Review: Management updates (Reviews on advances in treatment)

Outcomes of neuropsychological interventions of stroke

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Abstract

The reported prevalence of cognitive deficits within the first month of stroke ranges widely from 10% to 82%, depending primarily on the criteria used to define cognitive impairment and on the selected patient population. These cognitive defects progress toward impairment over a course of time if left untreated. Among the most common cognitive deficits are the attentional, the visuoperceptual, the memory and executive function deficits. As these impairments are being increasingly recognized in the scientific communities, more and more studies are being devoted to the outcomes of various therapies for these disorders. In this review, we focus on the outcomes of various therapies for these cognitive disorders over time. We reviewed all the possible medical databases using key words for individual cognitive deficit treatment outcomes. All the possible studies including randomized controlled trials, pre-post design studies, case series and single case reports were included in this study. On the basis of present literature review, we conclude that the evidence is definitively positive only for outcomes of attentional and visuoperceptive skill deficits. On the other hand, there have been very few studies to conclude for effectiveness of various therapies for memory and executive function outcomes.

Key Words

Cognition, interventions, neuropsychological outcome, stroke

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Introduction

As a well-documented outcome of several studies, more than half of the patients surviving a stroke attack suffer from cognitive impairment; although, the range of this reported prevalence is wide.[1,2] These cognitive deficits arise mostly from a combination of several neurological disturbances occurring in acute cerebrovascular accident (CVA). These deficits may be the consequence of a variety of factors including the location of lesion, the brain hypoperfusion, the functional deactivation of distant areas in the brain (diaschisis) or due to the exertion of pressure on the surrounding brain tissue by the lesion (Ferro, 2001). These impairments are not only a problem by themselves, but are also associated with greater overall disability and mortality and are more important determinants of functional outcomes after stroke than physical disabilities.[3-5] Further concerns have been regarding the long-term cognitive decline in CVA survivors occurring at a rate 12-56%,[6,7] which are much higher than the rates of age-related cognitive decline in normal adults occurring at 5-10%.[8,9] Such a progressive cognitive decline can lead to severe debilitating impairments in neuropsychological picture of the individual, which has been often termed as vascular cognitive impairment or vascular dementia, known to occur in 20-30% of stroke survivors.[10-12] It is thus essential to understand the nature of progression of these cognitive deficits, factors which are associated with enhancement of this progression as well as about various therapeutic techniques, which can slower or halt this progression. Although, there have been several studies, which have viewed at the longitudinal picture of cognitive status of CVA patients,[2,13] there have not been many studies focused on the outcome effects of specific therapies aimed at treating individual neuropsychological deficits.

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In this review, we will begin with describing the longitudinal progression of cognitive functions in CVA patients. As we do so, we will also mention some predictors of cognitive decline. Subsequent sections will be focused on various therapeutic strategies, which have been applied in such patients and their outcomes in such neuropsychological deficits.

Before taking this discussion further, it is important to make an appraisal on the present neuropsychological models of cognition. Neuropsychological models are theoretical frameworks of different cognitive functions, which attempt to make a singular model for explaining various domains of cognition. No single model has been uniformly or universally accepted and even the basic assumptions of these models differ.[14] There are several theoretical models of executive functions such as: The supervisory attentional system, the working memory model, the model of executive (self-regulatory) functions, the components of executive functions, the problem-solving frameworks and the executive control system. These models focus on different aspects of executive functions such as attention, working memory, self-regulation and problem-solving.[14] For the purpose of this review, we will choose the terminologies for the cognitive domain as used commonly in most of the studies.

Methodology

An exhaustive internet search of all relevant medical databases was carried out using a series of key word applications including The Cochrane Library, MEDLINE, EMBASE, CINAHL, AMED, SportDiscus, Science Citation Index, Index to Theses, ZETOC, PEDro and OT Seeker and OT search. We also searched for unpublished/non-English language trials, conference proceedings, combed reference lists, requested information on bulletin boards and contacted trial authors. For example, for neuropsychological outcomes of attention related deficits after stroke, the key words used were: Attention; Neuropsychology; Cognition; Therapy; Rehabilitation; Stroke; Outcomes; Treatment and so on. Similarly, searches were conducted for memory, executive functions and visuoperceptive skills. All the studies including randomized controlled trials (RCTs), cross-sectional studies, systematic reviews, case series and case-reports were included in the review. The present review was focused on the outcomes of various therapeutic techniques. So instead of enlisting studies, we clubbed together therapy and outcome related studies to highlight a fact.

Long-Term Neuropsychological Outcomes of Stroke

As described above, stroke often presents with impairments in cognitive functioning. However, little is known about the extent and recovery of cognitive functions over time. A number of studies have investigated recovery after stroke, most of them focusing on general cognitive recovery[15-18] over a relatively short period after stroke, usually 3-6 months.[19,20] Long-term improvement in general cognitive function has been reported.[21] Furthermore, there is an improvement in executive functioning after 10 months and 15 months after stroke.[22] Attention measured by trail making test (TMT) errors and time performances also improve over 2 years post-stroke.[21] Improvement on the TMT is related to side of stroke: Left sided stroke had a lower improvement on the TMT B and B errors made than right sided stroke patients.[21] Performance on the Stroop also improves over time (tested 21 days and 6-10 months after stroke).[22]

However, this improvement in cognitive performances may not be as simple. Studies have found that the progression tends to be different in different domains. Barker-Collo *et al*., for example tested the neuropsychological status of 5-year ischemic stroke survivors by Oxfordshire stroke classification and hemisphere of lesion. The sample produced scores within one standard deviation of the normative mean on tests of abstract visual reasoning, verbal memory and visual recall. Impaired performances were observed for executive function and processing speed. Profile analysis revealed no significant differences in overall cognitive performance or in the profile of performance across measures by hemisphere of lesion. However, groups defined by Oxfordshire Community Stroke Project categories produced significantly different cognitive profiles. *Post hoc* analyses indicate those with posterior stroke performed best overall on all tests except the Stroop Dots trial, whereas those with total anterior stroke produced significantly worse scores on tasks requiring visual abstract reasoning (Block Design, Rey Figure Copy), word finding (Boston Naming Test) and processing speed (Stroop Dots, Trails A).

Leśniak *et al*.,[13] aimed to assess the frequency of cognitive deficits in stroke patients and to evaluate the prognostic value of cognitive syndromes for functional recovery. The 200 consecutive patients were examined using a clinical screening battery for cognitive assessment in the 2nd week after their first-ever stroke of which 80 were re-examined after a 1-year follow-up. They found that in the post-acute stage, 78% patients were impaired in one or more cognitive domains. The most frequently affected cognitive abilities were attention (48.5%), language (27%), short-term memory (24.5%) and executive functions (18.5%). At the 1-year follow-up, attention deficits were still the most frequent symptom. In contrast, executive dysfunction, aphasia and long-term memory disorder were significantly less frequent than in the post-acute period. Logistic regression analysis showed that older age; lower score on the Barthel index (BI) and the presence of executive dysfunction on initial examination were significant predictors of a poor functional outcome at the 1-year follow-up examination. They found that executive deficits proved to be the most robust cognitive predictor of poor functional recovery after stroke.

Similarly, there have been other studies, which have tried to explore the predictors of long-term cognitive deterioration. Although not many predictors have been revealed, but some very strong factors have been identified. Among them, acute cognitive disorders are the most powerful predictors of long-term cognitive impairment, dementia, and dependence in basic and more complex activities of daily life.[22,23]

Outcomes of Therapies for Individual Cognitive Domains

Treatment of attention deficits

Impaired attention is the "most prominent" neuropsychological sequel of stroke with reported rates ranging from 46% to 92% in acute stroke survivors.[24-26] Consequently, there have been far more studies of cognitive therapies of attention related deficits as compared with other cognitive domains. However, these studies still suffer from some important statistical and study-design related pitfalls. These problems with current studies have been addressed in recent reviews on this topic. For example, in a stringent review, Lincoln *et al*.,[27] could find only two studies qualifying for inclusion.[28,29] On the basis of this review, the authors concluded that there was some evidence in favor of the fact that training improved alertness and sustained attention, but it was still insufficient to show improved functional independence after stroke. In another review, Cicerone *et al*.,[30] reported the findings of a subcommittee of the American Congress of Rehabilitation medicine. They reviewed the evidence for effectiveness of cognitive rehabilitation in people with traumatic brain injury (TBI) and stroke. The original review, among the selected 13 studies evaluating the effectiveness of remediation of attention deficits, only three met the criteria for Class 1 study (well-designed, prospective and randomized clinical trials). Other studies met criteria for less stringent Class 2 and Class 3 studies. This review supported the effectiveness of attention training during the post-acute stage.

These study-design related concerns aside, most of these studies do show an improvement in domains of attention post-stroke after implementation of attention-focused techniques. For this reason, early identification and rehabilitation of attention deficits after stroke are endorsed by the American Heart Association.[31] Most of studies have implied the attention training process as the therapeutic intervention. The attention training processes use the treatment model, which is grounded in attention theory. This model divides attention into five components: (1) Focused attention (2) Sustained attention (3) Selective attention (4) Alternating attention and (5) Divided attention.[32] The most basic principle of this training is that repeated activation and stimulation of attentional systems facilitates changes in cognitive capacity and results in improved attentional outcomes. In a typical retraining program, this is achieved by a series of repetitive drills or exercises.[32]

So far, most studies have provided positive results for this kind of training. Most studies of this kind of attention rehabilitation have examined specific attention deficits.[33-35] In a randomized controlled trial of 84 stroke survivors, attention retraining improved driving performance.[28] Unfortunately, this study was specific to visual neglect and did not have a sufficient statistical power. In a study of 16 stroke survivors and 13 controls, attention retraining improved attention, neglect and speed,[36] but it was nonrandomized, small, lacked follow-up and controls were unmatched. Furthermore, both trials[28,36] were not blinded in assessment of outcomes. Only randomized controlled study using the Attention Process training in Post-Stroke patients was conducted by Barker-Collo *et al*.[37] Participants in this prospective, single-blinded, randomized, clinical trial were 78 incident stroke survivors admitted over 18 months and identified through neuropsychological assessment as having attention deficit. Participants were randomly allocated to standard care plus up to 30 h of adaptive pacing therapy (APT) or standard care alone. Both groups were impaired across measures of attention at baseline, with the exception of paced auditory serial addition test, which was below average. They found that APT resulted in a significantly greater ($P < 0.01$) improvement on the primary outcome than standard care.

A recent version of this attention training is the computerized attention training. Computerized attention training programs were tested in a randomized controlled trial of 27 patients with left hemisphere damage, mostly attributable to stroke.[28] The results showed improved alertness and sustained attention as a result of this training, but the sample was small, daily life impact was not assessed and inclusion of TBI participants and differences in the intervention between groups impacted reliability of the findings. Recently an automated, computerized training program to treat adults who had sustained a stroke 1-3 years earlier was used by Westerberg *et al*.[38] The treatment protocol required home use of computer software, completing 90 trials (taking about 40 min) daily, 5 days a week for 5 weeks. When compared with an untreated control group, participants who completed the computerized intervention demonstrated improvements on untrained working memory and attention tests, as well as a decrease in self-rated cognitive symptoms.

Some other techniques have been studied as well in this context. Sustained attention training was evaluated by Robertson *et al*.,[39] in right hemisphere stroke patients with unilateral neglect. Eight patients were trained to sustain their attention by a self-alerting procedure. Using a multiple baseline design, they found statistically significant improvements in sustained attention and unilateral neglect, with no corresponding improvement in control measures. This supports the use of attentional training with stroke patients who have unilateral neglect.

In addition to these group studies, there have been single-subject studies for evaluating post-stroke attention deficits. Three studies[40-42] used single-subject methods to investigate the effects of direct attention training for individuals with mild aphasia after stroke. In two of these cases, improvements in reading comprehension were seen after APT.[40,41] In the remaining one case[42] improvement was limited to trained attention tasks with nominal change in auditory comprehension.

To conclude, although several group and single subject studies have been conducted on attentional training therapies of post-stroke attention deficits and most have produced encouraging results regarding the effectiveness of this therapy in stroke patients, these results cannot still be generalized. This is because of the inadequacies of these studies in terms of their designs, sample sizes or statistical adequateness. Better designed prospective studies are needed in the future to encourage a full-fledged application of these therapies in post-stroke attention related problems.

Treatment of visuoperceptual deficits

As pointed out by Cicerone *et al*.,[30] visual abilities can be divided into two categories. First category consists of a group of basic visual attention abilities such as visual scanning and visual perception. Second is a group of complex high level skills impaired in clinical conditions like "neglect." In this section, we will be only focusing on the basic visuoperceptive deficits as the topic of "Visual Neglect" will need much more elaborative description than the scope of this review.

Two main approaches to the treatment of perceptual disorders have received the most attention from researchers.[43] The transfer of training approach assumes that practice on a particular perceptual task will improve performance on similar perceptual tasks. On the other hand, the functional approach strives to promote functional independence through

Table 1: Summary of treatments of perceptual deficits post-stroke

Study	Sample size	Treatment	Outcome
Weinberg *et al*.[44]	57	Testing of reading, writing and calculation abilities	Positive
Weinberg *et al*.[45]	53	Tracing target practice, light searching, cancellation of stimulation, reading and sensory awareness and spatial organization training	Positive
Weinberg *et al*.[46]	33	Perceptual retraining	Inconclusive
Carter *et al*.[47]	33	Cognitive skill remediation and specific task training	Positive
Gordon *et al*.[48]	77	Perceptual remediation	Positive at discharge Negative at 4 months
Wagenaar *et al*.[49]	5	Visual scanning	+visual scanning −for transfer effect
Edmans *et al*.[43]	80	Transfer of training versus functional approach	Negative
Mazer *et al*.[36]	97	Training with useful field of view versus computerized VPT	Negative
Pizzamiglio *et al*.[50]		Visual scanning	Positive
Poggel *et al*.[51]		Cue based attention focus training	Positive
Akinwuntan *et al*.[52]	69	Simulator based training versus non-computer cognitive training	Positive for each group

the repetitive practice of particular tasks, usually activities of daily livings (ADLs).

Excluding the case reports, our review revealed 11 studies addressing the issue of treatment of visuoperceptive disorders in post-stroke patients [Table 1]. Among them, included are RCTs, single group intervention studies and comparative cohort studies. Five of the reviewed RCTs were of good quality while the remaining RCTs were of fair quality. Further in this section, we will review these studies individually so that their specifications and contributions to the treatment of visuoperceptual deficits can be understood.

Mazer *et al*.[36] evaluated the effectiveness of visual attention training on the driving performances of 97 patients with stroke, using the useful field of view (UFOV) training. Training with UFOV to address attention and processing speed was compared with traditional computerized visuoperceptual training. There were no significant differences between groups on measures of attention, visuoperception or resumption of driving. The authors suggested that although there was no benefit from targeting visual attention skills, but patients with right hemisphere stroke might benefit from specific skill training (e.g., using a driving simulator). One study with 22 stroke patients[50] investigated whether it is possible to strengthen the rehabilitation of visual hemineglect by combining a standard scanning intervention[53] with optokinetic stimulation. Results replicated the beneficial effects of scanning training, but the addition of optokinetic stimulation did not further enhance visual scanning or attention. A class I study[51] investigated whether the use of a visuospatial cue to focus attention improved performance in areas of partially-defective residual vision during vision restoration therapy. Visuospatial cuing extended the topographic pattern of recovery and improved vision within the cued area. This finding suggests that increased attention to the areas of partially-defective vision helps to compensate for the visual defect.

Another study using UFOV was conducted by Akinwuntan *et al*.,[52] where they investigated for the effects of two training programs on driving related skills. Data from 69 first-ever, moderately impaired stroke survivors who participated in a RCT to determine the effects of simulator training on driving after stroke were analyzed. Participants received 15 h of either simulator-based driving-related training or non-computer-based cognitive training over 5 weeks in addition to regular interventions at a rehabilitation center. Total percentage reduction in UFOV and performance in divided and selective attention and speed of processing subtests were documented at 6-9 weeks (pre-training), 11-15 weeks (post-training) and 6 months post-stroke (follow-up). Generalized estimating equation (GEE) model revealed neither group effects nor significant interaction effects of the group with time in the UFOV total score and the three subtests. However, there were significant within-group improvements from pre-through post-training to follow-up for all the UFOV parameters. *Post hoc* GEE analysis revealed that most improvement in both groups occurred from pre- to post-training. Both training programs significantly improved visual attention skills of moderately impaired stroke survivors after 15 h of training and retention of benefit lasted up to 6 months after stroke. Neither of the training programs was better than the other.

Treatment of memory deficits

Fewer studies have explored treatment outcomes for memory deficits as compared with other domains in post-stroke patients. Some studies have investigated group administered memory remediation. However, given the limited number and generally low quality of randomized clinical trials, the situation remains inconclusive about the effects of presently prevalent cognitive therapies on post-stroke memory deficits. For example, Majid *et al*.[54] identified only a single study that met their criteria for inclusion and found insufficient evidence to support or refute the effectiveness of cognitive rehabilitation for memory problems after stroke.

Cappa *et al*.[55] conducted a systematic review for the clinical effectiveness of cognitive rehabilitation across a vast array of non-progressive neuropsychological problems in stroke and TBI patients. The authors included other systematic reviews, small group studies and single case studies. As a result, the authors found that the use of memory training without the use of external aids as possibly effective, use of learning strategies such as errorless learning as probably effective and the use of a combined treatment approach involving non electronic external memory aids (e.g., diaries, notebooks) and internal strategy training (ST) (e.g., mnemonics) as possibly effective. Recommendations for future research endeavors and clinical practice were provided. One of the strengths of this review is that it appears that all relevant studies were identified using the appropriate databases and additional sources (e.g., text books). The biggest limiting factor in the applicability of the review's results is that the population covered by most of the reviewed studies involved mixed etiologies (stroke and TBI patients).

Hildebrandt *et al*.[56] used a randomized controlled trial to determine whether group oriented memory training programs led to improved memory and attention functions in 62 patients. The participants were randomly assigned to a process-oriented treatment (POT) group, a ST group or a control group. The results indicated that (1) more intensive treatment programs (POT and ST) led to significant improvements in verbal memory skills; (2) an emphasis on encoding and retrieval processes was more effective than teaching compensation strategies and that (3) trained skills generalized onto untrained tasks and attention tasks. Although this study arrived at important conclusions regarding memory rehabilitation, the results need to be interpreted with caution as the study had suffered from some important. Aside from the fact that a large enough sample size was included for discerning group differences reliably, the participant assignment methods were questionable. Specifically, the matching methodology was uneven so that half of the target number of participants was randomly assigned to one of three groups while the other half was matched on the basis of pre-defined demographic variables in order to yield statistically balanced groups. A random allocation procedure in combination with experimenter blinding considerations would have increased the internal validity of this study. The statistical analyses that were performed in this study are also debatable. In addition, no follow-up procedures or ecological rating scales were performed; thus, long-term effects could not be concluded.

Fish *et al*.[57] analyzed the effectiveness of the paging system for 36 participants with stroke. They found that the introduction of the paging system produced immediate benefits in compensating for memory and planning deficits. Unlike TBI participants, the behavior of stroke participants returned to baseline levels after removal of the pager. Further analyses suggested that maintenance of treatment benefits was associated with executive functioning and the stroke participants had poorer executive functioning.

Doornhein and deHaan[58] conducted a randomized controlled trial to evaluate the efficacy of a memory training program. After being selected to participate in the study, 12 first-time stroke patients were randomly assigned to either a treatment group that trained the use of mnemonic strategies or a control group that performed drill and practice exercises (between-subject factor). Both groups were compared on target and control tasks and on subjective judgment scales at pre- and post-training intervals (within-subject factor). A series of two-way ANOVAs revealed that training of mnemonic strategies facilitated face-name learning. However, memory ST had no significant effects on overall memory improvement or subjective memory complaints.

The authors used a two-way ANOVA for each outcome measure appropriate for the purpose of investigating the effects of two independent factors (treatment condition and pre- and post-training intervals) on memory performance as the dependent variable. A careful attempt was also made to control for potential learning or re-test effects (via the use of parallel forms of the three outcome measures) and for spontaneous recovery of memory (via the incorporation of control tasks in each experimental condition). Conversely, the results of this study should be taken with some caution as several important issues pertaining to methodology. Firstly, a small sample size was included and subject selection for the study was not randomized. The fact that the subject pool consisted of patients who had complained about memory problems on their initial neuropsychological assessment reflects a biased sample that may not be representative of the general population. Despite this flaw, the participants were randomly assigned to either experimental group thereby increasing the internal validity of the study. Furthermore, the testing procedure was not blinded as the evaluations were done by the same person who carried out the training sessions. Therefore, it is possible that researcher bias could have influenced the differences displayed in the results. Finally, the scope of this study is limited to the immediate outcome as long-term effects of the training protocol were not evaluated through the follow-up procedures.

Two of the studies[58,59] included objective memory tests as outcome measures. Out of a total on eight immediate outcome measures there were no significant effects of treatment on list learning, face recognition and immediate and delayed recall of stories, but there was a difference on the route learning task no treatment gains were observed on the total scores of either the Rivermead behavioral memory test (RBMT) or the WMS. Only one study[59] reported long-term effects using an objective memory measure (RBMT). No improvement was noted on the immediate and delayed recall of the RBMT story or the total RBMT score showing that there were no immediate and long-term effects of memory rehabilitation. The two studies used different outcomes on subjective measures of memory. One study[58] employed the memory questionnaire while the other[59] used the MAC-S (self) rating scale. No treatment effects were observed on either of these measures.

There have been various studies whose additional value cannot be well-established because of lack of adequate research design. Among them, one was a review paper,[60] one was a series of experiments[61] and therefore did not fit the criteria for treatment or psychological intervention as these experiments consisted of learning trials given on a single day. Furthermore, it was not certain whether there was random allocation of participants to the different trials. Two studies[62,63] did not have adequate randomization and concealment. In the study by Wilson *et al*.[63] the first 20 referrals were allocated to group A and the second 20 to group B, the next 10 to group A, 10 to group B and so on. Participant allocation was carried out by the researcher who also carried out the rehabilitation program.[63] Furthermore, the authors mentioned that there were certain restrictions to the randomization procedure' for reasons related to the individual patient's needs.[63,64] The other study used alternate allocation, with no concealment of allocation and assessment of outcome by the researcher giving the therapy Gasparrini and Satz, 1979.[62]

Vallat *et al*.,[65] implemented a multiple-baseline-across behavior design to train processing and storage components of verbal working memory in a single patient who suffered a left hemisphere stroke. After training eight working memory tasks, significant improvements were noted in processing and storage processes and on ecological questionnaires related to verbal communication and working memory during everyday life skills. Although this case study would rank lower on the hierarchy of research designs, it relays clinically valuable information with regards to a potentially effective rehabilitation approach for working memory deficits. Careful attempts were made by the authors to control for a number of extraneous factors. These included two baseline assessments controlling for spontaneous recovery of memory functioning, control measures ruling out potential non-specific training effects and parallel versions of the tests limiting re-test effects. Furthermore, the incorporation of a control group to the case study design served the dual purpose of achieving "typical" levels for each memory tasks, as well as for determining whether the patient's post-treatment scores approximated more typical response accuracies.

To conclude, the studies on the treatments of post-stroke memory impairments are few when compared to other cognitive domains. Although the results do indicate that memory impairments can be helped with cognitive treatments, these studies fall short of providing substantial evidence in support statistically. Further well-designed trials are needed to further substantiate these findings.

Treatment of executive function deficits

Executive functions are the cognitive mechanisms essential for goal-directed behavior and for responding to new and novel situations. These include the processes of planning, initiation, organization, inhibition, problem solving, self-monitoring and error correction.[66] These processes are executed through the mechanism of working memory where the cognitive processes of attention and memory are controlled by a central executive system.[67] It has been reported that up to 75% of stroke survivors who experience working memory impairment,[68] will also experience executive dysfunction as a consequence. Spontaneous recovery of these memory deficits is also limited at three months in both individuals with stroke and brain injury.[69]

Cognitive rehabilitation interventions for executive functions are based a combination of three strategies: (1) Improving executive function components, (2) compensation of executive function impairment and/or (3) adaptive methods of increasing independence.

Interventions targeted at improving executive function components are characterized by patients working to improve the actual skill. These interventions include strengthening actual executive functions like: (i) Planning and organization skills development; (ii) problem solving and strategy formation techniques; (iii) initiation, self-awareness and self-regulation of behavior; and (iv) inhibition of pre-potent responses.

Interventions for compensation of executive function impairment are characterized by the use of other cognitive assistances to compensate for fragmented or disorganized executive function processes. These mechanisms can be both internal and external assistances. These interventions include: (i) Goal management training (GMT); (ii) use of written strategies and electronic technology; (iii) self-instruction techniques; (iv) feedback methods including mirror and video-feedback; (v) systematic problem solving procedures.

Interventions, which develop individuals' cognitive abilities to formulate adaptive methods are characterized by the training of patients specifically aimed at ADL. Mainly these interventions are based on using external mechanisms to compensate for attention, memory or sequencing impairment when applied to specific training in alternative techniques for undertaking specific ADLs including simplification and environmental adaptation such as written cues within the house. In addition, interventions may contain a combination of the above categories; for example, restoring attention to enable an individual to use a memory aid. Thus, when applied together, these Interventions contribute to functional recovery by either restoring the functional loss (through the stimulation of neuronal growth), by providing a substitute for the functional loss (by teaching new strategies to replace the lost functioning) or by compensating for the functional loss (by increasing awareness and teaching ways to cope with the lost functioning).

Poulin *et al*.[70] recently reviewed the RCTs, pre-post, case-control, cohort and case studies for evaluating the existing data on the effectiveness of interventions on various executive functions of subacute and chronic stroke patients. They observed that for sub-acute stroke, limited evidence from one pre-post controlled group study (of nine aneurysm rupture patients and nine controls) suggested that computerized dual-task training was more effective than no intervention at improving specific executive functions (such as the ability to coordinate two actions). For chronic stroke on the other hand, limited evidence from a RCT of fair quality (103 participants of which 55 had had a stroke) supported the use of working memory training compared with no intervention for the remediation of working memory in chronic stroke. Limited evidence from four studies (one RCT, two pre-post studies and one case study) suggested that ST in problem solving using various formats was more effective than no intervention at improving executive functioning and possibly everyday functional abilities. Limited evidence from one RCT suggested that use of a paging system was more effective than no intervention to improve functional tasks. Limited evidence from a single subject study suggested that a pager was more effective than a task-specific checklist in achieving specific functional goals. Improvement in intelligence subtests and planning ability was demonstrated in a group of patients of stroke and TBI.[71]

In a controlled trial by Levine *et al*.,[72] an expanded version of GMT was compared with an alternative intervention, "brain health workshop" that was matched to GMT on non-specific characteristics that can affect intervention outcome. Participants included 19 individuals in the chronic phase of recovery from brain disease (predominantly stroke) affecting frontal lobe function. Outcome indicated specific effects of GMT on the sustained attention to response task as well as the Tower Test, a visuospatial problem-solving measure that reflected far transfer of training effects. There were no significant effects on self-report questionnaires, likely owing to the complexity of these measures in this heterogeneous patient sample. Overall, this study data provided adequate evidence to support the efficacy of GMT in the rehabilitation of executive functioning deficits.

Rand *et al*.,[73] conducted a preliminary study, which showed that a functional virtual environment of a supermarket could improve executive functioning and multitasking in participants with stroke.

Westerberg *et al*.[38] reported adaptive working memory training benefits (relative to no treatment) in a randomized study with 18 stroke patients.

Nordvik *et al*.[74] reported a case of a lawyer who sustained right hemisphere stroke. He underwent periods during, which he was receiving no formal cognitive rehabilitation, interspersed with computerized working memory training. The authors noted the difficulty of single-case interpretation, but point out that although the patient's other cognitive skills showed steady progress consistent with spontaneous recovery, his working memory appeared particularly responsive to training (improving during the two training periods but declining in between).

Stablum *et al*.,[69] conducted a study that was aimed at rehabilitation of executive functions in closed head injury (CHI) and anterior communicating artery (ACoA) aneurysm patients. The groups tested comprised 10 CHI patients, nine ACoA aneurysm patients and 19 controls. They employed a dual-task paradigm that taps the executive function of coordination between two actions. The treatment consisted of five experimental sessions, in which a dual-task paradigm was used. In the CHI study, the dual-task cost was measured before, immediately after and 3 months after the treatment. In the ACoA aneurysm study, the dual-task cost was also assessed 12 months after the treatment. A significant reduction of the dual-task cost from assessment to retest was found. This reduction remained stable in the follow-up sessions showing that the improvement in this specific executive function was stable over time.

To conclude, present data suggests that cognitive rehabilitation therapies are effective in treatment of executive function deficits after stroke. However, there have been few studies to conclude definitively about the effectiveness of any therapy on the executive functions impairment after stroke. Furthermore, the strategies used have varied much so that exactly what works for which condition cannot be pinpointed at present. Many more studies are needed in this field to provide a definitive picture of these effects.

Other non-specific neuropsychological rehabilitation therapies

In addition to the individual therapies directed toward specific cognitive skill deficits, there have been several studies aiming at the treatment of cognitive disorders using non-specific or general treatment strategies.

Mills *et al*.,[75] studied the effects of completion of an inter-disciplinary out-patient rehabilitation program on functional outcome of 19 patients with ACoA aneurysm. In their retrospective Community-based inter-disciplinary out-patient program, 19 patients of consecutively referred sample were recruited. The intervention was the Inter-disciplinary treatment of functional activities for duration of 2-5 h/day for 3-5 days/week. Main outcome measures were - supervision rating scale (SRS) and change in prevalence at admission and discharge of executive impairments, memory, confabulation, apathy, initiation, social inappropriateness and incontinence. They found that 60% of the patients showed a clinically significant improvement in their SRS from requiring full-time supervision to part-time supervision. Change in SRS was correlated with change in the impairments of executive function, memory and confabulation. They concluded that although pervasive impairments associated with this disorder may limit capacity for even moderate independence, substantial reduction in direct supervision by family members may be achieved.

Effects of exercise therapy on cognitive outcomes of stroke patients were measured by Marzolini *et al*.,[76] Outcomes were measured before and after 6 months of aerobic training (AT) and resistance training (RT) on 41 patients. Cognitive status was measured by the Montreal cognitive assessment (MoCA). Secondary measures included evaluation of gas exchange anaerobic threshold (ATge), body composition by dual energy X-ray absorptiometry and depressive symptoms by questionnaire. They found that there were significant improvements in overall MoCA scores as well as in the sub-domains of attention/concentration and visuospatial/executive function. There was a significant reduction in the proportion of patients meeting the threshold criteria for mild cognitive impairment (MCI) at baseline compared with post-training. In a linear regression model, there was a positive association between change in cognitive function and change in fat-free mass of the non-affected limbs and change in attention/concentration and change in ATge, independent of age, sex, time from stroke and change in fat mass and depression score. They concluded that a combined training model (AT + RT) resulted in improvements in cognitive function and a reduction in the proportion of patients meeting the threshold criteria for MCI. Another category of cognitive studies using physical interventions have used physiotherapy as an intervention. Pyoria *et al*.,[77] conducted a study with the purpose of examining the influence of physiotherapy on stroke patients' cognitive and physical functions and independent living at home compared with traditional treatment over a 12-month follow-up. The 40 patients who received activating physiotherapy were compared with 40 patients receiving traditional therapy. Patients' physical functional capacity was measured one week and 12 months post stroke with the BI, 10-m gait speed, the postural control and balance for stroke test, walking distances and patients' abilities to cope without outside help. Cognitive capacity was measured with specific neuropsychological tests: Language, visuospatial functions, visual inattention and memory. Results showed that physical functional capacity improved significantly in both groups at the 12-month follow-up, but no significant differences were found between groups. However, the patients in the activating therapy group coped better without outside help and covered longer distances outdoors. At follow-up all the measured cognitive functions had improved significantly in the activating therapy group and the change in memory in the same group differed significantly from that in the traditional therapy group ($P < 0.001$), where no significant improvement was observed. Activating therapy also improved stroke patients' cognitive and physical functional recovery and supported their return to independent life at home more than did traditional physiotherapy. Prokopenko *et al*.,[78] estimated the efficacy of computer correction programs on the restoration of impaired cognitive functions. 43 post-stroke patients aged 57-69 (male - 23, female - 20) were randomized into two groups. First group patients had been treated with the standard methods and supplementary neuropsychological computer training for 14 days, 25-35 min of duration per day. Control group received standard treatment according to Federal and local medical recommendations. Initial and achieved levels of cognitive functioning were estimated with the use of mini mental state examination, frontal assessment battery, the clock drawing test, the MoCA, Schulte's test, hospital anxiety and depression scale. Authors found that including the computer correction programs into the complex protocol of rehabilitation of post-stroke patients confirmed their efficacy in both clinical aspects and the patient global impression scale.

Another computer program based intervention was tested by Otfinowski *et al*.,[79] on the patients after stroke to treat their cognitive impairments and hemiparesis. The experimental group involved 10 patients after stroke who were trained on a computer every day during their three-week stay on the rehabilitation ward. The control group involved 10 patients after stroke who did not participate in any computer training during their rehabilitation process. The first part of the computer tasks was designed to train for the attention impairments and visual-motor co-ordination problems. Computer tasks were made in the way to stimulate both the cognitive functions and hand dexterity at the same time. Results showed a statistically significant improvement of the cognitive functions and hand dexterity among patients from the experimental group. Investigators we did not observe any significant improvement in the cognitive functions among patients who did not train on a computer (control group). The results of this research as well as that of Prokopenko *et al*.,[78] suggest the usefulness of these kinds of computer programs in training cognitive impairments and visual-motor co-ordination as well as hand dexterity among the patients after stroke.

Wilson *et al*.,[80] conducted a unique treatment study in TBI and stroke patient with a message-delivery system as an intervention. They hypothesized that because problems in remembering to act on one's own intentions, are among the most ubiquitous complaints in people with ABIs, so one simple form of intervention would be, therefore, to provide a reminder at the right time. In the study, patients and careers drew up a list of to-be-remembered activities that were then entered by service staff into a computer linked to the paging network. At the scheduled time, a message was automatically sent to the patient's pager or mobile phone. They demonstrated that the service could dramatically improve goal attainment. In a recent 10-year follow-up,[81] it was found that the service continues to be used primarily by people with TBI and stroke and that the most frequent message type continues to focus on medication. Changes have included increasing use of the system to help in mood management, for example, reminding users to think about/use a given anger management strategy if necessary.

Lazaridou *et al*.,[82] have done a systematic review on the effectiveness of Yoga and Mindfulness practices as a therapeutic intervention for stroke rehabilitation. They obtained five RCTs studies, four single case studies and one qualitative study. They found that studies reported improvement in cognition, mood and balance and reduction in stress. They concluded that yoga and mindfulness could be clinically valuable self-administered intervention options. They also reported that further research required evaluating these specific strategies and their suitability in stroke rehabilitation as these studies lack of controlled studies precludes any firm conclusions on efficacy.

Conclusion

Cognitive deterioration remains to be the most common cause of specific and overall disability of the individual suffering from a stroke. The present review suggests that there are sufficient evidences to support the fact that cognitive therapies are effective for treatments of attention-related and visuoperceptual problems in post-stroke patients. However, their effects on memory and cognitive function domains are still not clear mainly because of lack of studies in this field. Non-specific strategies can be effective in improving several of these cognitive domains and can be added for the cognitive rehabilitation therapies in post-stroke patients.

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