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Frontal Lobe Traumatic Brain Injuries and Executive Dysfunctioning

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According to Burke, Zenicus, Wesolowskis & Doubleday (1991,) the frontal lobe of the human brain plays a central and pervasive role in human cognition serving to organize and coordinate brain functioning. Often, the frontal lobe functions to assist individuals in participating in goal-directed and self-regulatory behavior. These behaviors fall under the category of executive functioning. Typically, executive functioning is defined as, "the ability to engage in independent, purposeful, self-directive and self-serving behavior" (Burke, Zencius, Wesolowski & Doubleday, 1991, p. 241). Since the frontal lobe controls these behaviors, it is possible that damage to the frontal lobe could limit their successful execution (Jennet, Snoek, Bond & Brooks, 1981; Kennedy, 2004; Lehtonen et al., 2005; Romine & Reynolds, 2005; Scheibel et al., 2003). Therefore, intervention techniques implemented after damage to the frontal lobe, could target executive functioning skills (Burke et al., 1991; Cicerone & Giacino, 1992; Coelho, DeRuyter & Stein, 1996; Demery, Larson, Dixit, Bauer & Perlstein, 2010; Levine et al., 2000; Rath, Simon, Langenbahn, Sherr & Diller, 2003; Robertson & Knight, 2008; Schweizer et al., 2011;; Sohlberg, Mateer & Stuss, 1993).

Development of the frontal lobe

Demery et al. (2010) noted that the acquisition of executive functioning abilities, controlled by the frontal lobe, develops throughout childhood, serving to form patterns of behavior for the rest of the brain. Development of the frontal lobe regions is known to continue through late adolescence and into early adulthood, in contrast to the earlier maturation of other cortical regions. At birth, primary areas of the brain are developed including the connective apparatus of the frontal lobes

(Demery et al., 2010). Secondary and tertiary systems involving learning, memory, emotion, cognition, language, and attention continue to develop beyond birth (Demery et al., 2010).

Structure and function of the frontal lobes change significantly after birth into early childhood. Typically, pruning of synaptic connections and maturation of subcortical prefrontal myelination occurs during this period (Demery et al., 2010). These processes increase metabolic rates for glucose resulting in more efficient information processing (Demery et al., 2010). Significant maturation of the frontal lobe is reached around the puberty years, but changes continue to occur into later years. It has been suggested by Demery et al. (2010) that pathways of the prefrontal cortex are among the last to myelinate fully, often times continuing until about the age of 20.

Development of executive functioning skills

Executive functioning is described as the capacity for anticipation of consequences, goal formation, planning and organizing, initiation of execution activities, as well as self-monitoring and self-correction (Romine & Reynolds, 2005). As previously stated, development of executive functioning, controlled by the frontal lobes, may be considered a multistage process, with different aspect of function maturing and realizing at different times (Romine & Reynolds, 2005).

Essentials of executive functioning are present early in development, including the behavioral development of self-control and the ability to adjust and direct goal-oriented behavior in response to the environment (Romine & Reynolds, 2005). Between the ages of 5 and 8, basic cognitive abilities are demonstrated reliably in the areas of recognition memory, concept formation, set shifting and rudimentary planning skills by the age of ten. The ability to inhibit attention to irrelevant stimuli as well as perseverating responses begin their development and are typically mastered by the age of 12 (Romine & Reynolds, 2005). However, a number of skills mediated by the frontal lobes, planning, visual working memory, coordination of working memory and inhibition, verbal fluency and motor sequencing, show a delayed period of development extending beyond the age of 12 (Romaine & Reynolds, 2005). Unlike skills mediated by other portions of the brain, the development of executive functioning skills continues into adolescence and adulthood. Functional gains have been associated with working memory capacity, planning, and problem-solving abilities evident between the ages of 15 years and 29 years of age (Romine & Reynolds, 2008).

A three-part hierarchical framework exists for understanding executive functioning skills and their development (Sohlberg et al., 1993). Each level associates with a system of self-monitoring feedback control. The first system analyzes incoming information in relation to current or stored experiences. This specific level of executive functioning can control even complex motor functions once they have become routine or practiced. When learning a novel task, frontal lobe functions are critical (Sohlberg et al., 1993). As practice of a specific learned skill increases and habits of response are strengthened, less and less frontal involvement is required. The second level of the framework is the managing function of the frontal lobes with relation to executive functioning. The reciprocal connections between the anterior brain regions and the multimodal association areas of the posterior zone and the limbic region provide the neural bases for these control functions (Sohlberg et al., 1993). The third and final level of this hierarchy of executive functioning is self-reflectiveness and self-awareness. Sohlberg et al. (1993) observed that this particular component supports the capacity to be aware of oneself and the ability to reflect on thinking or action patterns. Typically referred to as metacognition (Sohlberg et al., 1993), the capacity to self-reflect and self-monitor appears to be dependent on the prefrontal regions. Self-awareness is dependent on input from sensory and perceptual executive control systems, with its output influencing the nature and degree of executive control (Sohlberg et al., 1993).

However, the integrative and organizational nature of the frontal lobe functioning makes it difficult to tease apart the cognitive functions controlled by the frontal lobes (Sohlberg et al., 1993). The concepts of attention, executive functions, and various components of memory overlap, and each contributes to performance on various front functioning tasks (Sohlberg et al., 1993).

Traumatic Brain Injury

Disturbances in executive functioning are prevalent after traumatic brain injury (TBI) and present significant obstacles to social functioning, work and rehabilitation (Demery et al., 2010). , as defined by Demery et al. (2010), is a physiological disruption of brain function that results when the head is struck, strikes and object, or undergoes acceleration or deceleration movement. Such injuries are classified as either penetrating or closed head injuries (Coelho et al., 1996). An example of a penetrating injury would be a gunshot wound. Conversely, acceleration or deceleration forces, such as when a head strikes the dashboard of a car, can cause a closed head injury. The classification of head injuries depends largely on whether or not the meninges remain intact. Penetrating injuries usually result in focal lesions specific to areas of the brain. Closed head injuries may result in focal lesions, diffuse axonal (stretching, tearing and shearing of nerve fibers), or a combination of both.(Coelho et al., 1996). The American Congress of Rehabilitation Medicine, as noted in Coelho et al (1996), has defined mild TBI as

"Traumatically induced physiological disruption of brain function manifested by at least one of the following: any period of loss of consciousness, any loss of memory for event immediately before or after the injury, dazed confused or disoriented behavior, focal neurological deficits that result in loss of consciousness for 30 minutes or less, an initial Glascow Coma Scale score of 12-15, or post traumatic amnesia not greater than 24 hours" (Coelho et al., 1996, p. S8).

The most common forms of damage following TBI are contusions and hemorrhages, which can be seen after penetrating or non-penetrating injuries (Lehtonen et al., 2005).

Research has shown that fronto-temporal injuries can arise, regardless of the site of impact, as a consequence of the brain being contused against bony protrusions in these regions (Lehtonen et al., 2005). In comparison to other areas of the cerebrum, the frontal lobes and some areas of the temporal lobes are disproportionately susceptible to damage following a TBI . Typically, these types of injuries occur during motor vehicle accidents or falls.

Assessment of TBI

Jennett et al. (1981) discussed the use of the Glasgow Outcome Scale to assess the prognosis of a patient with a brain injury. This particular scale proposed four outcome categories for surviving patients, as follows: (a) vegetative state: this category of patients displays no evidence of meaningful responsiveness. These patients may breath spontaneously, have periods of spontaneous eye-opening while following moving objects, show reflex responses in their limbs to postural or painful stimuli, or the may swallow food placed in their mouths. Although a vegetative state may indicate a lack of function in the cerebral cortex, the structure may be intact. (Jennett et al., 1981); (b) severe disability: typically, patients indicate a state of consciousness but needs assistance from another person for some activities of daily living. This may range from continuous total dependency, for feeding or washing, to the need for assistance with only one activity. Classically these activities include dressing, getting out of bed or moving about their living space. More often, dependency is due to a combination of physical and mental disability as the result of insult to the brain (Jennett et al., 1981); (c) Moderate disability: these patients are characteristically summarized as “independent but disabled”. Jennett et al. (1981) notes this category as the most difficult to describe due to the complexity of these patients disabilities. The patient is typically able to look after him or herself in the home. However, some previous activities, either at work or in social life, now prove to be more difficult for the patient (Jennett et al., 1981); (d) good recovery: these patients typically display the capacity to resume normal occupation and social activities, although there may be minor physical or mental deficits present. (Jennett et al., 1981)

Studies have supported the use of functional magnetic resonance imaging and positron emission tomography to further investigate the cortical damage from a frontal TBI. Scheibel et al. (2003) discussed the use of functional brain imaging studies of executive functioning in normal adults using positron emission tomography. These techniques have previously identified neural networks that involve dorsolateral pre-frontal cortex in addition to other pre-frontal regions, temporal cortex and parietal cortex depending on the specific task regions studied (Scheibel et al., 2003). The use of these areas may be dependent on extra demands on monitoring and updating incoming stimuli during an executive functioning task. Working memory and executive functions, which interact during problem solving and response selections, are frequently impaired in patients following moderate to severe frontal lobe TBI (Scheibel et al., 2003).

However, interpretation of the mechanisms controlling executive dysfunction after a TBI is complicated by primary and secondary injury, including, focal structure lesions, diffuse axonal injury, ischemia and a number of different neurotransmitters. Nevertheless, changes in frontal lobe functioning following a TBI are observed in patients during performance of an executive functioning task. These changes give insight into the mechanical effects post injury. The presence of focal lesions in the patients with brain injuries could not account for the overall changes in the activation pattern observed, which the investigators attributed to the effects of diffuse axonal injury (Scheibel et al., 2003). Findings from this study demonstrated frontal dysfunction in survivors of diffuse brain injury without evidence of structural brain lesions in the region (Scheibel et al., 2003).

Functional magnetic resonance imaging studies utilizing positron emission tomography have also proven resourceful as an assessment tool during the later stages of recovery. Positron tomography has revealed cerebral hypometabolism of glucose during the later stages of recovery from a TBI (Scheibel et al., 2003). Overall, the pattern of imaging observed after a frontal lobe injury would suggest that a pattern of more extensive cortical activation would be predicted to occur during

non-routine activities such as problem solving, manipulation of information held in short term
memory, inhibiting a response and sustaining attention and response selection to attain a goal (Scheibel et al., 2003).

Impact of TBI on everyday functions

The degree to which a TBI can affect everyday life depends on the nature of the activities in which the individual participated before the injury (Coelho et al.,1996). The World Health Organization (WHO) classifies the levels of impairment, disability, and handicap and how they relate to as follows (Coelho et al., 1996). Impairment typically refers to an abnormality in physical or mental functioning. The impact of a TBI can be best understood when considered within the context of the WHO proposed classifications. WHO refers to impairment as an "abnormality in physical or mental function" (Coelho et al., 1996, p. s10). In relation to a frontal lobe TBI, the impairment may be noticeable as a cognitive disruption such as decreased attention, which is a typical outcome. Thus, a patient who has sustained a TBI could have a cognitive disruption such as decreased self-monitoring skills. Disability is considered by the WHO a limitation in performance of an activity because of an impact (Coelho et al., 1996). For example, a person who has sustained a TBI may have difficulty sustaining attention and therefore their ability to read or follow directions would be directly impacted. Finally, handicap is defined by the WHO as a loss of social role functioning because of a disability. A person with a TBI may have a reduced capacity to pursue premorbid interests and daily activities at the same functioning level (Coelho et al., 1996).

Sohlberg et al. (1993) discussed disruption at the most basic level of executive functioning that may alter a person's response to sensory input. This disturbance may affect a person's ability to carry out even previously well-known or routine behaviors effectively. These are often referred to as activities of daily living such as dressing, grooming, eating or driving (Sohlberg et al., 1993). After a frontal lobe TBI, behaviors previously mastered such as decision-making and organization or planning may be sequenced poorly or they may not be triggered at the appropriate time and place. Frequent errors of actions, such as putting ice cream in a cupboard, or failure to invoke appropriate actions at the appropriate time are also verified in association with damage to the frontal lobe. Finally, In addition to difficulty with activities of daily living, persons with TBI often find social relationships difficult to sustain (Sohlberg et al., 1993).

Treatment of executive dysfunction

Environmental modification

Treatment of TBI must incorporate environmental modifications and specific skill training. Executive dysfunction affects the patient across contexts and can be targeted during therapy in a number of ways. It is crucial to train specific tasks to maximize independence during activities of daily living, socialization, and vocational functioning. Environmental modifications are essential to the recovery and functioning of patients with executive dysfunction following a frontal TBI (Sohlberg et al., 1993). Clinicians should examine a patient's environment and evaluate how it can be organized to take on the functions previously carried out by the individual. Environmental modifications may be the only available strategy for more severely involved of very acute patients who are not capable of carrying out therapy routines

(Sohlberg et al., 1993). Examples of environmental modifications include visual cues. Sohlberg et al. (1993) suggested labeling cupboard contents, writing prompts to carry out specific actions, or positioning reminder lists of items to take before leaving the house. Such visual cues can also be similarly adapted for the workplace to maximize independence during vocational tasks. First, the clinician must perform a functional analysis of the individuals living situation to identify where deficits in executive functioning are interfering in daily performance (Sohlberg et al., 1993). Second, the clinician needs to determine an appropriate environmental manipulation. Third, it is the role of the clinician to train the individual or caretaker to attend to the environmental cues or changes.

Specific skills training

Interventions that teach patients specific skills or sequence of skills demonstrate the most success in patients with a TBI (Sohlberg et al., 1993). The clinician may need to utilize a compensatory strategy or a specific communication behavior that has been disrupted by damage to the executive control system.

Rath et al. (2003) proposed that people with TBI may not be capable of performing wide varieties of different action plans in different settings due to context dependence, perseveration, limited insight and awareness, and severe cognitive disorders in attention or memory. Examples of task specific routines that should be targeted are activities of daily living (ADLs). ADLs typically include grooming routines, showering, teeth brushing, and dressing. These routines are usually written in a step-by-step format and practiced with patients using progressively less cueing until the sequence can be followed with greatest independence.

In addition, a cueing system may have been used as a compensatory strategy. These external cueing systems allow patients to plan, organize and follow through with multi-step directions. Examples of cueing systems include watches, calendar systems, written notes, schedules, visual aids, books, or planners (Sohlberg et al., 1993). In order to successfully implement external compensatory strategies, patients with TBI should practice planning and executing tasks (Rath et al., 2003). Finally, use of the system in novel, real-world contexts should help in increasing carryover of efficacy (Sohlberg et al.,1993) Without carryover of efficacy, the patient will become context dependent and maximization of independence will not occur.

In a study conducted by Burke et al. (1991), when participants received a checklist or a visual cue, they were quickly able to perform their presented endeavor. When the checklist was removed, they continued to successfully perform various vocational tasks such as filling cases, preparing materials, stacking shelves, cleaning areas, clocking in and out of work, and arranging tools. After a three-month follow up, participant's performance remained at 97%-100% accuracy from baseline of 50% prior to the introduction of checklists. Secondary to a clinician-generated checklist, a self-initiated checklist was introduced to the participants. Clinicians then sabotaged vocational tasks by misplacing tools, or altering work settings to increase the demands on the participant's problem solving skills. Baselines were taken during these sabotaged vocational scenarios. Then self-initiated checklists were introduced to the participant's and accuracy baselines immediately and dramatically improved. Next, the checklist was removed from a different sabotaged vocational task, and baselines remained consistent. The introduction of this type of checklist reduced the amount of prompting and increased the number of tasks completed correctly (Burke et al., 1991).

Attention process, planning, and organizational training

Patients with frontal lobe traumatic brain injuries characteristically demonstrate difficulty with the ability to maintain attention, switch focus, divide attention or select out target information. They also demonstrate difficulty planning and organizing to achieve a goal (Cicerone & Giacino, 1992). Clinicians should train this specific task by administering exercises focused on retaining attention processes. Patients may also benefit from structured exercises that would provide multiple opportunities for initiation, planning and performing goal-directed activities. Multitasking focuses on the ability to manage multiple simultaneous tasks and the associated functioning involved in engaging and disengaging from such activities. Cicerone & Giacino (1992) suggested that in order to increase independence with these tasks, clients should be given the responsibility for and control over the completion of tasks on the agenda developed in accord with the clinician.

Goal Management Training

Levine et al. (2000) developed the Goal Management Training (GMT), a manual based rehabilitation protocol based on Duncan's (1986) theory of disorganization of behavior following frontal lobe damage as cited by Duncan (1986) in Levine et al. (2000). There are five stages to GMT. First, participants are trained to assess the current state of affairs and direct awareness towards relevant goals. Second, participants and clinicians select relevant goals that target their specific needs. Third, goals should be divided into sub goals. Fourth, clinician and patient collaborate in troubleshooting, discussing concerns, with resultant retention of goals and subgoals. Fifth, the outcome of the patient's action is compared with the goal state. Many studies have shown the efficacy of GMT with patients who have sustained a frontal lobe TBI. For example a study conducted by Levine et al. (2011) recruited 70 patients who had sustained a focal frontal lobe brain injury. The control group and the experimental group were then presented with tasks simulating real life multitasking scenarios. The experimental group utilized goal management training to complete their tasks and performed significantly higher than the control group.

The primary objective of GMT is to help patients to stop ongoing behavior in order to define goal hierarchies and monitor performance (Levine et al., 2011). This is achieved through instructional material, interactive tasks, discussion of patients' real-life deficits, and homework assignments. A study conducted by Levine et al. (2011) found that Goal Management Training has been associated with reduced attention lapses, increased behavioral consistency, and improved problem solving performance, suggesting that overall Goal Management Training targets aspects of executive dysfunctioning, which would help increasing independence in performing everyday tasks.

Cognitive self-management training

Cicerone & Giacino (1992) discussed the importance of cognitive self-management training when treating executive dysfunction in patients who have sustained a frontal lobe TBI. The dissociation between the demonstration of an intact skill and its failure to be executed independently is frequently cited as characteristic of patients with frontal lobe TBI (Cicerone & Giacino, 1992). The training of executive functioning strategies is critical in the rehabilitation process of patients regained executive functioning to successfully execute everyday routines. The approach develops the patient's ability to devise a plan of action in a variety of relevant situations, as opposed to teaching the patient to implement a plan of action appropriate to only specific scenarios (Cicerone & Giacino, 1992). Training of executive strategies is an attempt to treat executive dysfunction by developing the patient's ability to devise a plan of action into a variety of relevant situations (Cicerone & Giacino, 1992). These efforts incorporate components of self-regulation. S-talk behaviors proved to generate the most independence when completing an executive functioning task (Cicerone & Giacino, 1992). Cicerone & Giacino utilized a self-instructional training procedure that integrated self-monitoring statements in order to facilitate attention and memory skills. The researchers also utilized the use of self-instructional training procedures to teach a patient with a frontal lobe injury to plan ahead and monitor step-by-step performance while inhibiting inappropriate behaviors. Cicerone & Giacino (1992) suggested that this procedure should include gradual fading and internalization of the verbal regulation. Results showed generalization to untrained situations only after an extended period of training that included self-monitoring. Therefore, it is critical the clinician utilize this procedure in full to increase greatest independence executing everyday tasks. Eventually, Cicerone & Giacino (1992) noted a reduction in errors accompanied by reductions in various disinhibited, off-task behaviors during task performance.

Social Problem Solving

Robertson & Knight (2008) noted that, in everyday life, a lack of awareness may result in the persistence of socially inappropriate behaviors or the inability to solve social problems, leading to isolation. The study conducted by Robertson & Knight (2008) discussed the possibility of a cyclical phenomenon noted by researchers. As the result of a TBI, is was suggested that a person is less capable of successfully completing socially demanding interactions (Robertson & Knight, 2008). This manifests itself as a deficit in a social skill, which over time may affect relationships with other people. As a result of the deficit in social skill, increased isolation might occur with a reduction in the opportunity for applying interaction skills. Dissonance might make it less likely that there will be opportunities for the person who has sustained a TBI to unlearn their maladaptive orientation towards social situations (Robertson & Knight, 2008). Social problem solving skills are defined as the cognitive and behavioral ability to formulate and execute appropriate strategies in response to situations where there is no immediate or obvious solution (Robertson & Knight, 2008). These skills have considerable impact on successful reintegration of patients back into the community. A study conducted by Robertson & Knight (2008) revealed that most of the participants with a frontal lobe TBI performed normally when questioned about the nature of the problem presented and were able to understand the issues form the perspective of both characters in the scenario. However, the participants demonstrated difficulty with the execution of social problem solving behaviors (Robertson & Knight, 2008). Participants were capable of generating solutions to problems and discerning perspectives, however initiating and executing social problem solving proved difficult. Robertson & Knight (2008) emphasized the necessity to assess the patient's actual performance during social interactions, rather than relying solely on their ability to describe a solution to the problem

Summary

Despite varying definitions and research methodologies, researchers have been consistent in their findings regarding the association between damage to the frontal lobe and executive functioning negatively. The impact from executive dysfunctioning has proved to impede an individual's ability to accurately carryout daily tasks.

The development of the frontal lobe continues into early adulthood, fine tuning executive functioning skills. The development of this area of functioning is unique in the respect that it continues to develop past other areas of the brain and their functioning. Insult to the frontal lobe can have a significant impact on an individual's ability to engage in independent, purposeful, self-directive and self-serving behavior. Past research suggests that, despite the type of injury sustained, executive functioning skills are impacted by damage to the frontal lobe.

Several treatment efficacy studies of executive functioning rehabilitation were reviewed. A number of different therapeutic techniques have been successfully applied to deficits of executive functioning in patients who have sustained a frontal lobe (Burke et al., 1991; Cicerone et al., 1992; Coelho et al., 1996; Lehtone et al., 2005; Levine et al., 2000; Levine et al., 2011; Rath et al., 2003; Robertson et al., 2008; Sohlberg et al., 1993). The heterogeneity of these patients and their deficits prevents the application of a generic treatment approach for this population. Treatment has proven to be more effective when it is client centered and targets specific skill sets. Treatment may also focus on environmental modifications and the arrangement of compensatory strategies for the affected individual. For example the use of GMT has proven to increase a patient's attention to goal and task specific actions, a known deficit of executive dysfunctioning. Cognitive self-management allows an individual to relearn skills necessary to monitor their own progress towards successful functioning during day-to-day routines and tasks. As a result of cognitive and executive dysfunctioning, social problem solving skills also regress. A patient's ability to function successfully in social situations depends directly on their ability to self-monitor, make decisions, and initiate selections; areas of functioning hindered by a frontal lobe TBI. Therefore, it seems like Individuals with a frontal lobe may be able to rehabilitate certain skill sets of executive functioning necessary to executing everyday routines following interventions.

Future Directions

A need remains for continued research to further explore frontal lobe functioning. There are many unanswered questions about the development of the prefrontal cortex and the abilities it regulates. Likewise, it is also important to further research the functional connectivity between the prefrontal cortex and other neural regions with which it is connected. Such an area of future research is important because of the integrative nature of frontal lobe functioning. The neural transmission between the frontal regions with other regions of the brain during cognitive tasks, such as posterior and subcortical regions, is likely to have an impact on the functioning of the frontal and prefrontal cortex.

Another potential further area of research involves continued investigations into the role deficits in the frontal lobe play in common psychological and neurological disorders. For example, further research can examine whether a deficit in specific frontal lobe functioning is associated with injury or linked with a disorder commonly linked to frontal lobe dysfunction, such as attention deficit hyperactivity disorder. It is possible that longitudinal studies of children with attention deficit hyperactivity disorder into adulthood could provide information regarding the development of their frontal lobe functioning.

Additionally, in future research, generalization of therapeutic techniques should be examined. A longitudinal study of the effectiveness of treatment for executive dysfunction may give further insight into the patient's ability to generalize treatment into their everyday routines. Additional research should incorporate a variety of contexts into their protocols to assess the likeliness of the therapeutic technique to generalize.

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