

The Effects of Emotion Regulation on Non-suicidal Self-injurious

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Abstract. Non-suicidal self-injurious behaviours affect people's physical and mental health and are known to show a high incidence globally. Based on emotion regulation theory and the emotion cascade model, this study focused on the effects of four different emotion regulation strategies, namely cognitive reappraisal, expressive suppression, impulsivity, and rumination, on non-suicidal self-injurious behavior. Combined with magnetic resonance imaging, event-related potentials, and electrophysiological techniques, functional abnormalities in brain regions such as the amygdala, prefrontal cortex, and cingulate cortex, abnormalities in electroencephalographic indexes, and functional abnormalities in the autonomic nervous system are potential mechanisms by which emotion regulation affects NSSI. Future research should use objective measures, incorporate longitudinal studies, expand the study to clinical samples, and conduct culturally diverse studies.

Keywords: Non-Suicidal Self-Injurious; Emotion Regulation; Emotion Regulation Strategies; Neural Mechanism.

1. Introduction

Non-suicidal self-injury (NSSI) refers to an individual who, without suicidal intention, directly and intentionally destroys his or her body tissue using sharp cuts, burns, and blows (Nock, 2009; Jiang et al., 2011). Globally, the incidence of NSSI is increasing (Thippaiah et al., 2020) with a terminal incidence of 22.2% (Xiao et al., 2022) and more than 60% of adolescents in clinical samples have a history of NSSI (Hawton et al., 2012); According to the epidemiological data of China, the incidence of NSSI among middle school students in the mainland reaches 27.4% (Han et al., 2017).

Although the NSSI itself is not suicidal, it is strongly associated with other psychological disorders such as depression, anxiety, and borderline personality disorder (Swannell et al., 2014). In addition, those who have already performed NSSI have a higher risk of suicide in the future (Owens et al., 2002.; Whitlock & Knox, 2007), and repeated NSSI has been identified as one of the causes of attempted suicide and an increased risk of suicide (Manca et al., 2014). Therefore, clarifying the pathogenesis of NSSI is of great significance in preventing and intervening in NSSI behaviors.

Emotion regulation is one of the important factors that influence the occurrence of NSSI (Andover & Morris, 2014). Numerous studies have consistently indicated that individuals with maladaptive emotional regulation strategies are more likely to develop NSSI behavior in both clinical and non-clinical populations, and this behavior is usually accompanied by changes in brain function and physiological mechanisms (Lang et al., 2024; Selby et al., 2013). Based on the emotion regulation theories and the theoretical framework of NSSI, the present study reviewed the influence of different emotion regulation strategies on NSSI and the potential neural and physiological mechanisms.

2. Theoretical Framework

Emotion regulation refers to the individual's ability to identify, understand, and control emotions through a variety of psychological processes, including the ability to manage their own implicit and explicit emotions (Gratz & Roemer, 2004; Gross, 2002).

2.1 Theories of emotion regulation

According to the Process Model of Affective Regulation proposed by Gross (1998a, 1998b), affective regulation includes five parts: situation selection, situation correction, attention allocation, cognitive change and response adjustment. Based on when emotion regulation occurs, emotion

regulation strategies can be divided into two categories (Gross & John, 2003), namely antecedent-focused emotion regulation and response-focused emotion regulation. In the regulation of antecedent concern emotion, individuals adopted strategies related to the first four links before the formation of emotions and corresponding reactions, aiming to prevent or reduce the occurrence of negative emotions, thus optimizing emotional experience. Reaction-focused emotion regulation refers to reaction regulation after the emotional response is generated. Such strategies emphasize the management of the performance and influence of emotions when they are activated. Among many affective regulation strategies, Gross(1998a, 1998b, 2002) believed that cognitive reappraisal and expressive suppression were the most commonly used and valuable strategies, and the effects on subsequent emotions would be changed according to the adopted strategies. Cognitive reappraisal is a proactive emotion regulation strategy, which refers to understanding emotional events in a more positive manner (e.g., by changing the personal significance of the emotional events, or the understanding and appreciation of the situation) to reduce emotional pain. Expressive suppression belongs to reaction-focused emotion regulation strategy, and refers to the use of self-control ability to inhibit continuous (upcoming or ongoing) emotional expression behavior (Wang et al., 2003).

In addition, Gratz and Roemer et al. (2004) proposed the Difficulty in Emotion Regulation Model. The model of emotional adjustment difficulty includes multiple dimensions, namely, the understanding and acceptance of emotions, the use of emotional adjustment strategies, and the ability to control impulse and corresponding behavioral expression according to goals. Impulsivity is generally defined as the individual's tendency to react without thinking when facing a certain stimulus or situation, without taking into account the possible negative consequences (Yu et al., 2013). Although there is no unified definition for different types of impulse and corresponding measurement standards, it is generally believed that impulse behaviors caused by individuals' lack of control ability are highly correlated with NSSI (McHugh et al., 2019). Based on this model, individual impulsivity can be considered as one of the manifestations of insufficient control ability, and it will lead to emotional adjustment disorder. When individuals lack other adaptive emotional adjustment strategies, they easily produce impulsive behaviors due to the lack of control ability. When individuals mistakenly believe that such behaviors can alleviate negative emotions, impulsive behaviors are likely to be strengthened over time (Cyders & Smith, 2008), that is, this behavioral expression will eventually be considered one of the more direct and effective emotion regulation strategies in the corresponding emotional situation by individuals.

2.2 Theories of NSSI

Previous theoretical and empirical studies have unveiled the key role of emotion regulation in NSSI, where NSSI is generally considered to be the result of poor emotion regulation (Perez et al., 2012).

The Affective cascade model (ECM) pointed out that maladaptive emotion regulation affected the occurrence of NSSI. This theory emphasizes the important role of rumination in connecting individual emotional response with NSSI and points out that after experiencing the events that cause negative emotions, individuals encounter negative emotions and trigger rumination. This process then brings more negative emotions and corresponding emotional reactions, which mutually reinforce each other to form a vicious circle, leading to gradual out-of-control emotions and triggering emotional disorders. In this process, the rumination on negative emotions and their experiences increases the level of negative emotions (Selby et al., 2008; Selby & Joiner, 2009; Selby et al., 2013), and finally leads to individual attention being completely occupied by negative emotions, it is difficult to effectively use the adaptive emotion regulation strategy. Therefore, with the increasing aggravation of negative emotions, individuals may resort to more rapid and direct adaptive regulation behaviors such as NSSI as the only feasible way to break the negative cycle and transfer attention from the circular process of rumination and negative emotions to the physical feelings related to these behaviors (Selby & Joiner, 2009; Tuna & Özlem, 2014).

In recent years, the emotional cascade model has been developed. Hacking et al. (2017) proposed the cognitive-emotional model of non-suicidal self-injury (CEM-NSSI), and elaborated on the factors affecting the initiation and persistence of NSSI. First, the emotional response is the main driver of NSSI, including emotional sensitivity, the intensity and duration of emotional response, and attention allocation to emotional stimuli. People with strong emotional responses often experience strong and persistent emotional responses, which may be unbearable, prompting such people to understand and accept the concept of NSSI more actively, and then generate a higher tendency of NSSI initiation, and more easily identify it as a regulatory strategy to deal with emotional response. Second, the persistence of NSSI is affected by individual perceived emotional volatility and its interpretation. Emotional response is more severe, and individuals with adaptive cognitive evaluation are more likely to ruminate on the perceived emotional intensity when facing a situation that is easy to cause emotional excitement, thus aggravating emotional distress and promoting the recurrence of NSSI.

In conclusion, the cascade theory of emotions and the cognitive-emotional model of non-suicidal self-injury support the important effect of emotion regulation on NSSI and emphasize the key role of rumination.

3. The influence of emotion regulation on NSSI

Studies have shown that emotion regulation plays a vital role in NSSI. Especially when individuals have insufficient emotional adjustment ability, that is, they cannot use adaptive emotional adjustment strategies to effectively deal with negative emotions, they easily to choose bad strategies to immediately alleviate emotional pain (Gratz & Roemer, 2004), thereby inducing NSSI. In addition, studies have mentioned that people who have repeatedly performed NSSI believe that they will feel more relieved, relieved, and calmer after the occurrence of NSSI (Gordon et al., 2010), which undoubtedly emphasizes the strengthening feature of NSSI. Therefore, exploring the effect of emotion regulation on NSSI not only helps to understand the pathogenesis of NSSI but also provides a theoretical basis for formulating effective immediate intervention measures. This study will discuss the effects of four affective regulation strategies on NSSI, namely, cognitive reappraisal, expressive suppression, impulsivity, and rumination.

3.1 Cognitive reappraisal and NSSI

Gross believes that cognitive reappraisal, as an emotion regulation strategy that can reconstruct individuals' specific understanding of emotional events, helps individuals to identify possible positive consequences of the event, thereby effectively changing the negative emotional response and reducing the risk of NSSI (Hasking et al., 2017). Cognitive reappraisal does not affect or even enhance the positive emotional experience and the corresponding emotional expression behavior. By reducing the emotional pain caused by negative emotions, cognitive reappraisal can well regulate the emotional response and help individuals to maintain emotional stability, thereby reducing the risk of inducing NSSI due to poor emotion regulation (Troy et al., 2018).

In one study, the researchers screened out college students with high-risk backgrounds to participate in the experiment. Participants were randomly assigned to the cognitive reappraisal and other emotion regulation strategy groups. The test tasks were performed by means of NSSI assessment, NSSI intention test, etc. The experiment proved that cognitive reappraisal as an emotion regulation strategy had intervention effects on NSSI. After individuals adopt the cognitive reappraisal strategy, although they cannot change the NSSI thinking, it plays an important role in timely reducing the NSSI tendency and NSSI identity (Chen et al., 2023). Voon et al. (2014) conducted a three-year longitudinal study. Researchers recruited 3,143 high school students from 40 secondary schools and participated in the survey. Among them, 555 participants had NSSI history. Based on data from different time dimensions, the study focused on comparing the effects of different emotion regulation strategies on NSSI. After controlling for such variables as gender, age, and psychological distress, the results showed that a higher level of cognitive reappraisal corresponded to a lower risk assessment

for NSSI. Moreover, with time, the increased use of individual cognitive reappraisal would reduce the severity and frequency of NSSI. Other studies also have consistent results, namely, cognitive reappraisal is negatively correlated with the occurrence of NSSI (Hasking et al., 2017). A meta-analysis by Aldao et al. (2010) combined 114 studies comparing the effects of different emotion regulation strategies on psychopathological symptoms (depression, anxiety, diet-and drug-related disorders). The results showed that, compared with other emotion regulation strategies, cognitive reappraisal was effective in alleviating the negative emotional response, reducing the individual risk of developing psychopathological symptoms, and reducing the behavioral expression corresponding to such symptoms. Based on the previous study (Swannell et al., 2014) that NSSI is closely related to such psychological disorders and has the theory of high co-morbidity rate, this meta-analysis lateral verifies that cognitive reappraisal can reduce the occurrence probability of psychological disorders to weaken the occurrence risk of NSSI.

Although cognitive reappraisal can effectively alleviate emotional pain and effectively reduce NSSI risk, Gross also points out that when individuals face strong emotions, due to the limitation of their cognitive ability to emotional events and their mastery of emotion regulation strategies, they are often difficult to adopt the strategy spontaneously. Therefore, cultivating individual cognitive reappraisal ability may be an effective way to reduce the probability and frequency of NSSI. Intervention and treatment efforts can achieve more significant results by helping NSSI patients master and apply more adaptive emotion regulation strategies. For example, mindfulness, as an effective way to improve mood regulation, has been widely confirmed to improve the ability to adapt to cognitive reappraisal (Brockman et al., 2016). This is also an effective way to indirectly reduce NSSI.

3.2 Expressive suppression and NSSI

Different from cognitive reappraisal, expressive suppression does not focus on regulating the subjective emotional response, but rather the corresponding behavioral expression itself. Expressive suppression does not affect the emotional experience, but it produces the result of enhancing the corresponding physiological response due to the expressive suppression of emotional behavior (Gross, 2002; Gross & John, 2003). Although effective as an emotion-regulating strategy, expressive suppression was not effective in inhibiting the corresponding emotional experience or inhibiting thinking about emotion-inducing events (Webb et al., 2012).

Multiple horizontal studies have confirmed the association of expressive suppression with NSSI. For example, Forkmann et al. (2014) recruited 232 clinical patients to participate in the study, and the results showed that compared with the positive effect of cognitive reappraisal, expressive suppression can significantly predict suicide and NSSI intention. That is to say, when individuals are unable to apply cognitive reappraisal of adaptive affective regulation strategies, selective expressive suppression will increase the risk of NSSI in the future. Nicol et al. (2022) selected 404 young people aged 16 to 25 to conduct a survey, and they also found that individuals who often adopted expressive suppression as an emotion regulation strategy found more NSSI behavioral expression and had higher NSSI tendencies when dealing with negative emotions. A meta-analysis (Hu, 2014) using 48 studies on the relationship between cognitive reappraisal and expressive suppression and mental health showed that expressive suppression had a negative correlation with positive indicators of mental health and a positive correlation with negative indicators of mental health. Moreover, under the background of Eastern culture, the negative correlation of the latter is stronger. This indicated that individuals who frequently used expressive suppression had a higher probability of being in a psychological sub-health state and an increased incidence rate of NSSI. Another meta-analysis (Aldao et al., 2010) also confirmed that expressive suppression, as an adaptive emotion regulation strategy, increases the load of emotion regulation during individual selection and use, increases the probability of developing psychopathological symptoms, and finally increases the NSSI risk that such symptoms may accompany.

In a one-year longitudinal study by Tatnell et al. (2014), self-reported data indicated that expressive suppression and cognitive reappraisal had different relationships with the occurrence, cessation, and maintenance of individual NSSI. During the follow-up visit of the researchers, compared with the individuals who did not receive NSSI, the use of cognitive reappraisal was significantly less and the emotional distress was more in the individuals who received NSSI. Individuals who discontinued NSSI during the follow-up period used more cognitive reappraisal and had less emotional distress than those who maintained NSSI. In addition, a study (Navarro-haro et al., 2015) focused on patients with borderline personality disorder and concomitant eating disorders, combining clinical intervention and intervention, to observe the different effects of two emotion regulation strategies, cognitive reappraisal, and expressive suppression, on NSSI. The follow-up study found that in individuals with low levels of expressive suppression, cognitive appraisal can reduce NSSI behavior. However, for those with high levels of expressive suppression, the impact of cognitive appraisal on NSSI was weakened.

3.3 Impulsiveness and NSSI

It has been widely exhibited that impulsivity is one of the important factors that may influence the occurrence of NSSI (Herpertz et al., 1997). For example, one longitudinal study recruited individuals aged 14 to 24 years without a history of NSSI before the study. The results showed that impulsivity had a predictive effect on the occurrence of NSSI, that is, high impulsivity could induce the occurrence of NSSI in the future (Cassels et al., 2022). You et al. (2012) conducted a search survey of 4,782 high school students in two years. The evaluation showed that individuals who exhibited high impulsivity in the first year were found to be more prone to NSSI or repeated NSSI in the second year. This finding is consistent with the findings reported above, and studies have confirmed that NSSI populations are significantly more impulsive than non-NSSI populations. In addition, a survey of 2,292 college students also revealed that impulsivity not only directly affects the occurrence of NSSI, but also mobilizes individual strong negative emotions through expressing different negative consequences brought by different impulsive behaviors such as impulsive decision-making to produce indirect adverse effects and intensify the risk of NSSI (Lin et al., 2017).

The correlation between impulsivity and NSSI has been consistent in a large number of studies. Yu et al. (2013) conducted a questionnaire survey among a total of 920 middle school students. The results showed that the level and occurrence frequency of NSSI were highly correlated with impulsiveness. Based on the results of this investigation, the researchers detected through the experiment that the NSSI population exhibited poorer control over impulse response in behavioral expression, i.e., higher level of impulsivity. Moreover, Dir et al. (2013) compared the population performing NSSI with the general population and found that higher impulsivity indicated that individuals would perform NSSI more frequently in the future, take more diverse forms (such as cutting and burning) to complete NSSI, and last for a longer period of time. It has been fully demonstrated that impulsivity not only promotes the occurrence of NSSI, but also affects the persistence and severity of NSSI. A meta-analysis by McHugh et al. (2019) showed that adolescents with NSSI or suicidal behaviors were significantly more impulsive than those without such behaviors, and the researchers did not think this association was gender-and age-limited. Among them, the researchers conducted a detailed analysis and measurement of the correlation between different types of impulsive behavioral expressions and NSSI. The results confirmed the model theory of emotional difficulty in regulation and found that the two impulsive behaviors, the lack of expressive suppression and impulsive decision-making, had particularly significant effects on NSSI.

Previous studies have suggested that through impulsive behaviors such as NSSI, individuals can shift attention from mental pain to physical pain, to temporarily obtain emotional stability and controlled recovery (Glenn & Klonsky, 2010; Taylor et al., 2012). Since impulsive behavior can quickly relieve psychological suffering, individuals will be more inclined to rely on its short-term effects rather than try other, healthier, methods of emotion regulation. For example, when facing emotional distress, high-impulse individuals often difficult to use other appropriate emotion

regulation strategies and are more likely to take immediate but destructive behaviors (Glenn & Klonsky, 2010; Janis & Nock, 2009), such as NSSI, substance abuse, or other violence.

3.4 Rumination and NSSI

The ECM model points out that the circular thinking mode mutually reinforcing between rumination and negative emotions is an important reason for the initiation of NSSI. Multiple empirical studies have demonstrated that there are differences in the selection of ruminant strategies between NSSI groups and non-NSSI groups, with the emphasis on rumination aggravating the negative emotional response (Selby et al., 2013; Arbutnott et al., 2015), which in turn increases the risk of NSSI. Among them, studies emphasized that the occurrence probability of NSSI was affected by specific ruminant topics. When individuals experience such strong negative emotions as sadness or especially ruminate on past emotional events, their emotional instability will be enhanced, indirectly promoting the interaction between rumination and negative emotions, and significantly increasing the effect of rumination on NSSI (Selby et al., 2013).

Hatzopoulos et al. (2021) investigated 992 college students and studied the regulation of rumination on different levels of emotion (such as emotional response, its intensity, and persistence) and NSSI. The study found that different levels of negative emotions were correlated with NSSI, and verified the correlation between rumination and NSSI, that is, individuals with higher rumination tendency were more likely to have a history of NSSI, and rumination could not play an effective regulatory role between negative emotions and NSSI. Another study verified the intermediary effect of rumination between despair and NSSI. A survey of 915 junior and senior high school students revealed that rumination enhanced the association between the sense of despair and NSSI. Especially, when experiencing despair, the higher the rumination level was, the more likely the individual was immersed in negative emotions, increasing the sense of despair felt by them, which in turn acted as a reminder of NSSI (Gong et al., 2019). The same results were confirmed in a three-year longitudinal study (Buelens et al., 2019). The researchers explored the association between psychological distress, rumination, and NSSI, recruiting 528 participants (high school students) who reported psychological characteristic data for three consecutive years. A positive correlation was found between rumination and NSSI after verification by a cross-lag model. Individuals with higher rumination scores were more likely to undergo NSSI, and individuals with increased rumination were associated with more severe NSSI. Nicolai et al. (2016) also found that when individuals had high negative emotional levels and high rumination levels, the two had mutual influence. Rumination aggravates the negative emotional response, thereby increasing the possibility of NSSI and the frequency of individual NSSI. Similar results were presented in meta-analysis, where researchers explored the association of different subtypes of ruminants with NSSI. Rumination was divided into four types of rumination, i.e., general type, depressive type, meditative type, and reflective type. The results showed that there was a small to medium positive correlation between rumination and NSSI, and it was not related to the type of rumination (Cheung et al., 2024).

In addition, Schreiner et al. (2023) recruited 39 adolescents with major depression accompanied by NSSI in their study and obtained the brain functional activity indexes of individuals when completing rumination tasks. The results showed that individuals with high NSSI behavioral expression had greater activation of the anterior wedge and posterior cingulate cortex during ruminant tasks. This suggests that individuals with severe NSSI do not experience more severe rumination, but this may be due to their inability to get rid of rumination.

The above studies have shown that rumination has a strong negative effect on NSSI. Besides, negative emotions caused by rumination and the counterattack of corresponding emotional reactions will aggravate the probability and severity of individual NSSI.

Based on the above theories and models, expressive suppression, impulsivity, and rumination can be considered as adaptive emotion regulation strategies. Although these strategies can quickly alleviate individual emotional pain in the short term, making them feel temporary emotional release and emotional stability (Selby et al., 2008; Selby et al., 2013), this response was generally short-lived

and was not effective in truly managing and relieving negative emotions. Moreover, the strong emotional response brought about by the non-adaptive strategies would result in decreased individual perception of emotion and decreased tolerance to emotional pain, and make individuals more vulnerable to rely on the non-adaptive emotion regulation strategies to avoid or regulate emotions (Hasking et al., 2017; 2016). A study based on functional magnetic resonance imaging (fMRI) confirmed (Lang et al., 2024) that the activities of brain regions related to emotion regulation, such as the prefrontal cortex, between the NSSI population and non-NSSI population differ due to different choices of emotion regulation strategies. Among them, individuals who adopted the non-adaptive regulation strategy exhibited a low-activation state of brain activity and abnormalities of excitatory and inhibitory neurons, proving that the NSSI population was more inclined to adopt the non-adaptive emotion regulation strategy.

4. Mechanisms of the effects of emotion regulation on NSSI

The neural and physiological mechanisms of the impact of emotion regulation on NSSI have been revealed. It has been found that the prefrontal cortex (PFC), amygdala, and cingulate cortex (ACC) are key brain regions associated with emotion regulation and NSSI, which are the overlapping brain regions of these two functions (Cutuli et al., 2014). In addition, electrophysiological studies also confirmed that compared with individuals without NSSI, those engaged in NSSI exhibited abnormal electrophysiological parameters.

4.1 fMRI studies

Previous studies have shown that the neural mechanisms of emotion regulation mostly involve the amygdala, PFC, and ACC (Cheng et al., 2009). Among them, individuals using cognitive reappraisal reduced the activation of the amygdala for negative emotional stimulation; expressive suppression did not decrease amygdala activation (Ochsner et al., 2004). It has also been suggested that in the former case, the individual regulated the negative emotional stimuli through the medial orbitofrontal cortex (mOFC) to reduce the activation of the amygdala; The latter is achieved through inhibition of the amygdala by mOFC (Ohira et al., 2006). A meta-analysis compared the activity of brain regions when individuals used cognitive reappraisal and expressive suppression, and the results showed that when individuals used cognitive reappraisal, individuals activated brain regional networks, including bilateral ventrolateral and dorsolateral prefrontal cortex, parietal and temporal lobe regions, complementary motor region and ACC (Buhle et al., 2014; Kohn et al., 2014). In the case of expressive suppression, the individual exhibited dorsolateral, ventrolateral, and ventral prefrontal cortex activation, as well as increased ACC, parietal lobe, and insula activation compared with cognitive reappraisal (Goldin et al., 2008).

In addition, meta-analysis by Zhou et al. (2020) showed that rumination strategies involved a cerebral network with the anterior medial prefrontal cortex (amPFC) and posterior cingulate cortex (PCC) as the cores. And when the individual ruminates, the core brain regions of the network are overactivated, and simultaneously sustained activation of the dmPFC subsystem was observed. It proved that during rumination, individuals needed the above brain regions to promote their awareness of themselves and others. Impulsivity is observed to be highly correlated with PFC. Although the behavioral levels of different impulsivity subtypes involve different brain regions, PFC plays an important role in association. Lesion studies demonstrated that patients with orbital frontal cortex (OFC) lesions had more errors in the experiment and were more impulsive than healthy controls. It indicated that PFC, especially OFC, was involved in the corresponding neural activities in the individual decision-making process, and the abnormalities in this brain region led to impulsive behavioral expression (Berlin et al., 2007; Sellitto et al., 2016).

Therefore, brain regions co-activated by emotion regulation included the amygdala, PFC and ACC, and different brain regions participated in different emotion regulation strategies. These brain regions are also an important neural basis for developing NSSI.

Regarding the neural mechanism of NSSI, Schreiner et al. (2017) studied the amygdala network of the NSSI population through the negative emotional face-matching paradigm and multi-modal neural imaging technology. The results revealed that the NSSI group showed hyperconnectivity of the amygdala to the supplementary motor area (SMA), resting-state functional connectivity of the dACC, and abnormal functional connectivity between the amygdala and frontal lobe. Researchers believe that because SMA is closely related to habitual behavior, the excessive connection between the amygdala and SMA can be considered as one of the mechanisms for individuals to habitually associate negative emotions with the expression of bad behaviors. Another study exhibited consistent results (Hooley et al., 2020). Researchers performed NSSI-related image tests for both NSSI and non-NSSI groups using fMRI, and the results showed that the NSSI group had defects in emotion regulation.

These studies have shown that abnormal activation of the amygdala is usually associated with negative stimuli such as fear or disgust, and this abnormal activation reduces the NSSI negative stimulus to individuals in the process of emotion regulation (Cutuli, 2014) so that NSSI is repeatedly selected in the process and appears as a continuous occurrence of NSSI in behavioral expression. Second, the activities related to PFC and ACC control brain regions were related to the control ability in individual emotion regulation, and the abnormal activation level of brain regions meant the increase of individual impulsivity (Deng et al., 2022), which represented the inability to control emotional response and corresponding behavioral expression, i.e., the occurrence and persistence of NSSI.

In conclusion, the amygdala, PFC, and ACC were the overlapping brain regions related to both emotion regulation and NSSI, the abnormal functions in these brain areas may be the potential between these two variables. Although the disorder of different neurological functions means that individuals have different disorders in the process of emotion regulation, they will all lead to individuals being unable to correctly evaluate the negative consequences of NSSI. In the absence of adopting adaptive emotion regulation strategies, individuals are constantly stimulated by the activities of cerebral regions to strengthen their selection for NSSI (Hooley et al, 2020), which will lead to more severe NSSI or NSSI persistence.

4.2 ERP studies

Researchers selected some students with and without NSSI history as controls used the Go/Nogo task to induce the subject's impulse response, and obtained consistent behavioral and electroencephalogram indicators. Compared with individuals without NSSI behavior, the amplitude of N2 in those engaged in NSSI was higher and the latency was longer (Yu et al., 2013). Studies have shown that the functional deficit of PFC is one of the reasons for abnormal brain activity, and the individual is therefore highly impulsive. Studies have recruited patients with severe depression, NSSI patients, and the general population for comparative experiments. The participants were exposed to negative emotional stimuli for the experimental task of double-choice Oddball paradigm to test the behavioral performance and neuroreactivity of NSSI individuals. The results showed that NSSI individuals consumed more ACC resources when experiencing stimulation, and exhibited more significant increases in N250 and P300 amplitudes, steeper LPP waveforms, and faster regression to baseline. It proved that under the stimulation of negative emotions, NSSI individuals exhibited significant changes in the cognitive electroencephalogram related to emotional processing, and they needed to mobilize more cognitive resources to inhibit the negative emotional response (Zhao et al., 2023). A similar study also found neurological abnormalities in the NSSI population. It was found that the P3 amplitude of the NSSI population showed obvious abnormalities, manifested as the larger amplitude of P3d. P3 represents the process of reaction inhibition, indicating that NSSI individuals need more neural resources to successfully achieve the inhibition of negative emotional responses (Zhou et al., 2022). The experiment by Liu et al. (2022) showed that patients with severe depression and concomitant NSSI presented with significantly prolonged latencies of N2, P3a, and P3b, while significantly decreased amplitudes of P3a and P3b, which were mainly reflected in poor inhibition control and anti-interference ability in behavioral expression. Based on the data, the investigator

believes that baseline P3 can be considered a potential factor for predicting a decrease in NSSI in this population.

The above studies have proved that all NSSI individuals present with different abnormalities of electroencephalogram indicators in ERP and electroencephalogram. With the help of electroencephalogram correlation analysis data, we can have a deeper understanding of the brain dysfunction of NSSI individuals.

4.3 Electrophysiological studies

In the related research on NSSI combined with electrophysiology, the experimental work is mainly focused on the reactions of NSSI individuals when facing negative emotional stimulation.

Gross's study adopted a combination of experimental and physiological measurements. The participants were first guided to recall or be exposed to the situations that triggered the negative emotions, and then randomly assigned to cognitive reappraisal group and expressive suppression group. During the experiment, participants' emotional experience was assessed using a psychological questionnaire, and their cardiovascular and galvanic skin reactions were recorded using physiological measurement devices, thereby measuring the activation of the sympathetic nervous system. The experimental results showed that cognitive reappraisal could reduce the experience of negative emotions and the expression of corresponding behaviors, but had no significant effect on the sympathetic nerve activation of cardiovascular and cutaneous electrical systems (Gross, 2002; Gross & John, 2003; Wang et al., 2003). Therefore, when individual negative emotions decrease, NSSI is not easy to occur. When individuals try to control negative emotions by expressive suppression, not only the emotional problem remains, but also it may lead to the increase of physiological pressure in the body, such as accelerated heart rate and elevated blood pressure, bringing about negative effects (Gross, 2002; Gross & John, 2003; Wang et al., 2003). Therefore, when individuals suppress negative emotions by expressive suppression, it reversely promotes the repetition and superposition of negative emotions, aggravates the malignant influence of negative emotions, and increases the NSSI risk.

In addition, some studies have found through controlled trials that NSSI individuals exhibit decreased cortisol response (Kaess et al., 2012). There was a weak autonomic response to positive images (Tatnell et al., 2018). In addition, NSSI individuals generally showed difficulty in handling emotions in the experiment. For example, a study compared the NSSI population with the general population through facial electromyography. The results showed that NSSI individuals showed more activity of frown muscle when facing negative emotional stimulation, that is, they showed more negative emotions. And also show greater emotional responses when face positive emotional stimulation. The research has proved that even when facing positive emotions, NSSI individuals will show excessive reactions to emotions, affecting the normal progress of emotion regulation (Mettler et al., 2021).

In conclusion, individual NSSI stress response shows different physiological disorders, which hurt the negative emotional response, and thus increase the risk of NSSI.

The above studies based on neural and physiological mechanisms have proved that individuals need the participation of different nervous systems when adopting different strategies for emotion regulation. NSSI individuals lack the function of brain regions such as the amygdala, PFC, and ACC, and have abnormalities of electroencephalogram and physiological indicators. This study will provide a neurophysiological scientific basis for understanding the effect of emotion regulation on NSSI and help to develop more adaptive interventions for NSSI individuals. For example, mindfulness can enhance PFC activity while reducing amygdala activation (Goldin & Gross, 2010); And meditation has been shown to help enhance the activation of the left prefrontal cortex to achieve hemispheric balance (Barnhofer et al., 2007). Therefore, during the intervention of NSSI, individuals can be trained to use adaptive adjustment strategies such as mindfulness and meditation, so that negative emotions can be well regulated, and thus the occurrence and frequency of individual NSSI are reduced.

5. Limitation

Some limitations should be addressed in the future study. Firstly, in terms of research methods, most studies were cross-sectional design, which may limit the causality. Besides, the measurements of NSSI were mostly self-reported questionnaires, which may be unable to accurately recall the details of NSSI due to the passage of time, resulting in data deviation and distortion. The time lag may result in studies that do not fully reflect the occurrence and severity of NSSI. Therefore, in future studies, more methods such as Ecological Moment Assessment (EMA) can be considered to collect real-time or regular emotional and situational data facing individuals when NSSI occurred, to improve the immediacy and ecological validity of the data.

Secondly, studies exploring the relationships between emotion regulation is still lacking. Moreover, individual differences should also be clarified in future studies. Although one meta-analysis showed the association between emotion regulation and NSSI was not moderated by gender and age, most of the studies were female samples (Woff et al., 2019). Therefore, future studies should include more clinical populations, which can better understand the relationships and mechanisms between emotion regulation and NSSI and provide insights into the intervention of NSSI.

In addition, culture is a key factor that should be considered in this research area (Yang & Feldman, 2017). At present, most of the studies on NSSI focus on a single cultural background, which limits the understanding of the potential influencing factors of NSSI to a certain extent. For example, a meta-analysis showed that race moderated the association between rumination and NSSI (Cheung et al., 2024). The research on the potential influencing factors of NSSI reveals that in the Western cultural background, NSSI is often related to such factors as identity, religious belief, and social pressure. However, in the Eastern culture, NSSI may be affected by different cultural values and social norms, and the internalization of collectivism and emotion may lead to NSSI showing more hidden behavior patterns in these cultural backgrounds (Gholamrezaei et al., 2015). A qualitative study has found that gender bias in the specific geographical and cultural background leads to the more common and serious NSSI among female groups, and individuals will be accompanied by stronger pressure and social stigma. In Eastern culture, high expectations from others as part of inappropriate educational practices impose a high level of academic burden on individuals and also contribute to the occurrence of NSSI (Chen et al., 2021). Cultural background may significantly affect the risk factors for NSSI and individual cognition of NSSI (Gholamrezaei et al., 2017). Therefore, research on the correlation between emotion regulation and NSSI cannot be separated from the exploration of cultural background. However, research on the relationship between NSSI and different cultural backgrounds is still scarce. Future studies need to pay more attention to cross-cultural comparisons and explore how cultural background affects the occurrence and manifestations of NSSI as well as individual interpretations of and responses to NSSI. By conducting research in a multicultural context that covers more demographic factors, we can help this field establish a more comprehensive NSSI theoretical framework and provide a sufficient scientific basis for the development of more culturally appropriate intervention strategies.

Finally, this study showed that NSSI could be alleviated by intervening in emotion regulation. Previous studies have shown that adaptive emotion regulation strategies are usually a key component in the treatment of emotional disorders. For example, cognitive reappraisal is one of the important links between cognitive behavioral therapy and dialectical behavioral therapy (Aldao et al., 2010). Currently, many other methods can improve the ability of emotion regulation. For example, meta-analysis shows that mindfulness can help individuals reduce emotion regulation difficulties and achieve a healthier emotion regulation process (Roemer et al., 2015). Therefore, individuals can improve their emotional adjustment ability based on such methods, thereby reducing the occurrence of NSSI.

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