Rehabilitation of Attention and Executive Function Impairments

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Abstract

Disturbances of executive functions, including the executive control of attention, are recognized as among the most common, persistent, and debilitating consequences of traumatic brain injury (TBI) [1–6]. This chapter focuses on the application of empirically supported strategies for managing impairments of higher level attention and executive functions following TBI. We recognize that the clinical neuropsychology and cognitive rehabilitation literatures have typically considered attention and executive functions in relative isolation. However, there is considerable overlap and interdependence in the structure and function of higher-level aspects of attention and executive functions. Throughout the chapter, we use the term "attention-executive functions" to refer to executive functions (e.g., anticipating consequences, planning and organizing, initiating and sustaining activities) as well as skills associated with the executive control of attention (also referred to as supervisory, complex, or higher-level attention). Skills associated with executive control of attention include the ability to sustain attention in the face of distractions (selective attention), switch focus or mental sets (alternating attention), or manipulate and control information held online (working memory). The processes involving attention-executive functions are distributed throughout the frontal regions and connect with other frontal, posterior, and subcortical areas to exert executive (i.e., top-down) control over lower level, more modular, or automatic functions [7, 8]. The frontal lobes and interconnecting circuits are

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particularly vulnerable to focal and diffuse damage in TBI, which accounts for the frequency of deficits involving attention-executive functions in this population. Given the overlap in the structure and function of attention-executive processes, interventions targeting these processes are also intimately related.

The chapter begins with a review of attention-executive functions. We also provide a brief overview of recent empirically driven models of frontal lobe functioning, particularly as these frameworks relate to the conceptualization and remediation of attention-executive deficits following TBI. Next, we describe the nature of attention-executive functioning impairments and illustrate how associated impairments can manifest in individuals' everyday lives. This is followed by a review of interventions for attention-executive functioning, including empirical evidence that has culminated in recommendations for clinical practice. The remainder of the chapter is devoted to describing the application of metacognitive training, a class of interventions that have demonstrated empirical evidence of efficacy in ameliorating attention-executive impairments [9–12]. Based on our clinical experiences and judgments, we will emphasize key components of the described therapies with the intent of providing a greater understanding of the theory and application of metacognitive strategy training in the context of brain injury rehabilitation.

Keywords

Attention • Executive function • Frontal lobe • Brain injury • Cognition • Rehabilitation

Overview of Attention-Executive Functions

The term "executive functioning" is used traditionally to refer to a set of integrated higher-order processes that determine goal-directed and purposeful behavior. By supervising and coordinating underlying cognitive, behavioral, and emotional processes, executive functions allow the orderly execution of daily life activities. Executive functions include the ability to formulate goals, solve problems, anticipate the consequences of actions, plan and organize behavior, initiate relevant behaviors, inhibit irrelevant behaviors, and monitor and adapt behavior to fit a particular task or context [9]. Higher-level attentional processes responsible for allocating attention across more than one task, actively shifting attention between tasks, and selectively sustaining attention while inhibiting irrelevant information, also fall within the broad rubric of executive functioning [13, 14]. Working memory, defined as a process that allows the short-term storage, maintenance, and manipulation of information [15], is also intimately related to attention-executive functioning. The "executive" aspect of working memory is the ability to actively manipulate and control transitory information in the mind [16].

Attention-executive functions are also related to emotional and behavioral self-regulation, and metacognitive processes [14, 17]. Metacognition, or simply thinking about thinking, is a set of processes that involves *metacognitive knowledge or beliefs*, *self-monitoring*, and *self-control* that work together to enable self-regulation [12, 18]. Metacognitive knowledge is the moment-to-moment and more stable beliefs about one's cognitive abilities. The ability to self-monitor one's performance and use the resulting internal feedback to adapt to changes in the environment or task demands (a process labeled self-control) is also an integral aspect of metacognition. There is some debate as to whether metacognition is in fact a core "executive" function or rather reflects a distinct superordinate process at the highest level of the cognitive system [12, 18]. Nonetheless, there seems to be general consensus that metacognitive self-regulatory skills are mediated by the frontal lobes, are frequently disrupted following traumatic brain injury (TBI), and are critical to the execution of self-directed complex behaviors [12, 14, 17–25].

Models of Attention-Executive Functioning Impairments Following TBI

Recent developments in cognitive neuroscience, aided by advances in brain imaging methodologies (e.g., diffusion-tensor imaging–DTI; functional magnetic resonance imaging–fMRI), have led to number of new empirically driven, theoretical perspectives of attention-executive functioning. We will briefly review these perspectives with an emphasis on their relevance to the nature and rehabilitation of attention-executive impairments following TBI.

Posner and Peterson [26] have described an approach to understanding attention-executive processes based on principles of large-scale distributed neural networks [27]. Cognitive-neuropsychological and neuroimaging studies have identified distinct attentional networks for alerting, orienting, and executive control [26, 28–30]. The alerting attention network, which is characterized by reciprocal connections between right frontal and parietal regions, involves the ability to reach and sustain preparedness for potential stimuli [31]. The orienting attention network includes the superior and inferior parietal lobes, frontal eye fields, superior colliculus, and the pulvinar and reticular thalamic nuclei, and involves the ability to make covert shifts in attention [31]. The executive attention network involves the anterior cingulate, medial frontal cortex, and lateral prefrontal cortex, and underlies the capacity to use relevant information, ignore irrelevant information, and resolve conflicts among competing sources of information [31]. It is worth noting that the capacity for conflict resolution is a developmental process, which in early life evolves from the need for resolution (or delay) of emotional needs [32].

Niogi and colleagues [33] examined the operations of these attention networks in relation to structural connectivity of white matter tracts. They demonstrated distinct and separable relationships between attention components and structural connectivity, providing evidence of discrete networks. Alerting was related to the posterior limb of the internal capsule, which contains thalamic-parietal connections. Orienting was related to the splenium of the corpus callosum containing interhemispheric tracts connecting regions including the frontal eye fields and posterior parietal regions. The executive-conflict effect correlated with structural integrity of the anterior cingulate region, as expected. Niogi and colleagues also demonstrated an association between decreased performance of the executive network after TBI and reduced fractional anisotropy within the anterior corona radiata, including projections to the anterior cingulate gyrus [34].

The initial investigations of attentional networks were directed at establishing the efficiency and independence of functions involving alerting, orienting, and executive attention [35]. More recently, investigations have demonstrated consistent interactions among attention networks [36]. For example, the alerting and orienting system will typically operate together in real-world situations where a single event indicates both when and where a relevant stimulus occurs [30], suggesting that both of these networks serve a more general preparatory function [37].

This anticipatory function is likely a general, integral feature of higher cognitive processing, especially attention-executive processes [38].

Ghajar and Ivry [39] have described an anticipatory neural network involving the prefrontal-inferior parietal areas that provides a feed-forward mechanism that reduces performance variability by generating a "predictive brain state." This framework suggests that through the generation of moment-to-moment predictions about the immediate future, and the comparison of these predictions with sensory feedback, individuals will be less distracted by irrelevant information which will facilitate goal-oriented behavior. Disruption of this network may represent a fundamental defect after TBI resulting in a variety of deficits, including impairments of sustained attention, poor self-monitoring of errors, and loss of goal-directed behavior.

The interaction among various aspects of attention and executive functioning has also been related to three distinct, separable anterior attentional systems by Stuss and his colleagues [40]. One attentional system maintains a general state of readiness to respond, mediated primarily by superior medical frontal structures. A second attentional system serves primarily to bias attention toward specific criteria that guide responsiveness. Dysfunction of these processes, associated with damage to the left dorsolateral prefrontal cortex, is related to deficits of task initiation and setting of response criteria. The third attentional system maintains the criteria for response selection, so that relevant aspects of the environment are consistently selected and responses to competing or irrelevant targets are inhibited. Dysfunction in this network, associated with damage to right dorsolateral frontal cortex, produces deficits in sustaining attention to criteria and conflict resolution. This characterization of an anterior attentional system has significant correspondence with the attentional networks described by Posner and Peterson [26, 41]; specifically, an attentional network devoted to maintaining alertness or readiness to respond, a second network related to orienting and setting criteria to respond, and a third network related to "executive" attentional processes of response selection and conflict resolution.

Peterson and Posner [41] more recently noted the evidence supporting two brain systems related to the orienting network, through an interaction of endogenous and exogenous stimulus control [42]. Corbetta and Shulman described segregated networks corresponding to top-down and stimulus-driven regulation of attention, related to dorsal and ventral frontal-parietal connections, respectively [42]. While initially related to specific aspects of visual attention, more recent evidence suggests that these networks are related to more general, dynamic roles of reorienting between internally directed activity and attention to the environment [37]. They also noted that the orienting function is not restricted to visual information and overlaps with information from other sensory modalities. The operations of the executive network have also been elaborated, with evidence of dual networks involved in top-down cognitive control [43, 44]. The first executive system involves a fronto-parietal network, distinct from the orienting network, that serves primarily to adapt control over performance by maintaining a stable response set (including the maintenance and prioritization of information in working memory), while a network related to the cingular-opecular connectivity (consistent with the original executive network) provides moment to moment control over performance, perhaps by providing a continuously updated account of predicted demands on cognitive resources [45, 46].

Stuss has also described a "revamped attentional model" of executive functions, based on the fractionation of frontal lobe regions corresponding to fundamental cognitive operations [8]. Three of these proposed processes and their anatomic relations correspond to the earlier formulation of an anterior attentional system [8, 40]. Within this new framework, damage to the superior medial frontal lobes is associated with decreased performance on a range of (apparently dissimilar) tasks due to a failure of "energization," or the initiation and sustaining of any response. For example, superior medial damage might manifest as slow response on speeded tasks. Two aspects of "executive functioning" are related to the dorsolateral frontal cortices (DFC), as in the earlier model. Damage to the left DFC is related to initial task setting and goal orientation, while damage to the right DFC suggests poor monitoring of ongoing performance, deficits in sustained attention, and increased intra-individual variability. These three attentional networks can be further defined by their connections with other areas of the brain. The first is a ventral system involving orbitofrontal cortex and limbic structures related to emotional and behavioral regulation. The second is a rostral and lateral system with bidirectional connections between prefrontal cortex and posterior cortices related to "metacognitive" processes (i.e., the ability to self-monitor and self-regulate), including shifting between attention directed at the environment and internal trains of thought [47, 48]. Stuss and colleagues propose that metacognitive functions—positioned at the highest level of the cognitive system—coordinate the integration of attention-executive cognitive information with emotional and motivational processes, which ultimately guides and enables complex, purposeful behavior [8, 49]. The distinction between a more dorsal fronto-cingular-parietal pathway associated with more deliberate, slow-to-respond, volitional behavior and a ventral pathway that is more reactive (to either environmental stimuli or basic emotional states) and associated with quicker-to-respond, automatic behaviors may be another general principle of the brain's organization of complex attention-executive functions [50]. This dissociation is also central to dual-process approaches to cognitive-affective control [51–54] and provides a framework for metacognitive strategy training methods for affective and behavioral self-regulation [55, 56].

These empirically supported models suggest that the dissolution and restoration of cognitive functioning after TBI may be informed through an understanding of the efficiency and interaction of attention-executive networks, although this approach has to date had limited influence on our understanding of cognitive recovery or the development of rehabilitation interventions. Several authors have argued that these models have important implications for the rehabilitation of attention-executive impairments [14, 57]. Metacognitive processes are critical to the ability to use internal goals and desires to direct ones' thoughts and behaviors. Thus, metacognitive training, characterized by interventions to foster anticipation and planning, response monitoring, and self-evaluation, may be particularly beneficial in reestablishing top-down control over attention-executive cognitive, emotional, and behavioral functioning [9–12, 51, 57, 58]. Recent applications of metacognitive interventions have also emphasized the importance of addressing not only attention-executive cognitive functions, but also emotional/motivational, and behavioral functions, as these processes are anatomically and functionally related in the execution of complex, real-world behaviors [59–61].

The Nature of Attention-Executive Impairments Following TBI

Deficits involving self-directed attention and executive cognitive functioning, behavioral and emotional regulation, and metacognitive functioning are interrelated and commonly impaired following TBI.

Attention-Executive Cognitive Impairments

Impairments of task setting and response preparation can be associated with problems anticipating errors, analyzing situations, planning and executing solutions, and maintaining a flexible or pragmatic approach to tasks—all of which are common after TBI. Impairments in attention-executive function can impact memory through poor initial encoding and organization, or due to a failure to discriminate relevant from irrelevant (or current from past) information. These deficits are often expressed as a vulnerability to interference or false positive errors (or in extreme cases, confabulation). It is important to distinguish these "memory" problems due to breakdown in the attention-executive from a primary amnestic disturbance. Disturbances in task monitoring can result in difficulty sustaining attention, characterized by an increase in all types of errors as well as reduced awareness of errors. In addition, individuals with TBI often complain of being easily distracted, being unable to return to a task after distraction, problems "shifting gears" or switching back and forth between tasks, and problems doing more than one thing at a time. These problems are often most apparent under conditions of increased cognitive load or complexity, such as responding to rapid, externally paced information or responding to multiple simultaneous task demands. Problems with sustained attention may appear as momentary lapses of attention ("mind-wandering") or as increased performance variability due to less effective allocation of attention resources and goal-maintenance during task demands, with some evidence that these types of attentional difficulties reflect different attentional networks [62].

Impairments of Emotional and Behavioral Regulation

In the emotional realm, TBI-related dysfunction can result from damage to those areas of the brain that are responsible for inhibiting the limbic system and the direct expression of emotions. This can result in a loss or decrease in the ability to regulate or control one's emotions. This "release" of emotional expression is often manifested as emotional lability or pathologic affect. Emotional dysregulation after brain injury is characterized by precipitous onset and rapid dissipation (both reflecting the absence of cognitive mediation of affective responding). This can cause a person to feel more extreme or quickly alternate between emotional highs and lows, or to become overwhelmed when expressing emotions. These deficits stem from underlying brain dysfunction, which distinguishes them from those reactions that reflect a purely emotional reaction to perceived impairment that could be expected in many people without brain dysfunction, such as grief, sadness, anxiety, or frustration. Moreover, the nature of the underlying brain dysfunction distinguishes these emotional reactions from those seen secondary to mental illness and psychiatric disorders.

Behaviorally, persons with TBI often fail to think before they act and show corresponding impulsivity, disinhibition, hyperverbosity, poor emotional control, distractibility, and cognitive inflexibility. These "positive" symptoms are indications of behavior that is stimulus-bound or overly determined by the environment. This can lead to behaviors that are rigid, impulsive, and poorly thought out. Although these excessive thoughts, behaviors, and emotions are common, problems can also manifest as more "negative" symptoms that appear to be the opposite of "positive" symptoms. Negative symptoms can include difficulty initiating tasks, low drive or motivation, apathy, impersistence, or a spontaneity—a constellation of symptoms that sometimes is referred to as adynamia [56].

It is also important to note that individuals with TBI who exhibit problems with emotional and/or behavioral regulation often perform within normal limits on neuropsychological measures of attention-executive functioning, but exhibit significant attention-executive problems in their everyday lives [63]. One reason for this is that neuropsychological assessments are administered in highly controlled environments and involve at least some structured task instruction, whereas attention-executive deficits are most apparent in novel, unstructured, or ambiguous situations that are characteristic of real-life functioning.

Metacognitive Impairments

Deficits involving metacognitive self-regulatory skills can contribute to a host of cognitive, behavioral, and emotional problems that impair internally driven goal-directed behavior. Cognitively, people with TBI may have problems monitoring their own thoughts, and therefore lack the internal feedback that is necessary to regulate and guide self-directed behavior. For example, individuals may have problems identifying relevant goals and maintaining progress towards completing goals. Other people may appear to persist with a certain strategy even though it is not working. This may be due to a failure in recognizing the need to adjust an unproductive approach (i.e., poor self-monitoring) or because of difficulties altering thinking or behavior in response to changing task or environmental demands (poor self-control). Metacognitive deficits involving an inability to accurately predict and evaluate one's performance on a given task can manifest as inaccurate self-appraisals of cognitive abilities, an inability to set realistic goals, or unwillingness to accept feedback from others. Moreover, an inability to accurately predict and evaluate one's performance on a given task can contribute to poor self-efficacy as well as reduced motivation and persistence in the face of challenging tasks. Deficits in self-regulating behaviors and emotions can be reflected in the co-occurrence of "positive" symptoms (e.g., impulsivity, disinhibition, distractibility, poor emotional control) and "negative" symptoms (e.g., difficulty initiating tasks, low drive or motivation) in the same individual [56]. For example, when a person with metacognitive deficits lacks external stimulation, a lack of self-regulatory control can manifest as symptoms of low motivation, apathy, and a failure to engage in internally driven, goal-directed behaviors. However, when the same individual is externally stimulated, a lack of self-regulatory control and the concomitant release of lower level more automatic behaviors can manifest as symptoms of impulsivity, disinhibition, emotional lability, and inflexibility [56].

Real-World and Clinical Implications

Taken together, attention-executive impairments can have far-reaching consequences for the person with injury and their family members. These deficits can pose significant barriers to a person's ability to perform functional activities in everyday life (e.g., preparing meals, managing money, using transportation) and live independently [64–67]. Attention-executive dysfunction can also compromise full participation across a number of meaningful life situations, including the ability to work, attend school, manage home responsibilities, and engage in social/leisure activities [66–68].

The presence of attention-executive impairments also presents a significant challenge to the rehabilitation process. They can undermine the acquisition and application of compensatory strategies for other cognitive impairments (e.g., memory notebook training). Furthermore, attention-executive dysfunction in particular may limit the extent to which a patient is able to execute compensatory strategies for other cognitive impairments independently [69], particularly in novel situations or environments [70]. Thus, attention-executive dysfunction can interfere with the success and generalization of treatments for other acquired cognitive deficits. Clearly, there is a strong case for rehabilitation interventions aimed at improving attention-executive functions for persons with TBI.

Interventions for Attention-Executive Impairments

Two primary approaches to intervention have been investigated in the remediation of attention-executive deficits in person with TBI: direct training and metacognitive training. Consistent with the overall goals of cognitive rehabilitation, both approaches are directed at effecting cognitive change with the ultimate goal of improving patients' functioning in meaningful contexts, including functional activities, participation, and quality of life [9–11]. However, direct training and metacognitive training interventions differ with regard to the theoretical approach to treatment; the proposed mechanism of action; and the emphasis and delivery of treatment activities. In this section, we will review the rational, evidence-based literature, and clinical recommendations for direct training and metacognitive training interventions. Because most widely used direct training interventions involve commercially available software and treatment programs that are not in the public domain, we will not describe the specific application of this type of approach. Readers should consult the research studies referenced in this chapter for further information regarding proprietary treatment programs/materials.

Direct Training Interventions

Direct training (also referred to as process-specific training, cognitive remediation, restitution training, or restorative approaches) refers to a broad class of bottom-up interventions that aim to directly restore specific attention-executive processes. This type of intervention is based on the assumption that attention-executive processes can be isolated (e.g., working memory, selective attention, divided attention) and selectively damaged. By activating and stimulating discrete attention-executive processes through a stimulus drill approach, training is hypothesized to result in direct improvement of the selectively targeted attention-executive functions [58, 71–73]. In turn, it is predicted that patients will demonstrate improvements on untrained tasks that also involve the "trained" or targeted cognitive function, and ultimately, in their everyday life activities.

Training activities typically involve computerized or paper or pencil administration of repetitive drills or exercises (e.g., detecting targets in the presence of distracters, sorting words in alphabetical order) that are presented in a hierarchical manner so that tasks become increasingly difficult and remain challenging as patients demonstrate improvement [73]. Some direct training interventions target an individual skill, such as working memory or divided attention [74–79], while other interventions are more comprehensive and offer stand-alone exercises that target a range of attention-executive skills [75, 80]. For example, the Attention Process Training (APT), a commercially available program developed by Sohlberg and Mateer [81], is based on the author's clinical model of attention and includes exercises for five different types of attention that may be impaired following TBI: focused, sustained, selective, alternating, and divided.

The evidence-based literature is generally supportive of direct training interventions, with the caveat that this approach should be used in conjunction with metacognitive training [9–11, 58], which is detailed in the following section of this chapter. As we have discussed previously, deficits in metacognitive self-regulatory skills, including the ability to monitor and control one's thoughts and behaviors, are common after TBI. From a theoretical perspective, incorporating metacognitive training (e.g., feedback, self-monitoring, strategy training) should enhance the potential benefit of direct training by teaching individuals strategies to regulate their own thoughts and behaviors that can be applied outside the laboratory or clinical setting. Given the decontextualized nature of direct training (i.e., completing abstract exercises in the absence of meaningful contexts), metacognitive training that incorporates extensive practice in applying strategies in multiple real-world contexts is also critical to transfer and generalization of acquired skills. Research also supports the importance of combining direct attention training with metacognitive strategy training [58, 82, 83]. For instance, findings from a systematic review of the TBI direct attention training literature suggested that the most robust improvements following treatment were observed in studies that also included training in metacognitive strategies [58]. These recommendations have been echoed by Cicerone and colleagues who have emphasized that clinicians who use a direct training approach should use it in conjunction with a metacognitive training to promote the acquisition of specific compensatory strategies that can be applied in meaningful real-world situations [9–11]. As an example, the most recent version of the Attention Process Training program (APT-3) [84] also involves metacognitive self-regulation training as a critical component of treatment; however, it is important to note that the efficacy of APT-3 for persons with TBI has yet to be determined.

Due to advances in our understanding of neuroplasticity—that is, the ability of the nervous system to respond to internal and external stimuli by reorganizing its structure, functions, and connections, as well an increased emphasis on research that translates neuroplasticity research into clinical practice [85], a growing literature has investigated the efficacy of automated, computerized direct training programs to improve working memory in patients with brain injury [75, 76, 78, 79]. These studies have made explicit claims to be rooted in the mechanics and potential of neuroplastic changes in the brain [59]. In a seemingly opposite direction from the evidence-based clinical practice recommendations set forth by the Cognitive Rehabilitation Task Force of the American Congress of Rehabilitation Medicine

(ACRM) Brain Injury-Interdisciplinary Special Interest Group (BI-ISIG) [9–11], this type of intervention has minimal therapist involvement, as well as no instruction related to strategies or application to real-world activities. Rather, these "neuroplasticity-based interventions" are based on the premise that direct training alone has the potential to "lead to a less diffuse pattern of cortical activity or redistribution of neural activities within the network areas," [75] which in turn will contribute to restoration of targeted attention-executive functions. However, it is important to note that many of the demands that are inherent in "neuroplasticity-based" computerized cognitive training are also critical aspects of therapist-directed interventions: active engagement in the treatment process, attention to the relevant aspects of the treatment situation, ongoing provision of feedback, adaptive adjustment of task difficulty based on prior performance, and a planned progression of treatment demands.

Similar to findings reported in the earlier direct training literature, initial evidence from these plasticity-focused studies has shown improvements on untrained attention-executive tasks [75, 76, 78, 79] and patient-rated cognitive symptoms [75, 76, 79]. Using fMRI, Kim and colleagues also demonstrated changes in cortical activation following computerized neuroplasticity based training in a sample of patients with TBI [75]. This is suggestive of training-related brain plasticity; however, this line of research is still in its infancy and implications regarding these training-induced patterns of cortical activation remain open to various interpretations [13, 59]. Chen and colleagues [13] have noted that increased cerebral activation can represent the recruitment of remote areas into a functional system, compensatory changes in brain activation, effects of effort and motivation, or maladaptive forms of cerebral plasticity. Decreased activation may represent a failure of recruitment, increased neural efficiency, or automatic processing. It is also unknown if changes in functional cerebral activation are related to improvements in patients' everyday lives.

Despite these initial positive findings, several factors may limit the applicability of automated, computerized neuroplasticity-based training. First, the training has been described as "intense, demanding and tiring" [76] requiring participants to initiate and sustain about an hour a day of cognitive exercise, 5 days a week. Thus, this type of training may only be appropriate for patients with a high level of motivation, compliance, commitment, and stamina [59]. In addition, there is evidence that the treatment is most effective for patients with relatively preserved cognitive functioning, suggesting it may be inappropriate for patients with more severe impairments [76]. The lack of therapist involvement and the impersonal nature of the treatment may be inappropriate and unappealing for many patients. Lastly, from a theoretical perspective, automated, computerized direct training interventions are limited in that they addresses only attention-executive cognitive functions and fail to consider patients' emotional and behavioral concerns, which can influence the outcome of treatment (although it might be argued that some capacity for frustration tolerance is embedded in the training). Moreover, to the extent that direct training is capable of strengthening specific cognitive skills, a lack of explicit instruction in metacognitive strategies along with the decontextualized intervention (i.e., completing abstract exercises in the absence of meaningful contexts) suggests that individuals may have difficulty applying these skills outside of the laboratory or clinical setting.

In summary, the findings from direct training interventions have been generally positive; however, we stress that the use of direct training without therapist involvement and without training inmetacognitive strategies is not recommended. This is consistent with practice recommendations of the BI-ISIG Cognitive Rehabilitation Task Force that direct training should also involve metacognitive training to promote development of compensatory strategies and foster generalization to real-world tasks [9–11]. Based on emerging evidence regarding plasticity-based computerized training, the BI-ISIG Cognitive Rehabilitation Task Force also recommended that computer-based interventions may be considered as an adjunct to clinician-guided treatment for the remediation of attention deficits after TBI [86]. However, the Task Force emphasized that the sole reliance on repeated exposure and practice on computer-based tasks without involvement and intervention by a therapist is not recommended.

Metacognitive Training Interventions

A second broad approach to the remediation of attention-executive dysfunction involves metacognitive training—an umbrella term that applies to many top-down interventions that emphasize capacity for self-regulation. As we have discussed earlier, metacognitive self-regulatory processes, which are often impaired following TBI, involve the ability to monitor and control one's thoughts, emotions, and behaviors. Metacognitive processes allow for the execution of self-directed, complex behaviors by supporting a set of skills, including (1) identifying and setting goals, including anticipating task demands; (2) self-monitoring and comparing performance with goals or outcomes; (3) making decisions to change one's behavior or select an alternative approach to a situation; and (4) executing the change in behaviors [12, 87]. The goal of metacognitive training interventions is to reestablish these metacognitive processes in an effort to improve a patient's ability to exercise control over his or her behaviors and the cognitive functions that support or inhibit them. Towards this end, the therapist attempts to remove obstacles that interfere with this self-control. These obstacles can be cognitive, emotional, or behavioral. Often they comprise all three. This is accomplished through the training and internalization of metacognitive strategies that involve direct, step-by-step instruction to teach individuals how to regulate their own behavior [12, 87, 88]. Rather than train specific skills, metacognitive strategies can be used in a variety of different situations, thus enhancing the potential for generalization of behavioral improvements to novel, real-world contexts [13, 56, 60, 82].

Although the primary goal of metacognitive training is to enhance a person's ability to internalize awareness and control over his or her behavior, treatment usually begins with external cuing of a general rule or principle for the particular metacognitive strategy. Accordingly, patients are taught the process of self-monitoring and self-control by means of education, modeling, external directions, instructional handouts, and cuing. Over time, through practice and implementation in a variety of settings, this external strategy can become internalized, under the self-generated direction of the patient, including the cuing, structure, and execution involved in the strategy. Thus, what begins as an external strategy becomes an internal strategy.

Metacognitive strategies may be relatively simple or complex. For example, training a patient in the use of a simple problem-solving sequence is a simple strategy that may be appropriate for those patients with moderate to severe impairment. Other metacognitive training interventions are more complex, often involving multiple steps or targeting multiple problems. For instance, complex interventions may involve simultaneous training in self-regulation of cognitive and emotional processes. Complex strategies have the advantage of providing a much wider range of therapeutic challenges and experiences for a patient and may allow for the training of a wider range of target behaviors and situations, covering a wider range of applicability, and allowing for greater generalization and transfer of training; however, these strategies may be usable only by those with relatively mild to moderate impairment.

In the TBI rehabilitation literature, the majority of metacognitive training interventions have focused on improving general problem-solving skills [89–92], or more specific activities that are involved in problem solving, including goal management [93–96]; planning and self-monitoring [55, 56]; problem solving that involves time pressure management [97, 98]; and attentional self-regulation [93, 96, 99]. A recent investigation of metacognitive strategy training conducted by Spikman and colleagues [92] was unique in that it involved a multifaceted approach targeting eight different skills including, self-awareness, goal setting, planning, self-initiation, self-monitoring, self-inhibition, flexibility, and strategic behavior. Boelen and colleagues [57] noted that this intervention appears to address many of the components of Stuss' theoretical framework [8]. Moreover, the multifaceted intervention was successful in improving the amount and quality of daily life functioning across the domains of vocational functioning, social interaction, leisure activities, and mobility.

In addition to the cognitive aspects of problem solving, current interventions based on metacognitive strategy training have also addressed emotional aspects of behavioral regulation [60, 91]. In order to solve problems in a cognitively effective manner, individuals have to be able to control those emotional reactions that interfere with their ability to think clearly and effectively. These reactions are often associated with "negative self-talk" in the form of cognitive distortions or misattributions. Examples include: "I have to do a perfect job"; or "I'm a failure"; or "I have to be in complete control or it will be a disaster." Rath and colleagues [91] evaluated the effectiveness of an innovative intervention that focused on the development of emotional self-regulation strategies as the basis for maintaining an effective problem orientation, along with a "clear thinking" component that included cognitive-behavioral training in problem-solving skills. The intervention also involved a systematic process for analyzing real-life problems and role-play of real-life examples of problem situations. The intervention group demonstrated improvements on measures of executive functioning, self-appraisal of "clear thinking," self-appraisal of emotional self-regulation, and objective observer-ratings of interpersonal problem-solving behaviors in naturalistic simulations.

In summary, there is substantial evidence to support the use of metacognitive training for persons with TBI [9–12, 57]. Based on the current evidence, the BI-ISIG Cognitive Rehabilitation Task Force of ACRM has also recommended, as a practice standard, metacognitive strategy training for deficits in executive functioning after TBI, including impairments of emotional self-regulation [11]. As detailed in a systematic review and meta-analysis, metacognitive training for problem solving of personally relevant activities has demonstrated significant effect sizes in impairment, activity, and participation outcomes compared to control treatments and was recommended to improve problem-solving deficits following TBI [12]. The BI-ISIG Cognitive Rehabilitation Task Force of ACRM has come to a similar conclusion and has recommended, as a practice guideline, training in formal problem-solving strategies and their application to everyday situations and functional activities during post-acute rehabilitation after TBI [11].

From a theoretical and clinical perspective, an important benefit of metacognitive training is that these strategies can be customized rather easily to address problems with attention-executive, cognitive, emotional/motivational, and behavioral functioning. Cicerone and colleagues [60] have suggested that metacognitive training directed at improving patients' self-regulation of both cognitive and emotional processes leads to increases in patients' self-efficacy beliefs, specifically in their confidence in managing residual cognitive and emotional symptoms. Improvements in perceived self-efficacy (and related concepts, such as maintaining a positive problem orientation) are related to positive outcomes [61, 91], particularly patients' subjective well-being and life satisfaction [100]. In addition, metacognitive training can be applied to clients' personally relevant goals, which will enhance acquisition and generalization of strategies. This is also important as training that has meaning to the client may increase motivation and satisfaction with treatment.

Clinical Application of Metacognitive Training

In the section, we describe a general framework that is applicable to the majority of metacognitive training interventions. We also describe self-talk procedures—a simple metacognitive strategy that can be adapted to address multiple problems depending on the needs of the client. This is followed by a description of the metacognitive treatment of problem-solving deficits.

A General Algorithm for Metacognitive Strategy Training

Most interventions in this area follow a common structure, which parallels the structure of executive functioning: the creation of an internal plan or representation in anticipation of a desired goal state; execution of a response or sequence of responses; and the use of feedback to compare the internal plan with the achieved outcome, and modification of one's plan accordingly. A general algorithm involving the following sequence of steps can be applied to many different metacognitive training interventions: (1) raising awareness of deficits; (2) anticipation and planning of the potential response to novel tasks or problem-solving situations; (3) implementation and self-monitoring of selected responses; and (4) evaluation of the outcome of the response, comparing the outcome with the desired or anticipated outcome, and changing the approach of the task, if necessary, which then "resets" the sequence of operations.

While the specific language and aspects of interventions vary, this structure and process is common to most metacognitive and problem-solving interventions for impairments of attention-executive functioning and can serve as framework for understanding and implementing these various interventions. The general steps outlined below were utilized in studies by Von Cramon et al. [89], Fasotti et al. [97], Levine et al. [95], and Cicerone et al. [60] to address general problem-solving impairments. These steps were also utilized in the single-case studies of Ylvisaker and Feeney [101] and Dawson et al. [102], using a Goal-Plan-Do-Review strategy. Similar steps have also been utilized by Goverover et al. [103], and Cheng and Man [104] to address problems with self-awareness.

Awareness

In clinical practice, metacognitive training is often preceded by attempts to assess and foster the patient's awareness of deficits, identifying the relevant strategies and setting goals.

Effective treatment, particularly involving metacognitive training interventions, usually requires assisting the patient to develop an awareness of the underlying impairments and their negative functional consequences. For those with awareness deficits, it is generally helpful to help a patient to recognize deficits by pointing out the discrepancies between self-perception and reality. Fleming and Ownsworth [21] also recommend: (1) selecting key tasks and environments in which awareness behaviors are most important within everyday activities and roles; (2) providing clear feedback and structured opportunities to help patients evaluate their performance, discover errors, and compensate for deficits; (3) using habit formation, when necessary, through repetition and procedural or implicit learning; and (4) providing education and environmental supports. Patients may be asked to predict explicitly the expected outcome of their behavior, e.g., predicted number of errors, accuracy, speed to completion, or some other aspect of success or failure. After completing the task, the patient is asked to compare his or her performance to the actual scores obtained on the task [103–105]. This allows for comparison of expected and observed outcomes, an activity that can facilitate awareness and improve self-monitoring.

Formal intervention should be considered for individuals with neurocognitive unawareness. Readers are referred to Chap. 12 of this book and also the Cognitive Rehabilitation Manual by Edmund Haskins and colleagues [106] for a thorough description of awareness interventions. Treatment to address awareness is an inherent aspect of metacognitive strategy training and should be incorporated into essentially all interventions, not only to foster increased awareness of deficits but also to foster awareness of the use and application of strategies. Crosson and colleagues [107] provide a framework for relating specific compensatory strategies to different levels of impaired awareness.

Engaging the patient in the process of overt goal setting is another aspect of this stage of treatment [108]. In practice, the setting of goals for rehabilitation will occur simultaneously with the clinical assessment of a patient's intellectual awareness of their identified "deficits" and their implications for daily functioning. Patients' intellectual awareness, goal orientation, and identification of compensatory strategies all represent aspects of *metacognitive knowledge* [107, 109]. The concept of metacognitive knowledge has also been extended to include self-efficacy beliefs [60, 109].

Anticipate and Plan

This aspect of metacognitive strategy training is grounded in the view that the anticipation of events in the environment, preparation of a response, and expectations about the consequences of behavior are central aspects of attention-executive functioning. To anticipate something makes it more likely that you will attend to it if and when it occurs (and to notice if it does not). The use of a prediction paradigm can be an explicit aspect of this process, not only to increase anticipatory awareness [107], but to establish a structure to mediate the patient's approach to the task [56]. Patients are assisted with the processes of *task setting*, including setting the appropriate criteria for stimulus relevance and preparing for stimulus selection, response selection, and response inhibition. Self-instructional techniques are another practical application of these principles. For example, prior to initiating a given task, the patient is instructed to identify the demands associated with the task, and to plan the appropriate sequence of responses. A relatively simple self-instructional metacognitive strategy involves having the patient engage in a self-talk procedure by which patients are taught to "talk themselves through" tasks [55, 56]. This serves to prevent unwanted behaviors, while simultaneously encouraging planning and self-monitoring and attentional focus. Training occurs in three stages to promote the progressive internalization of verbal self-regulation. Training begins with overt verbalization (talking out loud), then transitions to faded verbal self-instruction (whispering), and finally to covert verbal mediation(inner talk).

Cicerone and Wood [55] found that this three-stage, self-talk procedure described above resulted in reduced task-related errors and also eventual cessation of off-task behaviors. Additional instruction and practice in the application of the strategy was also associated with increased spontaneous use of the strategy in novel situations. Cicerone and Giacino [56] subsequently evaluated training using the same self-talk protocol with five patients with TBI and one patient with falx meningioma. All patients exhibited impaired planning and self-monitoring. Five of the six patients showed marked reduction of task-related errors and perseverative responses.

At a more complex level, patients are asked to conduct an activity analysis that anticipates not only characteristics of the task but the potential impact of one's cognitive abilities, emotional responses, and environmental supports on their performance of the task as well as examining their self-efficacy belief in relation to managing these cognitive, emotional, and task demands [60]. The anticipation of situations that are likely to cause "information overload" and preparation of a plan to manage these situations is an example of this process, applied to Time Pressure Management [98].

Execute and Self-Monitor

Next, the person implements his/her plan to perform the task, actively self-monitors performance and use of strategies throughout, all of which reflect the process of *task-monitoring*. In most situations, the demands to execute and self-monitor the patient's behavior occur simultaneously and require some capacity to shift attention between the requirements of the task and monitoring one's internal train of thought. Emphasis is placed on the patient's capacity for online monitoring [109] and emergent awareness of performance [107]. Errors are most likely to occur during this process of task execution: errors due to failure to anticipate some aspect of a situation; errors related to inability to maintain a consistent response set; attentional lapses related to one's mind wandering, errors because things do not "go as planned"; errors because something "captured" one's attention or failed to gain one's attention; and errors related to emotional interference. It is not surprising that error management training can be an essential component of self-regulation during this phase, including the training of both metacognitive and emotional regulation strategies [24, 60, 110, 111]. The use of "errorful learning"—although also more effortful—can be beneficial in situations with inconsistent mapping of stimulus–response contingencies, to foster strategy application in situations with varied demands, and to facilitate transfer of learning, including functional activities [112, 113]. The therapist may need to direct attention and support to the patient's online monitoring of errors or problems and application of compensatory strategies at the appropriate time and situations (aspects of *metacognitive experience*).

The principles identified earlier in relation to neuroplasticity also apply to metacognitive strategy training, such as the need to continually adapt the task to maintain an appropriate level of success and challenge. The therapist should determine the amount of structure and cuing provided at this level of intervention to facilitate online monitoring (e.g., awareness and correction of errors) and strategy application, with the patient assuming greater responsibility for independent performance over the progression of treatment. An approach to compensatory strategy training based on the instructional process in natural contexts [114] varies the level of assistance provided (rather than changing aspects of the task itself) as a basis for continually adapting task demands. The therapist serves a mediating function to encourage self-monitoring and strategy application [115]. This approach allows the therapist to control those elements of the task that are initially beyond the patient's capacity, reinforcing attention to those elements within the patient's range of competence and emphasizing the patient's need to recognize and adjust to varied demands as a common occurrence. Errors are expected to occur as the therapist transfers responsibility for the task to the patient, and these occurrences provide the principal basis for determining the patient's competence, adjusting the level of intervention, and providing feedback.

Self-Evaluate

Finally the person compares the effectiveness of their actions with the predicted effects and consequences and evaluates their performance (typically while incorporating feedback from the therapist and/or others). This metacognitive evaluation process can be directed at the patient's immediate performance, compared with prior expectations, and related to the relevance and implications of deficits (or strengths) to the person's daily functioning. Therapeutic feedback can serve as the basis for the patient's modifying their awareness, adjusting their goals, and identifying the need to adjust the nature and application of compensatory strategies. The process of self-evaluation thus feeds back to the processes of awareness and goal setting.

Metacognitive Training for Problem-Solving Deficits

The treatment of problem-solving deficits using metacognitive strategies involves teaching patients to gain control over their cognitive processing by learning and following a formal problem-solving strategy. One example is the Goal-Plan-Do-Review sequence taken from Ylvisaker and Feeney (1998) [101]. However, it should be noted that any series of steps that reflect the evidence-based algorithm described earlier (i.e., Awareness, Plan, Execute, Self-Evaluate) can be used.

Patients are instructed to apply the Goal-Plan-Do-Review strategy to each new problem they face. Initially, patients are taught to complete a written, structured worksheet which outlines each step of the sequence. Through frequent repetition of this procedure across a range of tasks, patients can learn to apply the problem-solving strategy more effectively and quickly.

The long-term goal of problem-solving training is to enable the patient to become familiar and skilled with the problem-solving sequence that it is generalized to various situations with minimal external cuing. In effect, through practice and repetition it becomes an internalized strategy. For those patients who are unable to achieve internal control over their problem-solving attempts, an approach that relies on external cuing (e.g., external prompts from therapist or caregiver; using structured worksheets) may be necessary.

Case Example Illustrating the Use of Metacognitive Strategy Training

EF is a 44-year-old woman who sustained a TBI when she fell and was kicked in the head by a horse. She sustained a loss of consciousness with hemorrhagic contusions in the left dorsolateral frontal and bilateral inferior medial and lateral frontal lobes as well as an intraparenchymal lesion in the anterior cingulate. She received a course of acute rehabilitation and was discharged to her home (with her husband and two adolescent daughters). She was working as an attorney prior to her injury, but did not return to work. Her family noted that prior to her injury she had "held the family together" but since then she was more emotionally labile and would sometimes perseverate on an activity, such as asking family members repeatedly what they wanted for dinner and obsessively cleaning up after her husband and children. Two years after her injury she was offered the opportunity to work at her former firm on a part time basis as a "legal assistant" doing background research for other attorneys. After returning to work she had difficulty finishing tasks, often getting involved in tasks with less priority. Her husband expressed his concern to her neurologist and she was referred for neuropsychological evaluation and treatment.

When first seen, she generally attributed her problems on her job to having an "unreasonable amount of work," but she did acknowledge having difficulties because she would lose track of what she was doing while working on the computer or reading files, "train of thought goes off and then I lose everything," and she would "get stuck" and not be able to figure out another way of doing something. Neuropsychological evaluation was notable for intact processing speed but marked decline with dual task demands. On basic tasks of sustained attention she responded rapidly but missed targets, particularly on the later trials. On more complex tasks she still responded quickly but had difficulty establishing the correct set, and she would perseverate on an inappropriate sequence of responses early in the task. Her memory was average but she did exhibit increased susceptibility to both proactive and retroactive interference. The initial course of treatment was based on the use of verbal mediation as a form of self-instructional training, applied to a series of "transfer" problems (similar to the Tower of London or Tower of Hanoi) [55]. A baseline was established, in which it was noted that her latencies prior to starting each trial were quick, and unrelated to task difficulty, and she would initially make an extensive number of errors before realizing there was another, more efficient, solution to the task. In the initial stage of the intervention EF was instructed to verbalize the steps required to complete the task prior to any overt attempt at problem solution. She was prompted to anticipate or recognize errors during this process, and this was contrasted with her propensity to make errors without recognizing them during her baseline task performance. EF initially found this process "uncomfortable" and "more difficult," which was interpreted in relation to her need to "slow down" and adopt a more conscious, deliberate approach that contrasted with the difficulties she encountered due to her automatic, impulsive responding. Following her verbalization she was asked to complete the task, while again verbalizing the steps (and verbally noting any errors). She was provided multiple practice trials on the task following the same structure, while fading her overt verbal self-instruction. This process was used to formulate a more general (metacognitive) strategy reflecting her need to "stop, think and plan" (STP) while performing an activity, following the general algorithm described above. EF was then given the opportunity to practice the metacognitive strategy on multiple tasks having similar problem structure and demands but with varied content and varied levels of difficulty, to reinforce the near transfer of strategy use to a variety of situations. The intervention initially was applied to "artificial" tasks within the safety of the therapeutic environment; these same strategies were gradually applied to situations in EF's daily functioning, including her work responsibilities. During this process a distinction was made between "error recognition" and "error utilization," the latter emphasizing the practical (positive) value of recognizing errors as an opportunity to correct her mistakes. Interventions to facilitate error-management included feedback, open-ended prompts ("Is there anything else you can do? Are you sure?"), and modeling "correct" performance and positive self-statements [24, 61]. Throughout this process, she was encouraged to identify past experiences where she had successfully carried out an activity and to relate these to her current demands [116]. The emphasis of treatment sessions shifted from table-top exercises to analyzing examples from her daily life where she experienced difficulty, and simulating these functional activities within the treatment setting. Her use of the "stop, think and plan" strategy was gradually expanded to include formal aspects of "goal-plan-do-review" [102] and time pressure management [98]. These sessions also provided the opportunity to address her moment-to-moment self-monitoring and error management in relation to her difficulties sustaining attention in her daily functioning, reflected in her subjective complaints that her "train of thought goes off" and she loses track of what she is doing, and she "gets stuck" on one thing and cannot figure out another way of doing something. She could identify that this was particularly evident when she was attempting to conduct research as part of her work, which typically involved managing multiple cases and requests for information under time demands. The apparent contradiction between the extremes of her being "easily distracted" and "getting stuck on one thing" was interpreted in relation to a common, underlying problem of "dysregulation" [56] reflecting her need to regulate her attention more effectively in a variety of situations. Treatment for this aspect of her functioning was again introduced by incorporating structured attention exercises and functional tasks within sessions, providing an opportunity for monitoring attention lapses and task-unrelated thoughts. She was educated regarding the relationship between sustained attention and error awareness [117, 118]. The method of "content-free" cuing [119] was introduced as a means of self-monitoring whether she was "doing what I need to be doing" at intermittent intervals during task performance. This procedure was again applied to a variety of tasks, with increasing functional application (e.g., using the Internet for research) and gradually transferred to strategy use during her daily activities (including programming an auditory cue to occur at random intervals on her Smartphone). During this progression EF was also assisted in identifying signs of emotional reactivity (which within sessions manifested as her feeling frustrated and overwhelmed) that interfered with task performance. The use of a Likert-like Cognitive Energy Scale (CES) was introduced as a method for emotional self-monitoring and self-regulation [60, 110]. Her emotional reactions and attentional lapses were reinterpreted from representing negative, disruptive events to representing "stop" cues that signaled the need for her to institute a compensatory strategy. Over time, she was able to employ the STP and CES as "on-line" cognitive and emotional strategies to "reset" her attention to relevant aspects of the situation and when she became distracted, "stuck," or overwhelmed.

The latter progression of treatment was directed at generalizing the use of strategies in her daily life. During this extended period of treatment she was given multiple opportunities to apply her strategies and increasing responsibility for recognizing the need and implementing strategies in her daily functioning [55]. The Goal-Plan-Do-Review strategy was used as a way for her to plan and organize her daily activities, such as prioritizing work tasks for each day and a weekly menu for her home. Treatment for behavioral and emotional regulation shifted emphasis from the routine use of specific problem solving and emotional regulation strategies, to reinforcing the more general psychological aspects of self-appraisal—maintaining a positive problem orientation and keeping emotional reactions from interfering with her functioning—that allowed her to establish an acceptable sense of identity [120]. After several months of treatment she demonstrated the ability to apply metacognitive strategies for practical problem solving, attention regulation, and emotional regulation. She was "less emotional" and less likely to perseverate on household tasks in her daily functioning, although she remained less sociable. She was able to complete her household and work responsibilities more effectively, although this remained more effortful and she continued to function at a lower capacity than she did prior to her injury, and she had the advantage of a supportive environment both at home and at work. The improvements in her ability for self-regulation were accompanied by improvements in her self-efficacy and confidence that she could manage her cognitive and emotional symptoms.

This case illustrates the clinical application of evidence-based cognitive rehabilitation to a disturbance of the anterior attention-executive networks after a moderate–severe TBI. Although interventions are typically evaluated in isolation, in practice it is common to use multiple intervention methods simultaneously or in a progression [115], as seen in this case illustration. The patient exhibited significant problems with attention and executive functioning, but had other favorable prognostic signs including above average intelligence and education, relatively intact memory, at least an intellectual awareness of her problems, good motivation, and some capacity to recognize her mistakes and apply compensatory strategies, or to use a strategy in specific situations, and a supportive environment. Under these favorable circumstances, treatment based on metacognitive strategy training enabled her to regulate those aspects of her functioning that supported a positive identity.

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