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Neuropsychological rehabilitation for traumatic brain injury patients

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Abstract

The aim of this review is to discuss the basic forms of neuropsychological rehabilitation for patients with traumatic brain injury (TBI). More broadly, we discussed cognitive rehabilitation therapy (CRT) which constitutes a fundamental component in therapeutic interaction at many centres worldwide. Equally presented is a comprehensive model of rehabilitation, the fundamental component of which is CRT. It should be noted that the principles of this approach first arose in Poland in the 1970s, in other words, several decades before their appearance in other programmemes. Taken into consideration are four factors conditioning the effectiveness of such a process: comprehensiveness, earlier interaction, universality and its individualized character. A comprehensive programmeme of rehabilitation covers: cognitive rehabilitation, individual and group rehabilitation with the application of a therapeutic environment, specialist vocational rehabilitation, as well as family psychotherapy. These training programmemes are conducted within the scope of the 'Academy of Life,' which provides support for the patients in their efforts and shows them the means by which they can overcome existing difficulties. Equally emphasized is the close cooperation of the whole team of specialists, as well as the active participation of the family as an essential condition for the effectiveness of rehabilitation and, in effect, a return of the patient to a relatively normal life. Also presented are newly developing neurothechnologies and the neuromarkers of brain injuries. This enables a correct diagnosis to be made and, as a result, the selection of appropriate methods for neuropsychological rehabilitation, including neurotherapy.

Key words

executive dysfunctions, behavioural changes, cognitive rehabilitation therapy, neurotherapy, ERP's

INTRODUCTION

The rehabilitation of patients after brain injury is a global problem, one with which modern medicine is attempting to grapple [1]. Each year, it is estimated that 1.7 million people in the United States sustain a TBI. From 2000 – 2010, the number of military service members diagnosed with TBI nearly tripled, from just under 11,000 to more than 30,700 [2]. Here, the matter does not simply concern the fact that, and according to the World Health Organization, brain injuries will occur at a greater rate than many other illnesses and will be one of the main causes of death and disability by the year 2020 [2, 3]. The problem lies, on the one hand, in the reduction of financing for health services, including the rehabilitation of individuals with acquired injuries to the brain. An additional problem is the qualifying of the effective rehabilitation effects with regard to particular groups of patients. An equal problem is the lack of academic data which could serve in the discrediting of decisions made more on the basis of economic indications than the needs of the patients themselves [3].

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This slows down the development of effective rehabilitation programmemes which would allow these very patients to lead a relatively independent life. And as we know from the reports of many authors, this is no easy task, for in the case of brain injuries (TBI), various strategies, methods and therapeutic programmemes are applied. It is difficult, therefore, to evaluate the effectiveness of rehabilitation. Consequently, it is not surprising to discover that Rehabilitation Centres all over the world are wrestling with the problem [4, 5, 6, 7, 8]. One of the main reasons is the absence of strictly defined theoretical bases for therapy and the means for the constant monitoring of their effects [9, 8]. As a result of the individual differences in the functioning of the brain and the mind, the consequences of a brain injury are equally varied, even in cases where the localization of the injury is the exactly same. Additionally, as has been shown by A. R. Luria [9, 11], a brain injury does not add anything new to behaviour, for it rather removes significant components of behaviour itself.

Every brain injury results in greater or lesser disturbances to the so-called electric and chemical language of the brain, changes in the area of existing connections, as well as changes in the action and activity of neurotransmitters, which results in a destabilization of the systems of the brain (Fig. 1). This leads to a reduction in the effectiveness of action of specific (varied depending on the location and depth of the injury) constitutive activities, and therefore in disturbances

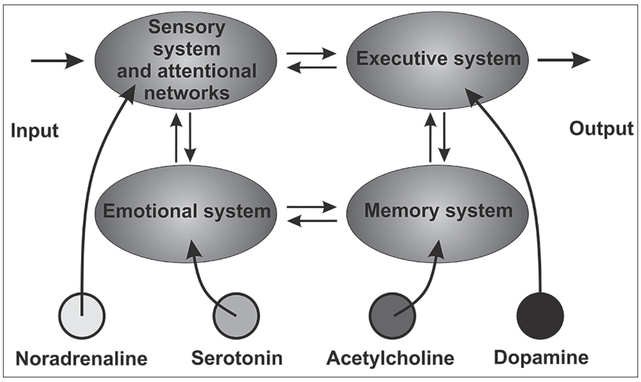

Figure 1. Schematic representation of the conditions of a given system's responses depending on their arousal on entry and activating neuromodulators in the brain. The reaction is defined as the response of the system to a small and elementary growth in arousal on entry.
Source: own study on the basis of Pachalska, Kaczmarek and Kropotov [13]

in behaviour which within the norm occur without any noticeable effort [12, 13].

The efficiency of every system (emotional, sensory, memory and executive) is defined as the ability for that system to react to small changes on input. Mathematically, the efficiency of a system is defined as the relationship: dO/dI, i.e. the relationship of the differential output to the differential input.

After brain injury, the level of activation also undergoes a decrease, that is the signal which stimulates the system (*output*), as equally the reaction of the system to changes in the input. This phenomenon is the reason for the change of the existing connections. This forces the formation of new principles in the functioning of these systems. From the biological aspect, this manifests itself in the form of neurological and cognitive disturbances, while from the social aspect, it results in disruptions in the patient's functioning within their previous environment, on the personal level this results in personality changes. Therefore, the family often claim that the patient is not the same person after brain injury as they were prior to the accident [13, 14, 15].

The symptoms which form after a brain injury may be dynamic in character and may change during the course of recovery and rehabilitation [13, 16]. Dynamic in their nature, connected to the course of recovery and applied rehabilitation, the process of the destabilization of the brain systems creates:

Diagnostic problems, as the same disturbance may occur in various forms, depending on the task given the patient during the course of testing, and as a result, lead to the creation of a different diagnosis. This may be observed in the case of testing the prefrontal environs, where individual researchers have described disturbances in memory, speech, attention, awareness or behaviour. As a result, there existed for a time the notion of the 'mystery of the frontal lobe' [14, 15].

Therapeutic problems, connected with the therapeutic approach adopted, e.g., stimulatory and compensatory. The stimulatory approach is directed through a 'reconstruction' of the lost functions, as emphasized by Luria [10, 11], while the compensatory approach is modelled through adapting the patient to the situation that has come about in accordance with their possibilities and potential.

The diagnostic problems described here are mutually connected. Both effective diagnosis as equally therapy requiring the appropriate knowledge and abilities/skills on the part of the therapist. This is one of the main conditions for patients obtaining the desired and expected progress in rehabilitation. Another important factor in patient achievement of the desired progress within rehabilitation is the phenomenon of brain plasticity, in which the following are involved:

1) *the spontaneous creation of new connections,* which are extremely weak and which can disappear with time unless they are sufficiently strengthened;
2) *the strengthening of the newly created connections* in the spontaneous activity of the given patient, although in the overriding majority this is thanks to external stimulation.

It should be remembered, however, that the effective rehabilitation of patients following brain injury does not give rise to merely the creation of new connections between the individual structures of the brain. For the fundamental condition is renewed stabilization, that is, restabilization of the whole system. And this is by no means an easy task for in cases of brain injury there occurs a disturbance in the working (destabilization) of the whole brain, and not merely the area which has been injured. This is connected with the fact that in the course of particular activities varied and often distant structures take part. For example, contrary to the widely-held conviction the correct course of cognitive activities is safeguared not only by the cortical areas, but also those subcortical structures and the brain stem [17–21]. Additionally, injury seriously affects the shaky, by the nature of things, balance between the individual brain systems, as has been shown above. As a result, in every brain injury patient we are dealing with a unique fluctuation in the state of the mind, something that finds its expression in the variable illness image, as well as in the frequently unforeseen behaviour of the patients themselves [13].

Guidelines for neuropsychological therapy. One of the proposals for solving this problem is the creation of the appropriate frameworks within which therapy could take place. In the global subject literature one can find many bases for the selection of a therapy programmeme [8]. The most important of these being:

Severity of disturbances and absence of self-awareness. The severity and duration of disturbances is the basic factor in planning the means by which rehabilitation is to be undertaken, whereby a significant factor conditioning the covering of a patient with a comprehensive programmeme of rehabilitation is the self-awareness dof isturbances. The above factors are more significant than the gravity of the injury itself, evaluated as an example by the Glasgow Coma Scale or PTA [7, 22]. It should be remembered that patients with a relatively small injury often experience severe and long-term disturbances [8, 13].

Chronicity of symptoms. The time that elapsed from the occurrence of the injury is a significant factor deciding on the intensity of the rehabilitation undertaken. In the case of a long passage of time, other factors come in to play – those connected with failed attempts at returning the patient to an active life. Often symptoms of depression appear in patients, and there additionally occurs an addiction to psychoactive substances. The patients are also socially isolated and have a low sense of self-esteem.

Depression. Close to a half of those suffering from TBI display symptoms of depression [13, 23, 24]. This is often disregarded by clinicians, who concentrate on problems of a medical nature. Depression does not occur, however, in patients with clear disturbances of self-awareness, for it concerns chiefly patients who are aware of their state [9, 25].

Addiction to psychoactive substances. Addiction to psychoactive substances of various kinds is a common problem for patients with brain damage [26]. Therefore, this should be taken into consideration during diagnosis and therapy. Addiction constitutes an additional factor pointing to the need to cover a given patient within a programmeme of comprehensive therapy. All the more so that patients often display disturbances in self-awareness connected with the type of addiction that existed before the brain injury. Usually, they also do not have a permanent occupation before falling ill, help is therefore also needed in this area.

Pre-illness factors. Finally, it is worth noting that although pre-illness factors affect the picture of the illness syndromes in a patient with TBI, they do not represent a statistically significant factor conditioning the possibility to overcome the problems that arise out of the injury [7, 22]. However, it is worth taking into consideration the possibility of the appearance of neurological disturbances and as well personality disturbances, equally, prior to the appearance of the brain injury. A comprehensive diagnosis of this type of factors constitutes the basis for a prognosis of the results of rehabilitation.

Cognitive rehabilitation therapy (CRT). Cognitive rehabilitation therapy (CRT), as a rule, is directed exclusively at the exercising of individual functions (e.g., attention, memory, awareness, executive functions), and covers a wide range of procedures carried out by health service staff in many areas [5]. Usually, the family or a patient's carers play an active part in this process. Although there is an absence of data confirming its unequivocal effectiveness, the clinical data, nevertheless, is encouraging. The main goal of CRT is to enable the patient with a brain injury to return within reason to a normal life through reconstruction or compensation of the lost functions. Reconstruction means the fresh exercising of the lost functions, while compensation has as its aim the adapting of a patient to coping with the existing disturbances. The ways of conducting oneself within CRT are almost as unique as the uniqueness in the variety of the individual patients themselves.

The process of being conscious of reality. A big role is played by consciousness in the process of learning and functioning within daily life. Patients after brain injuries display a big degree of changeability in their level of consciousness, at times not achieving a sufficient level to allow them to function normally, as well as forming various symptoms of self-awareness disturbances; for example, anosognosia [13, 27, 28], it is therefore necessary to conduct neuropsychological rehabilitation with these individuals. To-date, with the exception of a few case studies, there has not been any published research on the effectiveness of specific rehabilitation programmemes for patients suffering from disturbances in consciousness and self-awareness [28]. There is an absence of protocols for the treatment of patients with a full syndrome of self-awareness disturbances, as equally with heteromodal syndromes: frontal, parietal, temporal and occipital, as also on the treatment of patients who display mechanisms for coping of a non-defensive nature (e.g., excessive positive thinking connected with an absence of criticism). Therefore, below we present a few pointers for making easier the undertaking of rehabilitation activities.

Neuropsychological rehabilitation of patients with full self-awareness syndrome. A patient with a full self-awareness syndrome should, at an early stage following injury, be asssured comfort and the possibility for cooperation. This is extremely important for the majority of patients after a serious head injury with serious disturbances in self-awareness, who are are hostile in their attitude and claim that they in no way require any treatment. As a rule, they also demand discharge from hospital. Only patients with anosognosia for motor neurological deficit agree to rehabilitation, although they do not see the reason for carrying out exercises. Therefore, a significant condition for success in these cases is the patient's trust in the therapist [9, 27, 29]. Good outcomes in the rehabilitation of this syndrome is brought about by rehabilitation [28].

Neuropsychological rehabilitation of patients with partial self-awareness syndrome. The neuropsychological rehabilitation of patients with partial self-awareness syndrome chiefly depends on making the patients aware of this problem. In the process of therapy, they can utilize many forms of therapeutic help, which make easier the patient's understanding of the existing situation [27]. Filming a video conducted during the course of therapeutic classes has been found to be helpful. The viewing of such films in a group, with a commentary by the patient, enables the patients to become aware of their disturbance [9, 13].

Training of attention and memory. Data showing that cognitive rehabilitation positively affects the improvement of attention [6, 30]. Applied exercises have been described by many authors [8, 9, 13, 31, 32, 33, 34, 35]. Here, use is made of a gradual increase in stimuli complexity, as well as the application of several senses. Also of important significance is the appropriate gradation of the timing for the various sessions, exercises with the patient on the ability for self-control and the appropriate level of self-awareness prior to the commencement of attention exercises. Of course, in a case whereby disturbances to attention constitute the main problem, then we would begin any tests from that very system. The necessity to incorporate within any training programmeme the microgenetic (layered, procedural and dynamic) organization of attention should also not be forgotten [9, 32, 33].

Wilson et al. [36] assembled numerous data which showed that cognitive memory therapy may result in positive effects. The authors used three types of method:
1) cognitive training;
2) behavioural training;
3) mnemonic training.

The applied exercises have been fully represented in scientific works [9, 36, 37]. For patients who manifest florid confabulations, the techniques of self-monitoring brought about good results [9]. However, it is important to draw the patient's attention – without any open confrontation – to the contradictions, illogicality or impossibility of their recollections with the goal of incorporating critical mechanisms. While, on the other hand, a direct attack on the confabulation of content often results in manifestations of aggression.

The training of attention and memory should be conducted in stages, which is used in the development of an author's gradual training method for attention and memory disturbances (Table 1).

Table 1. *Stage training of attention and memory disturbances*

Objective	Increase in working memory (instant), concentration and selectiveness of attention in relation to the sequence of numbers.
Stimuli	Auditory or audio-visual
Instructions	Prior to the presentation of every sentence it is necessary to explain the semantic category, as equally the means of associating meaning with each set. The patient should repeat each series of numbers, potentially making use of compensatory strategies.
Compansatory strategies	It is necessary to group the numbers in sets (in threes, fours, fives, sixes), e.g. we give someone our telephone number. It is necessary to ensure that the series of numbers are significant and functional, e.g. in giving the town or city code, first we give the city in order for the patient to associate the numbers with something.

During the course of exercises use is made of carefully selected therapeutic material structured in stages [9].

The usefulness of the notes used, in which are entered systematically the data which the patient should remember, has been confirmed in clinical practice. [6, 30]. A description of the facts which are important for a given patient may be achieved in the relevant columns [33, 38]. The patient should be encouraged to gradually increase the amount of data recorded. Of importance is the fact that this type of diary turns out to be helpful not only in memory improvement but equally enables the solving of problems resulting from attention deficiencies or disturbances in executive functions [8]. The systematic recording of data is an equally important factor in the development of the sense of an integrated personality, while simultaneously helping in a more effective participation within the rehabilitation process itself.

Training of visual perception. Therapy of visual perception disturbances is only the beginning of the way to development [39]. This also occurs chiefly because the following remain to be classified

– the mechanisms of perception, both equally within the norm as well as in pathology, with the aim of reducing the complexity of the theoretical schemes that often lead to the increase of categories and subcategories at times of doubtful application;
– new strategies in therapeutic intervention are being still developed.

Within the existing subject literature it is admittedly possible to find descriptions of individual techniques which may be of use in the case of an isolated disturbance, yet there is an absence of comprehensive programmemes of neuropsychological rehabilitation for patients with perception disturbances.

Strategies of therapeutic interventions have been presented most fully by Kerkhoff [39]. The techniques of compensation often used for the possibilities for a return of basic (fundamental) functions within this scope are limited as a result of the relatively permanent topography of the brain in the initial sensory cortex. As Kerkhoff has emphasized [39], in patients with hemianopsia therapy involving visual search effectively reduces problems in daily life caused by a diminished field of vision (knocking into objects, slow reading, etc.), yet does not have an influence on the basic defect itself. In visual search therapy various forms of paper or computer aids are used (Fig. 2).

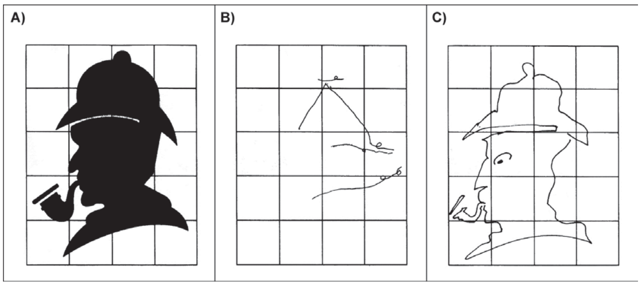

Figure 2. Sherlock Holmes – one of the AIDS used in the therapy of perception disturbances. The template (A), drawing by a patient with apperceptional agnosia and haemianopsia prior to therapy (B) and after therapy (C).
Source: author's materials

In a situation where there are no possibilities for either the restoration or compensation of visual functions, one may accordingly equip the patient with various aids, as well as modify and alter the patient's abode in order to make orientation within it easier, and to reduce the risk of falls.

Training executive functions. One may find within the subject literature many programmemes on CRT directed towards executive functions [40]. Here is emphasized that as a result of the complexity of these functions it is necessary to develop simple conceptual frameworks around which it would be possible to organize programmemes of therapeutic intervention. As a result of this, the author proposes the clinically tested reliable model of therapy based on the concept of a 'scheme of action.' This represents a hierarchical arrangement of activities for action organization: from the lowest level to organization at the highest level guaranteeing the monitoring of behaviour.

In our own research [9], the most effective turned out to be the model of executive functions therapy, encompassing three main stages. These include: 1) the construction of a scheme of action; 2) the activation of the scheme of action; 3) controlling of the scheme of action (cf. Tab. 2).

Table 2. Stage therapy of executive functions

No.	Stages	Tasks
1.	Constructing a scheme of action	Formulation of intentions to act, designating a goal, formulating expectation and planning
2.	Activation of the scheme of action	Initiating action, arranging activities into order, stimulation of the prospective memory, including recalling the intentions and goal of the action
3.	Control of the scheme of action	Controlling (rejection) of undesired forms of behaviour, concentration on the task, formulating situation judgements and evaluations, undertaking decisions (in relation to continuation or changes within the scheme of action), as well as problem solving (i.e. maintaining or changing the scheme of action)

Source: own study

Therapy may encompass a wide scope of action and patient behaviour. Therapeutic intervention should be commenced at the lowest stage in which patient problems arise. There is no point in involving oneself in the reconstruction of activation disturbances if the construction of the scheme is disturbed for without a dependable scheme of action the application itself simply leads nowhere. It is imperative to involve oneself in the construction of the scheme.

The majority of therapeutic interventions directed towards the reconstruction of executive functions may be reduced to three general strategies:

1) **Environment modification.** Involves a change in the physical context, or social (a change in the arrangement of the furniture, using a notebook or diary, the use of a dictaphone, etc.), as well as modification in the conditioning of rewards and punishments. Techniques known as behaviour modification are, admittedly, strongly criticized and not always justifiably. They may be most useful in deficits in the establishment of goals or in situations in which the patient cannot cope with an excess of stimuli within a given environment.

2) **Techniques of cognitive intervention.** Most frequently involves the recording of a definite task through repetition. This therapy is based on structured exercises within the context of formal therapy sessions. Such methods are most useful in the rehabilitation of patients with attention disturbances, although to-date it has not been proven whether they are particularly useful in the pathologies of executive functions. Some authors suggest that although we can obtain effects during the course of CRT, we do not obtain a transfer of capability to everyday life itself [41].

3) **Training of specific abilities or tasks.** Covers a range of methods derived from cognitive and behavioural psychology designed to teach how specific functions and activities of daily life can be carried out. These are often used in conjunction with a modification of a given environment. From one's own clinical practice, one may propose that the techniques for training specific abilities should be covered by cognitive mataprocessess. There are:
   - **Metamemory –** conscious control of memory processes;
   - **Metaattention –** conscious decisions about what attention should be directed towards, and what not directed;
   - **Metaemotions –** control of the emotions accompanying the tasks performed.

The application of these methods is not limited to work in a surgery or clinic. They may be equally successfully applied to the context of social life. In the rehabilitation of patients with disturbances in executive functions, computer games may also be applied [42].

Communication training, including communicative pragmatics. Aphasia appears relatively rarely as a consequence of TBI; however, the majority of patients experience difficulties in the correct utilization of communicative pragmatics, as well as in the range and scope of social abilities. This causes difficulties in establishing contact with others and disturbs already existing relations with those near them. Disturbances in communicative pragmatics concern the absence of the ability to listen, excessive garrulousness, as well as the lack of the ability to forget verbal contact. It often occurs that digression from the main topic of conversation is a feature. Social contacts are also disturbed by the absence or inadequate use of extra-linguistic signals, such as intonation, mime or gesture. Patients also manifest a lack of abilities relating to more complex social behavior, such as making requests, asking questions about the date or hour, or also the necessity to apologise for their wrong behaviour. The training of these abilities is best conducted in a group, in which the recording of all the activities conducted is most helpful [6, 13, 30].

Cognitive Rehabilitation Therapy (CRT). A module incorporated into a broader model of holistic rehabilitation. Holistic rehabilitation programmes take into consideration the interaction of several disturbances of the patient, while individual approaches concentrate on the exercising of each disturbed function in isolation. Moreover, the reaction of every patient to the conducted therapy is varied, depending on the type of injury, their previous state of health, and also their social situation. Therefore, therapeutic interaction undergoes change with the passage of time and there arises the need to apply other forms of therapy.

The model of holistic rehabilitation. The principles of a holistic model of rehabilitation originated in Poland in the 1960s and were developed by such pioneers of rehabilitation as Wiktor Dega [43], Marian Weiss [44], Aleksander Hulek [45] and Adam Pąchalski [46]. This incorporates four factors conditioning the effectiveness of this process: 1) comprehensiveness; 2) early intervention; 3) universality; 4) individualised character. The first programme of comprehensive patient rehabilitation following brain injuries was developed towards the end of the 1970s, and was subsequently implemented into clinical practice at the Cracow Rehabilitation Centre and the Reintegration-training Centre of the Polish Neuropsychological Society [4, 47, 48], as well as at the Centre for Cognition and Communication [49]; (for a recent review see Pąchalska, Kaczmarek and Kropotov [13]). This programme covered:
1) cognitive rehabilitation;
2) individual and group rehabilitation with the use of a therapeutic milieu;
3) vocational rehabilitation;
4) family psychotherapy.

Intensity of interaction. Cognitive rehabilitation, which constitutes the main component of comprehensive rehabilitation, is intensified thanks to the use of exercises performed individually and in a group. An additional element conducive for cementing the obtained effects is the therapeutic milieu [4, 47]. Our own innovation is the introduction of art therapy [4, 9, 47, 50], which stimulates mainly symbolic thinking [15].

The main components of a holistic programme of rehabilitation for TBI patients is presented in Table 3.

The time that holistic rehabilitation takes depends to a large degree on the needs of the given patient, and usually involves several months of intensive, daily exercises, and then less frequent meetings over the course of several years until a sufficient degree of independence has been achieved by the patient. Depending on the patient's needs, speech

Table 3. Components of a holistic rehabilitation programme for TBI patients

- Cognitive-behavioural approach
- Cognitive-behavioural approach combined with new neurotechnologies
- (neurofeedback, rTMS)
- Therapy planning in accordance with the microgenetic theory of the symptom covering an individualised goal setting.
- Development of self-awareness, skills applicable to social conditions
- Development of the therapeutic milieu: 'Academy of Life' programme
- Team of specialists in the rehabilitation of patients with brain injuries
- Large number of staff in relation to the number of patients
- Incorporating the family and those near the patient into the rehabilitation process
- Attempts to take up employment and start an independent existence
- Systematic monitoring of the results of interaction

Source: Pąchalski [46] in author's own modification

and physiotherapy may be also incorporated. Similar programmes have been conducted recently at Rehabilitation Centres worldwide [8, 51, 52]).

The therapeutic milieu – 'The Academy of Life'. Towards the end of the 1970s, a special programme 'The Academy of Life' was developed [4, 9, 50], in which the therapeutic milieu principles used in the rehabilitation of patients with head injuries were defined, with particular emphasis being placed on patient subjectivity. The name of the programme – 'The Academy of Life,' was thought up by a female patient suffering from brain injury and meant 'training' for life. The programme includes a variety of therapeutic activities for patients and their carers, designed for their reintegration into society.

Of importance are the group meetings of the members of the 'Academy of Life' and their families and carers, in the course of which they are able to share their problems, thoughts on potential solutions and on the progress made. During these meetings, specialist lectures and panel discussions are organized, covering the essence of brain injury and the ways in which one can cope with existing problems. The aim of these meetings is to prepare the family and carers for taking an active part in the further course of the patient's rehabilitation programme.

Training in day-to-day abilities and skills. The exercising of the day-to-day abilities and skills lost as a result of injury constitutes a necessary condition for any return to a normal life. These include both more complex activities, such as doing the shopping or using public transport, to more basic skills, such as cooking, cleaning or dressing oneself. These activities are practiced in conditions natural as possible during the course of specially organized exercises designed to ensure that the exercises are conducted in conditions as close to those of real life as possible, placing before the patient tasks which will allow coping in the future with the process of functioning independently. Various forms of therapeutic help is applied to those patients with a breakdown in dysexecutive activity (Fig. 3).

Such conditions, as results from the research conducted, produce the best effects in rehabilitation [8, 9].

The means of solving existing problems and crisis intervention. At the 'Academy of Life' the technique employed to solve existing problems has been successful in patients with cognitive disturbances. One example is a unique form of brain-storming, which commences with encouraging the patient to clearly define the difficulties with which they are grappling. The group helps the patient in defining many of the possible solutions to the existing situation, as well as in the evaluation of any possible consequences of the actions undertaken. Next, the patient undertakes those steps which have been designated as the most likely to lead to a realization of the goals intended. If the process undertaken does not result in achieving the intended goal, or when the success is only partial, the patient resorts to the action which was ranked next in the hierarchy.

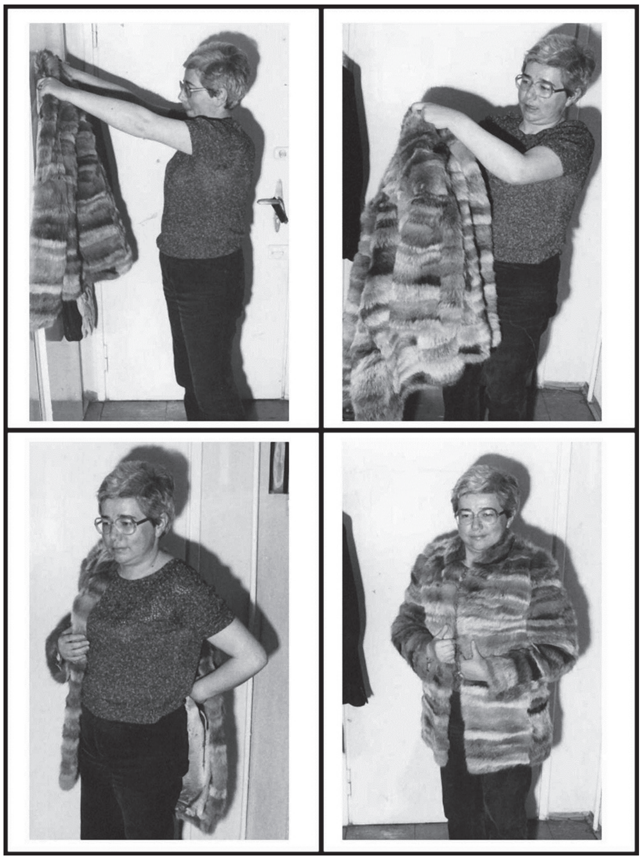

Figure 3. Album of daily activities – activity phases.
Source: Pąchalska [48]

The problems of appropriate behaviour in crisis situations are discussed. In practice, this relates first and foremost either to an exaggerated tolerance of peculiar patient behavior, or about the inclusion of any necessary commentaries and excessive patient criticism.

Problem Solving Training (PST) [53]. The fundamental problem is training a patient to cope with the subsequent aspects of problem solving. This type of training of the intellectual discipline may lead to an improvement in the test results over the course of a few weeks; however, the problem lies in the fact that a patient with disturbances of cognitive functions may indeed take in knowledge and abilities (skills), yet they are unable to apply this knowledge outside the training situation. The programme consists of four phases for problem solving:

– problem formulation (goal setting);
– creating possible solutions ('brain-storming');
– the selection of a single solution (resolution and option evaluation);
– verification of the desired results (recognition and correction of one's mistakes).

Table 4. An example of a conversation using the mechanism of delayed feedback

Interlocutor	Utterance (behaviour)	Evaluation
OB.	Does a decent individual beat his wife?	Problem formulation (defining the goal) in the form of a superficially objective question, i.e. without a clear accusation directed at the patient
T1	Beat his wife … no. no … one can … this is most unacceptable … I'd say quite disgraceful even …	Despite behavioural disturbances the patient is able to carry out a moral evaluation and express a judgement as if he were in no way conscious that the conversation referred to him.
OB.	What do we call someone who beats his wife?	Consideration of the possible consequences of the forbidden act.
T1	He's a scoundrel … I'd even say a tyrant …	The therapist deliberately arouses an expression of negative emotions, although we are seemingly speculating about the situation in the abstract.
OB.	And how should he be punished?	The next step in the course of reasoning.
T1	The consequences? Moral ones? He doesn't see it … he'll ask her for forgiveness and then continue to beat her … While legally … punishment … And if she bears the marks … then he has to pay in court!	The patient clearly has a practiced approach to the question of domestic violence.
OB.	Therefore what do you have to do?	The therapist takes the conversation from the abstract (i.e., from a talk about *someone*) to the concrete and specific (i.e., a talk about *one*).
T1	I can't answer that. I do think though that I really must start to control my aggression.	The first reaction is defence in the form of avoidance. However, the patient expresses a willingness to improve his behaviour, even though regret is not expressed.

Source: own materials

Strengthening self-evaluation. Usually used in cognitive-behavioural therapy – the undertaking of planned actions (activities) within real day-to-day situations, for instance, doing the shopping [54, 55]. This may be used to make patients aware that their memory is not as good as they thought. This is possible through the patient giving an account in front of the group of a task the patient has actually completed. At the 'Academy of Life' the patients are helped in their efforts through showing them different ways in which existing problems may be overcome. Our practice shows that this is a most fruitful route in making patients aware of existing defects, and may constitute an encouragement to undertake the effort required to overcome them.

Risk taking. In a similar way to the exercise on self-evaluation, tasks requiring the taking of risk can be extremely useful in making a patient aware of existing defects and overcoming mistaken convictions. However, the emotional state of a given patient and his/her reactions to existing difficulties must be taken into consideration. Most commonly, patients attempt to return to their previous profession (occupation) without realizing that this is beyond their current possibilities. It is worth pointing out to a patient the possibilities that exist to take up a different occupation. Equally important is the emotional support given both by the therapist and the group, because the inability to carry out activities that had been previously planned results in an extremely high level of frustration. This fact may equally result in frustration on the part of the therapist, particularly when it turns out that the patient is developing depression requiring professional treatment. That said, it is worth taking the risk because cases arise in which patient is able to carry out a task which, in our evaluation, was beyond their capabilities.

Emotional therapy and control of social behaviours. There exists a whole array of possible methods and treatment techniques for emotional disturbances [56]. At the 'Academy of Life' the following are used: 1) individual psychotherapy; 2) group therapy; 3) behaviour training; 4) pharmacological treatment in the most serious cases [9]. The control of asocial behaviours is conducted in accordance with the results of the research by Alderman and Burgess [57], who drew attention to the necessity of the patient understanding the relationship of 'reaction – consequence.' Improvement in this area is most often obtained through methods of behaviour modification, including an increase in privileges and rewards [58], although it must be borne in mind that jointly occurring attention disturbance may complicate the conditioning process. Therapeutic intervention, therefore, should occur immediately after the appearance of the behaviour. However, if the patient possesses a sufficient amounts of memory, they may make use of so-called feedback with a one-hour delay. In this way, we are encouraging the patient to reflect as well as to consider alternative, more socially accepted reactions [40]. An example of a conversation using the mechanism of feedback with a delay is presented in Table 4.

The implementation of such a technique into the therapy of patients following brain injury turned out to be highly effective in the regulation of asocial forms of behaviour.

Specialist team cooperation. A complex syndrome of disturbances in patients with TBI, and particularly disturbances of the executive functions, may result in frustration for therapists. Therefore, it is imperative that they work in close cooperation so that the interactions overlap. At the 'Academy of Life' meetings are often held during which existing problems are discussed and the best means to overcome them are established. Depending on need, a certain amount of time is devoted to reflection by the various members of the team. Walter Stobaugh, a social worker cooperating with Malec's team, has developed indicators making communication among members of a therapeutic team easier [8]. This has been used recently in the 'Academy of Life' programme.

Family participation. Active participation during the process of rehabilitation of those closest to the patient is a necessary condition for the patient's return to a relatively normal life. This requires teaching the family the means of working with the patient, and making him/her aware that many of the patient's undesired ways of behaving are not the result of bad will, but merely constitute the results of brain damage. This enables those closest to the patient not only give help, but also allows them to overcome the frustration and sense of helplessness, thanks to which they are able to help the therapists conduct the rehabilitation. Very often, it is those who are closest to the patient who also require psychological help as they are unable to cope with the existing situation.

Within the framework of the 'Academy of Life' a crisis telephone intervention line is operated, through which as much as much advice possible is given, and in the case of especially difficult cases, personal meetings [9].

Pointers and prompts. Pointers and prompts are extremely helpful in overcoming problems connected with attention, memory and behaviour disturbances. They may be varied in character depending on the existing situation and the creativity of the therapist and those closest to the patient. It is connected, however, with the possibility of making a patient dependent on this type of help; thus, with time, the use of prompts should be increasingly limited. Notes, signs and objects found within the immediate environment are the most usual sort of pointers used. These could be, for example, an alarm clock which rings every half-an- hour in order to remind the patient about the need to look into the notebook and check whether an activity had not been planned for that very moment [36].

Attempts to lead an independent life – the attempt to return to work. An attempt to return to work and undertake other significant life tasks is one of the most important tasks in the rehabilitation of patients following brain injuries. However, this might result in emotional disturbances because patients with TBI often overestimate their realistic possibilities. Constant support of the patient is necessary in order to avoid the development of depression. Offering a patient work that they they are actually able to perform is helpful. It is particularly important to emphasize the significance here of successes achieved. Also helpful is support from the patient's immediate environment and those cooperating with the patient, who need to be made aware of the nature of the problems the patient is struggling with, and to show the means of providing help in this respect. Another type of help is connected with changes at the workplace itself; for example, the need for more breaks, noise reduction and the use of special devices, etc. Obviously, this concerns not only existing at the workplace, but the same applies equally at home and in other situations in daily life.

Effectiveness of the 'Academy of Life' programme. The 'Academy of Life' programme was evaluated as part of a carefully planned scientific experiment. From a list of 547 patients with traumatic brain injuries, 40 patients were selected who awakened from long-term comas with injuries to the frontobasal area, and matched in pairs into two groups – A and B – on the basis of age, gender and extent of the brain injury, as well as the length of the coma duration. The location of brain damage was dually confirmed: intraoperatively as well as by MRI study. Strict criteria of exclusion and inclusion were introduced [59, 60]. The therapy in both groups lasted eight weeks (twice a week), and conducted according to a cognitive-bahavioural programme of rehabilitation. In Group A, the 'Academy of Life' programme was additionally administered. Analysis of the documentation (disease histories, results of tests), a clinical observation interview, standard batteries to evaluate cognitive functions, behaviour of the Frontal Behavioural Inventory (which tested the patients' carers), for the evaluation of social isolation – the Visual Analog Scale of Social Isolation for testing the links with others, and the questionnaire for the Modification of Family Ties, were all used to evaluate the effects obtained by the patients.

The Quality of Life Short Form – 36 Scale – was employed to evaluate the quality of life.

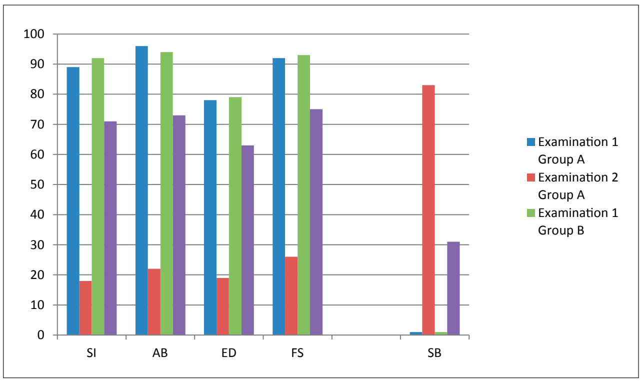

Figure 4. Performance of each group of patients in each subscale: social isolation (SI), antisocial behaviour (AB), executive dysfunctions (ED), frontal syndrome (FS), social bonds (S)

It is worth emphasizing that a significant difference was observed between Groups A and B, which shows that neuropsychological rehabilitation according to the 'Academy of Life' programme enables a reduction in the features of antisocial behavior, as well as the frontal syndrome (chiefly disinhibition and adynamia), a reduction of social isolation and rebuilding of cognitive, emotional and social bonds (Fig. 4).

It is worth noting that 18 patients (90 %) from Group A returned to work, while in Group B only two (10%) did so. All the patients who returned to work considered their quality of life as significantly better than those patients who remained on disability benefits.

One should therefore not be surprised that the therapeutic environment is equally valued and utilized in comprehensive rehabilitation in several countries in the world [61].

In the strategic approach directed towards a goal, the patient draws up with another patient a list of the essential steps, taking into consideration those individuals to whom they could turn for help. Equally important is the instructing of a patient about the necessity of consulting a doctor in the case of health problems or the occurrence of extreme pain. At the initial stage, such visits should take place with the assistance of a therapist [4, 9].

New neurotechnologies for the assessment of TBI. Recently, new technologies for the assessment of brain neuromarkers in TBI have emerged. These are: quantitative EEG as a measure of the cortical self-regulation of the brain and event-related potentials as measures of information flow within the brain [12].

Quantitative EEG. The QEEG method (also called neurometrics) was introduced into clinical practice mainly by the pioneering work of E. Roy John and his colleagues. According to him Neurometrics is:

a method of quantitative EEG that provides a precise, reproducible estimate of the deviation of an individual record from the norm. This computer analysis makes it possible to detect and quantify abnormal brain organization, to give a quantitative definition of the severity of brain disease, and to identify subgroups of pathophysiological abnormalities within groups of patients with similar clinical symptoms [62].

The spectral characteristics of spontaneous EEG defined in QEEG include absolute and relative EEG power in different frequency bands and different electrodes, as well as measures of coherence between the EEG recorded from pairs of electrodes. Numerous studies have shown that spontaneous EEG in a healthy brain represents a mixture of different rhythmicites which are conventionally separated into alpha, theta and beta rhythms. Recent research shows that each of these rhythmicities is generated by a specific neuronal network: posterior and central alpha rhythms are generated by thalamo-cortical networks, beta rhythms appear to be generated by local cortical networks, while the frontal midline theta rhythm (the only healthy theta rhythm in the human brain) is hypothetically generated by the septo-hyppocampal neuronal network (for a recent review see Kropotov [12]). In general terms, spontaneous oscillations reflect the mechanisms of cortical self-regulation implemented by distinct neuronal mechanisms.

There exist several normative EEG-based databases in the world (NxLink, introduced in John et al. [63], Neuroguide, described in Thatcher et al. [64], and Brain Resource Company presented in Gordon et al., [65]). These databases have been very helpful in defining the neuronal correlates of TBI [66].

Event related potentials. The other important aspect of brain functioning is its response to certain events associated with certain psychological operations. This electrical brain response is measured by event related potentials (ERPs). Technically, ERPs are obtained by simply averaging all the EEG epochs in many sequentially presented trials in a single subject and for a single electrode. Consequently, ERPs can be considered as voltage deflections generated by cortical neurons that are time-locked to some events, and are associated with information flow in the cortical areas.

All the research within this field indicates that ERPs are generated by multiple sources, which are associated with ERP waves which, in practice, are defined by its positive or negative polarity, its latency, its scalp distribution, and it relation to experimental variables [67]. Several ERP waves have been separated, such as mismatch negativity, N400, error related negativities, different types of P300, etc.

ERPs have proved to be useful for assessing the integrity of neural processing capabilities in TBI patients (for a review of somatosensory, auditory and visual ERPs see Folmer et al. [68]; for a review of the ERP correlates of cognitive control see Dockree and Robertson, [69]). In summary, research shows that a reduced speed within information processing is one of the critical features of ERPs in TBI. In addition, ERP markers of attentional allocation and cognitive control may reflect important deficits that are functionally significant for the everyday cognitive problems experienced by TBI patients.

Blind source separation methodologies. Recently, new techniques for the separation of latent (hidden) components from these waves have emerged. One of these techniques is independent component analysis (ICA). ICA is a decomposition technique which is regarded as a solution for the 'blind source separation' problem [70]. ICA decomposes data in such a way that the resulting component activities have minimal mutual information, which is a measure of the statistical independence of the components [71].

There are at least two major approaches for applying ICA to ERP analysis: single subject ICA [72, 73] and group ERP ICA analysis [74]. The input data for the first approach represent single-trial ERP epochs from a single subject. The ICA components are defined separately for each subject, with subsequent cluster analysis [73]. The input data for the second approach are from averaged ERPs recorded in a few task conditions but in many subjects [74].

The second approach was recently implemented in the HBI (Human Brain Index) reference database (http://www.hbimed.com/), which includes 19-channel EEG recordings of more than 1,000 healthy subjects in resting conditions, with eyes open and eyes closed, as well as in six task conditions. The tasks were specifically developed for recording components associated with visual and auditory processing, face emotional recognition, working memory, engagement (GO) and disengagement (NOGO) operations, mathematical and speech related operations, novelty reactions, etc. This approach is currently used by Jan Brunner and his colleagues for the assessment of brain mechanisms of cognitive impairment in TBI patients at Saint Olavs Hospital of the Norwegian University of Science and Technology in Trondheim. The data are collected for a large group of TBI patients and healthy controls of the same age and similar neuropsychological parameters. The results of the test-retest reliability of the group ICA and correlations of the ICA components with neuropsychological domains have been presented in recent publications [75, 76].

New neurotechnologies for the treatment of TBI: neurofeedback, TMS, tDCS – neurofeedback therapy in TBI. Interventions for the improvement of a cognitive deficit in TBI patients include neurofeedback. This method is based on three scientific facts:) the brain state (including any dysfunction or dys-regulation) is reflected in the parameters of EEG recorded from the scalp; 2) the subject can voluntarily and selectively change some EEG parameters; 3) the human brain has a plasticity to memorize the desired (rewarded) state.

Historically, the conventional neurofeedback protocols are based on comparisons of the QEEG of TBI patients with some normative databases [77]. Some studies claim that there are no clear unique QEEG features in mild TBI [78], while others claim opposite results [79]. The authors [79] validated a discriminant function equation across three independent samples of TBI patients and obtained a hit rate above 90%. In another study [80], the relative power of beta activity, obtained under three cognitive conditions, was found to be a negative predictor of cognitive performance.

The neurofeedback protocols in TBI are reviewed in Thornton and Carmody [81]. In the latest study, the neurofeedback therapy was shown to induce significant changes in structural and functional connectivity among young moderately injured TBI patients [82].

TMS in TBI. Transcranial Magnetic Stimulation (TMS) as a method of non-invasive direct modulation of neuronal activity is well suited for the treatment of TBI [83, 84]. Indeed, TMS generates a magnetic field in a coil placed on the scalp which induces an electrical current within the brain tissue resulting in alterations of neural excitability. Depending on the stimulation parameters, rTMS is able to modulate the cortical and subcortical function by increasing or decreasing cortical excitability [85]. Low-frequency rTMS results in a suppression of cortical excitability and has otential for the treatment of disorders characterized by cortical hyperexcitability, whereas high-frequency rTMS results in an increase of cortical excitability and has been investigated as a potential treatment for conditions characterized by reduced cortical activity [85].

The existing subject literature regarding the use of rTMS as a TBI treatment is in its infancy. To-date, there are only a few published case studies (for a review see Herrold et al., [84]) and there is only one non-randomized pilot study [86]. The case studies are diverse in that rTMS was customized to treat a specified neurological sequelae ranging from an overall neurobehavioural function [87], to a particular deficit [88]. The studies also range in TBI severity from severe to mild.

The randomized pilot study was performed on a sample of 15 m TBI participants [86]. This study did not include a sham control group, but it did provide preliminary evidence that high frequency rTMS intended to activate the left dorsolateral prefrontal cortex may improve the symptoms associated with mTBI [86].

tDCS in TBI. Trancranial Direct Current Stimulation (tDCS) is a noninvasive technique of neuromodulation, which uses low amplitude direct current applied though the skin of the head to alter the neuronal firing of cortical neurons. The method was introduced in the 1960s and received renewed interest in 2000. It was demonstrated that tDCS affects cortical excitability with anodal stimulations bringing forth prolonged increases in the cortical excitability while cathodal stimulation showing the opposite effects [89]. The duration of after-effects outlasts the period of stimulation and depends on the duration of tDCS. Moreover, consecutive sessions of stDCS result in behavioural effects lasting several weeks. For a recent review of the application of tDCS in the treatment of TBI patients see [90]. tDCS in combination with CRT has been successfully applied for PTSD and TBI [91].

A combination of neurofeedback and rTMS – a case study. In our own study [28], a severe TBI patient suffered from anosognosia, executive dysfunction, and behavioural changes, took part in 20 sessions of relative beta training and later in 20 sessions of rTMS; both programmes were combined with behavioural training. We used standardized neuropsychological testing, as well as ERPs before the experiment, after completion of the neurofeedback programme, and again after the completion of the rTMS programme.

The patient showed small improvements in executive dysfunction after the conclusion of the relative beta neurofeedbak training programme, and major improvement after the rTMS sessions. To monitor the physiological mechanisms of cognitive control in this patient the ERPs in the cued GO/NOGO task were measured before the therapy, after the neurofeedback sessions and after the rTMS sessions. Similarly to the behavioural parameters, the P3 NOGO component, as an index of cognitive control, showed small changes after relative beta training and a significant improvement after the rTMS programme (Fig. 5).

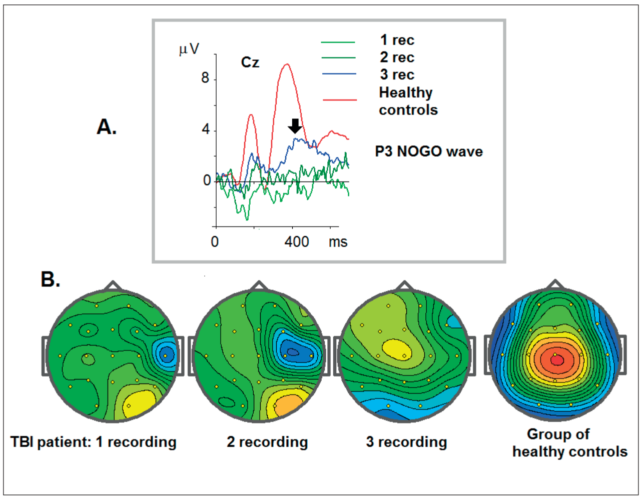

Figure 5. Increase of the P3 NOGO wave in a TBI patient during sessions of neurotherapy (adapted from Pachalska et al., 2011 [28])

A. Event-related potentials (ERPs) recorded at Cz in the TBI patient before treatment (1 rec), after neurofeedback sessions (2 rec) and after rTMS sessions (3 rec), in comparison to the ERP in the group of healthy subjects. *X*-axis – time in ms after NOGO stimulus presentation. *Y*-axis – potential in mV.
B. Maps of the P3 NOGO wave in time indicated by the arrow at A. before the treatment (1 rec), after neurofeedback sessions (2 rec) and after rTMS sessions (3 rec) in comparison to the map obtained from the grand average P3 NOGO wave in the group of healthy subjects. On the map, red corresponds to positive values, blue – to negative values.

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