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The Effect of Traumatic Brain Injuries on Risky Decision Making

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Abstract

Every year, over 2.8 million people sustain traumatic brain injuries (TBIs), with falls, motor vehicle accidents, and impact concussions accounting for 90% of TBIs. Despite the large number of people affected by TBIs, little is known about how TBIs can influence decision making, particularly risky decision making. Most TBIs that are sustained impact the frontal lobe. Given that the frontal lobe controls executive functions, it is hypothesized that damage to the frontal lobe would lead to cognitive dysfunction such as impaired decision making. However, the data supporting this remains very limited. In this review, non-human and human experimental studies on the effect of TBIs on risky decision making and current treatment options were identified in the literature. Non-human experimental behavioral data, primarily from rodents, largely suggest that frontal lesions result in suboptimal decision making despite learned associations. Similarly, in human studies, TBI patients show an impaired level of decision making, often making riskier or more suboptimal choices due to increased impulsivity. Treatment for TBI-related cognitive injury focuses on cognitive rehabilitation, but unfortunately, these treatments have only shown modest improvement for those with mild to severe TBI. In conclusion, a better understanding of the neurobiology underlying how TBI affects decision making could lead to better interventions to minimize the cognitive impacts of TBIs.

Keywords: Traumatic Brain Injury, Decision Making, Risk, Neuroscience

1. Introduction

Every year, over 2.8 million people suffer from traumatic brain injuries (Vonder Haar et al., 2020). A traumatic brain injury (TBI) is an injury that disrupts the normal functions of the brain. Bumps, blows, jolts, or penetrating head injuries cause TBIs (Marr & Coronado, n.d.). The leading causes of non-deadly TBIs are falls, which account for 35% of TBIs, motor vehicle-related injuries, which account for 17%, and strikes and blows to the head from or against an object, which account for another 17% (Faul et al., 2010) (sports-related injuries). The leading causes of deadly TBIs are motor vehicle crashes, suicides, and falls (Coronado et al., 2011).

In 2010, the Centers for Disease Control and Prevention reported that TBIs resulted in around 2.5 million emergency department visits, hospitalizations, and deaths in the United States (Center for Disease Control and Prevention, 2010). Of these 2.5 million TBIs, 87% were treated and released from the emergency department, 11% were hospitalized and discharged, while the remaining 2% died. While these numbers appear large, they significantly underestimate the number of TBIs in the United States, as they do not account for those who received outpatient care or no medical care at all (Faul et al., 2010).

The most common location for TBIs is the frontal lobe, especially the prefrontal cortex (Cotrena et al., 2014). Damage to the frontal lobe has been connected to damage to frontal executive functions, such as impulse control and decision making (Ozga-Hess et al., 2020). Lasting damage from TBIs has been known to exist in the form of impaired decision making abilities. One type of decision making that is known to be affected is risk-based decision making (Cotrena et al., 2014). Risk-based decision making includes larger reinforcers that are associated with risk rather than delays (Shaver et al., 2019). Risk-based decision making also includes impulsive choices in which smaller, immediate gains are preferred to larger, delayed gains (Dixon et al., 2005). Thus, when TBIs in the frontal lobe occur, decision making abilities will likely be variably affected, particularly because decision making is a complex executive function of the frontal lobe. This paper examines how traumatic brain injuries impact decision making by reviewing the literature from both non-human models and human studies of TBI and its influence on decision making to describe what is known about the neurobiology of TBI and current treatment options.

In this paper, a review was conducted in which information from existing studies on risky decision making following TBI was systematically collated and evaluated. Relevant publications were identified and analyzed, with key studies included for this review.

2. Neurobiology of Decision Making

Decision making is a complex neurobiological process. The decision-making function is the ability of an individual to seek out an optimal solution by suppressing interference and figuring out appropriate cognitive representation and strategy (Wang et al., 2024). Much of the decision-making process is based on time. As the stimulation duration decreases, or when a decision is made more quickly, the decision is usually much less accurate (Gold & Heekeren, 2014). While there are many different types of decision making, the most common is value-based decision making, which occurs when there are different options with different "values". After identifying internal and external factors, a value is assigned to each option. Then, the values are compared, and following that, the decision is implemented (Rangel et al., 2008).

One region of the brain that is strongly associated with decision making is the frontal lobe (Schoenberg, 2011; Swami, 2013). The frontal lobe can show active representations of behavioral strategies that were stored in long-term memory for driving action (Harlow, 1949). Prior task sets are evaluated according to outcome values and then incorporated into novel situations for maximum utility (Montague, 1999). The frontal lobe executive function utilizes multiple task sets to make decisions (Collins & Koechlin, 2012).

Risk-based decision making falls into the category of value-based decision making since one major modulator of value-based decision making is evaluating risk (Rangel et al., 2008). Risky decisions have clear outcome probabilities, but it is unclear which option will be chosen. There are three different types of decision-makers when making decisions with risk: risk-averse, risk-neutral, and risk-seeking. Someone is risk-averse if they would rather have a sure payment versus an outcome that is of a potentially higher value. A risk-neutral person would act indifferent between the various choices and their expected value. Risk-seeking decision-makers would value a better outcome from a risky prospect over a sure payment (Trepel et al., 2005).

When TBIs are sustained in the frontal lobe, they can damage executive functions (Cotrena et al., 2014). One of these very important functions is the ability to make decisions (Collins & Koechlin, 2012). When the decision-making ability is impaired, the person with a TBI tends to become a more risk-seeking individual (Shaver et al., 2019). Such decision-making impairments can lead to poorer quality of life (Shaver et al., 2019). Riskier decision making can lead to losing sight of delayed gains and the foresight to plan for important decisions. For all those who suffer from TBIs and their lasting impacts, there is very little research on how TBIs can affect decision making, particularly risky decision making. Not understanding how TBIs can affect this type of decision making can be dangerous to those who make riskier decisions without realizing it after sustaining a TBI to the frontal lobe (Figure 1).

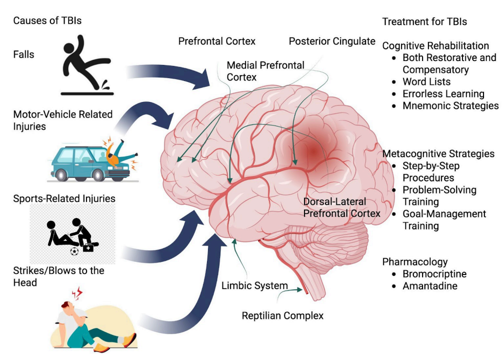

Figure 1. TBIs are caused by many etiologies, including falls, motor-vehicle related injuries, sports-related injuries, and strikes/blows to the head. These TBIs can affect different places in the brain, such as the prefrontal cortex, the posterior cingulate, the medial prefrontal cortex, the dorsal-lateral prefrontal cortex, the limbic system, and the reptilian complex. While TBIs cause damage to many areas of the brain, there are treatment strategies. These treatments comprise of cognitive rehabilitation, metacognitive strategies, and pharmacology.

3. Non-Human Studies on Decision-Making Impairments Due to TBI

To test if TBIs can affect risky decision making (Table 1), it was first necessary to test if TBIs could affect decision making and frontal lobe executive functions at all. One of the earliest studies performed a discrimination task on Sprague-Dawley rats to see how TBIs in different locations could affect decision making (Martens et al., 2012). The authors concluded that there was a clear effect of frontal lobe TBIs on frontal lobe functions and decision making (Martens et al., 2012). To provide further insight into decision making, subsequent studies examined a specific type of decision making, particularly risky decision making (Humphreys et al., 2016).

Table 1. List of Non-Human Studies on Decision-Making Impairments due to TBI.

Species	Technique for TBI	Assessment	Result	Reference
Sprague-Dawley Rats	Cortical Contusion Injuries (frontal, parietal, and sham)	The dig task was used to see how TBIs in different locations could affect decision making, where rats received dig training to find reinforcers hidden with either scented or unscented sand.	The Dig task is a simple experiment that can be used to assess deficits in decision-making behavior following TBI. There was a clear effect of frontal lobe TBIs on decision making.	Martens et al., 2012
Long-Evans Rats	Controlled Cortical Impact Procedures	The Rodent Gambling Task was used, in which the rats are presented with four options, each with a different chance of rewards and punishments. Within a certain time, the rats attempt to gather as many "rewards" as they can	The TBI caused alterations to risk-based decision making in the rats. Rats with TBIs preferred the riskiest/most suboptimal option.	Ozga-Hess et al., 2020
Long-Evans Rats	Controlled Cortical Impact Procedures	The Rodent Gambling Task was used.	Injury immediately caused the rats to choose both riskier and suboptimal choices. TBI also increased motor impulsivity over time.	Shaver et al., 2019
16 Long-Evans Male Rats	Frontal Controlled Cortical Impact Procedures	The Rodent Gambling Task was used.	TBI rats showed no deficits in choice behavior compared to sham rats. However, TBIs increased impulsivity.	Vonder Haar et al., 2020
Long-Evans Rats	Frontal Controlled Cortical Impact Procedures	The Delayed Discounting Task, which consists of illumination of hole 3, a nose poke would illuminate holes 1 and 5, and rats choosing between a one-pellet option that was delivered immediately or a four-pellet option that was delayed, was used.	Both mild and severe TBIs caused a chronic increase in impulsive decision making. Memory function was not impaired in more mildly injured rats.	Vonder Haar et al., 2017
109 Long-Evans Male Rats	Bilateral Frontal TBI	The Rodent Gambling Task was used.	There was a significant reduction in sensitivity and a bias towards riskier choices in TBI rats. TBI also caused a reduction in the tendency to choose a given option.	Vonder Haar et al., 2022
109 Long-Evans Rats	Closed-Head-Controlled Cortical Impact	There was a Probabilistic Discounting Task that required rats to choose between two levers, one with small/certain rewards and the other with riskier/larger rewards.	In the first week, rats with TBIs displayed a preference for risky decisions. Following that, in the fourth week, the male rats displayed a delayed effect on processing speed.	Knapp et al., 2024

When testing whether TBIs can affect risky decision making, one main method that has been used in many experiments is the Rodent Gambling Task. The Rodent Gambling Task (RGT) is a version of the Iowa Gambling Task that has been used to test risky decision making in humans (Shaver et al., 2019). Similarly to the Iowa Gambling Task, the rats are presented with four options, each with a different chance of rewards and punishments. This results in a set of reinforcement rates. Within a certain time, the rats attempt to gather as many "rewards" as they can (Shaver et al., 2019). Using the Rodent Gambling Task, one study tested how TBIs in the parietal lobe could affect risky decision making (Ozga-Hess et al., 2020). It was found that while the parietal lobe TBI did not directly affect the decision-making processes, it affected how quickly the rats learned, but not the actual learning (Ozga-Hess et al., 2020). This study emphasizes how decision making is a primarily frontal function that can be affected by frontal lobe TBIs.

Another study tested this theory by using the RGT to test how frontal lobe TBIs would affect the rats' decision-making abilities (Shaver et al., 2019). The conclusion from this study was that rats that had previously learned the reward variables following frontal lobe TBIs had a reduced preference for the best/most optimal choices and preferred the suboptimal choices instead. This reinforced the hypothesis that TBIs affect risky decision making regardless of

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learned history (Shaver et al., 2019). The authors hypothesized that the executive functions of the frontal lobe were affected by the TBI in this experiment. Furthermore, the results from the Rodent Gambling Task in this study proved that impulsive action was increased after a TBI to the frontal lobe (Vonder Haar et al., 2020). Beyond this, a third study was run on the relationship between sensitivity to immediate outcomes and risk-based decision making. There was a significant reduction in sensitivity to the overall outcomes of various choices and hence a bias towards riskier choices in rats who sustained a frontal TBI. The TBI also caused a reduction in the tendency to choose the optimal option (Vonder Haar et al., 2022).

To provide further information on the increase in impulsive action that seemed to appear after a TBI in the frontal lobe, another study was run examining the ability of delayed reinforcers to affect decision making following TBIs in rodents. The rodents with TBI in the frontal lobe displayed increased discounting of delayed reinforcers. There was increased impulsive choice as well in rodents with TBIs (Vonder Haar et al., 2017). Further, in another discounting task, the Probabilistic Discounting Task, Long-Evans rats with TBIs not only had increased impulsive choice, they, in fact, also displayed a preference for risky decisions. Interestingly, in this same study, in the fourth week after sustaining a TBI, the male rats also exhibited a delayed effect on processing speed (Knapp et al., 2024).

4. Human Studies on the Impact of TBIS

While the previous section focused on the effects of TBIs on decision making through rodents, this section focuses on the experimental paradigms in humans aiming at measuring the effects of TBIs on decision making, particularly risky decision making (Table 2). Based on previous studies that found that TBIs in rodents strongly affect decision-making abilities, human studies utilize a similar tool called the Decision Making Task, in which each scenario had two least important and two most important attributes, and then a final choice had to be made utilizing the provided information matrix. Akin to the findings in rodents, the group without TBIs (the control group) showed more effective decision making (Sood et al., 2023).

Table 2. List of Human Studies on the Impact of TBIs.

Species	Technique for TBI	Assessment	Result	Reference
71 Children (ages 7-15)	Unspecified location or severity, but occurred six months prior	Each scenario had two least important and two most important attributes, and the final choice had to be made in the information matrix.	The TBI group performed more poorly on the decision-making task.	Sood et al., 2023
11 Children	Moderate to severe post-acute traumatic brain injury	Children had to choose from four different card decks, and the different decks had different loss-gain rates. They were told to pick a deck to see how much money they would win or lose and was told that some decks were better than others.	Children with amygdala lesions were impaired on the task, while children with ventromedial lesions did not seem to be impaired.	Hanten et al., 2006
136 Adolescents (ages 11-18)	Varying levels of TBI severity	10 different moral dilemmas were presented, and the children chose an action to engage in and then provided justification for that action.	Adolescents with TBIs displayed more immature moral reasoning and had fewer socially adapted decisions.	Beauchamp et al., 2019
110 participants (ages 18-73)	Mild or Severe TBIs	Cards from one of four decks were chosen throughout 100 trials, and Decks A and B were considered disadvantageous, while decks C and D were considered advantageous. The total net score was calculated by subtracting cards from decks A and B from decks C and D.	TBI patients had different scores due to poor decision-making skills. There was no real difference in patients with and without frontal lesions or mild and severe TBIs.	Cotrena et al., 2014
77 participants	Subacute mild TBIs (1-3 months after injury)	The Iowa Gambling Task was used.	TBI patients had different degrees of impairment under risk, specifically in memory, attention, and information processing speed.	Wang et al., 2024
44 participants	Moderate to severe TBIs (6 months post-injury)	There were blue and red boxes with a token hidden under one of the boxes, and patients were asked to guess which color the token was under and make a bet.	TBI patients were found to have intact processing of risk adjustment and probability judgment. There was a patient preference for early bets, which indicates impulsiveness.	Newcombe et al., 2011
71 participants	TBI in the frontal lobe	Patients had to draw cards from four decks, and each card had win-loss rates. Two of the four decks had low gains and low losses, while the other two decks had higher gains and higher losses.	There was marked impairment in the patients with large frontal lesions.	Levine et al., 2005

69 participants	TBI survivors	There was a deck of 100 playing cards and they were labeled with different rewards and losses Participants were allowed to gamble on the tasks, but they didn't know that the deck was split into five blocks of twenty cards.	TBI survivors made more gamble choices than the controls. Age and subgroup (containing both TBI survivors and controls) were predictors of performance on this task.	Adlam et al., 2017
90 people	Moderate to Severe TBIs	The computer presented them with options, and they chose their preferred option for each task	The TBI group showed more temporal discounting than controls, leading to more impulsiveness.	Wood & McHug, 2013
Participants	TBIs	Iowa Gambling Task was used. Probability-Associated Gambling Task was used.	In both tasks, the patients with TBIs selected more disadvantageously than the controls. TBI patients' performance on the tasks correlates with executive function.	Bonatti et al., 2008
19 Adolescents	TBI that required overnight hospitalization	Participants inflated balloons that might pop at any time, but the bigger the balloon, the more points earned.	Both groups performed similarly on the task.	Chiu et al., 2012
71 Children (ages 7-15)	TBIs	There was a novel computerized Decision-Making Task.	There were major differences between the control group and TBI group on this task.	Sood et al., 2024

For testing decision making after TBI, another popular method is the Iowa Gambling Task (IGT). To provide evidence that this is an ideal way to test TBIs, a quantitative review was done by Moore et al. Their study showed that the IGT is sensitive to TBIs, specifically the decision-making impairment following TBIs. (Moore et al., 2025). Using the IGT, the evidence from one of the earliest studies showed a relationship between TBIs and poorer performance on the decision-making task (Hanten et al., 2006). The conclusion that TBIs affect decision making was further reinforced by a subsequent, more modern study done by Sood et al. In their study, children with TBIs performed very differently from the control group with detectable impairment in decision-making, working memory, functional outcomes, and behavior (Sood et al., 2024).

TBIs can also affect moral reasoning in decision making, which can only be studied in human subjects (Beauchamp et al., 2019). In these studies, adolescents with TBIs showed lower levels of moral reasoning maturity, which affects decision making in their everyday lives (Beauchamp et al., 2019). These studies display how TBIs affect decision making both in terms of riskier decisions and reduced ability to incorporate moral frameworks.

Since it is clear that TBIs affect decision making in both humans and rats, there have been more focused studies on how particular TBIs affect specific types of decision making, such as risky decision making in humans. One study tested risky decision making after cerebral lesions following closed TBIs, which are TBIs in which there was no visible trauma on examination or imaging. Using the IGT, the participants with these TBIs still had poorer performance and chose more cards from the disadvantageous decks than the control groups (Cotrena et al., 2014), revealing that TBI patients with even minor frontal lesions make riskier decisions.

The IGT was also used to examine the effect of TBI on decision making in multiple studies looking at the duration of the effect of TBIs. Patients recovered from TBIs also displayed different decision-making behavior and a decline in executive function compared to those without TBIs. The TBI patients were found to be more inclined towards riskier selections as they were unable to effectively use negative feedback and avoid risks in a timely manner (Wang et al., 2024). Similar to the previous study, a study using both the Iowa Gambling Task and the Probability-Associated Gambling Task, the patients with TBIs selected more disadvantageous options than the controls. TBI patients' reduction in performance on these tasks, even when they should have recovered, highlights their long-term issues with executive function (Bonatti et al., 2008).

To provide further evidence that TBIs impact decision making, another method called the Cambridge Gambling Task was used to test whether patients who suffer from TBIs had impaired decision-making abilities. In this alternative task, patients with TBIs had an impaired range on gambling tasks and were more impulsive (Newcombe et al., 2011).

Another study used the Gambling Task to examine whether the severity of the TBI correlates with the level of impairment in decision making. As in previous studies, Levine et al found that patients with TBIs scored lower on the Gambling Task than the controls. However, there was no noticeable difference in patients with more severe TBIs on the Gambling Task, though there was a larger impairment on the Gambling Task in patients with increasing frontal

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lobe TBIs (Levine et al., 2005). A separate group ran a similar study where they used the Bangor Gambling Task on thirty TBI survivors. The performance was measured by the number of "no gamble" decisions minus the number of "gamble" decisions, similar to how the IGT measures risk. This study found that the survivors of TBI did, in fact, make more gamble, or riskier, decisions than the controls, corroborating the findings from prior studies (Adlam et al., 2017).

To further support the theory that TBI patients make riskier decisions due to impaired executive processing, the effect of TBIs on temporal discounting was studied. Temporal discounting refers to the tendency for individuals to prefer smaller, sooner rewards over larger, later rewards (Crean et al., 2000). The choice of the delayed reward can show self-control, while the smaller reward can show poor judgment as a result of impulsivity (Ainslie, 2001). While both groups discounted and chose the sooner, smaller reward more often, depending on the period of delay time, the temporal discounting rate for those with TBIs was much higher (Wood & McHugh, 2013). Patients with TBIs choose the smaller, sooner reward more often, displaying increased impulsivity, making TBI patients choose the riskier decision.

In contrast to the previous results, Chiu ran a study that compared adolescent participants with and without TBIs using the Balloon Risk Analog Task. In this task, participants are presented with a virtual balloon and can inflate it by pressing a button, earning points with each pump. However, there's a risk of the balloon popping, which would cause them to lose any points earned on that balloon. The task measures how participants balance the potential for reward (inflating the balloon to earn points) with the risk of loss (the balloon popping). Both groups performed similarly on the task, which goes against other results, which may be a reflection of the developmental stage of the participants (Chiu et al., 2012).

5. Treatment

The research surrounding treatment for patients after suffering frontal lobe TBIs is limited, with very few studies about the treatment. This highlights the lack of research surrounding this topic and the need for more research to develop comprehensive treatment plans. However, the few studies available suggest that it is possible to treat TBIs, though current strategies have limited efficacy.

After TBIs, many people suffer from brain impairments. Brain impairments can affect daily life (Barman et al., 2016) heavily through many factors, including physical, emotional, and cognitive functioning (Andelic et al., 2009). Cognitive deficits include but are not limited to impaired memory, poor judgment, communication disorder, and poor executive function as exhibited in the studies described in the previous section (Arciniegas et al., 2002).

As described above, one of the main things that TBIs affect is executive function from frontal lobe TBIs. In daily life, executive function manifests as the ability to engage in purposeful, independent, self-serving behavior (Lezak, 2004). For many people with frontal lobe TBIs or brain impairments in general, this ability is impaired, leading to patients making poor decisions about their relationships, finances, and interpersonal interactions. One method that has proven effective in helping to combat these impairments is directed cognitive rehabilitation.

Cognitive rehabilitation, when used effectively, can enhance the recovery process and minimize functional disability. Cognitive rehabilitation patients work with a variety of medical personnel, such as neuropsychologists, clinical psychologists, occupational therapists, speech pathologists, nurses, and rehabilitation physicians (Nowell et al., 2020). Before starting the cognitive rehabilitation process, it is necessary to perform a cognitive assessment to evaluate the various executive functions (Barman et al., 2016). The assessment measures the specific impairments in a person's executive functions, which dictates how to proceed with the treatment process. After the assessment, day-to-day cognitive rehabilitation mostly includes cognitive retraining, functional compensation, and goal-setting (Nowell et al., 2020). Many strategies are used when it comes to cognitive rehabilitation. For example, word lists, errorless learning, and mnemonic strategies are popular methods of cognitive rehabilitation to help retrain long-term memory (Tsaousides & Gordon, 2009). In more recent times, computerized cognitive rehabilitation has been introduced to patients, has become more popular due to the time-intensive nature of human cognitive rehabilitation (Kim et al., 2022). Surprisingly, it has proven to be more effective than conventional treatment within TBI patients (De Luca et al., 2014).

For other executive functioning rehabilitation, metacognitive strategies have proven to be more effective than conventional rehabilitation techniques when dealing with executive function impairments specifically (Goverover et al., 2007). Metacognitive strategies assist an individual's performance and reduce/prevent errors by structured and repetitive cueing or by encouraging repeated assessment and self-monitoring. Complex tasks are broken up into smaller step-by-step procedures (Kennedy et al., 2008). In addition to metacognitive training, problem-solving training (von Cramon et al., 1991), and goal management training (Levine et al., 2000) are effective in post-TBI recovery phases when it comes to executive function impairments.

In conjunction with these cognitive rehabilitation training strategies, pharmacology has also proven to be effective when working with executive function impairments. Bromocriptine and amantadine (Ozga et al., 2018), both dopaminergic agents, have been proven to help improve executive functions. Dopamine influences the reward system of the brain, and it is hypothesized that by increasing the sensitivity of the reward system, they can improve the ability to evaluate future rewards to assist with decision-making. Both of these drugs are used off-label for TBI and while there is more data for amantadine in improving consciousness, there is only limited evidence that these drugs significantly improve attention or executive function (Riker et al., 2021).

The consequences of TBIs are varied in severity and impairment. When using cognitive rehabilitation as a strategy for rehabilitation, it has been demonstrated that it is most effective in patients with mild to moderate TBIs (Silver et al., 2009). As a whole, though, cognitive rehabilitation has been shown to be more effective than other, more common strategies when dealing with TBIs (Cicerone et al., 2005). While metacognitive strategies, problem-solving training, and goal management training have also proven to be effective strategies, it can be difficult to provide cognitive rehabilitation to patients with executive function impairments, as patients have a lack of self-awareness (Nowell et al., 2020). To further improve cognitive rehabilitation, more studies are needed to develop standardized treatment protocols for individuals with TBIs and longer-term assessments (Barman et al., 2016). When looking forward, future research should be directed at improving cognitive rehabilitation paradigms with the goal of impacting the long-term perspective of patients following TBI (Sveen et al., 2022).

6. Discussion

Through these studies, it has been revealed that there is a clear correlation between TBIs, especially ones in the frontal lobe, and riskier decision making. From the limited studies on how frontal lobe TBIs can affect decision-making, results from these few studies provide evidence for a clear correlation between TBIs in the frontal lobe and the impairment of executive functions in non-human studies. Using the RGT, these studies tested risky decision making and found that decision making becomes riskier after a frontal lobe TBI has occurred. One issue with the data, however, is the RGT itself. Haar and colleagues found that behavioral training with the rats involving exposure to uncertainty before performing the RGT overshadowed probabilistic choice. Furthermore, they found that environmental cues can affect preference when making decisions in the RGT (Vonder Haar et al., 2020). Similar to rodent data (Shaver et al., 2019), when looking specifically at how TBIs affect risky decision making in humans, Cotrena and Wang used the IGT and the results displayed how TBIs affect decision making, particularly in causing patients to become riskier even after recovery. Despite several groups providing opposing evidence about the impact of TBI on decision making in both rodents and humans, the majority of papers on risky decision making with TBIs support the notion that TBI affects risky decision making, as both rodent and human participants tend to become riskier and make suboptimal choices following TBI.

In studies with rodents and humans, the tasks performed are very similar. The IGT and the RGT, the two most frequently used tasks when testing risky decision making in humans and rodents, share many of the same qualities, such as having four options with different loss/reward rates and trying to achieve the highest score possible. After using both of these tasks, IGT and RGT, both yielded similar results in humans and rodents. After a TBI in the frontal lobe, both groups made riskier decisions. Cotrena used the IGT and saw that humans, after frontal lobe TBIs, made riskier decisions. Shaver found the same results when using the RGT with rodents, as after a frontal lobe TBI, the rodents made riskier decisions as well. Not only did rodents and humans both become riskier, but the rate of discounting that risk became higher. Wood and McHugh found that humans after TBI displayed impulsivity and a preference for smaller, sooner rewards. In line with this evidence, Haar and Marten found that after TBIs, rodents discounted more often and preferred the sooner, smaller reward. In sum, when risky decision making after TBIs in the frontal lobe was tested in both rodents and humans, similar results were produced, as rodents and humans both exhibit impaired decision making after TBIs, causing them to become more risky.

Looking to the future, more research is needed to identify which specific neural pathways in the frontal lobe are impacted by TBI that affect decision making. Identifying specific lesions may help improve treatments, both cognitive rehabilitation and pharmacologic, which currently only improve damage from mild TBIs and not severe ones. Given the large number of patients affected each year by TBIs, any improvement in treatment will impact the health of millions worldwide.

7. Limitations

While the author attempted to evaluate the available literature, the author acknowledges that the study may not be comprehensive. There were largely small studies in both rodents and humans, which limited the robustness of the data evaluated.

Second, decision-making is a complex process. The specific details of decision making remain elusive, and there are other factors that go into decision making that are not covered in this paper. For example, the prefrontal cortex and the limbic system are two key components in the decision making process. This manuscript addresses TBIs in the prefrontal cortex, but not ones that affect the limbic system. Another component in decision making processes that was not addressed was the impact of specific neurotransmitters whose levels are known to shape decision making at the molecular level. Without looking at all the components of decision making, it can be difficult to examine the full scope of the effect of TBIs on risky decision making.

Finally, while the main treatment strategies were discussed in this paper, evaluation of the full scope of the treatment strategies currently being tested was beyond the scope of this paper. Multiple psychiatric drugs and other devices are currently being explored and were not included as part of this study.

8. Conclusion

TBIs affect many people in this world every year, and there are severe consequences that are associated with mild to severe TBIs. One of the most common TBIs is in the frontal lobe, and it affects executive functions in the brain. An important executive function is the ability to make decisions. When someone sustains a TBI to the frontal lobe, it can cause decision-making abilities to become riskier and cause people to become more risk-prone. To address the issue of TBIs in the frontal lobe and risky decision making, treatment has largely been centered around cognitive rehabilitation. Cognitive rehabilitation is a strategy that tackles methods to deal with cognitive deficits, including decision making. Specifically for executive functioning disabilities, metacognitive strategies have proven to be the most effective rehabilitation techniques. In partnership with pharmacology, bromocriptine and amantadine have also been studied to further assist cognitive rehabilitation techniques.

Looking forward, cognitive rehabilitation would ideally be made more accessible to people all over the world. The frequency with which TBIs can affect an individual's executive functions is dangerous and may be underappreciated. With widespread access to cognitive rehabilitation, these strategies can not only improve decision-making abilities but also improve the ability of TBI survivors to function more effectively in their daily lives.

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