Cornell Research Program on
Self-Injury and Recovery

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Understanding the neurobiology of non-suicidal self-injury

Who is this for?

Individuals looking to learn more about the brain functions involved in non-suicidal self-injury

What is included?

An overview of brain structures

A summary of current neurological research

The neurological differences that are the bases of psychological differences for those who self-injure

Introduction

Although there is no doubt that our understanding of mental illness has come a long way, it is important to understand that stigma remains. **Mental health issues, like chronic physical diseases, can be due to a combination of environmental and biological factors.** The major difference between mental and physical illness lies in the complexity and fragility of the brain. Not only do we lack understanding of how social and psychological factors interact with biochemical mechanisms to make a person who they are, but we have made little headway in defining a baseline "normal" vs. "abnormal" function. The good news is that as medical technology continues to increase in precision and capability, so too will our ability to study the brain and understand the pathology of mental illness.

Non-Suicidal Self Injury, or NSSI, is often classified as a symptom of other common mental illnesses such as Depression, Anxiety, and Borderline Personality Disorder. However, some patients with NSSI don't meet the criteria for any mental illness. This might mean that something in the brain is happening to cause the self-injurious behavior, independent from global changes associated with other mental illnesses. For this reason, emerging research has focused on studying NSSI in terms of neurological functioning.

It is very important to keep in mind that even if there are underlying neurological or other physiological causes of mental illness, there are multiple ways to healthfully address this. One of the major properties of the brain is plasticity, or its ability to change. When someone is learning to play piano, for instance, they get better with practice because the neurological connection between the auditory processing of the notes and the movement of the fingers becomes stronger. **Emotional and cognitive connections can also be strengthened through practice**

Overview of different brain structures

The human brain is an extremely complex organ and scientists are still not sure exactly how everything works together to make a person who they are. The most recognizable part of the brain, which looks like a maze of crevices, is called the cerebral cortex. This part of the brain is responsible for most of the higher level thinking that humans do and is composed of two connected hemispheres: right and left. The cortex is also subdivided into four major lobes: frontal, parietal, temporal, and occipital.

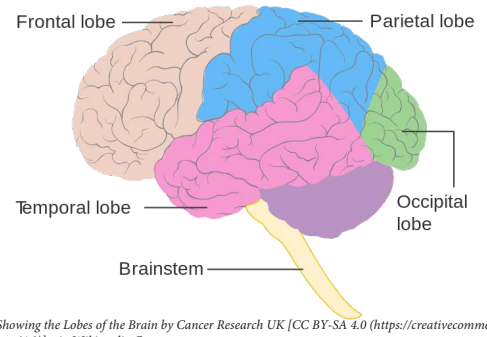

Diagram Showing the Lobes of the Brain by Cancer Research UK [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)], via Wikimedia Commons

A key part of the brain, hidden under the cortex, is the ***limbic system*****.** This part of the brain includes: the hippocampus, parahippocampus, and the amygdala. The hippocampus and parahippocampus play a major role in memory storage and the amygdala is an important emotional center of the brain. The limbic system is thought to be the more primitive region of the brain, while the cortex is associated with high level thinking such as evaluation, planning, and organization. Simply put, we can envision the limbic system reacting to incoming information by drawing on memory and/or producing emotion. The cortex is in charge of evaluating the information and the emotional experience. Because of their link to both memory and emotion, these areas are strongly implicated in non-suicidal self-injury behavior.

Key psychological differences and their neurological basis:

Emotional Dysregulation

When the human brain perceives stressful stimuli, it responds by activating parts of the brain that signal physiological stress responses (e.g. altered heart rate, adrenaline surges etc.). If the stressful stimulus is fleeting or can otherwise be mitigated, cognitive coping mechanisms assist in downregulating, or diminishing the heightened state of emotion, and the person feels better.

But what happens if the biological pathways and coping mechanisms aren't working properly and the mind stays stuck in a painful, high-stress state? Psychological theory and neurological research suggests that NSSI is an attempt to escape from that prolonged, highly emotional state in people with deficits in emotional regulation. The link between self-injury and emotions has been well-researched.

To empirically test the link between brain-based emotion regulation signals and self-injury, researchers compared brain activity in response to emotional stimuli of individuals with and without self-injury experience (Plener et al., 2012). They found that individuals with self-injury experience had higher activity in the amygdala in response to emotional images. We can imagine the amygdala as a sort of "relevance detector" of information, and the more reactive it is, the more information it can attach an emotional response to. For this reason, hyper-reactivity of the amygdala has been associated with increased feelings of distress—a trait also associated with people who self-injure.

These imaging studies have also shown increased activity in the hippocampus, anterior cingulate cortex (ACC), and the middle and inferior orbital frontal cortex (OFC) (Plener et al., 2012). Increased activity in the ACC and OFC has been associated with difficulties in processing emotions. Since the hippocampus plays a role in memory retrieval, it is possible that its over-activation signifies an automatic retrieval of emotional memory in response to perceiving emotional images, a process that would also heighten feelings of distress and resultant self-injury.

Please visit these web pages for additional information on the role of emotional regulation in Non-Suicidal Self-Injury:

http://www.selfinjury.bctr.cornell.edu/perch/resources/what-role-do-emotions-play-in-nssi-.pdf
http://www.selfinjury.bctr.cornell.edu/perch/resources/what-is-emotion-regulationsinfo-brief.pdf
http://www.selfinjury.bctr.cornell.edu/perch/resources/how-does-self-injury-change-feelings.pdf

For a more in depth and interactive diagram of the brain, visit:
https://www.brainfacts.org/3d-brain

Reward and Consequence Processing

Another psychological aspect being researched in its association to NSSI is the reward processing system (Vega et al., 2017). The reward system of the brain is thought to be comprised of a frontal-striatal network between the limbic system, which produces a hedonic experience, and structures in the frontal cortex that are responsible for evaluating that experience. When a stimulus is pleasurable, it produces a hedonic experience in the limbic system (emotional network) and the evaluative frontal cortex forms a judgment about the experience (e.g. keep doing it feels good or stop because it doesn't feel good or has other adverse consequences).

Individuals with self-injury experience show an overactivation of the OFC in addition to decreased connectivity between the OFC and the parahippocampus compared to healthy controls. This lack of connectivity suggests that the brain is unable to properly make an association between the hedonic experience of NSSI behaviors and possible long-term consequences of these behaviors (the evaluation). (Vega et al., 2017). In fact, diminished connectivity between the limbic system, namely the amygdala, and regions implicated in interoceptive awareness, decision making, and reward processing was found to be associated with a higher frequency of self-injurious episodes (Schreiner et al., 2018).

Atypical Processing of the Self

Self-injury behavior has also been linked to atypical processing of information regarding the self. As reviewed earlier, activity in the cortical midline structures (CMS) was increased during emotionally distressing tasks in individuals with self-injury history (Plener et al., 2012). Since structures of the CMS are known to engage in processing information about the self, this finding suggests that hyperactivation of these regions in individuals who self-injure may be related to altered patterns of self-processing. These may include negatively biased self-knowledge and unresolved identity formation, which have been shown to characterize individuals who self-injure (Quevedo et al., 2016) . Indeed, data from imaging studies exploring these neural systems has suggested that atypical functioning of brain structures related to self-processing may play a larger role in self-injury than in comorbid mental illnesses such as depression (Quevedo et al., 2016).

An additional goal of the same study was to investigate how the brain activity corresponding to interpersonal processing of self-injurers differed from controls. Researchers asked participants to think about themselves from an indirect perspective (from their classmates' or mother's perspective) during an emotionally distressing task or event. Individuals with self-injury history showed greater limbic activation than the depressed but non self-injuring group and the healthy controls, specifically during self processing from the mother's perspective. This heightened limbic response was also correlated with the parent's reported lack of support regarding their child's negative emotions (Quevedo et al., 2016). This suggests that perceived invalidation from the parent may contribute to higher limbic reactivity, and poor self regard

Social Processing and Sensitivity to Exclusion

Another important difference in the neurological functioning of people with NSSI is the relationship to and perceptions of social situations. A 2017 study (Brown et al., 2017) investigated the role of trait sensitivity to social exclusion in patients with Borderline Personality Disorder (BPD), patients with NSSI, and healthy controls. Patients with BPD reported *feeling* more sensitive to social exclusion than patients with NSSI or healthy controls. However, NSSI patients showed increased *neural reactivity* in response to social exclusion compared with social inclusion, relative to the control subjects and BPD patients. These findings also support the idea that, although self-injury and borderline personality disorder do often overlap, there are important differences in neural basis.

Summary

It is evident from emerging research on the neurobiology of non-suicidal self-injury that several systems in the brain may function differently between an individual with self-injury behaviors and those without self-injury behaviors. Due to the complexity of these systems, it is difficult to pinpoint a single cause or pathway to the behavior. Rather, there seems to be an interplay of genetic predisposition and environmental factors such as relationship quality with parents that influence brain pathways. A major structure thought to undergo functional changes in response to childhood experiences is the amygdala, which can become hyper-reactive due to prolonged stress in childhood. This hyper activation is associated with feelings of distress and an inability to regulate or "come down" from heightened emotion. It is posited that individuals with emotional dysregulation who are also predisposed to self-injurious behavior may utilize self-injury as an attempt to cope with or down regulate a painful emotional response. Self-injury has been shown to be associated with alterations in other psychological processes as well, including reward processing, atypical self-processing, and atypical social processing. It is important to note that the current research is limited in some studies that view non-suicidal self-injury as a symptom of a larger mental illness such as borderline personality disorder or depression. When studies do not account for the fact that self-injury occurs independent of mental illness, it is not completely clear whether findings result from self-injury or the comorbid mental illness. Fortunately, a number of studies have begun using self-injury only groups as well as self-injury with mental illness and healthy controls so there may be more clarity soon.

References:

Brown, R. C., Plener, P. L., Groen, G., Neff, D., Bonenberger, M., & Abler, B. (2017). Differential neural processing of social exclusion and inclusion in adolescents with non-suicidal self-injury and young adults with borderline personality disorder. *Frontiers in psychiatry, 8,* 267.

Plener, P. L., Bubalo, N., Fladung, A. K., Ludolph, A. G., & Lulé, D. (2012). Prone to excitement: Adolescent females with non-suicidal self-injury (NSSI) show altered cortical pattern to emotional and NSS-related material. Psychiatry Research: *Neuroimaging, 203*(2-3), 146-152.

Quevedo, K., Martin, J., Scott, H., Smyda, G., & Pfeifer, J. H. (2016). The neurobiology of self-knowledge in depressed and self-injurious youth. Psychiatry Research: *Neuroimaging, 254,* 145-155.

Schreiner, M. W., Klimes-Dougan, B., & Cullen, K. (2018). F74. Frequency of Nonsuicidal Self-Injury Associated With Amygdala Functional Connectivity. Biological *Psychiatry, 83*(9), S266

Vega, D., Ripollés, P., Soto, À., Torrubia, R., Ribas, J., Monreal, J. A., ... & Marco-Pallarés, J. (2018). Orbitofrontal overactivation in reward processing in borderline personality disorder: the role of non-suicidal self-injury. *Brain imaging and behavior, 12*(1), 217-228.

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