Fear on Repeat: Examining the Impact of PTSD on the Amygdala

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What is PTSD?

Post-traumatic stress disorder (PTSD) is a psychiatric disorder inflicted by experiencing or witnessing a traumatic event, triggering a variety of symptoms. Individuals with PTSD can experience symptoms such as nightmares, flashbacks, and detached behavior, leading to the inability to function normally, particularly in social or family life (Iribarren et al., 2005). These symptoms can affect a person for a lifetime, emphasizing the importance of this disorder.

What is the amygdala?

The amygdala is one of the main brain regions that is affected by PTSD. The amygdala is a cluster of nuclei that lies in front of the hippocampus and near the temporal lobe (Johns, 2016). The amygdala is divided into many different sections of nuclei, but the three main groups are the basolateral, corticomedial, and the central nucleus (Johns, 2016). The basolateral group receives visual and auditory projections from the temporal lobe, and the corticomedial group receives input from the olfactory bulb, which processes smell information. Therefore, the corticomedial group is more important in animals with a keen sense of smell. The central nucleus elicits emotional responses and projects them to the hypothalamus and autonomic region of the brain stem (Johns, 2016). In a study where lesions of the central nucleus were found, fear conditioned responses were eliminated, which suggests its involvement in experiencing fear (Ressler, 2010).

The amygdala processes external stimuli as well as regulatory stimuli that come from connections with areas of the brain that modulate the amygdala (Ressler, 2010). Areas such as the prefrontal cortex and the sensory cortical and thalamic areas mediate subregions in the amygdala and are involved in inhibiting its ability to elicit fear responses (Ressler, 2010).

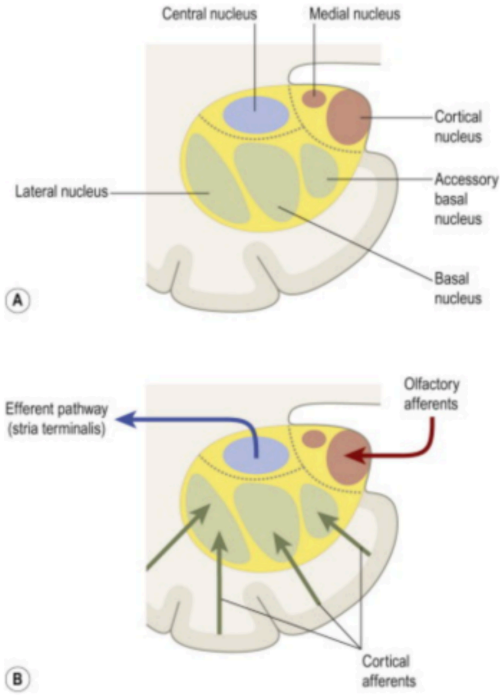

Figure 1. A) Diagram of the amygdala and its subregions. **B)** Central nucleus is involved in sending response output via the stria terminalis, which is a major output pathway for the amygdala. The cortical nucleus receives olfactory stimuli while the basal nucleus receives non-olfactory stimuli.

How does PTSD affect the amygdala?

The amygdala is one of the most strongly involved brain structures in the pathophysiology of PTSD (Morey et al., 2012). However, studies that have shown differences in amygdala volume in those with PTSD fail to draw a conclusive correlation between amygdala volume and the onset of PTSD (Pieper et al., 2020; Ousdal et al., 2020). Inconsistent results of these studies could come from varying demographics in the studies (sex, race, type of trauma) and measuring the amygdala as a homogeneous rather than heterogeneous structure (Haris et al., 2023). The amygdala can be seen as both one whole nucleus as well as a structure consisting of multiple subnuclei, thus making it hard to determine whether it should be measured as one whole or multiple subparts. However, the many symptoms of PTSD corresponding with fear suggest it is critically involved in PTSD (Morey et al., 2012).

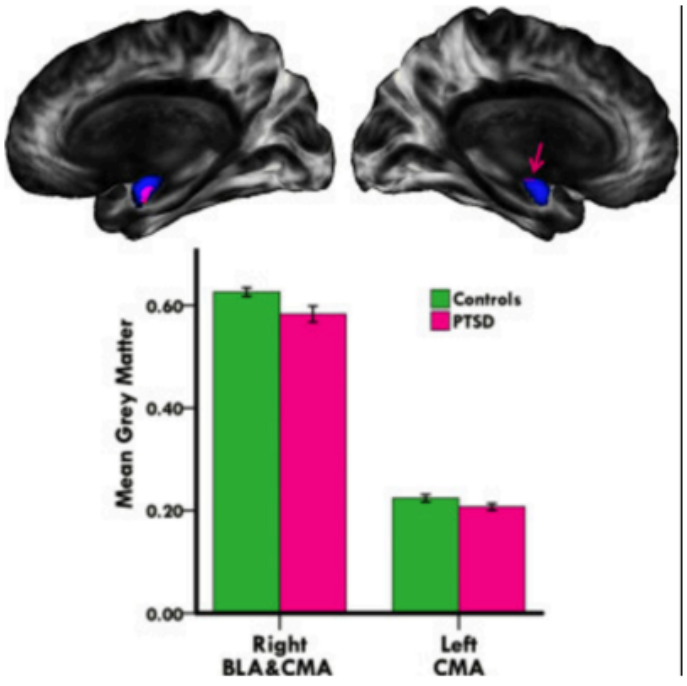

Figure 2. Abnormal amygdala volumes in adolescent PTSD patients. Bar graphs display smaller mean gray matter in both the basolateral amygdala and corticomedial amygdala for the right hemisphere in the PTSD patients. Left hemisphere displayed a smaller mean gray matter of the corticomedial amygdala in the PTSD patients.

Treatments for PTSD

Psychotherapy and pharmacology are both effective treatments for depressive disorders (Kamenov et al., 2017). There are also numerous studies done that have proven that healthy habits and practices such as exercise and diet greatly contribute to reducing PTSD symptoms as well (Schry et al., 2015; van den Berk-Clark et al., 2018; Correll et al., 2023). For example, Van der Kolk et al. published findings that yoga can greatly reduce PTSD symptomology and can help patients with PTSD control negative physical sensory experiences and overall functioning (2013). Treatments directly affecting the amygdala are limited, but one modern neurological technique called laser interstitial thermal therapy (LITT) or laser ablation has been shown to be effective (Patel & Kim, 2020). The surgical process of laser interstitial thermal therapy is outlined by Patel & Kim. The surgical procedure begins with an MRI or CT scan prior to surgery. Then, the optimal trajectory for the laser is planned using a computer-based navigation system. Once the patient is in the operating room, they are positioned properly to align with the laser probe, and a small stab incision is made at the planned entry site, followed by drilling a burr hole in the skull at the incision site. The laser probe is then inserted through the burr hole based on the pre-planned trajectory, and the patient is placed in an MRI scanner to verify probe position. When the probe is in position and secured, ablation can initiate, and periodic MRI images are taken. During the ablation, the laser emits photons, which are then absorbed by tumor chromophores (molecules in tumor cells that absorb light at specific wavelengths), releasing thermal energy. Once an ideal, elevated temperature is reached, proteins denature, cellular necrosis occurs, and tissue coagulates. After the ablation is completed and no other trajectories are planned, the patient is removed from the MRI scanner, the probe is removed, and the incision site is irrigated and closed. In a case study done in 2020 by Jon Willie et al., two patients with chronic PTSD underwent an amygdalohippocampectomy, a technique in which a neurosurgeon surgically removes the amygdala and/or hippocampus. The procedure targeted the amygdala in the right hemisphere and resulted in a reduced amount of seizures and a significant decrease in PTSD symptoms (Willie, 2020). The overall conclusion of this case series was that amygdalohippocampectomy can provide therapeutic healing for patients with PTSD, although it is a risky procedure.

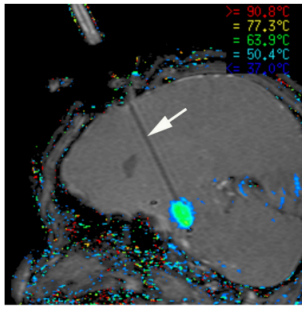

Figure 3. Laser interstitial thermal therapy uses a laser, shown by the white arrow, to ablate destructive or harmful regions of the brain such as tumors.

This method is still being developed and enhanced, such as innovations in laser probe design, probe cooling, and tissue temperature measuring technology (Patel & Kim, 2020). These developments continually make this procedure a more practical surgical technique and show promising indications to grow in the surgical field.

Conclusion

PTSD is a mental disorder that affects the amygdala, a fear-processing center and regulator for emotional responses. There are implications suggesting that PTSD affects amygdala physiology and volume, as it is often hyperactive in PTSD subjects. LITT is a promising treatment to treat patients with PTSD, and has potential to be more widely used as more research on its development continues.

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About the Author

Micah is a freshman at UIUC majoring in neuroscience. He became involved in Brain Matters to gain experience writing research articles. Outside of academics, you can find him staying active in the ARC by working out or playing volleyball. In the future, Micah hopes to make it to medical school one day.