IMPACT OF FRONTAL BRAIN INJURY ON EXECUTIVE FUNCTIONS AND PERSONALITY

Orhanović, Renata

University of Split
Faculty of Humanities and Social Sciences

Renata Orhanović

The Impact of Frontal Brain Injury on Executive Functions and Personality – scoping review

Final thesis

Prof. Ina Reić Ercegovac, PhD

Assist.prof. Linda Lušić Kalcina, PhD

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Introduction

The frontal lobe is the largest of the lobes and is among the last areas of the brain to mature; it may not be fully developed until halfway through the third decade of life (Kolk & Rakic, 2022). Within it, several areas house distinct functions. Posteriorly, the precentral gyrus holds the function of integrating motor function signals from different regions of the brain. Rostrally to the precentral gyrus is the premotor area which exercises control over movements of the contralateral side of the body. Anterior to the premotor area are the three parallel gyri – superior, middle, and inferior frontal gyri, within which the frontal eye fields are situated, being the region responsible for coordinating voluntary control of horizontal movement of the eyes. Parts of these gyri are also included in the integration of motor processes. Broca's motor speech area is located in one part of the inferior frontal gyrus of the dominant (usually left) hemisphere, and it is important for the motor components of speech. If this area is damaged the result is Broca's aphasia which is a form of language impairment in which the patient has difficulty repeating words and naming objects whilst the comprehension remains intact.

Prefrontal brain and executive functions

Another key area of the frontal lobe is the prefrontal cortex (PFC), which plays a role in processing intellectual and emotional events (Siegel & Sapru, 2019). Processing intellectual events relates to the process of cognitive control (CC), which is related to regions such as the cingulate cortex. Cognitive control has often been considered synonymous with executive function (EF) (Friedman & Robbins, 2022). CC constitutes the active maintenance of patterns of activity in the PFC that represent goals and the means to achieve them through providing bias signals to other brain structures. The net effect of these brain structures is to guide the flow of activity along neural pathways that establish proper mappings between inputs, internal states, and outputs needed to perform a given task (Miller & Cohen,2001, as cited in Friedman, 2022). A commonly used task to demonstrate this effect is the Stroop interference paradigm within which the participants are asked to name the colour of the ink used to print words (e.g. green) whose meaning is incongruent (not the same/matching) with that colour (e.g. red). The greater pre-potency of reading words over-reporting colour causes interference which is manifested as increased latency in decision-making and activation of the anterior cingulate cortex (ACC). The conflict caused by the aforementioned interference may be resolved by focusing attention on the colour of the ink, associated with control exerted by the

PFC regions. Nevertheless, the deduction of how the prefrontal cortex is organized to mediate the range of cognitive processes related to CC/EF is a major challenge. CC/EF includes monitoring, planning, updating working memory, switching between tasks, coordinating multiple tasks, controlling interference, and stopping automatic or dominant responses (Friedman & Robbins, 2022). Furthermore, the prefrontal cortex plays a critical role in the generation and regulation of emotion. Kensinger & Ford (2021) state that dorsomedial PFC (dmPFC) plays a key role in emotional memory through functions that subserve the abstraction of meaning from events and the control of memories. Moreover, they conclude that the role of dmPFC begins during the encoding of emotional experiences, continues through their stabilization, and endures during the retrieval of emotional content. Finally, they suggest that dmPFC has a role in controlling how emotional events are remembered by controlling the content and affective framing of memories.

Recent advances have uncovered important roles of the frontal lobes in a multitude of cognitive processes along with cognitive control/executive function, such as attention, memory, and language. Alongside these roles, the frontal lobe participates in processes underlying affect, mood, personality, self-awareness, as well as social and moral reasoning (Chayer & Freedman, 2001). If there is an injury to any of the listed brain areas, it results in brain damage which causes the destruction or deterioration of brain cells. There are several potential causes; brain tumours, strokes, closed head injuries, infections of the brain, traumatic brain injuries, neurotoxins, and genetic factors (Pinel & Barnes, 2017).

Prefrontal brain and personality

Personality refers to the enduring characteristics and behaviour that comprise a person's unique adjustment to life, including major traits, interests, drives, values, self-concept, abilities, and emotional patterns (APA Dictionary of Psychology, n.d.). Personality changes due to damage to the prefrontal cortex have been researched over the last few centuries. The first mention of personality change due to frontal brain injury was in 1835 by de Nobele (Blumer & Benson, 1975). Some decades after a fascinating case of Phineas Gage (P.G.) arose and was presented by Harlow in 1968. Gage had suffered a prefrontal brain injury due to a tamping iron which, as a result of an accidental explosion, penetrated his skull. P.G. had a personality change resulting from the injury. Before the injury, he was described as a polite, industrious, and responsible young man, whilst after the injury he had profound disturbances including poor judgement, emotional dysregulation, socially inappropriate behaviour, lack of planning, disinhibition, and insensitivity. Following this case, throughout the 19th and 20th centuries, there were several investigations on the relationship between frontal brain damage and personality changes. German investigators at the beginning of the 20th century documented apathy, poor planning, tactlessness, facetiousness, euphoria, and moral deficits, along with attention problems. In the late 20th century, Storey (1970) reported personality disturbances in patients with subarachnoid haemorrhage. Some patients had personality disturbances involving behaviour, emotion, and cognition. Storey referred to these personality disturbances as "frontal lobe syndrome" although the nature of observed differences was quite varied (Barrash et al., 2018) Similar personality differences following anterior aneurysms have been reported (DeLuca & Diamond, 1995, Steinman & Bigler, 1986). Numerous researchers have continued to refer to such personality and cognitive disturbances as "frontal lobe syndrome" (e.g. Lyketsos, Rosenblatt, & Rabins, 2004).

Stuss et al. (1992) argued that the term "frontal personality disturbance" was more appropriate, emphasising behavioural changes as the primary deficit from prefrontal dysfunction, than "frontal lobe syndrome" which refers to a broad heterogeneous complex of disturbances.

Differentiation of brain injuries

Acquired vs traumatic brain injury

In the scientific literature, the differentiation is made between acquired and traumatic brain injury. Acquired constituting an injury that has happened after birth, such as degeneration of certain brain regions due to different types of diseases (e.g. dementia, Parkinson's, and Huntington's disease), blows to the head, drug and alcohol use, or oxygen deprivation. Considering this information, traumatic brain injury is a form of acquired brain injury related to external forces such as a forceful bump or blow, a jolt to the head or body, or a foreign object piercing through the skull and thus damaging the brain. (National Academies of Sciences, 2019)

Penetrating and nonpenetrating traumatic brain injury

Within traumatic brain injury, a distinction is made between penetrating and nonpenetrating traumatic brain injury. The former occurs when an object pierces the skull (e.g. bullet, shrapnel, bone fragment, or a weapon such as a hammer or knife) and enters the brain tissue. Typically, the damage with this type of injury is restrained to one part of the brain (focal). The latter (non-penetrating TBI also known as blunt TBI or closed head injury) is caused by an external force strong enough to move the brain within the skull. Causes vary from sports injuries, traffic accidents, blast injuries, and falls through to being struck by an object. (https://www.ninds.nih.gov/health-information/disorders/traumatic-brain-injury-tbi).

Classification of TBI

Primary and secondary injury

TBI neuropathology consists of a primary injury that is a direct consequence of the traumatic insult and a secondary injury that results from a cascade of molecular and cellular events triggered by the primary injury, and which leads to cell death, axonal injury, and inflammation (McKee & Daneshvar,2015; Taylor & Gercel-Taylor, 2014).

Focal and diffuse injuries

Some types of TBI can cause temporary problems with normal brain function while others may have a longer-lasting effect on the way how a person thinks, understands, moves, communicates, and behaves (https://www.ninds.nih.gov/health-information/disorders/traumatic-brain-injury-tbi).

Diagnostics and assessment

Measures of severity of TBI

An important aspect of diagnosing brain injury is determining the severity of the injury. Categorization is made between mild, moderate, and severe brain injury, depending on the clinical presentation (Gennarelli & Graham, 2005). Typically the severity early after injury is determined by assessing the presence of altered consciousness or loss of consciousness (0-30 minutes, >30 minutes to <24 hours, and >24 hours), assessing the presence of posttraumatic amnesia (if present differentiation between up to 24 hours and >24 hours), neuroimaging (normal or abnormal) and Glasgow Coma Scale score (using the best score in the first 24 hours; 13-15, 9-12, <9) (National Academies of Sciences, 2019). Glasgow coma scale is used to assess the level of impaired consciousness in all types of acute and trauma patients. The scales assess the patients on three aspects of responsiveness: eye opening, verbal and motor responses (Jain & Iverson, 2023).

A TBI diagnosis is best documented at the time of injury or within the first 24 hours.

Measures of executive function and personality

Executive functions measures

Various tests of executive functions have been used in previous research regarding executive dysfunction, and it is important to note that different tests measure different executive functions. The executive functions that got the most focus and understanding from cognitive scientists are inhibition, working memory, and shifting. Each of these functions works in coordination with other executive functions but they are distinct enough to be measured separately.

Inhibition ensues when an individual ignores a prepotent response to reach a goal. Some psychometric assessment tools for measuring inhibition are the Stroop task, Stop Signal task, Tower of London task, and Go – No Go task. The Stop Signal task requires the participant to discriminate between X and O when they appear on the computer screen. Once the participant sees the symbol on the computer screen they are instructed to press the corresponding letter on the keyboard. In one quarter of cases, the symbol appears along with a sound signal, indicating that the participant shouldn't press the corresponding letter on the keyboard. The reaction time of the participant measures the inhibitory control as they must inhibit the prepotent response of responding to the letter (Logan et al., 1997, as cited in Carlock, 2011). In the Tower of London task, the participant is required to arrange three differently coloured balls to a required position while following a set of rules. The balls can be placed on three different pegs, and each peg can hold three, two, or one ball respectively. The participant is instructed to match the pictured arrangement of balls in the least number of moves possible (Berg & Byrd, 2002, as cited in Carlock, 2011). Finally, the Go No-Go task is similar to the Stop Signal task. The participant is presented with letters on a computer screen (one at a time) and is instructed to press the letter X on the keyboard when they see it on the screen. Along with the letter X (presented in 80% of the trials) fifteen other letters are presented (in the remaining 20% of trials).

Working memory refers to the temporary memory storage which holds only the most recently activated or conscious pieces of information. In other words, it can be described as the constant running record or experience the brain retains in consciousness to decide on behaviour (Carlock, 2011). Some of the psychometric assessment measures used for working memory are the Letter Memory task, Keep Track task, and the Wisconsin Card Sorting task.
In the Letter memory task, the participant listens to the test administrator read a series of letters, once the administrator stops reading the participant is required to remember the last 4 letters. As the administrator may stop reading at any time, this requires the participant to

remember 4 letters, and as the list goes on discard the oldest letter with the most recent one. The participant is required to update the 4 letters as the list goes on (Carlock, 2011).

Keep track test requires that the participant holds information in their working memory and updates the information based on the experience gained through the test. The task consists of six different categories of words (e.g. animals, colours, vegetables) and a list of words. Participants are presented with three categories and a list of 15 words. Their task is to mentally sort the words from the list into one of the categories. The words are presented in a random order and at the end of the list the participant must write down the last word from each of the three categories.

Ray – Osterrieth Complex Figure test is mainly used for evaluation of visuo-constructional ability and non-verbal memory, and it is consisted of immediate copy and delayed recall of the complex geometric figure. Drawing performance can be used to assess the neuropsychological dysfunction of a participant, involving fine motor coordination, non-verbal memory, spatial organization, visuospatial perception, planning and organization as well as attention and concentration. Graphomotor impressions are influenced by complex cognition, perception and motor skills (Zhang et al., 2021).

Wisconsin card sorting task (WCST) is one of the most used tasks to measure executive functions and seems to be a global measure of frontal lobe functioning. In this task, the participant is presented with a set of cards that can be organized according to shape, colour, and number. The administrator of the test decides which category is correct and informs the participant whether they have sorted the cards correctly. After some time, the administrator changes the rule, and the participant is measured on how long it takes for them to switch to new rules (new correct categorization) (Berg, 1948).

Shifting or cognitive adaptability describes the process of selecting and implementing strategies to complete tasks or solve problems (Carlock, 2011). Shifting exerts top-down, conscious control on cognitive processes to move from one behaviour to another (Monsell, 2003). Some of the psychometric assessment tools used to measure this executive function are the Number-letter task, the Plus-minus task, and the Wisconsin Card Sorting task.

Within the Number-letter task participants are presented with number letter pairs in one of four quadrants on a screen. If the number-letter pair is presented in the top two quadrants the participant is required to identify whether the numbers are odd or even, and if the pair appears in the lower 2 quadrants the participant must identify whether the letter is a vowel or a consonant. The task is consisted of three trials. In the first trial, the number-letter pairs appear only in the top quadrants, and in the second trial only in the lower quadrants. In the third trial, the pairs appear in all four quadrants following a clockwise pattern. The difference in response time in the third trial measures the cost of shifting tasks.

Plus-Minus task uses three simple calculation trials. In the first one, the participants are required to add number three to a series of numbers, and in the second they subtract three from a series of numbers. In the third trial, they must switch between adding to and subtracting from a series of numbers. The series of numbers is different in each task. The additional response time (in comparison to the average time in the first two) measured in the third trial indicates shifting ability (Carlock, 2011).

The everyday problems experienced with the dysexecutive syndrome are measured with a tool called The Dysexecutive Questionnaire (DEX). DEX is a qualitative and quantitative self-report measure intended to divide daily functioning into sub-scales of dysexecutive functioning. It was originally designed to assess impairment in frontal lobe patients, but it shows potential in comparing of rather specific executive dysfunctions across varying clinical populations (Shaw et al., 2015).

Regarding studying decision-making, the Iowa Gambling Task (IGT) has made great contributions. It was designed to assess decision-making abilities in patients with damage to the VMPFC. The instruction for the participant is to attempt to maximize their winnings. The participant chooses repeatedly from 4 decks of playing cards that unpredictably yield wins and losses. Possibilities of wins and losses are counterintuitively arranged in such way that the decks with the higher wins (100$) result in long term net loss and the decks with smaller wins (50$) yield a net gain. The participants who do not learn to prefer the decks with smaller wins, over the course of 100 trials, are considered to exhibit a decision-making impairment (Bull et al., 2015)

Personality measures

There are several approaches to measuring personality such as observation, testing, and self-report. The most widely used is the self-report approach. In this approach, the source of information is the person, so the information available is the information the person reveals. Self-report data can be obtained through a variety of means, including interviews, periodic reports, and questionnaires. Some of the tests regularly used to assess personality are NEO Personality Inventory, Minnesota Multiphasic Personality Inventory (MMPI), Iowa

Scales of Personality Change, Frontal Systems Behaviour Scale, Neurobehavioral Rating Scale, Ekman 60 faces test, and The Millon Multiaxial Clinical Inventory. A commonly used example of a self-report questionnaire, in the form of statements, is the NEO Personality Inventory (Costa & McCrae, 2005). Participants read each statement that is presented to them and indicate whether they agree with the statement and feel that it is true for them, or they disagree with the statement and feel that it is not true for them. The level of agreement is indicated using a 1-5 Likert scale ranging from strongly disagree to strongly agree. (Larsen & Buss, 2023 book) Another example of a self-report measure is the Minnesota Multiphasic Personality Inventory (MMPI), a common measure used to assess psychopathy and make inferences about psychological traits by comparison to the norm. The most common application of the MMPI is establishing or reevaluating care for an ambiguous clinical picture. It is comprised of 567 statements for which the individuals mark on an answer sheet whether they are true or false for them. There are separate versions for male and female responders (Floyd & Gupta, 2023).

Iowa Scales of Personality Change (ISPC) are a measure used to assess personality disturbances that may occur in individuals with brain damage. They were designed with the intent to assess a wide range of specific personality disturbances which have been linked with brain damage (regardless of aetiology and location). Application of the ISPC is for both clinical (diagnosis, rehabilitation, and treatment planning) and research purposes (Barrash & Anderson, 1997).

Frontal Systems Behaviour Scale (FrSBe) is a brief behaviour rating scale for the assessment of behaviour disturbances associated with damage to the frontal-subcortical brain circuits. Cummings proposed a model linking the main frontal behavioural syndromes to three frontostriatothalamic circuits. The dorsolateral prefrontal circuit has been associated with executive cognitive dysfunction; the lateral orbital prefrontal circuit has been associated with disorders of self-regulation; and the anterior cingulate circuit has been associated with disorders of activation, spontaneous behaviour, and motivation, resulting in syndromes such as apathy (Malloy & Grace, 2005). FrSBe measures both pre- and post-injury behaviours and is specifically designed to detect three main frontal behavioural syndromes: apathy, executive dysfunction, and disinhibition (Shreman & Hrabok, 2023). The FrSBe and ISPC are valid in discriminating frontal from non-frontal lesioned patients.

The Millon Multiaxial Clinical Inventory (MCMI) is a self-report measure consisted of 175 items to which the participant responds with true or false. The MCMI is consisted of scales grouped into 3 clusters that measure personality style, severe personality patterns, and clinical syndromes. Since its creation there have been several revisions and updates of the MCMI (Choca & Van Denburg, 1997).

The Neurobehavioral Rating Scale – revised (NRS-R) is a psychometric instrument developed to serve as a quick, easy-to-administer tool to measure changes in neurobehavioral functioning following brain injury. NRS is consisted of 27 items which the examiner rates by selecting one of 7 ratings from “not present” to “extremely severe”. In order to select an appropriate rating, the examiner evaluates the participants responses and integrates observational data attained through structured interviews (Sandberg, 2018).

Ekman 60 faces test from FEEST uses a range of photographs to test recognition of facial expressions of basic emotions (anger, sadness, happiness, disgust, fear and surprise). It comprises a total maximum score of 60 for correct recognition of all 6 emotions or a score of 10 for the recognition of each basic emotion.

Due to the presented complexity of the human brain functions and their measurement, we decided that a scoping review is necessary to present the current level of knowledge on the association of impact-based frontal brain injury and executive functions and personality. There are two objectives of this research. Firstly, to identify and describe the specific executive functions most commonly affected by frontal brain injury. Further, to explore the relationship between frontal brain injury and changes in personality traits. The population of interest for both of the objectives were people with acquired traumatic brain injury to the frontal lobe.

Methods

Protocol and registration

For this current study, a protocol was not preregistered. PRISMA ScR checklist followed.

Eligibility criteria

Eligibility criteria for study inclusion in this review start with the study characteristics. Firstly, the population of interest were individuals with frontal traumatic brain injury, since the aim was to assess the association of such injury with changes in executive functions and personality. The aetiology of the injury was narrowed to only traumatic because other forms of acquired brain injury may affect other brain areas as well. Studies that measured either executive functions, personality, or both, were included in the protocol. Studies that were included were published observational studies (cohort, case-control, and case studies), clinical studies, clinical trials, control clinical trials, comparative studies, multicentre studies, and randomized controlled trials published from 2004 until April 2024 in English. Systematic or meta-reviews were not included.

Information sources

Regarding the information sources, PubMed (PM) and Web of Science (WOS) were used. Both databases were searched on the 2nd of April 2024 and all the articles were imported into Zotero.

Search

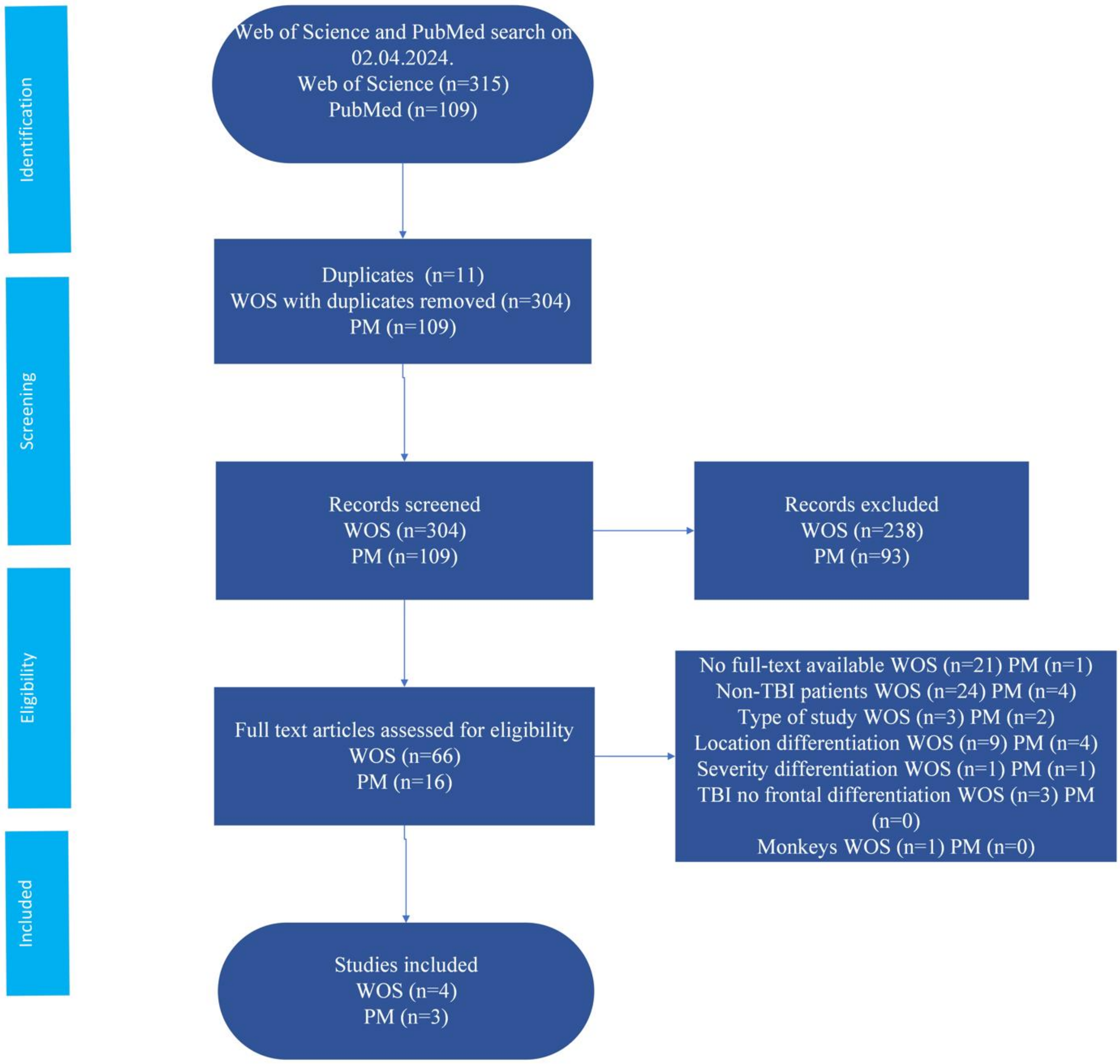
PubMed 02.04.2024. 109 results
Frontal Lobe Injuries OR Frontal Brain Injury OR Frontal Cortex Injury OR Prefrontal Cortex Injury) AND (Executive Function OR Cognitive Control OR Planning OR Working Memory OR Inhibitory Control OR Decision Making) AND (Personality OR Trait OR Temperament OR Character OR Behaviour) NOT (parietal[Title/Abstract] OR occipital[Title/Abstract] OR temporal[Title/Abstract])) NOT (children[Title/Abstract] OR pediatric[Title/Abstract] OR paediatric[Title/Abstract] OR child[Title/Abstract])
Additional filters: Classical article, Clinical study, Clinical trial, Comparative study, controlled clinical trial, Multicentre study, Observational Study, Randomized controlled trial, Humans, English, last 20 years (2004-2024)

Web of science 02.04.2024. 315 results (304 – without duplicate studies)
ALL FIELDS: (Frontal Brain Injury OR Frontal Lobe Damage) AND (Executive Function OR Cognitive Control OR Planning OR Working Memory) AND (Personality OR Trait OR Temperament OR Character OR Behaviour)
TOPIC: NO (rats OR rodents)
Not ABSTRACT: rats; rodents; primates; animal; parietal OR temporal OR occipital; mice OR mouse; case study OR case report
Not ALL FIELDS: children OR pediatric OR paediatric OR child OR infant
Not TITLE: case study OR case report
Last 20 years (2004-2024)
Document type: article

Selection of sources of evidence

For this scoping review, following the importation of articles into Zotero they were screened based on title and abstract by one reviewer and sorted into studies to be excluded from the review (due to not satisfying the eligibility criteria) or ones to continue into the full-text elimination. Full-text elimination started on the 28th of April 2024 and lasted until the 20th of May 2024. Out of 16 studies from PubMed which entered the full-text elimination we were able to find 15 full texts, regarding Web of Science out of 66 studies that went into full-text elimination, we managed to attain 46 full texts. From the full texts of the studies, information about participants was extracted along with participant differentiation in the results section (whether the participants were differentiated by the location or aetiology of brain injury). Based on the extracted information studies were sorted into include and exclude categories.

Figure 1 *PRISMA Flow diagram for the scoping review process*



Data charting process

Once the articles to be included have been selected, the following data was recorded in an Excel spreadsheet: article title, authors, year published, location, and study type. Along with the aforementioned general info, variables extracted were participant information, personality measure, executive functions measure, main findings for personality, main findings for executive functions, treatment suggestion, and further research suggestions.

Critical appraisal of individual sources of evidence

The studies included in this research were not critically appraised.

Synthesis of result

The data in this review will be synthesised using a narrative (descriptive) approach to synthesis.

Results

Selection of sources of evidence

The original search resulted with 315 studies on Web of Science (WOS) and 109 studies on PubMed, which in total makes 424 studies. There were 11 duplicates among these studies, making the total 413 studies. Following the removal of duplicates, a total of 413 studies were screened based on title and abstract and sorted into categories of studies to be included and those to be excluded based on the eligibility criteria. Studies which did not include the population of interest were excluded (based on the following criteria: aetiology and location of injury), also studies which did not measure personality or executive functions. Furthermore, studies which listed that the aetiology of the injury was not traumatic were also excluded.

The elimination of studies based on these criteria led to 66 studies for Web of Science and 16 studies for PubMed to go into the next stage of the process, any studies which were unclear on these criteria went into the next stage. Out of 66 studies for WOS we were able to attain 45 full texts, and for PubMed out of 16 studies we were able to attain 15.

Upon attaining the full texts, the studies were screened for information on the study population and the elimination criteria mentioned above. Based on this information studies were either included or excluded. Reasons for exclusion of studies at this stage were multiple. There were 28 studies which were excluded due to the participants being non-TBI patients, 5 studies were excluded due to the type of the study (either case study, review or theoretical framework study). 13 studies were excluded due to brain injury differentiation according to location and not aetiology, 2 studies were excluded due to severity differentiation, 3 studies were excluded due to no differentiation of the injury to frontal and one study was excluded due to the participants not being humans. Finally, 7 (Web of Science=4, PubMed=3) studies were included in this review and the relevant information was extracted from them.

Characteristics of sources of evidence

All included evidence were scientific publications from Web of Science and PubMed.

Table 1

Characteristics of sources of evidence

First author, year, country	Publication type	Publication aim
Rodriguez Bailon, 2012, Spain	Empirical research	To explore the attentional networks proposed by Michael Posner and Dehaene in 1994 by administering the ANT-I task for the first time to a group of patients with prefrontal damage.
Levine, 2005, Canada	Clinical research study	To determine the sensitivity of the Gambling Test (GT) to the neurocognitive effects of traumatic brain injury (TBI) and to examine the cognitive, neural, and psychosocial correlates of impaired GT performance in patients with TBI.
Visser Keizer, 2016, Netherlands	Empirical research	To enhance understanding of the role of fear recognition in guiding decision-making processes and its implications for rehabilitation and treatment strategies for TBI patients.
Fecteau, 2013, Canada & USA	Cross sectional	To investigate risk-taking behaviour in patients with acute traumatic brain injury (TBI) compared to healthy controls.
Hee Kwak, 2020, Korea	Cross sectional observational study	To investigate factors affecting cognition and emotion in patients with TBI, we evaluated executive function, memory, and emotion based on injury severity and lesion location.
Newcombe, 2011, UK	Clinical research investigation	To characterize the neuroanatomical basis of impaired decision-making and impulsivity following traumatic brain injury (TBI).
Xi, 2011, China	Comparative neuropsychological investigation	To investigate the impact of lesions in specific subregions of the prefrontal cortex—specifically the ventromedial prefrontal cortex (VMPC) and dorsolateral prefrontal cortex (DLPC)—on social cognition (theory of mind) and decision-making abilities.

Critical appraisal within sources of evidence

Critical appraisal of sources of evidence was not done as a part of this scoping review.

Results of individual sources of evidence

Rodriguez Bailon 2012 used The Million Multiaxial Clinical Inventory to measure personality and found that greater interference in executive control was shown in the patients with frontal lobe damage when compared to controls, related to measures of personality associated with cognitive and behavioural impulsivity and inflexibility. Furthermore, they found that conflict effect relates to personality variables, especially borderline personality traits, indicating that there is a common mechanism underlying cognitive and behavioural control deficits in patients with frontal lobe damage. They concluded that due to the presence of BPD secondary to brain injury associating with conflict effect there is a link between specific personality traits and impaired conflict resolution in individuals with frontal brain injury.

Regarding executive functions they found that patients with frontal damage showed significant neuropsychological impairments in executive functions (such as: abstraction capacity, planning, visual construction abilities) when compared to the control group. Patients with frontal damage also exhibited significantly greater interference in tasks requiring executive control when compared to control group. Finally, the results of this study show similar performance of patients and control groups in alerting and orienting tasks, whilst there were significant deficits in managing conflict in the executive control network, indicating specific impairment in the executive functions for frontal damage patients.

Levine et al. (2005) found that the performance on block 3 of the Gambling Task (GT) was significantly related to the total score on the Dysexecutive Questionnaire (DEX), and the subscales for executive memory, positive affect and negative affect. Examiner rated outcome on the Neurobehavioral Rating Scale – revised (NRS-R) also showed a moderate relationship with the total score on the GT. Intention/memory factor negatively related to GT performance on Blocks 2 and 5, whilst they had a reversed relationship on Block 1. Further, the researchers found a significant correlation between Low Emotional State and Block 5, also between emotional and behavioural hyperactivation and Block 3. Finally, NRS-R total score correlated with blocks 3 and 5. Related to executive functions, the study shows that the working memory tasks (such as Self-ordered pointing test and trail making test) significantly related to the GT performance. Moreover, executive function tasks (e.g. WCST) showed significant relation to GT performance.

As a part of the Visser-Keizer (2016) study, in the Iowa Gambling Task (IGT) the traumatic brain injury (TBI) patients exhibited reduced flexibility and stability in their choices reflecting the influence of executive functioning on performance. In this study, TBI patients showed delayed learning rates compared to controls. Also, in a specific block of the IGT higher recognition of fear was related to less risk behaviour in TBI's demonstrating a potential link between fear recognition and decision making. TBI patients performed more poorly on the Ekman 60 faces test, compared to healthy controls, demonstrating a significant impairment in recognizing facial emotions, particularly fear. Finally, the study found that TBI patients were less able to consistently guide their behaviour, showing greater risk-taking tendencies when compared to the control group.

In the Fecteau (2013) study no significant relationship was found between the severity of head injury and risk-taking behaviour in the acute phase of TBI. Further, they report that the right frontal lobe lesion patients displayed increased risk-taking behaviour when compared with patients without such lesions during the second and third sets of balloons in the Balloon Analogue Risk Task (BART). Healthy controls pumped the balloon more toward the end of the experiment compared to TBI patients who didn't show a significant increase in pumping the balloon. Further, the TBI group earned less money than the control group (22$ - 39$).

Hee Kwak et al. (2020) found that patients exposed to longer periods of loss of consciousness experienced more serious cognitive and emotional problems (agitated behaviour especially). There was no significant association found for depression and anxiety. Agitation was found to be more common in the acute phase (when the neurological state of the brain was unstable). Following this, the emotional disturbances due to organic factors were more frequently observed in patients with serious brain injury. Severe TBI patients frequently exhibited various emotional problems (apathy, disinhibition) which correlated with the severity of the brain injury. Finally, group differences based on lateralization of brain lesion were observed in anxiety and depression, with the greater levels of anxiety and depression in the bilateral lesion group than in both left and right lesion groups. In executive functions findings, longer loss of consciousness patients showed more severe deficits in agitated behaviour and everyday memory. Frontal lesion group demonstrated poorer performance in executive functions compared to the non-frontal lesion group, with the bilateral lesion group showing more deficits in executive functions and being more depressed than the unilateral lesion groups. Right frontal lesion group had worse results on executive functions than the left frontal lesion group.

Using the Cambridge Neuropsychological Automated Test Battery (CANTAB) Newcombe et al. (2011) found that the TBI patients did not differ significantly in risk adjustment, rational choices or amount of bet compared to controls. The TBI patients demonstrated a preference for consistently early bets indicating higher impulsivity compared to controls. TBI patients' deliberation time was slower in comparison to the control groups deliberation time.

The influence of lesion location was also demonstrated in the Xi (2011) study which shows that Ventromedial prefrontal cortex (VMPC) lesion patients exhibited severe impairments in real life decision-making as shown by their performance on the IGT as demonstrated with them selecting the more disadvantageous cards and placing higher bets on simple probabilistic decision when compared to control group. VMPC patients didn't exhibit advantageous shift in decision making like the dorsolateral prefrontal cortex (DLPC) patients and the healthy controls. On the Risky Gains task, the DLPC and the controls showed a similar inhibition effect of punishment that VMPC did not. The VMPC group had more risky responses after reward or punishment in comparison to the other groups. The study also showed that the lesion side in sub prefrontal lesions did not have a significant influence on decision making performance.

The executive functions which are most affected by frontal brain injury range from greater interference in executive function tasks (Rodriguez Bailon, 2012), through issues with managing conflict (Rodriguez Bailon, 2012), all the way to risk taking (Visser Keizer, 2016; Fecteau, 2013), inhibition and even everyday memory and decision making (Xi,2011; Hee Kwak, 2020). The individual with frontal brain injury has a lot of potential problems in everyday functioning and not a lot of rehabilitation suggestions. Some of the difficulties experienced may even act in tandem, like you would imagine that managing conflict when you have issues with emotional regulation might become increasingly difficult. Aside from deficits in executive functioning individuals with TBI which affected the frontal lobe may also develop certain changes to their personality, as suggested by the finding of greater interference related to behavioural and cognitive impulsivity and inflexibility (Rodriguez Bailon, 2012) or the research finding of significant impairment in recognizing facial emotions (Visser Keizer, 2016). Furthermore, frontally brain injured patients exhibit emotional disturbances linked to organic factors and various other emotional problems, such as apathy and disinhibition (Hee Kwak, 2020).

The findings of several research papers included in this scope suggest the connection of executive functioning deficit and personality changes and suggest the existence of a common underlying mechanism for both cognitive and behavioural control (Rodriguez Bailon, 2012; Hee Kwak, 2020; Visser Keizer, 2016).

Table 2

Reported deficits presented per study

Affected function/Study	Rodriguez Bailon, 2012	Levine, 2005	Visser-Keizer, 2016	Fecteau, 2013	Hee Kwak, 2020	Newcombe, 2011	Xi, 2011
Executive functions							
Risk taking			+	+			
Memory	+	+			+		
Impulsivity	+					+	
Decision making		+					+
Planning	+						
Abstraction capacity	+						
Interference in executive function tasks	+	+			+		
Conflict management	+						
Learning			+				
Personality							
Impaired recognition of fear			+				
Anxiety and depression					+		

Discussion

Traumatic frontal brain injury may be the result of a fall, a motorcycle or car accident, a forceful bump or blow, or a foreign object penetrating the scull. Research has shown that traumatic frontal brain injury has varied consequences on individuals but in most cases the damage is associated with a disfunction in the executive system along varying aspects of the same. The executive function which is impacted may be abstraction capacity, planning or visual construction, even managing conflict may be challenging after such injury (Rodriguez Bailon, 2012). Abstraction capacity entails the ability to contemplate concepts which do not have a physical form, and it is considered to be of essence to higher cognitive functions such as learning or making judgements (Kim, 2024). Along with delayed learning rates, brain injured patients have been found to have reduced flexibility and stability in their choices (Visser Keizer, 2016). Planning is an essential skill which involves thinking about required actions to reach a certain goal and it is used on a daily basis. The ability to see an object as a set of parts and the ability to the construct a replica of the original from these parts is known as visuospatial construction, we use it to build a piece of non-assembled furniture or to button a shirt. Other executive functions which may be affected by a traumatic frontal brain injury are risk taking and decision making. The Fecteau et al. study (2013) found that individuals who suffered from frontal brain injury had increased risk taking behaviour when compared to healthy controls, whilst Xi et al. (2011) found that VMPC brain injured individuals had severe impairments in real life decision making as they didn’t exhibit the advantageous shift in decision making as controls and DLPC injured individuals did. Further, the VLMP patients lacked the inhibition effect of punishment. Patients with frontal brain damage also demonstrate issues with working memory as Levine et al. (2005) showed in their study. Kwak et al. (2020) also found that the patients have issues with memory but in their research, they refer to it as everyday memory. All of the executive functions listed above are used by humans on a daily level, and the patients who suffered from traumatic frontal brain injury have decreased quality of life due to these deficits. More focus needs to be put into researching the influence brain damage has on an individual in real life situations and appropriate rehabilitation techniques need to be developed. Other than executive functions, and perhaps partially due to the impairment in executive functions, personality of a brain injured individual is affected post injury. Levine et al. (2005) state that personality changes are linked to the deficits in the executive functions. In regard to prior mentioned deficits in conflict management, Rodriguez Bailon et al. (2012) claim a link between specific personality traits (bipolar disorder traits especially) and impaired conflict management. Other than conflict management patients with frontal brain injury suffer from other emotional disturbances due to organic factors, such as apathy or disinhibition (both correlate significantly with severity of injury). Apathy is defined as a lack of interest or concern. Disinhibition is defined as orientation towards immediate gratification, leading to impulsive behaviour driven by current thoughts, feelings and external stimuli, without regard for past learning or future consequences (APA, 2013 as cited in Mullins-Sweatt et al., 2019). Disinhibition includes five lower-level traits: irresponsibility, impulsivity, distractibility, risk taking, and rigid perfectionism (lack thereof). Some of these lower-level traits have been mentioned in research included in this scope, and those are risk taking (Visser Keizer, 2016; Fecteau, 2013) and impulsivity (Newcombe, 2011), showing greater support for the issues faced due to disinhibition.

Only two studies included in this scope mentioned rehabilitation but still mainly focus on further research in deficits in emotion processing (Visser Keizer, 2016) or the simple inclusion of elements into rehabilitation practices (Hee Kwak, 2020), which is to show that rehabilitation of frontally brain injured patients needs significant amount of work to be put into further research. Further research suggestions include researching cognitive mechanisms and neural correlates of various executive control tasks with an aim of understanding the interplay between cognitive functions and personality traits. Also, relating test performance to real life outcomes has been suggested by Levine et al. (2005).

Future research suggestions in the field of traumatic frontal brain injury should also incorporate large samples of individuals followed over time and depending on the phase of the injury. Individuals in different stages of their injury should be recruited and followed over a certain period of time. Their executive functions and personality should be observed, and any changes marked down. Along with measures for EF and personality, future studies should gather information about the habits and daily life of the patient in order to attempt to find real life habits which may aid recovery. More attention is needed in the field of developing rehabilitation for brain injured patients but also in educating the close people of the patient in how to aid recovery and live with a brain injured individual to attempt and better the life quality of the household as a whole.

Limitations

Regarding the limitations of this study there was a lack of a preregistered protocol which has affected the study with regards to its quality. Further, the recommended second reviewer was not a part of this study during the elimination process, affecting the objectivity of the process.

Conclusion

This study presents that frontal brain injury has many unfavourable consequences which decrease the injured individual's quality of life in various ways. Influencing their planning, visual construction abilities, decision-making, memory, conflict resolution, just to name a few. Frontal brain injury has devastating effects on the life of the individual, on their behaviour, cognition, emotion and it requires an all-round approach to rehabilitation. Special attention needs to be given to the different aspects of one's life which are affected by the brain injury but also to the individuals who support the patient (brain injured) through their recovery.

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Abstract

This study explored the knowledge attained in the last 20 years on the effects traumatic frontal brain injury has on a person's life. Affected areas are life quality, behaviour, emotions, cognition. Specifically, various executive functions may be affected like conflict management, risk taking, or decision-making. Other than the individuals functioning, their emotions may be affected as well. Increased amounts of anxiety and depression have been found in brain injured individuals. Also, recognition of emotions may be affected as well.

Key words: traumatic, frontal, brain injury, executive functions, personality

Sažetak

Ovo istraživanje je predstavilo znanje prikupljeno u posljednjih 20 godina o učincima traumatske frontalne ozljede mozga na život osobe. Traumatska frontalna ozljeda mozga ima kao svoje posljedice smanjenu kvaliteta života, promjene u ponašanju, emocijama i kognicijama (spoznajama). Specifično, razne izvršne funkcije mogu biti oštećene kao upravljanje konfliktom, poduzimanje rizika, ili dovođenje odluka. Osim izvršnih funkcija pojedinca, i njihove emocije mogu biti pod utjecajem ozljede. Povišene razine anksioznosti i depresije su pronađene kod pojedinaca s ozljedom mozga. Također, prepoznavanje emocije može biti otežano.

Ključne riječi: traumatska, frontalna, ozljeda mozga, izvršne funkcije, osobnost

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Thesis Co-supervisor (first and last name, academic degree and title)

Linda Lušić Kalcina, PhD, Assistant Professor

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