Clinical Implications of Brain Implants on Post-Traumatic Stress Disorder Patients

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Introduction to Eaton Collection of Science Fiction Literature

The Eaton Collection of Science Fiction and Fantasy utilizes many aspects of cognitive neuroscience and psychology to incorporate real science into science fiction. The short story *We Can Remember It For You Wholesale* by Philip K. Dick incorporates neuroscience into the story when the main character, Douglas Quail, visits REKAL, Incorporated to implant memories of a trip to Mars. However, the story later unfolds and the readers find out that Douglas Quail was a real Interplan agent who completed a mission on Mars (Dick). After his real trip to Mars, Quail realizes he has a telepathic-transmitter device wired in his brain which allows Interplan to know his thoughts and communicate with him at any given moment. This fictional story about Douglas Quail explores the plausibility of implanted memories and the limitations that coincide with it. In *Marcel Proust, Incorporated* by Scott Dalrymple a group of scientists called the Amygdala Group produces a drug called 'Proust' and its sole purpose is to enhance the amygdala into an aroused emotional state, allowing for increased memory retention. The amygdala is described as "A pair of almond-shaped neural clusters deep inside the brain—amygdala means almond in Greek—it governs both our emotions and our long-term memory." (Dalrymple, 2017) The science behind this is explained in the story; the amygdala releases dopamine, and in an emotionally aroused state, it releases more dopamine. In turn, higher levels of dopamine aid in memory (Dalrymple, 2017).

Amygdala

The amygdala controls the fear memory network in the brain and allows individuals to embed negative emotional memories through consolidation and reconsolidation (Glannon, 2017). During these negative events, our stress hormones rise and this indirectly aids the process of protein synthesis, which is necessary for consolidation (Pitman, 2015). The process of reconsolidation in the amygdala has shown to assist in Pavlovian extinction training (Pitman, 2015). During extinction training, there is a depotentiation of the conditioned stimulus inputs in the amygdala which leads to reversal of the conditioning-induced effect. (Pitman, 2015)

Fear memories become embedded in the brain through consolidation; a process that is aided by the release of noradrenaline during stressful or negative events (Glannon, 2017). The process of reconsolidation allows us to strengthen the synaptic connections of fear memories in the amygdala (Pitman, 2015; Glannon, 2017). Past research has shown the possibility of infusing a protein synthesis inhibitor into the amygdala may disrupt the process of reconsolidation and allow for the erasure of the fear memory; however, the use of drugs may impair other parts of the brain (Glannon, 2017). To avoid the usage of drugs and comply with ethical implications, research has shown that the use of electrical stimulation through a brain implant may be plausible by the inactivation of select neurons to disrupt reconsolidation and weaken the synaptic connections of fear memories (Glannon, 2017).

Amygdala's Role in Post-Traumatic Stress Disorder

The amygdala plays a role in assessing threatening or fearful stimuli and is essential in fear conditioning (Shin, 2006). In turn, the amygdala has shown to be hyperresponsive and over-activated in post-traumatic stress disorder (PTSD) patients (Shin, 2006). Past literature has shown that erasing fear memories that caused or are related to the traumatic event can aid in PTSD patients when other treatments have been deemed ineffective (Glannon, 2017). Deep brain stimulation could allow for inactivation of select neurons in the fear memory network by blocking protein synthesis, a process needed for reconsolidation; moreover, DBS can avoid impairing other parts of the brain (Glannon, 2017). Deep brain stimulation is facilitated by neuro-surgically implanting electrodes to patients' brains under anesthesia, while they are fully awake, in order to stimulate the correct areas without damaging others (Lozano & Lipsman, 2013). The DBS probe has dual uses as a probe and modulator; meaning it allows surgeons to target a part of the brain and record activity from specific neurons in response to specific stimuli or tasks (Lozano & Lipsman, 2013).

The aim of this research proposal is to identify the role the amygdala plays in clinical disorders, such as post-traumatic stress disorder. Past research utilizing neuroimaging has shown that the amygdala is hyperresponsive in post-traumatic stress disorder patients (Shin, 2006). In order to connect science to science fiction literature, we aim to analyze the plausibility of a brain implant to aid in fear memory erasure for clinical populations. The brain implant would be inserted into the amygdala of the brain and utilize deep brain stimulation (DBS) to track the activity of the fear memories, block the process of reconsolidation, and erase the fear memories in patients diagnosed with post-traumatic stress disorder.

Plausibility of Memory Erasure

The plausibility of a brain implant to be inserted into the amygdala may sound like a work of science fiction. Over the last three decades, imaging and neuroscience have led to new invasive practices to treat clinical populations (Lozano & Lipsman, 2013). The most commonly used implantable device is deep brain stimulation (DBS) that has the objective to replace or reestablish connectivity in neural circuits that are dysfunctional in the brain (Berger et al., 2011). DBS is used in treatment of numerous different neurological and psychiatric disorders such as Parkinson’s disease, depression, obsessive-compulsive disorder, and many other clinical applications (Montgomery & Gale, 2008). DBS could help patients when their tremors are not treated through medications alone. For that reason, it is plausible that interventional DBS has the potential to treat individuals suffering with PTSD due to its capability to target dysfunctional circuits.

PTSD involves substantial trauma that is not limited to suffering but also impairments in social and occupational functioning. In the short story by Dick, the main character suffers a traumatic past of being a secret agent on Mars that left his future survival undetermined. The act of a brain implant to alter or erase a residual memory in prospects of reconstructing the traumatic emotional tie into a more positive one will be beneficial for the PTSD clinical populations. To make this science fiction into a plausible procedure, the area of the brain that is a target to track the activity of fear memories and be suitable for high-frequency DBS in PTSD is the basolateral nucleus (BLn). The BLn works within the amygdala as a relay nucleus that forms a looping network to receive connections from the lateral nucleus and then sending it outwards to the central nucleus (Koek et al., 2014). Since there is an association of amygdala hyperactivity from recurrent reminders of traumatic events, the BLn may modulate sensory inputs by either enhancing or suppressing emotional responses (Koek et al., 2014).

Hyperactivity in the basolateral amygdala is where the negative emotional memory of the past traumatic event or series of traumatic experiences form and solidify in the brain. The BLn mediates cognitive control of emotional responses, however, they do not erase them. Dick's short story exemplifies how powerful fear memories can take a toll on a person. Although REKAL Incorporated implanted false memories for the general population, the main character, Douglas Quail would have benefitted more if the fear memories from his trauma were completely erased. A plausible approach to help clinical populations, especially PTSD patients, would be to interfere with the process of reconsolidation so that fear memories may be prevented or altered (Glannon, 2017).

During reconsolidation in the brain, memories are the most flexible to alteration (Pitman, 2011). Emotionally arousing memories, such as fearful ones, will reside in the brain synapses. In order to interfere with the window of reconsolidation for memory erasure of clinical patients, it is vital to stabilize and destabilize the fear memories. Only then will it open the potential of extinction to erase the fear memories (Quirk, et al., 2010). Extinction may update prior learning if it occurs during the time window of retrieval where the fear memories are most flexible and can be disrupted. In other words, the extinguished fear can be renewed or modified with a change of context, therefore reconstructing an event similar to the original (Monfils, Cowansage, Lann, & LeDoux, 2009).

A study conducted on rats of intervening learned fear at different stages of development demonstrated that with appropriate extinction, they will react to the tone condition stimulus (CS) as if they never occurred (Quirk et al., 2010). However, new research found that the extinguished response of the learned fear returned after a period of time in the amygdala. For that reason, to prevent the return of fear, the extinction training needs to be mediated during the reconsolidation phase, specifically in the time when fear memory is destabilized. Thus, effectively altering and updating the fear association as safe (Quirk et al., 2010).

Although there is previous evidence to suggest that fear memory reconsolidation can be blocked in various animal studies, it may be difficult to test them on humans without the necessary modifications. Development in research would need to improve on the effectiveness of extinction-based therapies to make it more applicable to humans, as well as for the clinical populations. One major huddle that arises in reconsolidation for humans is due to compounds, such as anisomycin, necessary for block reconsolidation are toxic in humans. Disrupting reconsolidation by nonandrogenic blockade could have the potential to produce amnesia for the original fear response in humans (Soeter & Kindt, 2010). For that reason, the benefit of the brain implant could be a more effective way of blocking reconsolidation to eliminate the emotional representation of the memory. For example, in Dalrymple's short story, the Amygdala Group produces a drug that essentially enhances the amygdala to arouse emotional states to help increase memory retention. For the brain implant to successfully block reconsolidation of the fear memory, it would need to locate the memory trace. During the process of retrieval, this is where potentially new information can be incorporated into the retrieved memory encountering reconsolidation (Quirk et al., 2010). Therefore, this process is beneficial in the prevention of amplified emotional reaction to stimuli associated with the fear memory trace.

The amygdala in humans also mediates the acquisition, consolidation, and extinction of fear responses (Koek et al., 2014). This provides the plausibility for brain implants to aid in memory erasure as DBS will help in monitoring its effects on the critical neurons and synapses. The utilization of DBS reduces the activity in the neurons, such as in the BLn, which then disrupts the memory regulation of the fear that turns in a compulsive belief or behavior. In addition, DBS could also help problems with localization to ensure that the maladaptive fear memory is erased, but the adaptive fear memories are still present (Glannon, 2017). With the use of the brain implant and utilization of DBS, this will help target the specific nuclei for inactivation and memory erasure (Pitman, 2015). In the future of brain implants and invasive neural devices, brain implants could impede reconsolidation to completely weaken or erase the individual's traumatic memory.

Moral and Ethical Implications

The Eaton Collection of Science Fiction and Fantasy encompasses many facets of science. However, it does not abide by the moral and ethical implications considered in authentic scientific research. In actual scientific studies, researchers must follow a distinct set of standards reviewed and approved by the Institutional Review Board. These standards help guide researchers as to what actions they should or should not take when experimenting. Researchers risk harming humans, animals, and the general population if they do not meet ethical standards. Ignoring ethical standards can be especially harmful in experiments with clinical trials, such as the proposal of creating brain implantations for memory erasure. With brain implants, there is the risk of affecting someone's personality, losing their self-rule, and so much more (Gilbert, 2015). Although the human brain is a powerful organ, it is also a delicate one. Following ethical standards minimizes error, holds researchers accountable for their work, and forms a trusted baseline.

If researchers follow these guidelines' protocol, they may be more likely to establish the public's trust in the discipline. With public support and establishing integrity, researchers are more likely to receive funding for their research projects (Delistary, 2014). Funding allows researchers to conduct more scientific experiments, which allows for the opportunity to create more scientific advancements. Scientific advancements such as brain implantation to erase traumatic memories of PTSD patients can ease their past and potentially improve their quality of life. Researchers first need to prioritize the ethical and moral implications to make brain implants applicable to clinical populations.

The first ethical concern is that our sense of self is made-up of our autobiographical memories, and erasing them may affect our personality. Our autobiographical memories hold the long-term memories that make up the history of who we are. This type of memory allows individuals to remember stages of their life. Such as their childhood, events such as the first time they learned how to ride a bike, and even more specific events such as when they realized they are in love with their significant other (Gregory, 2011). Erasing these memories may affect our personality because our experiences make up who we are.

Another aspect to consider when erasing memories is that if individuals wish to erase a memory, it may do more harm than good. Erasing memories can potentially make one a happier person or a sadder person. The outcome depends on whether they wish to erase a happy memory or a sad memory. Many individuals in the world carry memories of tragic events that occurred in their past, and these tragic memories can potentially make those individuals prisoners in their minds (Delistraty, 2014). Therefore, memory erasure may be beneficial for some, such as individuals with PTSD. However, as previously mentioned, memories make up a great deal of who we are, so in this instance, it is essential to think about both the negative and positive effects of erasing tragic memories. A positive effect of memory erasure would be that the individual will feel liberated from that event. However, one should consider that the individual may subconsciously retain the emotions behind those memories, just as Douglas Quail felt the urge to go to Mars in Dick's science fiction story. If the emotions behind those memories do linger, then the individual may experience some distress and confusion.

It also needs to be considered that dependency on invasive brain implants may entail the risk factor of false security, which is a threat to autonomy. Autonomy is the ability to make informed and uncoerced decisions (Gilbert, 2015). With false security, one may believe they have complete control over their thoughts, actions, and memories. However, a question to consider is, will the individual still pertain to complete control of their mind after the implantation? In the case of implanting a brain implant to erase memories, its purpose is to essentially take away one or more of one's past experiences (Gilbert, 2015). Past experiences shape who later becomes and often influence the types of decisions they make, and certain decisions take them on specific paths. After taking away parts of one's past, a threat towards autonomy could exist because one may no longer have a say in making uncoerced decisions.

A patient may also become reliant on brain implantation technology and lose their sense of self-rule (Gilbert, 2015). Memory erasure may be wanted for several reasons, such as forgetting an embarrassing event, a regrettable relationship, or a past trauma memory that has affected their well-being. These events may be so detrimental to one's well-being that it impedes the ability to succeed and endure challenges one faces in life. Therefore, it becomes a reasonable thought when individuals may want to abandon an experience. However, where is the line drawn between which memories are lost and which are not? Also, who is the one that draws that line?

For instance, will a PTSD patient be able to decide on a brain implant on their own, or will they need someone, such as a family member, to decide for them? Sense of self-rule becomes a risk if one becomes reliant on brain implantation technology because they may no longer have complete control over their memories. All evaluated evidence would indicate ethical and moral implications as crucial components to scientific research advancements. If researchers wish to create technology that will help those in need, they must consider any consequence.

Further Directions

While exploring the Eaton Collection of Science Fiction and Fantasy, we analyzed the plausibility of brain implants to aid in memory erasure. We found that past research has identified the areas of the brain, such as the amygdala and basolateral nucleus, that are responsible for consolidating our fear memories. Empirical evidence suggests that the amygdala is hyperresponsive in post-traumatic stress disorder patients; moreover, we studied how deep brain stimulation can aid in blocking the reconsolidation process of those fearful memories, and ultimately erasing them. This type of treatment would only be used in extreme measures, when all other treatment options have failed to be effective. It would be unethical to allow this type of memory erasure to the general population because the effects may be irreversible and cause detrimental effects to neuro-typical individuals. This type of issue was presented in Marcel Proust, Incorporated when the drug, Proust, was discontinued and taken from the general population. The story unveils that after the drug was vanished, the general population lost their jobs, college degrees, and sense of self because they could no longer recall the information they learned while under the influence of Proust.

The brain implant we have studied would only be used on high-risk patients that are failing to respond to other treatments. Offering this type of treatment to neuro-typical individuals may cause a detrimental effect on society and people may start to become heavily reliant on it. Therefore, this treatment should only be administered to a clinical population in a controlled environment. After exploring the plausibility of brain implants on memory erasure we have found that this type of implant would not be ethical to use in neuro-typical individuals; rather, it could possibly be effective to aid those suffering from clinical disorders. Although the concept of memory erasure would be an enjoyable part in a science fiction novel, it would be morally unacceptable to erase the memories that are essential to our autobiographical self. However, offering this implant to post-traumatic stress disorder patients may help them live the life they wish for, and make it a reality, not fiction.

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