neuropsychological factors and health-related quality of life (HRQoL) and participation three months after discharge from inpatient acquired brain injury (ABI) rehabilitation; and (2) to determine the best neuropsychological predictor of HRQoL and participation after controlling for demographic and injury-related factors. Patients with ABI (*n* = 100) were assessed within approximately two weeks of enrolment in inpatient rehabilitation. Predictor variables included demographic and injury-related characteristics and the following neuropsychological factors: active and passive coping, attention, executive functioning, verbal memory, cognitive learning potential, depressive symptoms, motivation, extraversion, neuroticism and self-awareness. Bivariate analyses revealed that passive coping, executive functioning, depressive symptoms, extraversion and neuroticism were significantly associated with HRQoL and/or participation. Neuropsychological factors significantly explained additional variance in HRQoL (18.1% - 21.6%) and participation (6.9% - 20.3%) after controlling for demographic and injury-related factors. A higher tendency towards passive coping was the only significant neuropsychological predictor (beta = -0.305 to -0.464) of lower HRQoL and participation. This study shows that neuropsychological functioning, and in particular passive coping, plays a role in predicting HRQoL and participation after inpatient ABI rehabilitation and emphasizes the importance of addressing patients' coping styles in an early phase of ABI rehabilitation.

Introduction

Acquired brain injury (ABI) sequelae can substantially impact patients' long-term health-related quality of life (HRQoL) and participation.[1-4] HRQoL is a multidimensional construct referring to 'how health impacts on an individual's ability to function and his or her perceived well-being in physical, mental and social domains of life'.[5] Participation reflects patients' involvement in life situations (e.g., employment, leisure)[6] and is considered part of HRQoL.[7] Variations in HRQoL and participation after ABI are not fully explained by demographic characteristics and injury-related factors.[8] Therefore, in recent years, increasing attention is being directed towards the role of neuropsychological factors such as patients' cognitive, emotional (e.g., depression) and psychological functioning (e.g., coping). Information concerning the predictive role of such factors may offer directions for neuropsychological rehabilitation of patients with ABI.

Impairments in cognitive domains, such as attention and memory, have been repeatedly identified as important predictors of reduced long-term HRQoL after ABI (see for example [4,9-12]). Closely related to cognitive functioning is patients' self-awareness. For self-awareness, mixed findings have been reported in patients with ABI. Some studies have shown that impaired self-awareness may lead to unfavourable participation (i.e., employment outcomes)[13,14] and lower HRQoL,[15] whereas another study found no significant association between self-awareness and HRQoL.[16]

The role of emotional and psychological factors on HRQoL and participation has also been examined in several studies. In a systematic review on psychological predictors of post-stroke HRQoL,[8] it was, for example, concluded that personality, coping, internal locus of control, self-worth, hope, and optimism were all significant predictors of HRQoL post-stroke. A psychological factor that was found to be a significant predictor of HRQoL in other patient populations (e.g., prolonged musculoskeletal disorders[17]; severe mental illness[18]) is motivation. The role of treatment motivation on long-term HRQoL and participation has not yet been examined longitudinally in patients with ABI.

Besides assessing the predictive role of individual neuropsychological factors on HRQoL and participation, it is also important to determine which of those neuropsychological factors is the most influential in predicting patients' outcomes. In outpatients with subarachnoid haemorrhage (SAH), it was examined whether demographic and SAH characteristics, cognitive and emotional complaints, depressive symptoms, anxiety, memory, attention, executive functioning, visuoconstruction, and a passive coping style play a role in predicting physical and psychosocial HRQoL one year later.[4] In that study, cognitive complaints and passive coping were the strongest predictors of psychosocial HRQoL, and visuoconstruction of physical HRQoL.[4] In a study in inpatients with stroke,[11] demographic and clinical factors, global cognitive functioning, anxiety and depression were considered as potential predictors of HRQoL. Of these, depression was the strongest independent, neuropsychological predictor of HRQoL four years post-stroke.

At present, there is a paucity of longitudinal studies examining the predictive value of multiple neuropsychological factors on long-term HRQoL and participation following ABI rehabilitation. Hence, in this study we examined a variety of possible neuropsychological predictors assessed at the start of inpatient ABI rehabilitation: attention, executive functioning, verbal memory, cognitive learning potential, self-awareness, depressive symptoms, coping style, motivation, and personality. The objectives were: (1) to assess associations between early neuropsychological functioning and long-term HRQoL and participation in patients with ABI; and (2) to determine which of these neuropsychological factors is the best predictor of HRQoL and participation after controlling for demographic and injury-related factors. More knowledge of predictors of rehabilitation outcome may prove useful in tailoring treatment to the individual.

Methods

Participants

Patients in this longitudinal, prospective cohort study were recruited between November 2012 and December 2013 from inpatient clinics of five rehabilitation centres in the Netherlands. Inclusion criteria were: (1) diagnosis of ABI based on medical records; (2) ≥ 18 years of age; and (3) sufficient command of the Dutch language based on clinical judgment. Exclusion criteria for this study were: (1) severe aphasia based on a Dutch Aphasia Foundation (Stichting Afasie Nederland, SAN)[19] scale score less than 4 or clinical judgment; (2) premorbid psychiatric disorder and/or substance abuse for which hospital admission was necessary; (3) minimally conscious state or post-traumatic amnesia at the time of recruitment; (4) degenerative or progressive brain disease; (5) active participation in another study to avoid participation burden; and (6) no informed consent.

Measures

Rehabilitation outcome

Health-related quality of life (HRQoL)

HRQoL was measured with the Stroke Specific Quality of Life Scale – 12 (SS-QoL-12).[20] The SS-QoL-12 consists of 12 items divided into two dimensions: physical HRQoL and psychosocial HRQoL. The dimension scores are the unweighted averages of the item scores. For both dimensions, scores range from 1 to 5 with higher scores indicating better physical HRQoL (e.g., “Did you need help taking a bath or shower?”) or psychosocial HRQoL (e.g., “I had trouble remembering things”). The SS-QoL-12 has good reliability and validity in patients with stroke and SAH.[20,21]

Participation

The Utrecht Scale for Evaluation of Rehabilitation – Participation (USER-P)[22] is a generic measure of participation. It consists of 31 items divided into three scales: Frequency, Restrictions, and Satisfaction. The Frequency scale consists of 12 items such as "In the last four weeks, how many times did you visit your family or friends?". Possible answers are "0", "1-2", "3-5", "6-10", "11-18" or "19 or more". The Restrictions scale consists of 10 items such as "Are you, because of your disease or condition, limited in doiong sports or other physical exercise?". Possible answers are "I do not perform this activity, but this is not due to my condition or disease"; "I do not perform this activity and this is due to my condition or disease"; "I do perform the activity without any trouble or help"; "I do perform (part of) the activity but receive help because of the disease"; "I do perform (part of) the activity but need considerably more time, rest or help or do it less often or for a shorter period of time". The Satisfaction scale consists of 9 items such as "How satisfied are you about the relationship with your partner?". Possible answers range from "very unsatified" to "very satisfied". For this study, the Restrictions and Satisfaction scales were used. These scales focus on participation in vocational, leisure and social activities. The sum of scores for the two scales are based on the items that are applicable to the patient's situation and each sum score is converted to a 0-100 scale with higher scores indicating better participation (i.e., less restrictions, higher satisfaction).[22] The USER-P has adequate reliability and validity in patients with physical disabilities.[22]

Possible predictors

Demographic characteristics and injury-related factors

Demographic predictors included age, gender and education. Education was categorized into high level of education (this includes higher general secondary education, pre-university education, higher vocational education and university education) and <high level of education (< higher general secondary education). Injury-related factors were time since injury, type of injury (traumatic *vs*. non-traumatic brain injury), length of inpatient stay, and ADL independence. ADL independence was assessed with the Barthel Index (BI)[23] score at admission to inpatient rehabilitation. Scores range from 0 to 20; a higher score reflects more ADL independence.

Neuropsychological functioning

Coping style

To assess patients' coping style, two frequently used subscales of the Utrechtse Coping Lijst (UCL)[24] were used: active problem-solving and passive reactions. For both subscales, scores range from 7 to 28; higher scores indicate a higher tendency towards active problem-solving or passive reactions. The UCL has good feasibility and responsiveness in an ABI population.[25]

Cognitive tests

Attention was evaluated with the Trail Making Test parts A and B (TMT).[26] Executive functioning was evaluated with the Category Fluency Test using 'animals' (CFT)[27] and the Letter Fluency Test using the letters 'N' and 'A' (LFT).[28] Verbal memory was assessed with the Rey Auditory Verbal Learning Test (R-AVLT)[29] immediate and delayed recall. The TMT, CFT, LFT and R-AVLT are described in more detail elsewhere.[27] Cognitive learning potential was examined with the dynamic Wisconsin Card Sorting Test (dWCST).[30] The dWCST was administered following a one-session pre-test–train–post-test design. The pre- and post-test were administered according to standard WCST administration procedures.[31] During the brief training, additional feedback and instructions were provided. The dWCST administration procedures are described in more detail elsewhere.[32]

Depressive symptoms

The presence of depressive symptoms was evaluated using the depression subscale of the Hospital Anxiety Depression Scale (HADS-D).[33] Scores range from 0 to 21 with higher scores indicating more depressive symptoms. A cut-off score of ≥8 was used to classify patients in a 'no depression' (0-7) or a 'possible depression' (8-21) group.[34] The HADS-D has adequate psychometric properties in a stroke population.[35]

Motivation

Motivation for rehabilitation was examined with the Motivation for Traumatic Brain Injury Rehabilitation Questionnaire (MOT-Q).[36] The MOT-Q is a 31-item self-report questionnaire used to assess the desire and interest to undertake rehabilitation. A sample item is "Therapists would waste my time". Total scores range between -62 and 62; higher scores indicate higher motivation for rehabilitation. The MOT-Q total score has adequate psychometric properties in patients with ABI.[36,37]

Personality

Personality was assessed using two subscales of the Eysenck Personality Questionnaire Revised Short Scale (EPQ-RSS)[38,39] Extraversion and Neuroticism. These subscales were selected because of their reported relation with health.[39] Scores range from 0 to 12 with higher scores indicating more extraversion and neuroticism. Both subscales have adequate reliability and construct validity in clinical populations.[39]

Self-awareness

The Patient Competency Rating Scale (PCRS)[40] assesses self-awareness using a self-other discrepancy method. An informant rating was obtained from the patient's neuropsychologist. Awareness scores were obtained by calculating the discrepancy in ratings between the patient and the neuropsychologist. A sample item of the patient's version is "How much of a problem do I have in preparing my own meals?" and of the neuropsychologist's version "How much of a problem do they have in preparing their own meals?". Discrepancy scores range from -120 to 120 with greater discrepancies indicating poorer self-awareness. Positive discrepancies indicate overestimation and negative discrepancies indicate underestimation of difficulties. The PCRS has good reliability and validity in patients with ABI.[41]

Procedures

At the start of inpatient rehabilitation, all patients were screened for eligibility by the treating rehabilitation physician. Eligible patients were asked whether they were willing to participate in the study. After written informed consent was obtained, demographic characteristics and injury-related factors were obtained from the medical records. The initial assessment took place within approximately two weeks of enrolment and included the dWCST and all questionnaires. All measures were administered in a quiet room by a trained clinician or trained neuropsychology student. Within seven days of the initial assessment, the treating neuropsychologist of each patient completed the PCRS and a cognitive screening was conducted by a psychological assistant as part of routine assessment procedures. A follow-up assessment was completed three months after discharge from inpatient rehabilitation, and included the SS-QoL-12 and USER-P. These outcome measures were administered by a trained clinician or trained neuropsychology student by phone, mail or at the patients' home depending on the patient's preference.

The medical ethics committee of the University Medical Centre Utrecht and the five participating rehabilitation centres approved the study protocol. All patients gave informed consent.

Statistical analyses

Normality was assessed using skewness, kurtosis and visual inspection of histograms. Non-parametric statistics were used in case of non-normally distributed data (skewness and kurtosis ≥1). Descriptive statistics were used to describe characteristics of the patients. A non-response analysis was performed by comparing patients who were re-examined at follow-up and those who were not. Chi-square tests, independent samples t-tests or Mann-Whitney *U* Tests, and one-way between-groups analysis of variance (*ANOVA*) or Kruskall Wallis Tests were used to evaluate between-group differences in demographic characteristics (gender, age, education) and injury-related factors (ADL independence, type of diagnosis, time between ABI and admission).

For all questionnaires, except the USER-P, missing values were replaced with the mean of the non-missing values within the same (sub)scale. None of the patients had missing values on the UCL, HADS-D and the neuroticism subscale of the EPQ-RSS. Twelve patients had maximally one missing value on the MOT-Q, four patients had maximally one missing value on the extraversion subscale of the EPQ-RSS, six patients had maximally one missing value on the physical subscale of the SS-QoL-12 and one patient had one missing value on the psychosocial subscale of the SS-QoL-12. For the PCRS, the maximum number of missing values per patient was higher but data were imputed only for patients for whom no more than 25% of the PCRS-items were missing (*n* = 35 patients). For the USER-P, subscale sum scores were calculated based on the items that were applicable to the patient's situation (no data were imputed). Cognitive domain scores were calculated for attention, executive functioning and verbal memory by averaging percentile scores of tests belonging to the same cognitive domain. Mean percentile score were considered impaired when ≤ 5th percentile. For the dWCST, previously establishes cut-off values[30,32] were used to categorize patients as 'high achiever' (pre- and post-test ≥43 correct); 'strong learner' (pre- to post-test improvement ≥15 points); 'poor learner' (pre- to post-test improvement <15 points); or 'decliner' (pre- to post-test decline ≥15 points).

Pearson or Spearman correlation coefficients were used to check for collinearity between continuous predictor variables. Collinearity was considered present in case of Pearson or Spearman correlation coefficients exceeding 0.80. One-sample *t* tests or one-sample Kolmogorov Smirnov Tests were used to compare patients' scores for physical and psychosocial HRQoL and for participation restrictions and satisfaction. Bivariate analyses,

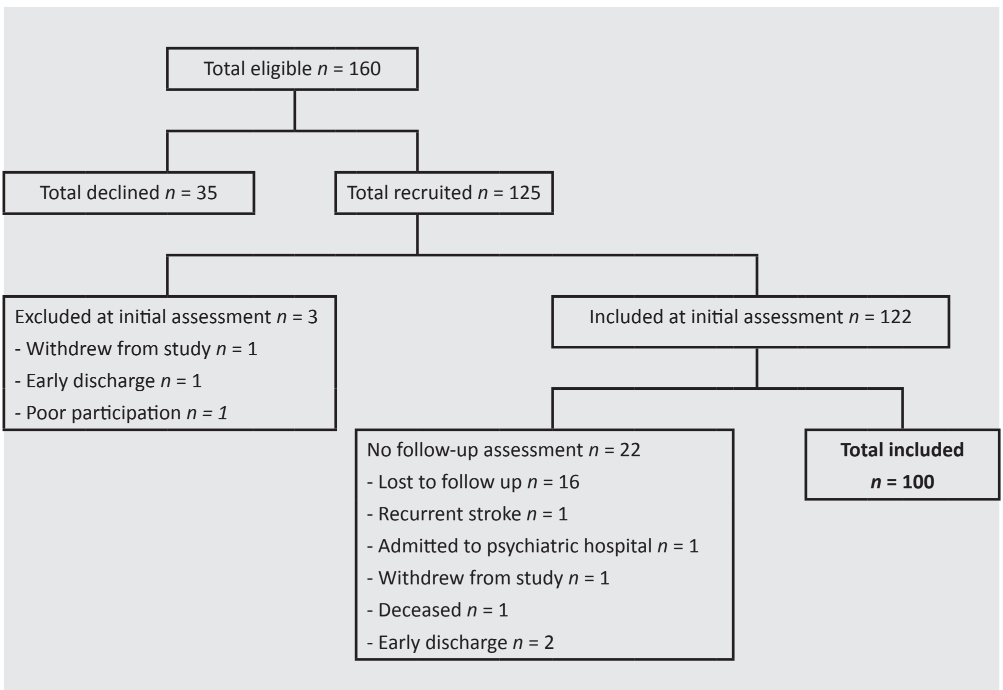

Figure 7.1 Flowchart patient inclusion

Table 7.1 Patient characteristics (*n* = 100)

Gender, % male	59%
Mean age in years (*SD*; range)	53.9 (13.4; 20-78)
High education, %	48%
Diagnosis, %	
Cerebrovascular accident	62%
Traumatic brain injury	21%
Tumour	7%
Post-anoxic brain damage	6%
Neuro-inflammatory disease	4%
Mean time between injury and initial assessment (*SD*) (days)	50.4 (35.0)
Mean length of inpatient rehabilitation (*SD*) (days)	66.8 (37.8)
Mean Barthel Index at admission (*SD*)[a]	15.7 (4.8)

[a] *n* = 92

using Pearson or Spearman correlation coefficients with Bonferroni correction for multiple comparisons (0.05 / 11 neuropsychological tests), were used to calculate associations between neuropsychological variables and HRQoL and participation. Subsequently, hierarchical regression analyses were conducted to assess the ability of neuropsychological variables, that were significant in bivariate analyses, to predict HRQoL and participation, after controlling for the influence of demographic and injury-related factors. For all analyses, continuous scores were used when available. Alpha was set at 0.05 for bivariate analyses and 0.01 for multivariate analyses. Data were analyzed using SPSS version 22.0.

Results

Participants

Patients were excluded from participation in this study for various reasons: insufficient command of the Dutch language, aphasia, active participation in other studies, premorbid psychiatric disorder or substance abuse, and minimally conscious state at the time of recruitment. Figure 7.1 shows that 160 patients were eligible and were approached for participation in the study and 35 patients refused to participate. Eventually, 125 of the 160 eligible patients with ABI were recruited from the five rehabilitation centres. Of these 125 patients, three were excluded at initial assessment and 22 patients were not assessed at follow-up. In total, data of 100 patients were used in this study (Figure 7.1). There were no significant differences between patients who were included (*n* = 100) and patients who were excluded at the initial assessment or who did not complete the follow-up assessment (*n* = 25) regarding age (U = 1120.0, z = -0.8, p = 0.42, r = -0.08); gender (χ^2 = 0.074, p = 0.785, phi = 0.024); education (χ^2 = 3.25, p = 0.072, phi = -0.161); ADL independence (U = 809.0, z = -1.5,

Table 7.2 Descriptives potential neuropsychological predictors and outcome measures

Domain	Measure(s)	Score used (range)	*n*	Mean (*SD*)	Median	Range	% impaired
Neuropsychological predictors							
Coping							
Active coping	UCL	Total score (7-28)	100	19.5 (3.7)	19.0	12-28	-
Passive coping	UCL	Total score (7-28)	100	9.9 (2.5)	9.0	7-20	-
Cognitive domains							
Attention	TMT-AB	Mean percentile score (0-100)	89	20.4 (21.6)	11.5	0-82	33.7%[a]
Executive functioning	CFT, LFT	Mean percentile score (0-100)	96	19.2 (21.2)	9.3	0-89	28.1%[a]
Verbal memory	R-AVLT	Mean percentile score (0-100)	98	220 (27.4)	7.8	0-99	43.9%[a]
Learning potential	dWCST	Learner groups	88	-	-	-	25.0%[b]
Depressive symptoms	HADS-D	Total score (0-21)	99	4.7 (3.7)	4.0	0-16	22.5%[c]
Motivation	MOT-Q	Total score (-64-64)	100	24.1 (12.4)	25.0	-22-51	-
Personality							
Extraversion	EPQ-RSS	Total score (0-12)	100	7.1 (3.0)	7.0	0-12	-
Neuroticism	EPQ-RSS	Total score (0-12)	100	3.0 (2.8)	2.0	0-11	-
Self-awareness	PCRS	Discrepancy score (-120-120)	88	9.4 (20.2)	10.5	-30-54.4	-
Outcome measures							
Physical HRQoL	SS-QoL-12	Unweighted average (1-5)	98	4.3 (0.6)	4.5	2.7-5	-
Psychosocial HRQoL	SS-QoL-12	Unweighted average (1-5)	99	3.6 (1.0)	3.7	1.2-5	-
Participation restrictions	USER-P	Converted sum score (0-100)	100	75.4 (20.1)	81.0	26-100	-
Participation satisfaction	USER-P	Converted sum score (0-100)	96	66.6 (18.2)	71.9	16-100	-

Notes. TMT-A=Trail Making Test part A; TMT-B/A=Trail Making Test part B corrected for part A; CFT=Category Fluency Test; LFT=Letter Fluency Test; R-AVLT=Rey Auditory Verbal Learning Test; SCT=Star Cancellation Test; UCL=Utrechtse Coping Lijst; HADS-D=Hospital Anxiety and Depression Scale Depression subscale; dWCST=dynamic Wisconsin Card Sorting Test; MOT-Q=Motivation for Traumatic Brain Injury Rehabilitation Questionnaire; EPQ-RSS=Eysenck Personality Questionnaire Revised Short Scale; PCRS=Patient Competency Rating Scale; SS-QoL-12=Stroke Specific Quality of Life Scale-12; USER-P=Utrecht Scale for Evaluation of Rehabilitation – Participation.
[a] Mean percentile score ≤ 5th percentile; [b] Poor learners; [c] Total score ≥ 8.

$p = 0.14$, $r = -0.15$); and type of diagnosis ($\chi^2 = 2.47$, $p = 0.116$). The groups did significantly differ in the time between ABI and admission ($U = 725{,}5$, $z = -3{,}2$, $p = 0.001$, $r = -0.32$); patients who were included in this study were admitted to inpatient rehabilitation approximately two weeks earlier than the other patients (median = 14 *vs*. 28 days, respectively).

Table 7.1 shows the characteristics of the patients who were included in this study. Most patients suffered non-traumatic brain injury (79.0%), in particular stroke (62.0%). The mean BI at admission was 15.7 (*SD* 4.8); 65.2% of patients were ADL independent or mildly disabled (BI 15-20) and 34.8% were moderately to severely ADL disabled (BI 0-14) The initial assessment of the majority of patients took place within three months post-ABI (93.0%). Table 7.2 presents the descriptives of the measures that were administered during the initial and follow-up assessment. All outcome measures, but not all predictor variables, showed a normal distribution. There was no collinearity between continuous predictor variables.

In Table 7.2 it can be observed that, of all cognitive domains, impairments in attention (33.7%) and verbal memory (43.9%) were most common. About one quarter of patients had impairments in executive functioning (28.1%) and cognitive learning potential (25%), Further, 22.2% of patients were classified as having a possible depression.

Health-related quality of life (HRQoL) and participation

Patients' mean physical HRQoL score (4.3 ± 0.6) was significantly higher than patients' mean psychosocial HRQoL (3.6 ± 1.0) ($p < 0.01$). The mean score for participation restrictions (75.4 ± 20.1) was higher (i.e., better) than the mean score for satisfaction with participation (66.6 ± 18.2) ($p < 0.01$).

Neuropsychological factors and physical health-related quality of life (HRQoL)

Bivariate analyses revealed that two neuropsychological factors were significantly associated with lower physical HRQoL: a higher tendency towards passive coping ($r = -0.391$, $p < 0.001$) and more depressive symptoms ($r = -0.355$, $p < 0.001$) (Table 7.3). Multiple regression analyses showed that demographic and injury-related factors explained 26.6% of the variance in physical HRQoL (step 1). Neuropsychological factors (passive coping, depressive symptoms) explained an additional 18.1% of the variance in physical HRQoL (*F* change = 13.1, $p < 0.001$) (step 2). In the final model, lower ADL independence (beta = 0.446, $p < 0.001$), traumatic brain injury (beta = -0.245, $p = 0.08$) and a higher tendency towards passive coping (beta = -0.418, $p < 0.001$) were significant predictors of lower physical HRQoL ($R^2 = 0.447$).

Neuropsychological factors and psychosocial health-related quality of life (HRQoL)

Bivariate regression analyses showed that three neuropsychological factors were significantly associated with lower psychosocial HRQoL: a higher tendency towards passive coping (*r* =

Table 7.3 Associations and predictors (start of inpatient rehabilitation) of physical and psychosocial health-related quality of life (HRQoL) three months after discharge

Predictor	Physical HRQoL			Psychosocial HRQoL		
	Bivariate (Spearman's *r*)	Multivariate (Beta)		Bivariate (Spearman's *r*)	Multivariate (Beta)	
		Step 1	Step 2		Step 1	Step 2
Demographic & injury-related						
Age		0.061	-0.023		0.110	0.014
Education (0 = <high, 1 = high)		-0.083	-0.067		0.008	0.020
Gender (0 = male, 1 = female)		-0.175	-0.086		-0.231	-0.131
ADL independence		**0.403****	**0.446***		0.062	0.112
Length of inpatient stay		-0.131	-0.092		-0.094	-0.038
Type of injury (0 = traumatic, 1 = non-traumatic)		-0.184	**-0.245***		-0.014	-0.079
Time since injury		0.053	0.047		0.066	0.055
Neuropsychological						
Coping						
Active coping	-0.004	NE	NE	0.123	NE	NE
Passive coping	**-0.391****	NE	**-0.418***	**-0.513****	NE	**-0.464***
Cognitive domains						
Attention	0.014	NE	NE	0.022	NE	NE
Executive functioning	**-0.271***	NE	NE	-0.058	NE	NE
Verbal memory	0.175	NE	NE	0.056	NE	NE
Learning potential	-0.061	NE	NE	-0.003	NE	NE
Depressive symptoms	**-0.355****	NE	-0.069	**-0.452****	NE	-0.115
Motivation for rehabilitation	-0.122	NE	NE	-0.009	NE	NE
Personality						
Extraversion	0.095	NE	NE	0.134	NE	NE
Neuroticism	**-0.265***	NE	NE	**-0.328****	NE	0.047
Self-awareness	0.142	NE	NE	0.105	NE	NE
R^2		0.266	0.447		0.084	0.300
Adjusted R^2		0.204	0.385		0.006	0.213

** Bivariate analyses: significant after Bonferroni correction $p \leq 0.005$; * Multivariate analyses: $p \leq 0.01$; NE = not entered.

Table 7.4 Associations and predictors (start of inpatient rehabilitation) of participation restrictions and satisfaction with participation three months after discharge

Predictor	Participation restrictions			Satisfaction with participation		
	Bivariate (Spearman's *r*)	Multivariate (Beta)		Bivariate (Spearman's *r*)	Multivariate (Beta)	
		Step 1	Step 2		Step 1	Step 2
Demographic & injury-related						
Age		-0.006	-.068		0.006	-0.085
Education (0 = <high, 1 = high)		0.104	.127		0.007	0.026
Gender (0 = male, 1 = female)		**-0.299***	**-0.267***		-0.086	-0.003
ADL independence		0.205	.206		0.077	0.117
Length of inpatient stay		-0.304	**-0.324***		-0.158	-0.125
Type of injury (0 = traumatic, 1 = non-traumatic)		0.040	-0.004		-0.058	-0.124
Time since injury		-0.180	-0.177		0.095	0.090
Neuropsychological						
Coping						
Active coping	0.122	NE	NE	0.148	NE	NE
Passive coping	**-0.307****	NE	**-0.305***	**-0.416****	NE	**-0.453***
Cognitive domains						
Attention	-0.050	NE	NE	-0.016	NE	NE
Executive functioning	-0.031	NE	NE	-0.096	NE	NE
Verbal memory	0.026	NE	NE	-0.114	NE	NE
Learning potential	0.117	NE	NE	0.017	NE	NE
Depressive symptoms	**-0.286****	NE	0.056	**-0.342****	NE	-0.053
Motivation for rehabilitation	0.028	NE	NE	0.046	NE	NE
Personality						
Extraversion	0.131	NE	NE	0.217	NE	NE
Neuroticism	-0.157	NE	NE	-0.253	NE	NE
Self-awareness	0.041	NE	NE	-0.093	NE	NE
R^2		0.372	0.441		0.060	0.263
Adjusted R^2		0.319	0.379		-0.021	0.179

** Bivariate analyses: significant after Bonferroni correction $p \leq 0.005$; * Multivariate analyses: $p \leq 0.01$; NE = not entered.

-0.513, $p < 0.001$) and neuroticism (r = -0.328, $p = 0.001$), and more depressive symptoms (r = -0.452, $p < 0.001$) (Table 7.3). Multiple regression analyses demonstrated that demographic and injury-related factors explained 8.4% of the variance in psychosocial HRQoL (step 1). Neuropsychological factors (depressive symptoms, passive coping, neuroticism) explained an additional 21.6% of the variance in psychosocial HRQoL (F change = 8.3, $p < 0.001$) (step 2). In the final model, a higher tendency towards passive coping (beta = -0.464, $p = 0.001$) was a significant predictor of lower psychosocial HRQoL ($R^2 = 0.300$).

Neuropsychological factors and participation restrictions

According to bivariate analyses, a higher tendency towards passive coping (r = -0.307, $p = 0.002$), and more depressive symptoms (r = -0.286, p=.004) were significantly associated with more participation restrictions. Multiple regression analyses showed that demographic and injury-related factors explained 37.2% of the variance in participation restrictions (step 1) (gender was the only significant demographic predictor). Neuropsychological factors (passive coping, depressive symptoms) explained an additional 6.9% of the variance in participation restrictions (F change = 5.0, $p = 0.009$) (step 2). In the final model, female gender (beta = -0.267, $p = 0.004$), longer inpatient stay (beta = -0.324, $p = 0.008$), and a higher tendency towards passive coping (beta = -0.305, $p = 0.005$) were significant predictors of more participation restrictions ($R^2 = 0.441$).

Neuropsychological factors and satisfaction with participation

Bivariate analyses revealed that two neuropsychological factors were significantly associated with lower satisfaction with participation: a higher tendency towards passive coping (r = -0.416, $p < 0.001$) and more depressive symptoms (r = -0.342, $p = 0.001$ (Table 7.4). Multiple regression analyses showed that demographic and injury-related factors explained 6.0% of the variance in participation satisfaction (step 1). Neuropsychological factors (depressive symptoms, passive coping) explained an additional 20.2% of the variance in participation satisfaction (F change = 5.8, $p < 0.001$) (step 2). In the final model, a higher tendency towards passive coping (beta = -0.453, $p < 0.001$) was a significant predictor of lower satisfaction with participation ($R^2 = 0.263$).

Discussion

This longitudinal study investigated the predictive role of neuropsychological factors on HRQoL and participation three months after discharge from inpatient rehabilitation. The results showed that neuropsychological factors explained additional variance in physical and psychosocial HRQoL, participation restrictions, and satisfaction with participation after controlling for demographic and injury-related factors. Across all outcomes, a higher tendency towards passive coping was the only significant neuropsychological predictor of lower HRQoL and participation.

Neuropsychological factors and HRQoL and participation

Neuropsychological factors made up a substantial part of the total explained variance in physical (18.1% of 44.7% = 40.5%) and psychosocial HRQoL (21.6% of 30.0% = 72.0%) and satisfaction with participation (20.3% of 26.3% = 77.2%). Although less pronounced, these neuropsychological factors also contributed significantly to predicting patients' participation restrictions (6.9% of 44.1% = 15.6%). For all four outcomes, passive coping emerged as the only significant predictor of all neuropsychological factors considered. Passive coping being such an important predictor may be explained by the fact that a passive coping style implies a tendency to not taking any action when problems or changes occur which does not seem to be an efficient strategy to maximize rehabilitation outcomes. In a previous study in patients with ABI, an increase in the use of non-productive coping styles has been reported between the start of rehabilitation and five months later. Decreased use of passive coping styles and increased use of active coping styles predicted higher quality of life in the long term.[42] Therefore, it is important to target patients' coping styles in an early phase post-ABI to optimize rehabilitation outcomes. Effective coping strategies may, for instance, be taught by means of cognitive-behavioural therapy.[43,44]

Although passive coping was the strongest neuropsychological predictor, bivariate analyses also showed significant relations between depressive symptoms and neuroticism and HRQoL and participation. It should be noted that in our study the percentage of patients who were classified as having a possible depression (22.2%) was lower than typically found. Prevalence of depression usually varies from 27% to 61% in studies with patients with TBI[45,46] and around 33% in stroke patients.[47] The difference between the prevalence of depression found in our study and the prevalence reported in other studies may be due to differences in time post-onset (one previous study for example included outpatients[46] and another study studied patients who on average were eight years post-onset,[45] whereas the patients in our study were inpatients at the time of assessment of depression and on average were 50 days post-onset), or may be due to the use of different measurement instruments. Nevertheless, in our study depressive symptoms were significantly correlated with HRQoL and participation.

The significant role of depressive symptoms may be explained by previous findings reporting that depression can substantially interfere with patients' recovery,[11] their efficient use of rehabilitation services,[48] and patients' life satisfaction.[49] Depressive symptoms may also negatively influence patients' responses on health status measures. It has been found that patients' ratings of mood are positively related to quality of life ratings.[50] Additionally, depression is considered part of HRQoL which suggests a conceptual overlap between measures.[8]

Regarding the role of personality, patients who are inclined towards neuroticism generally tend to overreact to unpleasant events (e.g., frustration) and have difficulty adapting to new situations.[39] Those patients are likely to report more symptoms and consequently may experience lower HRQoL and participation.[51]

Neuropsychological factors unrelated to HRQoL and participation

In the current study, attention, executive functioning, verbal memory, cognitive learning potential, active coping, motivation, extraversion and self-awareness were not significantly associated with HRQoL and participation. The previously reported relations between HRQoL or participation and attention, executive funcitoning and verbal memory,[4, 9,10] and cognitive learning potential[32] were not replicated in the current study. This may be explained by the use of different cognitive tests, other outcome measures and different patient populations. In the current study, only one or two tests were used for each cognitive domain. For example, verbal memory was examined with the R-AVLT whereas a previous study used verbal and nonverbal tests including the R-AVLT and three other memory tests.[4] In addition, not all cognitive tests were completed by all patients for instance due to visual problems. This may have influenced the predictive value of cognitive impairments on patients' HRQoL and participation. Regarding cognitive learning potential, this was the first study that examined its role in predicting HRQoL and participation after inpatient ABI rehabilitation. Most previous studies were performed in patients with psychiatric disorders and used specific outcome measures on the level of community, vocational or social functioning.[32] This limits the comparison of results.

Regarding active coping, it was previously reported that problem-focused coping (e.g., active coping) starts to play a significant role in HRQoL five months after discharge.[8] Hence, the timing of assessment in the current study (~3months post-discharge) may explain the lack of an association between active coping and HRQoL and participation. Also, it should be noted that patients obtained relatively high scores on active coping which were comparable to those obtained by healthy individuals.[52]

The timing of assessment may have also played a role in the findings on motivation. Patients' motivation for rehabilitation was assessed about four weeks after admission to inpatient rehabilitation. At that time, most patients were relatively highly motivated for a rehabilitation treatment. Unmotivated patients may have been discharged before being approached for the study or they may have declined to participate. Alternatively, the instrument used to assess motivation (i.e., MOT-Q) may also explain the lack of a significant association with HRQoL and participation. Higher scores on the MOT-Q do not per se imply better motivation and may reflect socially desirable responding. For instance, some patients might be reluctant to admit not wanting to follow treatment advice in order to avoid making a negative impression.[37] Different motivation questionnaires measure different aspects of motivation, and may therefore yield other results on predictive validity.

For extraversion, no significant associations were found with HRQoL and participation. This is in agreement with previous findings that extraversion and HRQoL are unrelated in patients with stroke.[8] Other studies did however report a positive association between extraversion and life satisfaction in healthy individuals.[53,54]

Further, despite the perceived importance of self-awareness for rehabilitation success[55] and the previously reported relations between self-awareness and HRQoL[15] and participation,[13,14] the results of this study suggest otherwise. The lack of a significant association in the current study may be explained by differences in measures used to examine self-awareness. Previous studies[13-15] used the Awareness Questionnaire (AQ)[56] whereas the PCRS was used in the current study. A conceptual difference between these measures is that the AQ asks patients to rate their ability to perform certain tasks as compared to before their brain injury (e.g., much worse) whereas the PCRS asks patients about current competencies.[41]. Also, in the current study, ratings were compared between the patient and the neuropsychologist whereas in previous studies[13,14] ratings of the patient and a significant other were compared. In the current study, neuropsychologists were asked to complete the PCRS at the start of inpatient rehabilitation. That may have been too soon for a reliable judgement of a patient's self-awareness. This is illustrated by the fact that one quarter of neuropsychologists' ratings showed missing values varying from 1 to 8 items with a missing response.

Limitations of this study

This study has several limitations. First, although the studied neuropsychological factors significantly contributed to predicting HRQoL and participation, a considerable part of the variance remains unexplained. Based on previous studies, other demographic, injury-related or neuropsychological factors may have played a significant role in predicting patients' HRQoL and participation. For example, socioeconomic status, stroke severity,[57] locus of control, self-worth, hope, optimism,[8] cognitive complaints,[4] and, visual perception.[4,9,12] Regarding the latter, data on the presence of visuospatial neglect were available but showed unimpaired performance for the vast majority of patients (85.3%). Further, pre-injury factors may also contribute to patients' perceived post-injury functioning. In a previous study, a decrease in the frequency of participation between pre- and post-stroke was associated with more participation restrictions and lower satisfaction with participation.[58] Another study reported that pre-injury factors such as employment and learning problems, accounted for 6.7% of the variance in life satisfaction 1 year after TBI.[59]

A second limitation is the timing of the follow-up assessment. Patients' HRQoL and participation was assessed at one point in time; approximately three months after discharge from inpatient rehabilitation. Immediately after discharge from inpatient rehabilitation, 56 patients were referred to outpatient clinics for further treatment. We do not know exactly how many of these patients still were receiving outpatient treatment at follow-up assessment. However it is likely that some patients were still receiving outpatient treatment at follow-up which may have influenced their perceived HRQoL and participation.

Third, inherent to a longitudinal design is the risk of losing patients at follow-up. In total, 20% of patients were lost to follow-up for varying reasons. This may have biased the results.

Fourth, disparities in reported predictors of HRQoL and participation may be attributed to the use of different neuropsychological and outcome measures as compared to previous studies. Other measures of, for instance, motivation and self-awareness may have yielded different results. Also, relatively narrow measures were used to predict broad, subjective rehabilitation outcomes. That is, HRQoL and participation are container concepts which cover a wide variety of life domains (e.g., work, leisure, physical functioning). Narrow measures may be better at predicting narrow outcomes.

A final limitation is the total number of predictors that were examined in this study. Although the sample size was acceptable for the commonly used ratio of 10 patients per predictor, a 15:1 ratio is generally preferred. This implies that the sample size may be underpowered. Therefore, the results should be viewed with some caution and require replication in larger samples.

Conclusion

Neuropsychological functioning at the start of inpatient ABI rehabilitation play a role in predicting rehabilitation outcome three months after inpatient ABI rehabilitation. Particularly, a tendency towards passive coping was a strong predictor of poor HRQoL and participation after inpatient rehabilitation. These results emphasize the importance of assessing patients' coping styles in ABI rehabilitation. Further research is needed to evaluate the role of other neuropsychological factors in predicting rehabilitation outcomes and to examine methods of teaching effective coping strategies in an early phase post-ABI.

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CHAPTER 8

General discussion

The chapters in this thesis were arranged around the concepts of learning ability and learning style. The aims were to examine methods of measuring these concepts in patients with brain injury, and to determine the role of learning in predicting inpatient acquired brain injury (ABI) rehabilitation outcomes. In this chapter, the main findings are described followed by lessons learned, clinical implications, methodological considerations, directions for future research and our main conclusions.

Main findings

The online survey in **chapter 2** revealed that the vast majority of Dutch clinicians take learning ability into account when making a prognosis in patients with brain injury. Commonly used methods for the assessment of learning ability were cognitive tests and observations during therapy. Cognitive functioning, self-awareness and motivation were the top three most frequently mentioned factors perceived to influence learning ability of patients with brain injury. An aspect of learning ability is patients' potential to learn and benefit from training or guidance, their so-called 'cognitive learning potential'. A one-session dynamic cognitive testing procedure can be used to explore a patient's cognitive learning potential. In **chapter 3**, a systematic review was performed to provide clinicians and researchers insight into the concept and methodology of dynamic cognitive testing and to explore its added and predictive value in adult patients with cognitive impairments. The systematic review provided preliminary support that dynamic cognitive tests can provide a valuable addition to conventional cognitive tests to assess patients' cognitive abilities. Although promising, there was a large variability in methods used for dynamic cognitive testing. The most frequently used dynamic cognitive test was the dynamic Wisconsin Card Sorting Test (dWCST). In **chapter 4**, a prospective cohort study was performed to examine the validity of the dWCST in patients with ABI. This study showed that the dWCST has adequate psychometric properties in patients with ABI.

Regarding learning style, chapter 6 demonstrates that Dutch rehabilitation professionals were generally positive about using learning style in ABI rehabilitation. In the retrospective cohort study in **chapter 5**, the cognitive correlates of the Adapted Learning Style Inventory (A-LSI) were examined in patients with ABI. No support was found for an association between learning style and cognitive impairment, and in **chapter 6** doubts were raised about the validity and feasibility of the A-LSI for patients with ABI. Hence, the role of learning in predicting inpatient ABI rehabilitation outcomes could only be examined for cognitive learning potential and not for learning style. The results in **chapter 7** showed that neuropsychological factors, and in particular passive coping, significantly contributed to predicting health-related quality of life (HRQoL) and participation after inpatient rehabilitation when controlling for demographic and injury-related factors. Cognitive learning potential on the dWCST was, however, not a significant predictor of HRQoL and participation.

Lessons learned

Learning: what?

An important lesson learned is that concepts that are considered important in clinical practice are not necessarily those that are widely targeted in scientific research. In this respect, the concept of learning ability is a prime example. Since learning ability is considered paramount for rehabilitation success,[1] it is of high importance to define, operationalise and empirically study this concept. In an effort to select a measure for assessing patients' learning ability, clinical and research practice were explored. In this endeavour, the focus was on the measurement of learning ability rather than its definition. Hence, a caveat remains regarding the definition of learning ability. Unfortunately, in the online survey in chapter,[2] clinicians were not asked about their definition of learning ability. How learning ability is defined determines how it will be addressed. So, what is learning ability? Although this may sound like a relatively simple question, it is likely that different psychologists will give somewhat different answers given the lack of a clear definition of learning ability. In Psychology, learning is commonly defined as 'any relatively permanent change in behaviour that occurs as a direct result of experience',[2] and ability can be defined as 'possession of qualities required to do something; necessary skill, competence, or power'.[3] Taken together, learning ability would be defined as 'possession of qualities required for a relatively permanent change in behaviour that occurs as a direct result of experience'.

Even though there is not yet a consensus definition for learning ability, the vast majority of psychologists surveyed in chapter 2 reported to use cognitive tests to assess patients' learning ability. Thus, there seems to be a general agreement that cognition, and in particular memory, is an important aspect of learning ability. Anecdotally, several psychologists reported to use dynamic procedures in case of poor cognitive test performance (e.g., testing-the limits). These are, however, applied in an individualised, non-standardised manner. While we were writing chapter 3, we learned that such individualised dynamic methods are part of the concept dynamic assessment rather than dynamic testing. Dynamic testing refers to a transparent, objective and repeatable procedure whereas dynamic assessment covers procedures that are paired with clinical and highly individualised intervention.[4] Given the paucity of scientific research on standardised, one-session dynamic cognitive testing procedures in patients with ABI, it is not surprising that such procedures are not yet widely applied in neuropsychological rehabilitation.

To our knowledge, this thesis contains the first longitudinal study on a one-session dynamic cognitive test, the dynamic Wisconsin Card Sorting Test (dWCST), that was administered to patients in inpatient ABI rehabilitation. The dWCST was selected as it appeared to be a frequently used and promising dynamic cognitive test in patients with cognitive impairments (see chapter 3). From our prospective study in chapter 4, we learned that patients with ABI differ in their responsivity to brief training (i.e., their cognitive learning potential). This additional information about patients' abilities was obtained at the cost of only about 10 minutes extra administration time. Chapters 2 and 4 suggest that these between-patient differences in cognitive learning potential could partially be ascribed to patients' cognitive functioning particularly in the domains of language and memory.

We acknowledge that adequate cognitive performance is no guarantee for good learning ability in rehabilitation. Patients' conventional and dynamic cognitive test performance is only one aspect of their learning ability. Several factors can potentially influence, and thus complicate, a patient's learning process among which neuropsychological factors like self-awareness and motivation.[5] In line with that suggestion, Dutch clinicians in chapter 2 also perceived adequate self-awareness and sufficient motivation to be important prerequisites for learning ability in ABI rehabilitation. Altogether, this suggests that, when addressing a patient's learning ability, one should take a broad view on learning ability by looking beyond cognitive performance.

Learning: how?

An important finding in chapter 6 was that rehabilitation professionals were generally positive about using learning style in ABI rehabilitation. This is in accordance with a previous study that found paediatric rehabilitation professionals' to be positive about classifying learning styles in the context of teaching motor activities.[6] In that study, the feasibility of the learning style classifications of Kolb's original Learning Style Inventory (LSI) and Myers–Briggs Type Indicator (MBTI)[7] were examined qualitatively. In accordance with the results in chapter 6, the authors reported limited feasibility for the LSI and MBTI mainly due to the use of adult terminology, unsuitability in case of low levels of cognition, unclear descriptions about the test situations (e.g., therapy or class setting), and overlapping learning style descriptions.[6] This is partly in accordance with the negative aspects of the A-LSI that were reported in chapter 6; completion of the A-LSI requires a relatively high level of cognitive functioning and the items are not always well comprehended.

Unfortunately we did not succeed in validating a learning style instrument for patients with ABI (chapter 6). The key difference with most previous studies on learning styles is that we included patients with ABI rather than healthy individuals. Differences in age, context (education vs. rehabilitation) and neuropsychological abilities hamper the comparison of results. Neuropsychological and motor deficits may require patients to approach learning situations in a different manner compared to before their ABI. In the process of recovery, patients may take on a more active role in their learning process. This may again induce changes regarding a patient's learning needs and preferences. This is supported by patients' responses while completing the A-LSI. Several patients reported discrepancies in their pre- and post-injury learning style as well as differences in learning style preferences across situations (e.g., therapy versus work). This is in line with Kolb's theory which considers learning styles to be flexible and relatively situation-specific.[8]

Although the findings in chapters 5 and 6 were largely non-significant, we would like to stress that these studies are among the first studies that examined learning styles in patients with ABI. In two previous studies,[9,10] the Verbalizer-Visualizer Questionnaire (VVQ)[11] was administered to patients with ABI. The VVQ examines patients' tendency to use visual or verbal strategies during information processing. When solving a problem, one patient may prefer to use visual imagery whereas another person prefers a verbal mode of thinking.[9] Although the psychometric properties of the VVQ have not yet been examined in patient with ABI, several interesting findings were reported in those studies. The authors suggested that patients may use learning strategies that do not match their cognitive abilities.[9] It has, for example, been reported that the tendency to visualise was high in patients with visuospatial neglect and low in patients with impairments in attention and memory.[10] These findings support our conclusion that learning style and cognitive dysfunction are independent in patients with ABI (see chapter 5).

Role of learning in predicting brain injury rehabilitation outcomes

Given the lack of a well-validated learning style instrument, we only examined the predictive role of cognitive learning potential along with several other neuropsychological factors that were perceived as important barriers for learning according to chapter 2. Despite promising results in other cognitively impaired patient populations (see chapter 3), the role of cognitive learning potential in predicting ABI rehabilitation outcomes was not supported in chapter 7. However, several other neuropsychological factors, that were perceived to substantially influence learning in chapter 2, did show a significant relation with HRQoL and participation. The strongest neuropsychological predictor, passive coping, may influence HRQoL and participation indirectly through its effect on the learning process. As mentioned in chapter 7, a passive coping style implies a tendency to not taking any action when problems or changes occur. Obviously, learning or relearning skills requires a great deal of effort and commitment on the part of the patient.

Clinical implications

When using the concept of learning ability in clinical practice, it is important to realise that it is a poorly defined concept. Learning is often used as synonym for memory and, therefore, the term learning ability may be prone to misinterpretation. Further, different rehabilitation professionals may use other sources of information to estimate patients' learning ability. A physical therapist may, for instance, judge patients' learning ability on a patient's functional task performance whereas a psychologist may use cognitive test results for this purpose. This emphasises the need for a multidisciplinary perspective when evaluating patients' learning ability. Herewith, patients' learning ability should preferably be discussed in the context of a specific, well-defined learning goal.

Regarding dynamic cognitive testing, it should be noted that little research has been done on this topic in an ABI population. Clearly, this limits its clinical implementation. There is an ongoing debate regarding the generalisability of cognitive learning potential.[12] It is unclear whether patients with ABI who have poor cognitive learning potential on the dWCST, also obtain poor scores on other dynamic cognitive tests. It is possible that cognitive learning potential is domain-specific or even test-specific. Conventional cognitive tests are basically subject to the same problem. Poor performance on a memory test does not necessarily imply a memory deficit. In clinical practice, a common guideline for cognitive impairment is failure of at least two tests within the same domain. This cut-off may also apply when evaluating a patient's cognitive learning potential. This would imply that a patient would need to perform poorly on two dynamic cognitive tests before concluding that a patient's cognitive learning potential is compromised. Obviously, test results should be interpreted in combination with other findings and observations. Particularly to examine why a patient showed poor cognitive learning potential.[13]

Further, one should keep in mind that different learning theories can offer other explanations for a patient's test performance.[13] Adequate cognitive learning potential may, for instance, be explained by positive reinforcement by the psychologist (behavioural learning theory), the provision of additional instructions which yields better understanding of the task (cognitive learning theory), or patients' willingness to work harder to meet a personally relevant goal (social learning theory).[13] In addition, when conventional and dynamic cognitive tests are used to examine patient's learning ability, we would like to stress that such tests take a relatively narrow focus on learning, restricted to cognitive learning. In terms of the ICF[14] chapter 'learning and applying knowledge', dynamic cognitive testing procedures are best covered by the subchapter 'applying knowledge'. Knowledge about patients' learning ability can, for instance, be extended by focusing on the other two ICF subchapters 'purposeful sensory experiences' (e.g., watching, listening) and 'basic learning' (e.g., learning to read and write). Several other concepts may also provide valuable additional information on patients' learning skills (e.g., motor learning).

Concerning the use of learning styles in ABI rehabilitation, we strongly advice not to use the A-LSI to examine patients' learning style. At this point, conclusions about the appropriateness of other existing learning style measures for ABI rehabilitation are premature. So should clinicians still care about learning styles? Yes and no. Yes because we believe it is important that clinicians are aware that patients' can differ in what they can learn but also in how they learn. No because of the limited knowledge base concerning the assessment of learning styles in an ABI population. More research is required to determine the extent to which findings from studies in other populations are applicable in ABI rehabilitation. Although research in other populations or settings provide a good starting point for research into learning style and learning in general, caution is recommended when adopting or adapting such knowledge in an ABI rehabilitation setting. This requires research into issues such as feasibility and validity. However, since learning is a key ingredient of rehabilitation, this should by no means discourage future researchers from exploring the applicability of educational and didactic concepts in an ABI rehabilitation setting.

Methodological considerations

Strengths

A strength of the studies in this thesis is the use of qualitative and quantitative research methods to study learning ability and learning style. We evaluated expert opinion, executed a systematic review and performed retrospective and prospective cohort studies. Although expert opinion is commonly regarded a low level of evidence, it was a good starting point to examine methods of assessing learning ability given the lack of research evidence. The same accounts for the retrospective analyses in chapters 5 and 6. Given the paucity of studies examining learning style in a patient population or treatment setting, we considered it important to start with evaluating an existing learning style instrument to gain familiarity and experience with learning style in ABI rehabilitation. Further, a strength of the prospective study described in chapter 7 is its longitudinal, multicenter design.

Limitations

Besides the methodological limitations mentioned in the individual chapters, there are several overarching limitations that affect the generalisability and reliability of the findings in this thesis. The generalisability of the results are limited by the mixed aetiology of the patient samples and the inpatient rehabilitation setting. However, we were interested in all patients with ABI, naturally occurring in a rehabilitation setting, irrespective of diagnosis. Particularly diagnostic groups that are commonly referred to a neuropsychologist for neuropsychological evaluation to provide a good representation of current neuropsychological practice. Further, with exception of the systematic review, all studies in this thesis were performed in the Netherlands. Generalisability to other countries may be limited due to differences in healthcare. However, cognitive and physical sequelae after ABI are similar across countries and, therefore, it is believed that the samples are representative.

Directions for future research

Learning profiles

Ascertaining that a patient has poor cognitive learning potential on the dWCST or another dynamic cognitive test raises the question as to why the patient performed poorly. Besides cognitive impairments, patients' test performance can be negatively influenced by a variety of factors such as fatigue, pain, motivation, anxiety, stress, depression, and frustration.[15] For future research, it would be interesting to determine the characteristics of patients with poor cognitive learning potential. Besides assessing neuropsychological characteristics of poor cognitive learning potential, one can also examine relations between neuronal networks and cognitive learning potential. In previous studies, it was, for example, reported that different neuronal networks were involved in patients with schizophrenia compared to healthy controls while completing the dWCST.[16,17] Establishing comprehensive learning profiles may provide useful information for consequent rehabilitation treatments.

Translating assessment to treatment

The ultimate goal of assessing patients' cognitive learning potential or learning style was to facilitate learning, optimise learning outcomes, and to further tailor treatment to individual patients' needs and preferences. However, before dynamic cognitive testing procedures and learning style assessments can help bridge the so-called 'gap' between assessment and treatment, ample knowledge about the 'active ingredients' of rehabilitation treatments is required. Active ingredients refer to treatment characteristics that are most powerful for inducing change in performance.[18] An important first step may be to identify teaching techniques that have a sound evidence base. The important role of feedback in learning is, for instance, well documented.[19] Also, beneficial effects have been reported for the use of distributed practice, expanded rehearsal, variability of practice and state dependent learning on the learning process.[20,21] More information about the active ingredients of rehabilitation treatments may eventually provide valuable information about learning competencies required for specific treatments. With respect to dynamic cognitive testing, it may be informative to match the active ingredients of a particular rehabilitation treatment with specific dynamic training methods. This may provide a priori information about the feasibility of a particular treatment. If the active ingredients of a treatment are, for example, feedback and expanded instruction, the dWCST may be an appropriate dynamic cognitive test to examine patients' suitability for that specific treatment. In contrast, if feedback and strategy training are the most powerful treatment ingredients, the dynamic CVLT-II may be the test of choice.

One can also attempt to bridge the gap between assessment and treatment by using technological advances in assessing patients' learning skills. Since learning is often facilitated in a multisensory environment,[22] Virtual Reality may be a valuable technological resource. Virtual Reality simulators offer the possibility to more closely mimic actual learning situations including environmental distractions.[23] An example is the 15-minute Virtual Reality Cognitive Performance Assessment Test (VRCPAT)[24] which yields separate scores for learning and memory.

Facilitating the learning process

In neuropsychological rehabilitation, increasing attention is being given to errorless (ELL) and errorbased (EBL) learning principles to teach new information or skills to patients with cognitive impairments. In contrast to trial-and-error (or errorful) learning, ELL is an externally focused bottom-up approach where errors are prevented,[25] and EBL is an internally focused top-down approach where a patient learns to monitor and correct their own errors.[26] EBL is said to pose an advantage over ELL as it is supposed to promote generalisation of skills to novel tasks by teaching patients how to anticipate, monitor and correct their own errors.[26] In an ongoing RCT in Australia, it is examined whether EBL actually elicits greater error self-regulation and self-awareness compared to ELL in outpatients with severe traumatic brain injury.[26] Besides comparing the effectiveness of ELL and EBL, it would be interesting to examine neuropsychological and neurological characteristics of patients who profit most from ELL and those who benefit most from EBL. In the context of cognitive learning potential, it can be hypothesised that patients with poor cognitive learning potential profit most from ELL while EBL may be more suitable for patients with good cognitive learning potential. In line with these hypotheses, one study[27] already showed evidence for a short-term beneficial effect of ELL over conventional work skills training in patients with schizophrenia or schizoaffective disorder who had poor cognitive learning potential.

Conclusions

The findings in this thesis contribute to our understanding of learning concepts after ABI and can act as a starting point for further research into learning style and learning ability. In this sense, this thesis sheds some light on the 'black box of learning' by determining that:

- Clinicians considered learning ability as one of the most important factors for the success of ABI rehabilitation. They mainly use cognitive tests to assess patients learning ability. Dynamic cognitive tests, and in particular the dWCST, were shown to be a promising addition to conventional cognitive tests to assess patients' abilities. In patients with ABI, the dWCST showed good psychometric properties.

- Clinicians were generally positive about learning style assessment in rehabilitation. The measure used to assess learning style, the A-LSI, showed no association with cognitive functioning and questionable psychometric properties.

- Neuropsychological factors significantly contributed to predicting patients' physical and psychosocial HRQoL, participation restrictions and satisfaction with participation. Patients' cognitive learning potential on the dWCST was not significantly associated with HRQoL and participation.

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Summary

Neuropsychological impairments are common following acquired brain injury (ABI). These include impairments in cognitive, emotional, psychosocial, and behavioural functioning. Patients with ABI are often referred to a neuropsychological rehabilitation program to learn how to manage such 'hidden' deficits. During neuropsychological rehabilitation, patients re-learn old skills and learn new skills to optimize social participation and quality of life. When the organ that is responsible for learning – the brain – has suffered damage, the learning process can be considerably disturbed. Brain damage can influence *what* is learned, but also *how* learning takes place.

Chapter 1 presents a general introduction which starts with a brief outline of the concepts ABI and neuropsychological rehabilitation. Subsequently, *what* patients can learn is viewed in terms of learning ability and *how* patients learn in terms of learning style. In an effort to expand our knowledge of learning ability and learning styles following ABI, a research project was conducted. This project was funded by the National Initiative Brain and Cognition (NIBC) and embedded in the pillar 'The Healthy brain, Program Cognitive Rehabilitation'. The general objective of this thesis was to explore the concepts of learning ability and learning style in patients with ABI. This thesis had the following three aims (a) examining methods of measuring learning ability in patients with ABI; (b) examining methods of measuring learning style in patients with ABI; and (3) determining the role of learning ability and learning style in predicting outcomes in ABI rehabilitation.

Chapter 2 focuses on the concept learning ability. Patients' learning ability is frequently discussed in brain injury rehabilitation practice and is perceived to be important for rehabilitation success. The scientific literature, however, provides little insight into this complex concept. To gain more knowledge about learning ability and barriers for learning, we started with exploring current clinical practice in chapter 2. An online survey was completed by 37 physicians, 83 psychologists and 43 therapists. The survey enquired whether clinicians take learning ability into account; about factors influencing learning ability; and about assessment tools used to assess learning ability. The survey revealed that the vast majority of clinicians take learning ability into account when making a prognosis. Learning ability was perceived to be influenced mainly by cognition, motivation and self-awareness. Assessment methods that were frequently used to assess learning ability were cognitive tests and observations during therapy. Thus, in chapter 2, it was concluded that a patient's learning ability may be influence by not only cognition but also by motivation and self-awareness. Structured and standardized assessment of these factors may be suggested for standard use in clinical practice.

An aspect of learning ability is patients' potential to improve cognitive performance in response to training or guidance, their so-called ‘cognitive learning potential’. A standardized assessment method that has been used in various populations to examine cognitive learning potential is dynamic testing. Dynamic testing is an umbrella term for procedures that examine the effects of brief training on test performance (test-train-test procedure). **Chapter 3** presents a systematic review on the methodology and predictive value of dynamic cognitive testing procedures that were administered in one session to patients with cognitive impairments. The majority of 24 studies were performed in patients with psychiatric diseases and relatively few in patients with ABI or neurodegenerative diseases. In total, 11 dynamic cognitive tests were applied of which the dynamic Wisconsin Card Sorting Test (dWCST) was the most frequently used. The review showed a lack of consensus regarding the content of the brief training and the computational methods that were used to quantify cognitive learning potential. In most studies, the training consisted of a combination of performance feedback, reinforcement, expanded instruction, or strategy training. Learning potential was quantified using numerical (post-test score, difference score, gain score, regression residuals) and categorical (groups) indices. Furthermore, several longitudinal studies in the systematic review found that dWCST learning potential was a significant predictor of rehabilitation outcome and that the dWCST provided unique information beyond the conventional WCST in predicting outcome. Altogether, the review provided preliminary support that dynamic cognitive testing, and in particular the dWCST, can provide a valuable addition to conventional cognitive tests to assess patients’ cognitive abilities.

Little is known about the feasibility and psychometric properties of the dWCST in patients with ABI. Further psychometric validation of the dWCST would provide researchers and clinicians with a better understanding of what the dWCST actually measures and how to interpret test results. Therefore, in **chapter 4** the validity of the dWCST was examined prospectively in patients with ABI. Patients completed the dWCST at the start of inpatient rehabilitation (n = 104). The median dWCST administration time was 30 minutes. The dWCST showed no floor or ceiling effects and the numerical cognitive learning potential indices (post-test and gain score) were significantly intercorrelated. The dWCST pre-test score showed no significant associations with other cognitive tests, whereas the numerical cognitive learning potential indices were significantly associated with tests measuring language and/or memory. To examine whether pre- to post-test improvement reflects a practice effect, an additional group of patients with ABI were administered the conventional WCST according to a test-test-test procedure (repeated WCST; rWCST). The rWCST did not include a training phase. The scores of patients in the dWCST (n = 63) and rWCST (n = 28) group were compared. In contrast to the dWCST group, the rWCST group did not show significant improvement between the pre- and post-test. This suggests that the dWCST measures cognitive learning potential opposed to practice effects. Furthermore, dWCST performance was compared between patients with ABI (*n* = 63) and matched healthy controls (*n* = 30). Compared to healthy controls, patients obtained similar pre-post gains but significantly lower pre- and post-test scores. The ratio of poor learners between-groups was not significantly different. This is partial support for the sensitivity of the dWCST to discriminate patients from controls. Altogether, the results in chapter 4 support the feasibility and validity of the dWCST for assessing cognitive learning potential in patients with ABI.

In clinical practice, it is not only important to examine what patients can learn, but also to determine the way patients prefer to approach or choose learning situations, their so-called learning style. In healthy individuals, there is preliminary evidence that learning styles are associated with specific cognitive skills. Therefore, in **chapter 5** it was retrospectively explored whether learning styles are associated with specific cognitive impairments in patients with ABI. In this chart review study, we used data from files of 92 patients with ABI referred to inpatient rehabilitation. From the routine neuropsychological assessment, we used cognitive tests for the following four major cognitive domains: attention, memory, perception and executive functioning. We selected patients who completed the Adapted Learning Style Inventory (A-LSI) and at least one of the cognitive tests. No significant associations were found between learning style and cognitive impairment. The results of this exploratory study suggest that learning style and cognitive impairment are independent in inpatients with ABI.

One of the possible explanations for the lack of an association between learning style and cognitive disfunctioning in chapter 5 was that the learning style instrument, the A-LSI, was not a valid instrument to assess learning style in inpatients with ABI. Therefore, in **chapter 6** the validity and feasibility of the A-LSI was examined retrospectively. The aims were to determine the distribution of learning styles in patients with ABI (*n* = 99) and healthy controls (*n* = 42); to evaluate the validity of the A-LSI in patients with ABI (n = 99); and to evaluate rehabilitation professionals' perceptions (*n* = 12) on the A-LSI and learning style in general. The results showed that the vast majority of patients and healthy controls had an 'observer' or 'thinker' learning style and only few had a 'doer' or 'decider' learning style. This skewed distribution may be explained by the moderate internal validity of the A-LSI. Nonetheless, the majority of patients and controls had some degree of recognition of the A-LSI learning style indicating moderate content validity. The qualitative evaluation revealed that rehabilitation professionals were generally positive about using learning style in ABI rehabilitation. The rehabilitation professionals reported positive and negative aspects of the A-LSI and suggestions for using learning style in rehabilitation. Chapter 6 concludes that, although rehabilitation professionals were positive about the concept of learning style, the study raised doubts about the validity and feasibility of the A-LSI for this population.

Besides assessing patients' abilities and preferences in the area of learning, it is of interest to determine whether such information contributes to predicting patients' functioning on the long term. In **chapter 7** the role of learning, as compared to other neuropsychological factors, in predicting rehabilitation outcomes was examined. This was done in a prospective, longitudinal cohort study. Given the lack of a valid instrument to assess patients' learning style, the role of learning in predicting inpatient ABI rehabilitation outcomes could only be examined for cognitive learning potential and not for learning style. First, we assessed associations between neuropsychological factors and health-related quality of life (HRQoL) and participation three months after discharge from inpatient ABI rehabilitation. Second, the best neuropsychological predictor of HRQoL and participation was determined after controlling for demographic and injury-related factors. Patients with ABI were assessed within approximately two weeks of enrolment in inpatient rehabilitation. Predictor variables included demographic and injury-related characteristics and the following neuropsychological factors: active and passive coping, attention, executive functioning, verbal memory, cognitive learning potential, depressive symptoms, motivation, extraversion, neuroticism and self-awareness. Within approximately two weeks of enrolment in inpatient rehabilitation, several tests and questionnaires were administered to patients with ABI. The results showed that neuropsychological functioning, and in particular passive coping, play a significantly role in predicting HRQoL and participation after inpatient rehabilitation when controlling for demographic and injury-related factors. With respect to learning, cognitive learning potential was not associated with HRQoL nor with participation.

Chapter 8, the general discussion, provides a brief summary of the main findings of this thesis. The results are discussed in terms of lessons learned and implications for clinical practice. This is followed by methodological considerations in which strengths and limitations of the studies in this thesis are mentioned. Subsequently, directions for future research are given. These include directions for the assessment of specific learner profiles, for translating assessment results into treatment advice, and for the use of errorless and errorbased learning when attempting to facilitate the learning process. It was concluded that the findings in this thesis contribute to our understanding of learning after ABI and can act as a starting point for further research into concepts such as learning style and learning ability.

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Samenvatting (Dutch summary)

Neuropsychologische problemen komen frequent voor bij patiënten met niet-aangeboren hersenletsel (NAH). Deze omvatten problemen in het cognitief, emotioneel, psychosociaal en gedragsmatig functioneren. Om patiënten zo goed mogelijk te leren omgaan met dergelijke 'onzichtbare' gevolgen worden zij vaak verwezen voor deelname aan een neuropsychologisch revalidatieprogramma. Neuropsychologische revalidatie is gericht op het leren van nieuwe vaardigheden en het herleren van oude vaardigheden om zo de sociale participatie en kwaliteit van leven van patiënten te optimaliseren. Wanneer het orgaan dat verantwoordelijk is voor leren – het brein – beschadigd is, kan het leerproces aanzienlijk verstoord zijn. Hersenletsel kan beïnvloeden *wat* patiënten kunnen leren, maar ook *hoe* zij leren.

In **hoofdstuk 1** wordt een algemene introductie gegeven waarin de concepten NAH en neuropsychologische revalidatie worden toegelicht. *Wat* patiënten kunnen leren wordt vervolgens besproken in termen van leerbaarheid en *hoe* patiënten leren in termen van leerstijl. Om onze kennis over de concepten leerbaarheid en leerstijl na NAH te vergroten is een onderzoeksproject uitgevoerd. Dit project is gefinancierd door het Nationaal Initiatief Hersenen en Cognitie (NIHC) en maakt deel uit van de pijler 'Het Gezonde Brein, Programma Cognitieve Revalidatie'. Het doel van dit proefschrift was om de concepten leerbaarheid en leerstijl te verkennen in patiënten met NAH. Dit werd gedaan aan de hand van de volgende drie onderzoeksdoelen: (a) onderzoeken van methoden om leerbaarheid te meten bij patiënten met NAH; (b) onderzoeken van methoden om leerstijlen te meten bij patiënten met NAH; en (3) vaststellen of leerbaarheid en leerstijl een rol spelen in het voorspellen van revalidatie-uitkomsten bij patiënten met NAH.

Hoofdstuk 2 richt zich op het concept leerbaarheid. De leerbaarheid van patiënten wordt vaak besproken in de revalidatie bij hersenletsel en wordt gezien als een belangrijke factor voor revalidatiesucces. De wetenschappelijke literatuur geeft echter weinig inzicht in dit complexe concept. Om kennis op te doen over leerbaarheid en leerbarrières, zijn we in hoofdstuk 2 gestart met het verkennen van de huidige klinische praktijk. In totaal hebben 37 artsen, 83 psychologen en 43 therapeuten een online enquête ingevuld. In de enquête werd aan clinici gevraagd of zij leerbaarheid meenemen in de prognostiek; over factoren die leerbaarheid kunnen beïnvloeden; en over meetmethoden die zij gebruiken om leerbaarheid te meten. Volgens de enquête neemt de overgrote meerderheid van de clinici leerbaarheid mee in de prognostiek. Volgens clinici wordt leerbaarheid vooral beïnvloed door cognitie, motivatie en inzicht. Meetmethoden die frequent worden gebruikt om leerbaarheid in kaart te brengen zijn cognitieve tests en observaties tijdens therapie. In hoofdstuk 2 werd geconcludeerd dat de leerbaarheid van patiënten niet alleen lijkt samen te hangen met cognitie, maar ook met motivatie en inzicht. Voor de klinische praktijk wordt aanbevolen om deze factoren op gestructureerde en gestandaardiseerde wijze in kaart brengen.

Een aspect van leerbaarheid is ‘cognitieve leerpotentie’. Dit is het vermogen van patiënten om hun cognitieve testprestaties te verbeteren wanneer training of begeleiding wordt gegeven. Dynamisch testen is een gestandaardiseerde meetmethode die in meerdere populaties is gebruikt om cognitieve leerpotentie te meten. Dynamisch testen is een paraplubegrip voor procedures waarbij gekeken wordt naar het effect van een kortdurende training op de testprestatie (test-train-test procedure). **Hoofdstuk 3** presenteert een systematisch literatuuronderzoek naar de methodologie en voorspellende waarde van dynamische cognitieve test procedures die in één sessie zijn afgenomen bij patiënten met cognitieve problemen. De meerderheid van de 24 studies waren uitgevoerd in patiënten met een psychiatrische aandoening en relatief weinig studies in patiënten met NAH of een neurodegeneratieve ziekte. De dynamische Wisconsin Card Sorting Test (dWCST) werd het meest frequent gebruikt. Het literatuuronderzoek toonde aan dat er een gebrek aan consensus is wat betreft de inhoud van de kortdurende training en de methoden die worden gebruikt om de mate van cognitieve leerpotentie te kwantificeren. De training bestond meestal uit een combinatie van prestatiefeedback, bekrachtiging, aanvullende instructies of strategietraining. De mate van leerpotentie werd gekwantificeerd aan de hand van numerieke (post-test score, verschilscore, gain score, regressie residuen) en categorische (leergroepen) maten. In verscheidene longitudinale studies in het systematische literatuuronderzoek werd geconcludeerd dat leerpotentie op de dWCST een significante voorspeller was van revalidatie-uitkomsten en dat de dWCST unieke informatie bood ten opzichte van de conventionele WCST bij het voorspellen van uitkomsten. Het literatuuronderzoek bood bewijs dat dynamisch testen en in het bijzonder de dynamische Wisconsin Card Sorting Test (dWCST), een aanvulling kan zijn op conventionele cognitieve tests bij het in kaart brengen van het cognitief functioneren van patiënten.

Over de bruikbaarheid en psychometrische eigenschappen van de dWCST bij patiënten met NAH is weinig bekend. Onderzoek naar de psychometrische eigenschappen van de dWCST geeft onderzoekers en clinici beter inzicht in wat de dWCST meet en hoe de testresultaten moeten worden geïnterpreteerd. Daarom is in **hoofdstuk 4** de validiteit van de dWCST prospectief onderzocht in patiënten met NAH. De dWCST is bij 104 patiënten met NAH afgenomen bij start van de klinische revalidatie. Het afnemen van de dWCST kostte 30 minuten (mediaan). De dWCST liet geen vloer- of plafondeffecten zien en er was een significant verband tussen de numerieke cognitieve leerpotentie maten (post-test en gain score). De dWCST pre-test score liet geen significante associaties zien met andere neuropsychologische tests. De twee numerieke cognitieve leerpotentie scores waren significant geassocieerd met tests op het gebied van taal en/of geheugen. Om te bepalen of oefeneffecten een rol spelen in vooruitgang tussen de pre- en post-test werd bij een aanvullende groep patiënten met NAH de conventionele WCST afgenomen volgens een test-test-test procedure (repeated WCST; rWCST). Bij de rWCST werd geen training aangeboden. De scores van de patiënten in de dWCST (*n* = 63) en rWCST (*n* = 28) groep werden met elkaar vergeleken. In tegenstelling tot de dWCST groep, werd in de rWCST groep geen significante vooruitgang gezien tussen de pre- en post-test score. Dit resultaat suggereert dat de dWCST cognitieve leerpotentie meet en geen oefeneffect. Verder is de prestatie op de dWCST vergeleken tussen patiënten met NAH (*n* = 63) en gezonde controles (*n* = 30). De gezonde controles en de patienten lieten een vergelijkbare vooruitgang zien tussen de pre- en post-test. Patiënten behaalden echter significant lagere pre- en post-test scores dan controles. Het aantal poor learners was niet significant verschillend tussen de twee groepen. Er was dan ook gedeeltelijk bewijs voor de sensitiviteit van de dWCST om onderscheid te maken tussen patiënten en controles. Tezamen genomen, lijkt de dWCST een valide instrument voor het meten van cognitieve leerpotentie bij patiënten met NAH.

In de klinische praktijk is het niet alleen belangrijk om te bepalen wat patiënten kunnen leren, maar ook is het belangrijk om te bepalen hoe een patiënt leersituaties benadert of kiest, hun zogenaamde leerstijl. Bij gezonde personen zijn er aanwijzingen voor een relatie tussen leerstijlen en specifieke cognitieve vaardigheden. Daarom is in **hoofdstuk 5** op retrospectieve wijze onderzocht of leerstijlen zijn geassocieerd met specifieke cognitieve stoornissen in patiënten met NAH. In dit onderzoek, hebben we de dossiers van 92 patiënten met NAH in de klinische revalidatie onderzocht. We hebben cognitieve tests geselecteerd voor de volgende vier cognitieve domeinen: aandacht, geheugen, perceptie en executief functioneren. Patiënten werden geselecteerd als zij de Adapted Learning Style Inventory (A-LSI) hadden ingevuld en ten minste één van de cognitieve tests was afgenomen. Er werden geen significante associaties gevonden tussen leerstijl en de cognitieve stoornissen. De resultaten van deze exploratieve studie suggereren dat leerstijl en cognitieve stoornissen niet samenhangen bij patiënten met NAH.

Een van de mogelijke verklaringen voor het gebrek aan een associatie tussen leerstijl en cognitief functioneren in hoofdstuk 5 is dat de door ons gebruikte leerstijl vragenlijst, de A-LSI, geen valide instrument is om leerstijlen te meten bij patiënten met NAH. Daarom is in **hoofdstuk 6** op retrospectieve wijze de validiteit en bruikbaarheid van de A-LSI onderzocht. De doelen van dit onderzoek waren: (a) vaststellen van de verdeling van leerstijlen bij patiënten met NAH (*n* = 99) en gezonde controles (*n* = 42); evalueren van de validiteit van de A-LSI bij patiënten met NAH (*n* = 99); en evalueren hoe revalidatieprofessionals staan tegenover het gebruik van de A-LSI en leerstijl in het algemeen. De resultaten lieten zien dat de overgrote meerderheid van patiënten en gezonde controles een ‘dromer’ of ‘denker’ leerstijl hadden en slechts enkelen hadden een ‘doener’ of ‘beslisser’ leerstijl. Deze scheve verdeling kan worden verklaard door de matige interne validiteit van de A-LSI. Desalniettemin gaf de meerderheid van de patiënten en controles aan enige mate van herkenning te hebben van de aangegeven A-LSI leerstijl. Dit geeft aan dat de A-LSI matige inhoudsvaliditeit heeft. Revalidatieprofessionals waren over het algemeen positief over het gebruik van leerstijlen in de NAH revalidatie. De revalidatieprofessionals rapporteerden positieve en negatieve aspecten van de A-LSI en suggesties voor het gebruik van leerstijlen in de revalidatie. In hoofdstuk 6 werd geconcludeerd dat revalidatieprofessionals positief zijn over het concept leerstijl, maar dat de validiteit en bruikbaarheid van de A-LSI voor deze populatie onvoldoende is.

Naast het in kaart brengen van de vaardigheden en voorkeuren van patiënten op het gebied van leren, is het interessant om te bepalen of zulke informatie daadwerkelijk bijdraagt aan het voorspellen van het functioneren van patiënten op de lange termijn. In **hoofdstuk 7** is de rol van leren, ten opzichte van andere neuropsychologische factoren, in het voorspellen van revalidatie-uitkomsten onderzocht. Dit is gedaan in een prospectieve, longitudinale cohort studie. Vanwege het gebrek aan een valide instrument om leerstijlen te meten is de rol van leren alleen onderzocht voor cognitieve leerpotentie en niet voor leerstijl. In het onderzoek is eerst gekeken naar associaties tussen neuropsychologische factoren en gezondheidsgerelateerde kwaliteit van leven kwaliteit van leven en participatie drie maanden na ontslag van klinische NAH revalidatie. Vervolgens is bepaald welke neuropsychologische factor de beste voorspeller was van gezondheidsgerelateerde kwaliteit van leven en participatie wanneer gecontroleerd wordt voor demografische en letselgerelateerde factoren. Potentiële voorspellers waren demografische en letselgerelateerde factoren en de volgende neuropsychologische factoren: actieve en passieve coping, aandacht, executief functioneren, verbaal geheugen, cognitieve leerpotentie, depressieve symptomen, motivatie, extraversie, neuroticisme en inzicht. Binnen ongeveer twee weken na klinische opname werden verschillende tests en vragenlijsten afgenomen om deze factoren te meten. De resultaten lieten zien dat neuropsychologisch functioneren, en in het bijzonder passieve coping, een significante rol speelt in het voorspellen van gezondheidsgerelateerde kwaliteit van leven en participatie na de klinische revalidatie wanneer gecontroleerd wordt voor demografische en letselgerelateerde factoren. Cognitieve leerpotentie, gemeten bij opname, was niet significant geassocieerd met gezondheidsgerelateerde kwaliteit van leven en participatie drie maanden na ontslag.

IHoofdstuk 8, de algemene discussie, biedt een korte samenvatting van de belangrijkste bevindingen van dit proefschrift. De resultaten worden bediscussieerd in termen van geleerde lessen en implicaties voor de klinische praktijk. Dit wordt gevolgd door methodologische overdenkingen waarbij de sterke kanten en beperkingen van de studies in dit proefschrift worden besproken. Vervolgens worden suggesties gedaan voor vervolgonderzoek. Deze betreffen suggesties voor het in kaart brengen van specifieke leerprofielen, voor de vertaling van testresultaten naar behandeladviezen en voor het gebruik van errorless en errorbased leren om het leerproces te faciliteren. Er wordt geconcludeerd dat de bevindingen in dit proefschrift bijdragen aan ons begrip van leren na NAH en als startpunt kunnen fungeren voor verder onderzoek naar concepten als leerstijl en leerbaarheid.

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*

About the author

Curriculum Vitae

Hileen Boosman werd op 9 oktober 1985 geboren te Oldeberkoop. Zij behaalde in 2004 haar VWO-diploma aan het Linde College te Wolvega. Van 2004 tot 2008 studeerde zij Psychologie aan de Universiteit Utrecht waar ze afstudeerde in de richting Neuropsychologie. In de twee daaropvolgende jaren heeft zij gewerkt als psycholoog op de neurologische revalidatie van verpleeghuis Ter Valcke te Goes. Tegelijkertijd was zij werkzaam als junior onderzoeker bij het Universitair Medisch Centrum Utrecht (UMC Utrecht) en De Hoogstraat Revalidatie. In 2010 is ze gestart met een promotieonderzoek bij het Kenniscentrum Revalidatiegeneeskunde Utrecht. In het laatste jaar van haar promotie heeft ze internationale onderzoekservaring opgedaan bij neuropsycholoog en internationaal gerenommeerd onderzoeker dr. Tamara Ownsworth aan Griffith University te Brisbane, Australië. Momenteel is zij werkzaam als postdoc in het Kenniscentrum Revalidatiegeneeskunde Utrecht.

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