Attention rehabilitation following stroke and traumatic brain injury
A review

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Attentional capacities, which are frequently impaired following brain injury, have also been found to be amenable to rehabilitation. This review discusses various approaches to attention rehabilitation in adult clients following stroke and traumatic brain injury. Attention process training has been accepted by many as a practice standard in postacute clients, however, its ability to generalize to new situations and to functional capacities is unclear. There is evidence for the use of psychostimulant medication, which may be most helpful when prescribed in combination with attention training. Biofeedback is a new avenue for intervention and is beginning to show some promising results. Rather than train underlying processes, another approach which shows promising results in a few small studies is training clients on specific functional skills, such as driving or vocational duties. Finally, modifications to the environment, implementation of strategies, provision of emotional support, and introduction of external supports/aids are important parts of a rehabilitation program, especially as the client returns to their home environment.

Key words: Attention - Rehabilitation - Stroke - Trauma - Brain injury.

The most common sequelae following brain injury in both children and adults are deficits in attention, concentration, memory and executive function. The idea that deficits in attention impeded the recovery of other cognitive and functional abilities was first proposed and investigated by Ben-Yishay et al. This theory proposes that intact attention is required so that an effective utilization of higher functions may take place. Without attending to information and being able to hold information in mind, one is unlikely to be able to remember or to use that information to help solve problems and guide appropriate behavior.

Following brain injury, basic attentional processes (e.g. focused attention) recover in the great majority of patients, while problems with higher-order attentional processes may persist. These continuing problems may include: orienting to novel stimuli, vigilance, speed of processing, shifting set, divided attention and working memory (which can be considered to be an impairment of attentional control).

The goal of this paper is to summarize the approaches to and review the evidence for remediation of attention deficits in individuals with stroke and traumatic brain injury (TBI). Ipsilateral neglect will not be included due to the specific assessment and treatment considerations for the disorder. Three broad categories for remediation will be included: 1) direct remediation of attention processes (including training attentional processes, medication and biofeedback); 2) specific skills training (intensive training on a specific functional task); 3) modification of the environment, self-management, and supports. While for the purposes of this review the evidence for each of these areas will be examined separately, in practice, most

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Clinicians combine interventions, for example combining direct attention training with external aids, modifications to the environment, and training in cognitive and emotional self-regulation.

**Direct remediation of attention deficits**

*Training attentional processes*

Beginning in the late 1980’s, there was an increasing interest in providing direct training to rehabilitate attention functions following acquired brain injury. Training attentional process usually involves a series of repetitive drills or exercises which increase hierarchically in attentional demand as the client progresses. The theoretical basis of this approach is that repeated activation and stimulation of attentional systems facilitates changes in cognitive capacity, and results in improved attentional processes. The treatment activities are, at least at the start, typically not functional activities (e.g. meal planning, vocational tasks), as functional activities involve multiple cognitive processes. The activities resemble laboratory tasks, such as detecting targets with the presence of a distracter noise, engaging in more and more demanding working memory tasks, working on tasks that involve shifting of set, and engaging in more than one task at once (to practice divided attention). As improvements are made in these tasks, the focus of treatment shifts to practicing the skills in real life activities, and in more naturalistic settings.

With training attentional processes, it is important to use a treatment model that is grounded in attention theory. The model which drives the attention program to use a treatment model that is grounded in attention to practicing the skills in real life activities, and in these tasks, the focus of treatment shifts once (to practice divided attention). As improvements are made in these tasks, the focus of treatment shifts to practicing the skills in real life activities, and in more naturalistic settings.

Training attentional processes is that each task should provide sufficient repetition to stimulate improved attentional processing. An investigation of the factors associated with a positive response to cognitive remediation in 48 adult psychiatric outpatients revealed that there was a threshold of treatment intensity below which there was no treatment effect. Repetition may be carried on in therapy sessions, or with the cooperation of caregivers outside of clinical hours. For example, a recent study by Boman et al. evaluated the effectiveness of cognitive rehabilitation in adults with mild to moder-
ate acquired brain injury in their own home or vocational environment. Treatment involved APT, implementa-
tion of a generalization plan, and teaching compensatory strategies for self-selected cognitive prob-
lems. It was a 9 h program conducted over 3 weeks. The study suggested some improvement at the level of specific attentional impairments, but not for activities of daily living or general everyday functioning. However, this study suggests that, even when conducted in the patient’s natural environment, with a strong focus on generalization, improvement may not be seen in functional activities. This study was quite brief, and, therefore, does not rule out the possibility of success of a more intensive program. It does, however, highlight the importance of attention to generalization. Clinicians must plan for and measure generalization from attention process tasks to real-world activities. Throughout treatment, clients should be encouraged to apply the trained skills to everyday activities which involve multiple cognitive processes. For example, the APT program includes Generalization Sheets where clients can track their performance on everyday tasks which are specific to the type of attention they are training.

In examining the literature on the effectiveness of attention training, factors relating both to the individual and to the nature of the training must be taken into account. Individual factors include: 1) injury severity; 2) time postinjury (e.g., acute vs subacute); 3) location and nature of injury (e.g., left vs right, focal vs diffuse), and other patient characteristics, including education, motivation, age, and comorbidity. Important characteristics of the training include: 1) type of skills trained; 2) duration/intensity; 3) frequency; 4) setting. Given the myriad of individual and injury characteristics and variety of training approaches, “When does it work best and for whom?” may be a better question than “Does it work?”

There have been a number of recent reviews of the effectiveness of training attentional processes. The effectiveness of attention training may be evaluated at multiple levels including changes on: 1) the training task itself; 2) other psychometric measures of attention; 3) psychometric measures of other abilities (e.g., memory); 4) functional or everyday tasks; 5) neurophysiological measures (e.g., electroencephalography, EEG, or magnetic resonance imaging, MRI).

At the first level (changes in performance on the training task), improvements have consistently been shown across studies even in studies of patients with severe brain injury. However, Park and Ingles suggest that if the only evidence is that individuals improve on a similar task to the training task, what has occurred is the learning of a specific skill (e.g., mentally manipulating numbers) rather than improving an aspect of attention. A more rigorous approach is to look for generalization of skills to untrained tasks (including measures of attention or other cognitive abilities). In addition, the goal of any rehabilitation program is to produce changes in the person’s ability to function in their everyday life. Functional changes have been the most difficult to demonstrate experimentally.

A Cochrane review examined the evidence for the effectiveness of attention training following stroke. Only 2 studies, with a total of 56 participants, met the stringent criteria required of a Cochrane review. These studies both showed a benefit of training on measures of alertness and sustained attention compared to control treatments or in a crossover design. Only one study examined measures of functional independence, and these showed no significant improvement with attention training. This review concluded that there appears to be some support for treating attentional deficits in stroke patients to improve alertness and sustained attention. However, as neither study was conducted with the assessor blind to the intervention category, the authors suggested that the routine use of attentional training cannot be supported or refuted.

A review by Park and Ingles highlighted the importance of including control groups, and suggested that the findings from attention training studies in acquired brain injury may be primarily due to practice effects rather than true gains acquired from training. They found that while all measures of cognitive function significantly improved from pre to post-test, none significantly improved when control estimates were accounted for. Of those 12 studies which included a control condition, 6 reported no statistically significant improvement after training. In those 6 studies which did report improvement, Park and Ingles suggest that the improvement seems to be more attributable to the acquisition of specific skills rather than improvement in attention per se. Criticisms of this review include the fact that its inclusion criteria were overly broad, for example including studies which included participants with severe brain injury who would not be expected to significantly benefit from training. In addition, the types of programs and what was measured varied extensively between studies included in
the review.

In another review, Cicerone et al. 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 TBI and stroke. One article reviewed the evidence up to 1997,16 followed by an updated review of the literature from 1998 through 2002.13 The original review selected 13 studies which examined the effectiveness of remediation of attention deficits. Three met criteria for a Class 1 study (well designed, prospective, randomized clinical trials). The others met criteria for less stringent Class 2 and Class 3 studies. This review supported the effectiveness of attention training during the postacute stage. The most recent review found 2 additional Class 1 studies, 1 on attention training and 1 on strategy training,18 1 small Class 2 study, and 2 Class 3 studies. The authors concluded that these recent studies support the earlier conclusions regarding the effectiveness of attention training. Attention training was recommended as a practice standard for individuals in the postacute stage of TBI or stroke.

Sohlberg et al. provided a review of the evidence and practice guidelines for the implementation of direct attention training in individuals with TBI.9 As an alternative to answering the binary question, does it work or does it not work, a template of 5 key questions are proposed which can be used to evaluate the literature. These questions are as follows: 1) who are the participants who received the intervention? 2) What comprises the attention training? 3) What are the outcomes of the intervention? 4) Are there methodological concerns? Are there other explanations for given outcomes, and may results be either exaggerated or hidden? 5) Are there clinically applicable trends across different attention remediation studies? The authors use these questions to evaluate the studies identified by Cicerone et al.16 and Park and Ingles,4 as well as 3 well designed studies published after those reviews.17, 19, 20 In turn, they developed a set of clinical recommendations/practice guidelines which follow the above questions: 1) mildly injured, postacute clients with intact vigilance are best suited for attention training; 2) attention training should include complex attention tasks, be conducted in conjunction with metacognitive training, and should be individualized; 3) the outcomes which can be expected are task specific, at the impairment level. It is unknown whether generalization to untrained or functional level tasks occurs.

A task force of the European Federation of Neurological Societies also evaluated the effectiveness of cognitive rehabilitation.12 This report specifically reviewed the evidence for acute (1 Class 1 and 2 Class 2 studies) versus the evidence for postacute (2 Class 1 and 2 Class 2 studies) attention training. They concluded that while evidence is not able to distinguish the effects of attention training from spontaneous recovery in the acute phase of recovery, there is sufficient Class 1 evidence to support attention training in the postacute phase.

Given the evidence that specific aspects of attention can be improved through training, the next question is: what are the neurophysiological correlates of these changes? This question is beginning to be addressed by researchers who examine changes in brain functioning before and after attention training. For example, Sturm 21 conducted functional magnetic resonance imaging (fMRI) before and after alertness training in 8 postacute subjects with right hemisphere vascular lesions, in order to test the hypothesis that improvement on an attention task is related to reorganization of attentional processes in the brain. Four subjects were given computerized attention training using a car-driving paradigm. Four control subjects were trained in verbal and topographical memory. Fourteen 45-min sessions were conducted with pre and post fMRI and PET scans. Three of the 4 in the treatment group improved and showed the expected change of activation pattern in the right fronto-parietal area. The one who did not improve showed an increase of activation only in the left hemisphere. In contrast, only 1 of the 4 in the memory group improved, while another participant in the memory group showed a change in the activation pattern similar to the treatment group. This suggests that an increase in attention can only occur if at least part of the right hemisphere network (and especially the frontal region), is reactivated.

Medication

Methylphenidate (MP) and other psychostimulant medication have been successfully used to treat attention deficit hyperactivity disorder (ADHD). A recent meta-analysis of the last 40 years of research concluded that MP consistently improves the core clinical features of ADHD.22 Whyte et al.23 conducted a detailed review and cri-
tique of research into the use of psychostimulant medication in TBI. They found 10 controlled studies of the effects of MP in brain injury (2 of these were in the pediatric population). Of these 10, 6 reported some measure of attentional function. However, large differences in sample characteristics, experimental rigor, statistical power, dependent measures and other factors made the studies difficult to compare. Overall, they concluded that the evidence indicates that psychostimulant medication does not have a very strong effect on aspects of attention such as sustained attention or resistance to distraction. In contrast, medication does seem to have a positive effect on processing speed. A recent double-blind, placebo-controlled study of 34 adults in the postacute stage of moderate to severe TBI supported this conclusion. Three variables showed statistically significant improvement in both the pilot and the replication samples: speed of information processing, attentiveness during individual work tasks and caregiver ratings of attention. Effect sizes were small to medium. Whyte et al. have suggested that medication may provide incremental benefit when combined with training attentional processes, as medication affects speed of processing, an area typically unaffected by attentional training.

Biofeedback

EEG biofeedback is an operant conditioning procedure where, through feedback, an individual is trained to modify the amplitude, frequency or coherence of his or her brain waves. A number of studies have supported the notion that people with attentional problems (e.g. ADHD) have increased power in delta, theta and alpha frequency bands (the bands involved in drowsy conditions), and decreased power in the beta frequency band (involved in more active cognitive processes) relative to arousal. Biofeedback treatment in ADHD typically involves theta-beta training, where individuals are trained to increase beta and decrease theta waves (see a review of EEG use in the assessment and treatment of ADHD). A similar beta-increasing biofeedback procedure has been found to be effective in enhancing attention in normal subjects.

A number of investigators have found EEG differences in patients with acquired brain injuries, and EEG biofeedback has been used as a treatment in such individuals. For example, in one study, a group of 27 individuals with brain injury (stroke, TBI or hemispherectomy) received 3 to 5 thirty-min biofeedback sessions per week. Successful alterations of EEG parameters were found in patients with mild to severe brain damage. Symptom improvement (based on agreement between client, caregiver and physician report) was also found, but did not correlate with EEG changes.

Stathopoulou and Lubar suggested that attentional processes training may work in the same way as biofeedback, by training individuals to modify their brain waves. They examined 5 subjects with TBI before and after 22 sessions of computerized APT. While results showed an improvement in attention on psychometric measures in all participants, the expected EEG changes were not consistently found. Only a reduction in alpha frequency was consistent with the hypothesis in most of the participants. Follow-up with a larger sample size and a nontreated control group is necessary.

Another study administered 6 months of standardized, computerized cognitive remediation to 21 adults with severe closed head injury. Subjects were compared to 22 matched head-injured controls who did not receive training. While the groups showed some significant differences on neurophysiological measures following treatment, the authors concluded that the pattern of differences was consistent with increased motivation, attentional effort and improved stimulus processing, rather than improved attentional selectivity.

Finally, Penkman and Mateer examined both behavioral and event-related potential (ERP) correlates of brain activity using the P300 oddball paradigm. Multiple baseline measures of attentional behavior and brain activity were taken before 3 weeks of attention training, administered in a group format, and again after training. Although pretreatment baseline measures were stable, post-treatment, there were both improvements on attention measures and changes in the pattern of N100 and P200 waveforms associated with the P300 tasks. The changes differed across participants, however, suggesting that underlying brain based correlates of attentional problems differed across subjects or that training effects had different neural substrates.

Specific skills training

Training attentional processes has been criticized for its lack of focus on functional changes, and specific skills training has been proposed as an alternative.
Specific skills training attempts to train (or retrain) skills of functional significance, such as driving, or specific vocational tasks. The theoretical rationale behind specific skills training is that it is possible for brain-damaged individuals to develop skills that rely on preserved brain areas. When a specific skill is learned in this way, the cognitive processes used in the tasks may be different from the processes a non-brain-damaged individual would use. This contrasts with the theory behind training attentional processes, in which basic attentional skills are retrained such that the individual uses the same processes as a non-brain-damaged individual performing the same task. In specific skills training, there is little or no expectation of generalization to untrained abilities, whereas in attentional processes training, the theory is that it is possible to train underlying attentional processes, which will in turn improve higher, more complex cognitive functions.

In their meta-analysis of attention rehabilitation, Park and Ingles found 4 studies which focused on performing a specific functional skill, or a closely related skill, that required attention. The review concluded that all specific areas assessed (activities of daily living, driving and attention behavior) increased from pre to post-test. Unlike APT, which yielded non-significant results when the control conditions were accounted for, driving and attention behavior remained significant even when the control condition was accounted for. It should be noted that the sample sizes for specific skills studies were extremely small. For example, only one subject was included in each of the 2 categories with pre/post control. However, the small studies are encouraging, and worthy of increased attention.

A major challenge for rehabilitation professionals is how to actually work with individuals in functional settings. Working in people’s homes, communities, schools, and places of employment might be very valuable, but is often expensive and/or difficult to implement within the limitations of medical rehabilitation programs. One promising approach in other areas of psychological treatment has been the use of virtual environments. These three-dimensional, immersive environments have begun to develop virtual environments that mimic household, community, and office settings in which attentional, memory and planning tasks can be presented. Practice in these virtual contexts has been shown to generalize in a number of studies to real world environments as well.

### Strategies and supports

Self management strategies, environmental supports, and environmental modifications may be implemented in conjunction with, or as an alternative to, training of attentional processes or functional skills. They may be most useful later in the recovery phase, when an individual is reintegrating into home and work environments. At these times, specific strategies or supports may be the most practical form of mitigating problems in specific situations. Strategies and supports can be divided into 2 broad categories: 1) external support and modifications (which involve modification of the environment in some way); 2) self-management strategies. Careful attention to assessment of a client’s strengths and weaknesses will help the clinician to choose the most effective strategies. To increase the chances of success, clients should be involved as much as possible in the selection and development of strategies and supports.

### Supports and modifications

Implementation of external modifications, supports and strategies to minimize the effects of attention deficits should be considered as part of any rehabilitation program. For example, if distracting environments are a problem, the client may be encouraged to avoid those environments whenever possible. Modifications could also include strategies to reduce or eliminate distractions during tasks which require attention (e.g. facing away from visual distractions, using earplugs, shopping in less crowded environments). In addition, specific modifications may be made to the client’s environment to reduce attentional demands. Organizational systems (e.g. filing systems, bill paying systems, labeling of cupboards) are one such approach. Another approach is reducing visual distractions and clutter.

Some have found the use of external devices helpful. A recent review describes the state of the art in assistive technology for cognition (ATC) for those with...
deficits in a diverse range of cognitive skills. ATCs range from alarms to remind a client to take their medication to robotic technology utilizing artificial neural networks to assist with everyday activities. This review discusses ATCs for problems with initiation, attention, memory, executive function, and sensory processing impairments as well as for social and behavioral problems. Of note is the high level of customization (and recustomization as the client’s needs change) required in order for an ATC device to be of practical use. Indeed, today there are a number of assistive devices designed specifically for individuals with cognitive deficits. Some programs provide a high level of guidance and structure, such as walking a client through the steps required to make dinner. In addition, a new generation of devices provides context-sensitive cues based on sensors placed in the client’s environment (e.g. a cue to wash hands when in the bathroom if the water has not yet been turned on). The clinician should note that anyone, especially someone with cognitive deficits, needs time to effectively utilize supports and modifications. Therefore, sufficient time should be set aside for teaching their use.

**Self-management strategies**

Sohlberg and Mateer describe 3 types of self-management strategies aimed at helping clients deliberately focus their attention. The first is orienting procedures, which encourage clients to consciously monitor their activities in order to avoid lapses in attention. This may be a general orienting procedure (e.g. to focus them on the task at hand), or may be designed for a specific task (e.g. to avoid forgetting their destination while they are driving). Second, pacing strategies may be helpful for clients who experience fatigue or difficulty maintaining concentration over an extended period. These may involve setting realistic expectations, building in breaks, or self-monitoring of fatigue/attention levels. Finally, the “key ideas log” involves teaching people to quickly write or tape record questions or ideas which they want to address later, so that they may continue with the task at hand. As with supports and modifications, it is important to allocate sufficient time to effectively establish a strategy.

Typically, the research literature in this area is restricted to case reports which describe the procedures and outcomes for an individual client. However, one approach which has been studied in a small group format is time pressure management (TPM). This program was designed to provide cognitive strategies to compensate for deficits in speed of processing during daily tasks such as holding a conversation or preparing a meal. Strategies involved included enhancing awareness, planning and organization, rehearsing of task requirements or modifying the environment, all with the goal of preventing or managing time pressure. The study included 22 individuals in the chronic or subacute stage following a severe to very severe closed head injury. Subjects were randomized into 2 conditions: 12 subjects participated in TPM training while 10 participated in concentration training (a control condition). While both groups showed some improvement, TPM produced larger gains and also appeared to generalize to other measures of speed and memory function.

Another approach to research into the effectiveness of strategy use is combining it with direct attention training. Cicerone took this approach, combining working memory training with encouraging participants to consciously use strategies to allocate attention and manage the rate of information. Strategies included verbal mediation, self-pacing strategies, sharing attentional resources during multiple tasks, self-monitoring of mental effort, and management of secondary emotional reactions during task performance. Compared to untreated controls, those who participated in treatment were more likely to exhibit clinically significant improvement on measures of attention and reduction of self-reported attentional difficulties in their daily functioning. However, in this study, strategy use was confounded with attention training. Further research is required which would examine the incremental benefit of adding strategy training to attention training.

It is well acknowledged that awareness of and insight into the nature of one’s own difficulties may be compromised after brain injury. In a recent study by Sawchyn et al. individuals with moderate to severe brain injury tended to underappreciate cognitive impairments, whereas individuals with mild brain injury often appeared to report much greater difficulties in cognition than were observed by others. Working on attentional skills can often assist the injured individual in gaining some insight into the nature of their cognitive difficulties and in managing their emotional response to cognitive challenges (often frustration or hopelessness). Mateer emphasizes the importance of integrating cognitive interventions with interventions designed to manage such emotional respons-
es and to correct negative beliefs about cognitive ability that lead to catastrophic reactions and avoidance of cognitive challenges. In particular, blending principles of cognitive-behavioral therapy (CBT) with cognitive interventions has been found to be beneficial. This approach builds self-confidence in cognitive abilities, and assists the individual in feeling that their own actions (metacognitive strategies, external aids, etc.) can influence how successful they are in managing everyday cognitive demands.

Conclusions

Twenty-five years of research has demonstrated that while attentional capacities are sensitive to brain injury, they are also amenable to intervention. One method of rehabilitation is direct training of basic attentional processes. Numerous studies have supported the ability of attentional process training to improve attentional functioning in individuals in the postacute stage. However, its ability to generalize to untrained abilities or functional capacity has yet to be conclusively demonstrated. Psychostimulant medication appears to be another avenue for rehabilitation, primarily impacting processing speed, and, therefore, may be particularly useful when used in combination with training attentional processes. While a number of studies have demonstrated neurophysiological changes (e.g., fMRI, EEG, ERP) changes with attention training, evidence is just beginning to accumulate for the effectiveness of biofeedback as a treatment.

There are a few studies which suggest that training of specific skills, such as driving, can be a successful method for retraining those with attention deficits. The availability of specialized virtual reality programs provides an exciting new avenue for such training. Finally, modifications to the environment, the implementation of strategies, emotional support, and external supports are important parts of a rehabilitation program, especially as the client returns to their home environment. Whatever approach is taken, it is vital that it be guided by the individual’s strengths and weaknesses and be implemented in full cooperation with the client.

References