REVIEW ARTICLE

Cognitive Remediation in Traumatic Brain Injury: Update and Issues

Yehuda Ben-Yishay, PhD, Leonard Diller, PhD

ABSTRACT. Ben-Yishay Y, Diller L. Cognitive remediation in traumatic brain injury: update and issues. Arch Phys Med Rehabil 1993;74:204-13.

• Cognitive Remediation (CR) is a relatively new treatment technique for alleviating residual cognitive deficits following traumatic brain injury. This is a promising yet still changing technique. The future of CR as a rational and systematic endeavor requires the incorporation of important new ideas that have been emerging in allied fields. For example, the emerging field of instructional psychology has contributed relevant concepts such as scaffolding, metacognition, and generalization. It is furthermore argued that the issues of awareness, self-concept, and self-efficacy are vital to the process of CR intervention, and an integrative (holistic) approach to the remedial endeavor is thus indicated.

KEY WORDS: Cognitive remediation; Metacognition; Intergrative-holistic-remedial intervention

Although cognitive remediation (CR) is a relatively new treatment, it has aroused unusual controversy. In 1988, 1989, and 1990 alone, several articles have appeared supporting the efficacy of CR,[1-3] opposing use of CR,[4,5] finding CR of limited value yet worth pursuing,[6] and expressing skepticism about its validity (though calling for multicenter clinical trials, as does Levin[7]). Critics of CR have been surprisingly polemical and passionate in tone (eg, "anecdotal reports belong in the theater," or "research should invest in biologic markers rather than psychologic studies."[5] Differences in conceptual/philosophical approaches to recovery of functions after brain injury and issues of public concern are possible reasons for this heated controversy.

DIFFERING CONCEPTUAL/ PHILOSOPHICAL ORIENTATIONS

CR has been viewed from the perspective of two disparate models of recovery of functions. The first is an essentially biological model: recovery of functions is determined by events in biological systems; learning and/or re-adaptation processes play a secondary role.[4,5] The second model attributes a primary role to learning and other psychological processes, as well as to the influence of environmental inputs/interventions, in the recovery of functions. Psychological and environmental factors are seen as facilitating/mediating events in the biological system.[8,9] Adherents of a biological model tend to be skeptical in interpreting ambiguous results or findings from psychological/remedial intervention studies.[4,5] Adherents of the second model are, in general, more optimistic.[1-3,6]

Biologically-oriented investigators hope to understand the mechanisms underlying dysfunctioning and develop reasonable guidelines for rehabilitative interventions, using advances in biological theory and biological research. Biological markers are sought as guides for determining what is an effective treatment, as well as what may be the limits of remedial intervention.

Investigators operating within a psychological/learning framework rely heavily on three developments of the past several decades: (1) Clinical studies in remedial intervention with stroke patients,[10,11] learning disabled,[12] mentally retarded,[13] and aged populations,[14] which provided a basis for the application of CR interventions to improve cognitive functioning following brain injuries. (2) The increasing use of computer-assisted training procedures, as inexpensive substitute therapists or as cognitive prostheses. (3) Psychological research data, which have increased our understanding of the mechanisms of cognitive dysfunction as well as suggests instructional/remediation techniques for head injured individuals. The work of Schachter[15] and Posner[16] in cognitive psychology is an attempt to identify mechanisms that may be implicated in cognitive dysfunctions. In addition, educational psychology research has contributed to the development of a psychology of instruction[17,18] applicable in CR. Further understanding of how to capitalize on motivational and malleability factors in the learning and mastery process of CR instruction is also needed.[19-21]

This review has been undertaken from a particular perspective: CR is both a theoretical concept as well as a body of remedial intervention techniques, and it is still evolving. It would be premature to draw definitive conclusions regarding its validity and use for rehabilitation purposes based on the current evidence. Furthermore, we would argue that whereas it is important to undertake more clinical

From the Head Trauma Program, Rusk Institute of Rehabilitation Medicine, New York, NY.

Submitted for publication March 22, 1991. Accepted in revised form April 6, 1992.

This research supported in part by grant RSA 13-P-55623 and RT-93, Rehabilitation Services Administration, Department of Health, Education, and Welfare; and by grant G008300039, National Institute on Disability and Rehabilitation Research.

No commercial party having a direct or indirect interest in the subject matter of this article has or will confer a benefit upon the author(s) or upon any organization with which the authors are associated.

Reprint requests to Yehuda Ben-Yishay, PhD, Head Trauma Program, Rusk Institute of Rehabilitation Medicine, Room 818, 345 East 24th St, New York, NY 10010.

0003-9993/93/7402-0166$3.00/0

studies for validation of various CR techniques, or replication of previous findings, it is also important to deepen our understanding of the more basic underlying psychological processes of instruction/learning.[22] There are important precedents for this. For example, at a conference on the possible applications of academic/theoretical psychology to rehabilitation, which was held three decades ago, several principles of behavioral learning theory were translated into specific clinically testable hypotheses in a rehabilitation context.[23] These served as a strong platform from which to launch techniques of behavioral management for chronic pain[24] that emerged a decade later.

PUBLIC POLICY ISSUES

Traumatic brain injury (TBI) is a problem of great magnitude—there are an estimated 450,000 cases each year.[25] There are today more than 600 programs of neuropsychological rehabilitation across the nation, whereas barely 60 existed 10 years ago.[26] Cognitive remediation services are offered in more than 90% of the 252 programs that recently responded to a survey.[27]

The proliferation of services gives rise to issues of quality control, with professional societies,[27] and the Commission for Accreditation of Rehabilitation Facilities (CARF) moving to set standards for practice in traumatic brain injury programs. However, these efforts are basically attempts to set floors with regard to services and to resolve credentialling issues. They do not address the harder issues of scientific substance. In view of the fact that many programs have been developed by the for-profit sector of the rehabilitation industry, skepticism based on legitimate issues of validity and efficacy is often fueled by perceptions that the advocacy of the use of one form or another of CR intervention is driven more by a profit motive than by conviction of its scientific merit.[28]

The need for developing priorities for health care delivery, given the prevailing fiscal constraints, throws what should otherwise be a discussion of issues of scientific validity and efficacy into the public spotlight. Economic and ethical dimensions enter the debate. Questions of service delivery and science are weighed in terms of cost/benefit priorities. Thus, for example, the state of Oregon has already established a priority for reimbursement by Medicaid for various medical conditions.[29] And the outlook is for more of the same.

Considerations of legal implications might also enter the debate on CR. Stone[30] and Klerman[31] have debated the case of a patient who was treated with psychotherapy in 1979 and who many years later sued the physician, and the institution with which he was affiliated, for providing allegedly inappropriate therapy and thus prolonging the patient's suffering. One can easily picture a scenario where 10 years from now a suit is brought against a provider for administering or not administering CR, depending on where the weight of the evidence falls.

THE CASE AGAINST CR

Our concern in this article is to acknowledge the legitimate criticisms of CR and to present a broader perspective on the issues. We wish to avoid both uncritical enthusiasm for CR as well as unjustified backlash. The arguments against CR boil down to the contention that there is weak evidence for its validity and efficacy and that CR lacks an adequate basis in theory. Critics of CR[4,5] assert that the studies obtaining positive results have had such poor experimental design as to render their findings suspect. Similarly, it has been asserted that single case design studies were inadequate because they were not hypothesis driven, or that their authors gave insufficient consideration to alternative explanations. Furthermore, it has been argued that single-case design studies allow for limited generalization to other cases because of the absence of an adequate taxonomy of brain injury. Without an adequate taxonomy, the essential components of a case cannot be identified in sufficient detail to tell us which cases might be similar or different. Group design studies have also been criticized because (a) they are said to have capitalized on natural recovery or socialization; or (b) because the psychometric instruments used to assess outcomes lacked ecological validity; and because (c) such group studies failed to demonstrate a relationship between the psychometric measures of outcome and the treatments given in CR training.[4,5]

Whereas some of the criticism levelled against positive studies is justified (see Benedict[6] for a review), much criticism has been too global. There are a number of studies that have demonstrated efficacy of CR in circumscribed areas.[1-3,6] There have also been some studies that have reported negative results.[32] In criticizing research outcomes, important issues must be considered. First, in clinical studies of intervention, the absence of quality control can/does result in a failure to replicate the outcomes of a treatment. There are methodological issues that cut both ways, ie, criteria that must be applied whether results are positive or negative. Though principles of good design are generic for any intervention with any population, their application and their operationalization require assembling patients and procedures whose characteristics can be identified with enough validity and specificity. Ruff and Camenzulli[33] have outlined issues that are relevant for group-design studies in CR. Second, though this field surely needs replication studies, the few replications that are in existence differ in significant ways. This renders interpretation of results ambiguous. As Gordon and Hibbard[3] noted, the failure of Ponsford and Kinsella[32] to find a positive effect of training in attention may be due to insufficient treatment time.

It would be premature to conclude that CR is without proven value. CR is a rapidly evolving field that is developing methods for the management of clinical problems that previously have not been well addressed in rehabilitation. Progress is being made. In a review conducted a decade ago, Diller and Gordon[34] found only a handful of studies on CR for individuals with TBI, whereas less than a decade later Benedict[6] reviewed 35 studies. It is only recently that we are beginning to see the emergence of bodies of data that permit evaluative statements.[35]

A second major criticism leveled against CR is that it lacks a sound rationale.[4,5] This criticism has two aspects. One aspect is based on a misreading of the role of practice in CR. It has been alleged that the improvements noted follow-

ing CR are practice effects rather than genuine gains in skill and that proponents of CR view it as a process analogous to muscle-building programs.[4] This is misleading. Though massed and prolonged practice is certainly one of the necessary conditions for the success of CR interventions, the muscle-building metaphor is an oversimplification of the CR process, as Gordon and Hibbard[3] have pointed out. Practice, as in any skill building program, serves to make behavior patterns (semi) automatic, freeing energy to deal with other information demands of tasks.

CR has been criticized for lacking a basis in neuropsychological theory.[4] Though the relationships between patterns of neural damage and recovery of functioning following brain injury and CR methodologies are still not well mapped, the criticism that there is no neuropsychological rationale for CR intervention ignores the earlier formulations of Luria[8] and the more recent studies of neural plasticity and synaptic regeneration,[9] the results of which point toward a theoretical basis for brain injury rehabilitation.

Even if it were possible to define more precisely the relationships between neuropsychological events in the brain and CR interventions, an adequate theory of intervention requires much more than the identification of biological markers. A comprehensive theory of instruction must encompass the who (ie, what type of brain injured individual), the when, the what, the how and the question of the composition of the overall remedial curriculum.[20] This requires an adequate taxonomy of subtypes of brain injured patients, a taxonomy of remedial techniques, as well as precise knowledge of relationships between patterns, of deficit and selection of techniques (Gross and Schutz[36]). A theory of CR should also suggest how CR instruction ought to be interdigitated with appropriate clinical management techniques.[20] It must also provide guidelines for the prioritization and the coordination of CR with the delivery of other rehabilitative services.[37]

In short, a theory of remediation cannot be based on a simple inference from a theory of brain damage, or even a theory of brain damage and recovery of functions. Although instruction plays an obvious and central role in rehabilitation, the concern with theoretical issues of instruction has, hitherto, been only marginal. A theory of cognitive remediation must therefore confront the issue of how exactly one teaches a brain-injured person to successfully overcome cognitive deficits and to perform certain functional tasks more adequately.

DEFINING CR AND ITS OBJECTIVES

Most commonly CR is viewed as a systematic endeavor aimed at improvement of cognitive functions that have been impaired following damage to the central nervous system. There is some variability in definition, however. CR is seen as (1) a means of remediation for disorders of perception, memory, and language;[38] (2) as the application of specific cueing systems for enhancing ability on specific functional tasks;[39] and (3) as systematic amelioration-through intensive remedial training-of interference in problem-solving ability in order to promote functional competence in a broader array of everyday life situations.[20,40]

An early distinction offered by Zangwill in 1947[41] helped frame thinking about CR in subsequent years. Zangwill[41] distinguished between direct retraining (to reduce the effects of a deficit) and substitutive retraining. Benedict,[6] referring to essentially the same dichotomy, characterized the two different approaches to CR as restorative versus compensatory. Whereas restorative approaches attempt to remediate specific cognitive functions that are impaired via systematic retraining (eg, attention, memory, etc), compensatory approaches seek to bypass the deficit area and teach the patient how to use certain strategies (ie, templates of approach to a task, along with the use of specific props) for successful solution of functional problems. Carried to their logical extremes, these two approaches seem to imply different consequences. The restorative approach suggests that if one trains to remediate an impaired core area of cognitive function (such as attention, or memory, or constructional praxis) the individual will be able to resume competent functioning in those daily life situations that involve these core cognitive functions. The compensatory approach, on the other hand, implies that if one trains an individual until he/she masters the use of some coping strategies and/or the use of appropriate props, then one can be expected to reattain functional competence in performing daily life tasks despite the presence of the underlying deficit(s). The distinction between the restorative and the compensatory approaches may be partially analogous to the distinction between treating an impairment and treating a disability. An impairment is commonly thought of as a disturbance in the structure of the organism due to underlying pathology, whereas a disability is a difficulty in carrying out a functional act, in a given situational context, requiring assistance from others.[42]

Thus, following this analogy, the restorative approach aims at the direct amelioration of the effects of the core impairments, and the compensatory approach facilitates functional adaptation by providing the patient with well rehearsed techniques ("mental prostheses") that make shunting around the impairments, or deficits possible.

Although neither the restorative nor compensatory approaches are explicitly tied to theories of brain function, Butler and Namerow[4] speculate that by subscribing to a restorative approach one can assume that the challenge to the nervous system inherent in a CR intervention mobilizes biologic functions in the impaired brain whereas, they argue, the compensatory approach capitalizes merely on other-intact-abilities in a depleted brain. In our view, however, until specific constellations of brain dysfunction can be related to specific CR interventions, attempts at basing CR practice on specific neuroanatomical or neuropsychological theory will remain metaphorical.

RESTORATIVE APPROACHES

Most criticism of CR is aimed at the restorative approach. Restorative approaches have indeed had a limited direct impact on enhancement of functional activities. However, one must also note that studies using this approach are heuristically meaningful and provide excellent

building blocks toward developing future technologies of CR instruction.

Restorative approaches dissect an impaired area of cognitive functioning and present appropriately challenging tasks to restore competence. Reflecting the psychometric and laboratory perspective in neuropsychology, which guided earlier developments in CR, restorative studies have been useful in helping to elucidate and calibrate applicable procedures. Because this paradigm lends itself to task analysis, feedback, and shaping of behavior, it is hospitable to computer applications, which might perform the same operations with greater precision.

Differential Impact of CR Training

If cognitive function is viewed traditionally, ie, as encompassing perception, attention, memory, etc, a review of remediation studies in these areas suggests that retraining attention has yielded positive results, whereas retraining memory, for example, has not.[6] This conclusion is based on attempts by investigators pursuing independent lines of clinical research to improve attention.[43-47] The robustness of these findings is open to question because some investigators[32] have been unable to obtain positive results. However, as was already noted, these studies have not really duplicated the methods used in the original experiments that they sought to replicate.

Our experience in teaching brain injured patients suggests other important considerations: the motivation of the student engaged in the activity; the nature and content of the stimulus materials; the didactic techniques used; the manner and rate in which units of information were presented; and the duration of the training, including the number of rehearsals needed for mastery. Due to limited journal space, it is often difficult to tell from published reports of research exactly what was done. The clinical management of patients' frustration, anxiety, and/or resistance is seldom mentioned. Sbordone[48] has called attention to some of the ways in which the emotional sequelae of traumatically brain injured persons can be managed during rehabilitative interventions. However, the effect of such sequelae on clinical studies in cognitive remediation has not been fully explicated.

Scaffolding

The therapist, perhaps even more than the diagnostician, must be aware of the coexistence of multiple deficits and the fact that, within a given defective skill area, incompetence may be the byproduct of defects in subskills. Several remedial approaches have been offered. One remedial approach uses an intuitive disassembly of a particular task in accord with the phenomenology of the task. Thus, Ben-Yishay and coworkers[49] found that breaking down a Purdue Peg Board task into different subtasks, and then training on each of the subtasks, yielded results more powerful than just simple practice on the Purdue Peg Board task. A similar approach was used in analyzing basic attentional deficits and then, based on the analysis, a training methodology was developed. For example, in one attention training study, the different components of attention were trained in a hierarchical manner.[45] The order of training was also based on a phenomenological analysis. Training in each component of the program resulted in improved performance on particular subtasks without carry-over to any remaining "untrained" subtasks. However, retesting at the end of the aggregate program resulted not only in improved performance on all trained subtasks, but also on other tasks that had not been part of the training. One byproduct of this approach was the demonstration of task-specific training, ie, level of performance on a task increased in a manner directly related to the amount of specific training on that task. Others[46] have developed a hierarchical retraining procedure based on theoretical formulation of the constitution of sublayers of an attentional deficit.

A number of approaches to remedial retraining deliberately attempt to build upon skill components that were developed in previous training and used in the training of new tasks. The outcomes of such studies suggest that previously acquired skills can be used to facilitate mastery of new, more complex skills. The skills acquired from previous training can thus serve as a platform for the acquisition of new skills.[50] The platform concept is implicit in the approach of Cicerone and Wood,[51] who taught a patient to inhibit impulsive behavior by training on the Tower of Hanoi problem.[52-54] Webster et al,[55] have used a similar strategy in training stroke patients to navigate with a wheelchair over an obstacle course. Scanning training preceded navigation training. The latter study is of additional interest because it relates training to ameliorate basic impairments (eg, defective visual scanning) to training to improve a functional behavior (ie, the effective use of a wheel chair).

Emerging theories of instruction and general learning have implications for remediation. For example, Collins and associates[18] speak of "scaffolds of skill training" in which previously trained abilities are used to train new abilities. Bruner[56] has called attention to the notion of a "spiral curriculum" in education: previously learned materials are repeated in increasing level of detail as the child advances through a school system. The concept of spiral curriculum has not received the attention it deserves in CR teaching.

Severity of Impairment

Individual differences constitute an important variable when evaluating responsiveness to CR intervention. Ryan and Ruff[57] found that attention/memory training was effective for a group of persons with TBI of mild/moderate severity of impairment, but not for a group with severe impairment. On a more analytic level, in an earlier study with stroke patients, it was found that initial competence in performing block designs related inversely to the amount of cueing required for successful completion of failed designs; when patients failed a given design and cueing was needed, more severely impaired patients required more cues than less impaired patients.[58,59] This observation is in accord with results of studies comparing the ability of experts and novices in the same domain of competence to respond to cues.[60] Experts were able to respond to cues more rapidly and completely than did novices. Clearly, then, initial com-

petence in a given area (before remedial intervention), can be a powerful predictor of level of cueing needed during CR training. More severely impaired persons may require a greater articulation, ie, more explicit and elaborated cues during CR training, than less severely impaired patients.

SUBSTITUTIVE APPROACHES

Substitutive or compensatory approaches have met with greater acceptance than restorative approaches, perhaps because substitutive approaches are generally geared toward facilitation of the functional activities of everyday life. Mayer and colleagues[61] used a stepwise procedure to teach brain injured individuals to brush their teeth. Patients with hemiplegia due to stroke were taught a sequence of operations needed to transfer from a bed to a wheelchair.[62] Though these activities essentially involve motoric components of activities of daily living, substitutive retraining has also been applied to more complex cognitive functions. A key element is the reliance on metacognitive[63] strategies to help individuals compensate for specific core deficits and thereby improve their functional competence.

Performance on a cognitive task can be analyzed in several ways. One way is to focus on questions involving competence levels; for example, the ability to process information (including amount and complexity of the information), the speed with which information can be processed, the length of time information is retained, and the efficiency with which it can be applied. A second way is to focus on questions involving control processes. The latter are "rules" that govern how information is organized and/or response styles indicating which strategies are used for information retrieval or utilization. Control elements are used in the assimilation/acquisition of new information (eg, memorizing by "chunking"; rehearsing; and by using mnemonics) and play a significant role in the forming of mental algorithms that are used in problem-solving activities.

Metacognition,[63] "knowing about knowing," has become an important tool in the study of cognitive processes. The distinction between competence levels and control or metacognitive aspects of cognition is important for the study of CR. Even when, as a result of brain injury, there has been a diminution or loss in the capacity level of a given cognitive function, it may be possible to improve the patient's functioning by systematically retraining him or her to take alternative paths to solving a problem. This retraining inevitably taps into control processes. Though some aspects of the control processes may be related to issues of personal history, goals, and motivation, other aspects of control processes are closely tied to executive functions, ie, the planning, prioritizing, organizing, and self-monitoring elements of problem-solving behavior.[64] In this context, however, we wish to focus attention on those aspects of metacognition that are related to executive functions.

Although our concern is primarily with issues of remediation, the distinction between the competence and processing aspects of cognitive performance is also seen as significant in assessment of brain injured persons, because most of traditional psychometric tests measure competencies, ie, whether the person passed or failed to complete the assigned tasks, instead of measuring process or style of approach to task.

Ben-Yishay and associates[65,66] analyzed the manner that blocks were handled and maneuvered during both passing and failing block design performances of unilateral, right, and left hemisphere impaired (stroke) patients and matched controls. Stroke patients were significantly less persistent (ie, they performed fewer continuous exploratory motions until a perfect match with the model was achieved) than control patients. The control patients tended to adopt a persistent style; they kept trying to match each quadrant of a block design stimulus card with the proper block until they obtain a satisfactory result. They then moved on to the next quadrant. Brain-injured persons, on the other hand, tended more frequently to perform fewer systematic attempts at matching a given quadrant. They typically gave up trying to solve a matching problem before going on to a different location.

A second example of recording and analyzing process involves a particular testing procedure that was designed by and is currently used as part of the assessment battery of the New York University Head Trauma Program (unpublished data). The test was designed as a basic, nonverbal, practical measure of executive skills. A subject is instructed to assemble nuts, bolts, and washers of different sizes according to three preassembled models that are displayed on a working board in front of the subject. All the spare parts and the necessary tools (ie, two wrenches and a screwdriver) are mixed together, in disarray, in a transparent plastic bowl. The subject is instructed to examine the models and then proceed with the task of assembling the required nine duplicates. Every move committed by the subject is recorded by the examiner, without comment, until the test is completed. (This test differs from Lezak's[64] Tinker Toy Test, TTT. The scoring system of the TTT consists, strictly speaking, of measures of an examinee's final product, rather than the process of the performance itself).

The written performance protocol is then scored, according to a five-point scheme of adequacy, along several process dimensions. These include: (a) degree of preparation, ie, organization and preselection activities exhibited by the subject in handling the tools, parts, and work space; (b) degree of methodicalness, ie, prioritization and consistency in the sequencing of the operations; effectiveness of self-monitoring, ie, error detection/correction, in-process and/or error detection/correction at the end of the performance; (c) flexibility (eg, refraining from repetition of an ineffective procedure, or shifting—as the task progresses—to a more effective procedure). Thus, whereas content or capacity measures of the pass/fail variety often fail to reflect the severe and functionally incapacitating nature of certain deficits (particularly defective executive functions, or various manifestations of unawareness associated with frontal lobe impairment) process measures may reflect it. The field of CR must explore systematic utilization of both metacognitive assessment and remedial techniques.

Research examples of the use of metacognitive techniques are seen in Glasgow and associates'[67] PQRST (Preview; Question; Read actively; Study; Test for Recall) pro-

cedure to facilitate comprehension and recall of written material, and Lawson and Rice's[68] work on improvement of executive functions. At the other end of the spectrum we find the use of a variety of "scripts" and systematized (therapeutic) "exercises" designed to enhance awareness of deficits, to foster compliance and malleability during treatment, and to facilitate self-acceptance.[19,69]

The Problem of Generalization

Difficulty with concrete thinking is a hallmark of brain damage. This places a severe limitation on the ability of brain injured people to transfer what they have been taught from one context to another. Parente and DiCesare[70] distinguish between generalization, the ability to use a newly learned strategy in a novel situation, and transfer of learning that involves training skills applicable in specific situations. They provide a framework for defining degree of similarity between the training and criterion tasks. Gordon[71] distinguishes between three levels of transfer that should be kept in mind when a TBI patient receives CR: (a) Is there a carryover of the training on alternate forms of the task within and between training sessions? (b) Is there a carryover of improvement following training on one task to tasks that are similar but one step removed from the original training task? (c) Can it be demonstrated that the improvement following CR has also carried over to specified functional life activities of the patient? Westling and Floyd[72] report 27 studies assessing efficacy of generalization in developmentally disabled (DD) populations. The principles and methods used for DD populations may well apply in the case of patients with TBI, in particular to enhancement of instrumental activities of daily life and community reentry skills via CR training. Our central point, concerning the issue of generalization, is that expectations about generalization should be made explicit at the start of treatment and, furthermore, that these should include specification of particular functional outcomes.

PERSON VARIABLES

Awareness

Though it has been long recognized that individuals with TBI are unaware of their own deficits, the past decade has seen the development of measures designed to help identify the nature and incidence of this lack of awareness.[73,74] Prigatano and Schachter[75] and McGlynn and Schacter[76] provide excellent reviews of the many studies in this area. Barco and coworkers[77] have presented a model of awareness along with methods of facilitation and compensation. They distinguish between intellectual awareness, emergent awareness (recognition of a problem when it is occurring), and anticipatory awareness, (recognition that a deficit related problem will arise before it takes place). Prigatano and Altman[78] present evidence that unawareness in head injured patients, in the sense of overrating self-assessed competencies, when compared with ratings of relatives, tends to be associated more frequently with bilateral and multiple site lesions as detected by computed tomography and magnetic resonance imaging scans. However, unawareness as an issue is of great interest not only from a theoretical or diagnostic standpoint, but also as a central problem in rehabilitation of traumatically head-injured persons, and has a direct relevance to CR.[21] Without awareness and acknowledgment of deficits, it is difficult to engage a head injured patient in sustained and effective remedial training. Indeed, it is hard even to obtain patients' consent to enter into a rehabilitation program or to comply with an elementary request when they are unaware of the reasons for the treatment or the request.

Whereas unawareness is well described in the TBI literature, systematic management methods are less well explored. Ben-Yishay and Gold[79] and Ben-Yishay and Prigatano[21] have noted in TBI patients that unawareness is a factor in their inability and poor motivation to optimally engage in sustained CR activities. Only when a patient is made (at least minimally) aware of his or her deficits and becomes engaged in the training activity, can one expect the patient to achieve optimal compensation for deficits following CR (ie, the assimilation and the reliable application of compensatory repertoires). Furthermore, awareness of shortcomings, along with optimal engagement in the rehabilitation process, and the acquisition of compensatory repertoires, are necessary preconditions for subsequent emergence of the patient's acceptance of his or her predicament.[20] Acceptance includes voluntary endorsement by the patient of realistic living and occupational options, as well as calm acceptance of one's self and one's predicament. There are phases through which a patient must pass in order to attain success in neuropsychological rehabilitation. The specific landmarks of each of the steps in the hierarchy have been defined in functional behavioral terms.[20]

CR and Self-Concept

Cognitive deficits, impaired generalization, impairment of self-awareness, lack of awareness of maladaptive behaviors, and changes in self-concept are common after TBI. These coexist and are often causally interrelated; the interrelationships play an important role in CR. It has been noted that TBI patients who are unaware of or who deny their deficits pose a serious problem for rehabilitation professionals. Denial of a cognitive problem and limited self-awareness pose particular difficulties for "restorative" types of CR interventions because these require prolonged and intensive engagement in "layered" exercises, whose immediate relevancy to concrete functional objectives is often totally obscure for the TBI patient. It is, therefore, a critical task of the remediator to relate the remedial activities to meaningful "real-life" goals.[20,21]

The need to actively point out connections between remedial exercises and functional goals to the TBI patient is in contrast to successful coaching of normals in sports.[80] In sports coaching, students are told to "forget about winning" and concentrate on "lining up the racket" in certain positions, or keeping their "eyes on the ball." The instruction to ignore the goal and concentrate on technique, is merely a temporary ploy designed to perfect certain elements of the

larger skill. The goal is enhancement of one's skill in order to increase competitive edge. With the TBI patient, on the other hand, the goal is to make the patient aware of the relevancy of the CR exercise, as well as to motivate the patient to engage in training activity.

If one asks a person with TBI "who are you?" the answer, generally, is in terms of pretraumatic vocational role/status (eg, "I am an engineer"; "I am a computer technician"; "I am a manufacturer, a businessman"). Many TBI patients have difficulty in reconciling their preinjury sense of self or ego identity with current reality because of a combination of cognitive and emotional factors. On one level the goal of neuropsychological rehabilitation is to ameliorate interferences with cognitive functions and aid in mastery of compensatory repertoires in order to improve functional competence. On another level the goal is to promote in TBI patients the necessary alteration of their sense of self or ego-identity so that in spite of the current limitations imposed by the brain injury they can reattain a minimum degree of self-esteem and self-worth.

Most published studies on different CR techniques have approached remediation issues as if they can be divorced from self-concept. Few attempts have been made to deal with the issues of awareness and self-concept as they pertain to the CR intervention process. In clinical practice, however, the two are closely connected, and must, therefore, be addressed remedially in a closely coordinated fashion.[21]

Studies on populations with difficulties in metacognition have shown a tendency to attribute problems in performing/mastering tasks to generalized negative, self-devaluative beliefs about the self.[81] Bandura[82] has demonstrated that self-efficacy (ie, that outcome is dependent on personal effort) is an important mediating factor in determining both level of effort and effectiveness of performance; that ability to perform alone, without a sense of effort, will not ensure self-efficacy. In contrast to earlier approaches in applying learning theory to behaviors in rehabilitation, which relied primarily on external reinforcers (derived from animal models), more recent studies have placed greater emphasis on conditions of intrinsic reinforcers in learning.[83,84] It is clear that facilitation of effective performance as well as fostering of self-efficacy are important components in CR intervention and merit serious consideration in neuropsychological rehabilitation of brain-injured individuals.

THE CASE FOR MULTIMODAL APPROACHES

Multimodal interventions have been criticized because they do not permit disentangling of the effects of different simultaneous interventions, complicating the attribution of gains. However, clinical realities suggest that cognitive problems are both layered and coexistent. Therefore, if one wishes to produce functionally meaningful improvements through systematic CR, a multimodal approach may be the most appropriate. From a research standpoint this appears to pose some problems. However, these are not insurmountable.

It is possible to test the effects of individual methods of intervention by systematically varying the amounts and types of treatment, as shown in the work of Ben-Yishay and associates.[85-87] Three matched groups of traumatically brain injured patients were subjected to three different mixes of remedial intervention. For each group, the frequency, duration, and overall number of hours of treatment, amount of personal counseling, and social-peer group activity were held constant, and the subjects of each of the three groups were given initial systematic training to improve basic attention. The three groups were given different remedial training as follows: One group received both individualized CR training and, simultaneously, intensive training on an interpersonal skills training module. The interpersonal module consisted of a hierarchy of structured interpersonal communications exercises designed to promote willingness/ability to own up to problems and to publicly assert awareness of deficits and acceptance of the disability. The CR training hierarchies consisted of a set of constructional praxis tasks, a set of visual analytic tasks, and a set of verbal logical reasoning exercises. The second group of patients received training on the interpersonal skills module but did not receive training on the various CR hierarchies, whereas a third group received CR training but no training on the interpersonal skills module. The three different treatment emphases produced similar outcomes in return to work and differential outcomes in other areas. Those subjects who received training in the interpersonal sphere only achieved higher ratings, compared with the group that received CR only, on selected measures of empathy, social cooperation, and self-appraisal. In contrast, the CR group scored higher than the interpersonal group on selected cognitive psychometric criterion measures. On the other hand, the group of subjects who received both types of remedial training simultaneously showed all the gains achieved by the other two groups. Thus, multimodal programs can be studied systematically. Indeed, there may even be an advantage over traditional uses of "no treatment" control groups in attempting to ferret out the relative importance of differently packaged remedial interventions, because the possibility of attributing gains to therapeutic handling or socialization effects is greatly diminished when one compares differentially treated groups of patients in this manner.

Though traditional research methodologies, such as were used in many restorative studies of CR, play an undeniable role in tool development, for purposes of clinical rehabilitation, multimodal (holistic) approaches to CR[19,85-88] will, most likely, have greater importance. In addition, the interrelationships between cognitive impairment, unawareness and/or denial, and impaired self-concept in TBI patients necessitate the modification of conventional forms of psychotherapeutic approaches as well, if one is to achieve good results in therapy.[19,70,80] Embodied in holistic approaches to neuropsychological rehabilitation is the notion that a therapeutic community, also known as a therapeutic milieu (in which CR interventions, specially modified psychotherapeutic interventions, and aspects of clinical management are systematically integrated) serves as a powerful clinical lever, capable of producing optimal results in terms of the cognitive functioning of TBI patients and in terms of the desired changes in self-concept. Conceptual and clinical formulations[19-21,69,79] with regard to the holistic approach

still need experimental validation, but they seem to have great heuristic value and are promising methods of dealing with elusive problems in the rehabilitation of brain-injured persons.

WHERE DO WE GO FROM HERE?

Rapid developments in the field of CR suggest that continued growth will proceed on many fronts simultaneously. Approaches, procedures, instruments, and techniques are in a state of flux. Several areas can be highlighted for further study:

(1) Further replications of successful studies are needed.

(2) Improved instruments and procedures for assessing the functional dimensions of cognitive impairment and disability are needed to document patients' problems as they are manifested in naturalistic environments. Data on the cognitive and behavioral psychology of everyday life are needed to supplement more formal standardized tests.

(3) New concepts have emerged in the last decade with significant applicability to CR. These include (a) metacognition, (b) awareness and acceptance of limitations imposed by brain injury, (c) ways in which generalization of remedial interventions can be obtained, and (d) development of a systematic theory of instruction, complete with relevant didactic techniques specially suited for the needs of brain injured persons.

(4) The field would also profit greatly from more studies aimed at clarifying which CR techniques are best suited for which TBI patients. More studies are needed to clarify the relationship between degree of unawareness and memory impairment and the ability to assimilate, via CR interventions, various compensatory repertoires and/or to produce improved self sufficiency.

(5) Levin[7] suggests that multicenter clinical trials would help to establish the value of CR. In our view, however, we need first (a) to establish valid taxonomies of TBI, (b) to further replicate studies in intervention, and (c) to study outcomes and achieve a better calibration of diagnosis and treatment. Further research, preliminary to such clinical trials, is required in order to develop both the proper instruments as well as gather additional data.

References

1. Berrol S. Issues in cognitive rehabilitation. Arch Neurol 1990;47:219-20.
2. Gordon WA. Approaches to cognitive rehabilitation. In: Wood RLI, ed. Management of behavioral sequelae of traumatic brain injury. London: Taylor and Francis, 1990.
3. Gordon WA, Hibbard M. The theory and practice of cognitive rehabilitation. In: Wehman PE, Kreutzer J, eds. Cognitive rehabilitation for persons with traumatic brain injury. Baltimore: Brookes, 1991.
4. Butler RH, Namerow NS. Cognitive retraining in brain injury rehabilitation: a critical review. J Neurol Rehabil 1988;2:97-103.
5. Volpe BT, McDowell FH. The efficacy of cognitive rehabilitation in patients with traumatic brain injury. Arch Neurol 1990;47:220-2.
6. Benedict RH. The effectiveness of cognitive remediation strategies for victims of traumatic head injury: a review of the literature. Clin Psychol Review 1989;9:608-26.
7. Levin HS. Cognitive rehabilitation, unproven but promissing. Arch Neurol 1990;47:223-4.
8. Luria AR. Restoration of function after brain injury. New York: Macmillan, 1963.
9. Bach-y-Rita P, ed. Recovery of function: theoretical considerations for brain injury rehabilitation. Baltimore: University Park, 1980.
10. Weinberg J, Diller L, Gordon W, et al. Visual scanning training effect on reading related tasks in acquired right brain damage. Arch Phys Med Rehabil 1977;58:479-86.
11. Ben-Yishay Y. Training hemiplegics to pass block designs. In: Diller L, ed. New York University Medical Center, Rusk Institute, Rehabilitation Monograph No. 50, 1974, 1-85.
12. Gelzheiser LM. Generalization from categorical memory tasks to prose by learning disabled adolescents. J Educ Psychol 1984;76:1128-38.
13. Ellis NR, ed. Handbook of mental retardation; psychological theory and research. Hillsdale, NJ: Erlbaum, 1979.
14. Vroman G, Kellar L, Cohen I. Cognitive rehabilitation in the elderly: a computer based memory training program. In: Pereeman E, ed. Integrating theory and practice in clinical neuropsychology. Hillsdale, NJ: Erlbaum, 1989:395-414.
15. Schachter DL. Toward a cognitive neuropsychology of awareness: implicit knowledge and anosognosia. J Clin Exper Neuropsychol 1990;12:155-79.
16. Posner MI, Boies SJ. Components of attention. Psychol Rev 1971;78:391-408.
17. Resnick LB, ed. Knowing and instruction: essays in honor of Robert Glazer. Hillsdale, NJ: Erlbaum, 1989.
18. Collins A, Brown JS, Newman SE. Cognitive apprenticeship: teaching the crafts of reading, writing and mathematics. In: Resnick LB, ed. Knowing, learning, and instruction: essays in honor of Robert Glaser. Hillsdale, NJ: Erlbaum, 1989.
19. Prigatano G, ed. Neuropsychological rehabilitation after brain injury. Baltimore: John's Hopkins, 1986.
20. Ben-Yishay Y. What rehabilitation means in terms of real world function. Keynote address, NHIF, Seventh Annual National Symposium. Atlanta, GA, November 15-19, 1988.
21. Ben-Yishay Y, Prigatano GP. Cognitive remediation. In: Rosenthal MR, Miller JD, eds. Rehabilitation of the adult and child with traumatic brain injury. 2nd ed. Philadelphia: Davis, 1990:393-409.
22. Hooper S, Hannafin MJ. Psychological perspectives on emerging instructional technologies: a critical analysis. Educational Psychologist 1991;26:69-95.
23. Meyerson L, Michael JL, Mowrer OH, Osgood CE, Staats AW. Learning, behavior and rehabilitation. In: Lofquist LH, ed. Psychological research and rehabilitation. Washington, DC: American Psychological Association, 1960.
24. Fordyce W. Behavioral methods for chronic pain and illness. St Louis: Mosby, 1976.
25. National Head Injury Foundation, Information Center, Southborough, MA, 1990.
26. National Directory of Head Injury Rehabilitation Services. Southborough, MA: National Head Injury Foundation, 1990.
27. Mazmanian PE, Martin KO, Kreutzer JS. Professional development and educational program planning in cognitive rehabilitation. In: Kreutzer JS, Wehman PH, eds. Cognitive rehabilitation for persons with traumatic brain injury. Baltimore: Brookes, 1991.
28. Williams BC, McKay SA, Torner JC. Home health care: comparison of patients and services among three types of programs. Medical Care 1991;29:583-7.

29. New York Times 1990 Mar 1(col 1).
30. Stone AA. Law, science and psychiatric malpractice: a response to Klerman's indictment of psychoanalytic psychiatry. Am J Psychiat 1990;147:428-32.
31. Klerman GL. The psychiatric patient's right to effective treatment: implications of Osherhoff vs Chestnut Lodge. Am J Psychiat 1990:419-25.
32. Ponsford JL, Kinsella G. Evaluation of a remedial program for attentional deficits following head injury. J Clin and Exper Neuropsych 1988; 10:693-708.
33. Ruff RM, Camenzulli FL. Research challenges for behavioral rehabilitation: searching for solutions. In: Kreutzer JS, Wehman PH, eds. Cognitive rehabilitation for persons with traumatic brain injury. Baltimore: Brookes, 1991.
34. Diller L, Gordon W. Rehabilitation and clinical neuropsychology. In: Filskov SB, Boll TJ, eds. Handbook of clinical neuropsychology. New York: Wiley, 1981:702-33.
35. Brooks N. The effectiveness of post-acute rehabilitation. Brain Injury 1991;5:103-9.
36. Gross Y, Schutz LE. Intervention models in neuropsychology. In: Uzzell B, Gross Y, eds. Clinical neuropsychology of intervention. New York: Gilford, 1986.
37. Grimm BH, Bleiberg J. Psychological rehabilitation. In: Handbook of clinical neuropsychology. vol. 2. New York: Wiley, 1986:495-527.
38. Gianutsos R, Gianutsos J. Rehabilitating the verbal recall of brain injured patients by mnemonic training: an experimental demonstration using single case methodology. J Clin Neuropsychol 1979;1:117-22.
39. Kreutzer JC, Gordon WA, Wehman P. Cognitive remediation following traumatic brain injury. Rehab Psychol 1989;34:117-23.
40. Ben-Yishay Y. Cognitive remediation after TBD: toward a definition of its objectives, tasks and conditions. In: Ben-Yishay Y, ed. N.Y.U. Rehabilitation Monograph No. 62. 1981:14-42.
41. Zangwill OL. Psychological aspects of rehabilitation in cases of brain injury. Br J Psychol 1947;37:60-9.
42. Diller L. Neuropsychological rehabilitation. In: Meier MJ, Benton AL, Diller L, eds. Neuropsychological rehabilitation. London: Churchill-Livingstone, 1987:1-17.
43. Ben-Yishay Y, Rattok J, Diller L. A clinical strategy for the systematic amelioration of attentional disturbances in severe head trauma patients. In: Ben-Yishay Y, ed. N.Y.U. Rehabilitation Monograph No. 60, 1979:1-27.
44. Ben-Yishay Y, Rattok J, Ross B, Lakin P, Cohen J, Diller L. A remedial module for the systematic amelioration of basic attentional disturbances in head trauma patients. In: Ben-Yishay Y, ed. N.Y.U. Rehabilitation Monograph No. 61, 1980:70-127.
45. Ben-Yishay Y, Piasetsky E, Rattok J. A systematic method for ameliorating disorders in basic attention. In: Meier MJ, Diller L, Benton AL, eds. Neuropsychological rehabilitation. London: Churchill-Livingstone, 1987:165-81.
46. Sohlberg MM, Mateer CA. Effectiveness of an attention training program. J Clin Exper Neuropsychol 1987;9:117-30.
47. Neimann H, Ruff RR, Baser CA. Computer assisted attention retraining in head injured individuals: a controlled efficacy study of an out-patient programs. J Clin Consult Psychol 1990;58:811-7.
48. Sbordone RJ. Overcoming obstacles in cognitive rehabilitation in persons with severe traumatic brain injury. In: Kreutzer JS, Wehman PE, eds. Cognitive rehabilitation for persons with traumatic brain injury. Baltimore: Brookes, 1991.
49. Ben-Yishay Y, Gerstman L, Gordon W. A model for the systematic diagnosis and remediation of impaired finger dexterity in brain injured persons. Presented at the International Neuropsychology Society, Boston, February 8, 1974.
50. Weinberg J, Diller L, Gordon WA, et al. Training sensory awareness and spatial organization in people with right brain damage. Arch Phys Med Rehabil 1979;60:491-6.
51. Ciccerone KD, Wood JC. Planning disorder after closed head injury. a case study. Arch Phys Med Rehabil 1987;68:111-5.
52. Glosser G, Goodglass H. Disorders in executive control functions among aphasic and other brain-damaged patients. J Clin Exper Psychol 1990;12:485-501.
53. Shallice T. Specific impairments of planning. Philo Trans R Soc London 1982;B298:199-209.
54. Simon HA. The functional equivalence of problem-solving skills. Cognitive Psychol 1975;7:268-88.
55. Webster JS, Cotton G, Gouvier WD, Planton P, Bersol GF, Ashford J. Wheelchair obstacle course performance in right cerebral vascular accidents victims. J Clin Exper Neuropsych 1988;11:295-310.
56. Bruner JS. Toward a theory of instruction. Cambridge: Belknap, 1966.
57. Ryan TV, Ruff RM. The efficacy of structured memory retraining in a group comparison of head injured patients. Arch Clin Neuropsychol 1988;3:165-79.
58. Ben-Yishay Y, Diller L, Gerstman L, Gordon W. Relationships between initial competence and ability to profit from cues in brain damaged individuals. J Abnorm Psychol 1970;75:248-59.
59. Ben-Yishay Y, Diller L, Mandleberg I. Ability to profit from cues as a function of initial competence in normal and brain injured adults: a replication of previous findings. J Abnorm Psychol 1970;76:378-9.
60. Bellazza FS, Buck DK. Expert knowledge as mnemonic cues. Appl Cogn Psychol 1988;2:147-62.
61. Mayer NH, Keating JJ, Rapp D. Skills, routines, and activity patterns of daily living: a functional nested approach. In: Uzzell BP, Boston Gross Y, eds. Clinical neuropsychology of intervention. Dordrecht, The Netherlands: Martinus Nijhoff, 1986.
62. Stanton KM, Pepping M, Brockway JA, Bliss L, Frankel J, Waggener S. Wheelchair transfer training for right cerebral dysfunctions. an interdisciplinary approach. Arch Phys Med Rehabil 1983;64:276-81.
63. Flavell J. Metacognition and cognitive monitoring. Am Psychol 1979;34:906-11.
64. Lezak M. Neuropsychological assessment. 2nd ed. New York: Oxford, 1983;507-6.
65. Ben-Yishay Y, Diller L, Mandleberg I, Gordon W, Gerstman L. Similarities and differences in block design performance between older normal and brain injured persons: a task analysis. J Abnorm Psychol 1971;78:17-25.
66. Ben-Yishay Y, Diller L, Mandleberg I, Gordon W, Gerstman L. Differences in matching persistence behavior during block design performances between older normal and damaged persons: a process analysis. Cortex 1974;10:121-32.
67. Glasgow RE, Zeiss RA, Barrera MD, Lewinsohn P. Case studies on remediating memory deficits in brain damaged individuals. J Clin Psychol 1977;33:1049-54.
68. Lawson MJ, Rice DN. Training in the use of executive strategies. J Clin Exp Neuropsych 1989;271-95.
69. Ben-Yishay Y, Lakin P. Structured group treatment for brain-injury survivors. In: Ellis D, Christensen AL, eds. Neuropsychological treatment after brain injury. Boston: Kluver, 1989:271-95.

70. Parente R, DiCesare A. Retraining memory: theory, evaluation and application. In: Kreutzer JS, Wehman PE, eds. Cognitive rehabilitation for persons with traumatic brain injury: a functional approach. Baltimore: Brookes, 1991.
71. Gordon W. Methodological considerations in cognitive remediation. In: Meir JJ, Benton AL, Diller L, eds. Neuropsychological rehabilitation. London: Churchill Livingstone, 1987: 111-31.
72. Westling DL, Floyd J. Generalization of community skills: how much training is necessary? J Spec Educat 1990;23:386-406.
73. Fordyce DJ, Roueche JR. Changes in perspectives of disability among patients, staff and relatives during rehabilitation of brain injury. Rehabil Psychol 1986;31:217-9.
74. Anderson SW, Tranel D. Awareness of disease states following cerebral infarction, dementia and head trauma: standardized assessment. Clin Neuropsychol 1989;3:327-39.
75. Prigatano GP, Schachter D, eds. Awareness of deficits after brain injury: theoretical and clinical implications. New York: Oxford, 1991.
76. McGlynn SM, Schachter DL. Unawareness of deficits in neuropsychological syndromes. J Clin Exper Neuropsych 1989; 11:143-206.
77. Barco PB, Crosson B, Bolesta MM, Werts D, Stout R. Training awareness and compensation in post-acute head injury rehabilitation. In: Kreutzer JS, Wehman PH, eds. Cognitive rehabilitation for persons with traumatic brain injury: a functional approach. Baltimore: Brookes, 1991.
78. Prigatano GP, Altman IM. Impaired awareness of behavioral limitations after traumatic brain injury. Arch Phys Med Rehabil 1990;71:1058-64.
79. Ben-Yishay Y, Gold J. Therapeutic milieu approach to neuropsychological rehabilitation. In: Wood RLI, ed. Neurobehavioral sequelae of traumatic brain injury. London: Taylor and Francis, 1990:194-215.
80. Gould D, Hodge K, Peterson K, Gianini J. An exploratory examination of strategies used by Elite coaches to enhance self-efficacy in athletes. J Sport Exerc Psychol 1989;11:128-40.
81. Carr M, Borkowski J, Maxwell SE. Motivational components of underachievement. Development Psychol 1991;17:108-18.
82. Bandura A. Regulation of cognitive processes through perceived self-efficacy development. Psychology 1989;25:729-35.
83. Sedek G, Ane Kofta M. When cognitive exertion does not yield cognitive gain. towards an informational explanation of learned helplessness. J Pers Soc Psychol 1990;58:729-43.
84. Leeper M. Motivational considerations in the study of instruction. Cognition Instruction 1988;5:289-309.
85. Ben-Yishay Y, Piasetsky E. Rehabilitation of cognitive and perceptual deficits in persons with chronic brain damage—a comparative study. In: Diller L, ed. Annual progress report, R. T. Center, NIHR Grant No. G0083 00039, 1985. Project #133 40003. Department of Education, Washington, DC.
86. Ben-Yishay Y, Piasetsky E. Rehabilitation of cognitive and perceptual deficits in persons with chronic brain damage—a comparative study. In: Diller L, Ed. Annual progress report, R. T. Center, NIHR Grant No. G0083 00039, 1986, Project #133 40003. Department of Education, Washington, DC.
87. Rattok J, Ben-Yishay Y, Ezrachi O, et al. Outcomes of different treatment mixes in a multidimensional neuropsychological rehabilitation program. Neuropsychology 1992;6:395-415.
88. Scherzer BP. Rehabilitation following severe head trauma: results of a three year program. Arch Phys Med Rehabil 1986;67:366-74.