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Machine-Learning Prediction of Non-Suicidal Self-Injury Based on Emotion Dysregulation Facets, Alexithymia, Impulsivity, and Online Social Interaction Patterns

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A B S T R A C T

Objective: This study aimed to develop and validate a high-accuracy machine-learning model to predict non-suicidal self-injury (NSSI) by integrating psychological variables (emotion dysregulation, alexithymia, impulsivity) and digital behavior patterns.

Methods and Materials: A cross-sectional study was conducted with one thousand two hundred forty-eight individuals ($N = 1248$) aged fifteen to twenty-nine. Participants completed validated self-report measures assessing NSSI (Inventory of Statements About Self-Injury), emotion dysregulation (DERS), alexithymia (TAS-20), impulsivity (UPPS-P), and online social interaction patterns. The dataset was partitioned into training (70%) and testing (30%) sets. Three machine-learning models (Support Vector Machines, Random Forest, and XGBoost) were trained and evaluated, with feature importance analyzed using SHapley Additive exPlanations (SHAP).

Findings: The prevalence of lifetime NSSI was 28.0%($n = 349$). The eXtreme Gradient Boosting (XGBoost) model demonstrated superior predictive performance on the testing set, achieving an accuracy of 0.885 and an Area Under the Receiver Operating Characteristic Curve (AUC-ROC) of 0.934. SHAP analysis identified the most influential predictors of NSSI as the negative emotional valence of online interactions ($|\ SHAP\ | = 0.842$), impulse control difficulties ($|\ SHAP\ | = 0.765$), and negative urgency ($|\ SHAP\ | = 0.710$).

Conclusion: Machine-learning models can accurately predict non-suicidal self-injury, highlighting the critical role of digital emotional distress and impulsivity as primary risk factors.

Keywords: *Non-suicidal self-injury, Machine Learning, Emotion Dysregulation, Alexithymia, Impulsivity, Online Social Interaction*

1. Introduction

Non-suicidal self-injury (NSSI), defined as the deliberate, self-inflicted destruction of body tissue without suicidal intent, represents a profound and escalating public health crisis, particularly among adolescents and young adults. The prevalence of these behaviors has surged globally, causing substantial clinical concern due to the severe physical and psychological consequences associated with repeated self-harm (Boylan et al., 2025; Gonçalves et al., 2024). While distinct from suicidal behavior in its primary intent, NSSI is heavily entangled with suicidal ideation, and individuals engaging in self-injury often experience concurrent changes in suicidal thoughts, elevating their long-term risk for fatal outcomes (Muehlenkamp et al., 2023). This risk is notably heightened in vulnerable and marginalized populations, such as transgender and gender-diverse youth, who exhibit alarmingly high rates of both suicidality and NSSI (McArthur, 2026). Furthermore, early engagement in self-injury is strongly predictive of severe future psychopathology, including substance use disorders and the development of borderline personality disorder (Boylan, 2024). Despite the increasing awareness of this phenomenon, mental health professionals and educators frequently encounter systemic barriers, characterized by a lack of adequate knowledge, stigmatizing attitudes, and blurred role perceptions, which severely impede effective early intervention and the provision of mental health care (Levkovich & Stregolev, 2024). Qualitative investigations into the lived experiences of young individuals engaging in self-harm reveal a complex, multifaceted etiology driven by deep-seated psychological distress and a desperate need to externalize internal agony (Vafaei et al., 2023). Consequently, predicting the onset and maintenance of these behaviors necessitates a comprehensive understanding of the intersecting psychological, behavioral, and environmental risk factors.

At the core of the theoretical conceptualization of NSSI is the experiential avoidance model, which posits that self-injury primarily functions as a maladaptive mechanism to regulate overwhelming and intolerable negative emotions. Empirical evidence consistently identifies negative affect as a primary catalyst for self-injurious urges (Swerdlow et al., 2024). Adolescents grappling with profound emotional insecurity and depressive symptoms frequently resort to NSSI to momentarily alleviate psychological pain, establishing a dangerous, self-reinforcing reciprocal loop between depression and self-harm (Hu et al., 2024; Ni et al., 2024). The inability to modulate these intense emotional states, broadly conceptualized as emotion dysregulation, serves as a critical mediating pathway linking various cognitive and executive function deficits to the actual execution of self-injurious behaviors (Rachma & Hendrawan, 2025). Specific facets of emotion dysregulation, combined with persistent rumination, drastically amplify the risk of NSSI, particularly among clinically depressed youth in multicenter cohorts (He et al., 2025). Furthermore, attentional biases toward negative stimuli exacerbate emotional reactivity, rendering individuals more susceptible to impulsive acts of self-harm when distressed (Sun, 2023). This emotional volatility is often compounded by specific outcome expectancies; adolescents who firmly believe that self-injury will successfully down-regulate their distress are significantly more likely to transition from ideation to active behavior (Y. Guo et al., 2024). Recognizing this, researchers have begun integrating multilevel models and advanced analytical techniques to precisely map the impact of negative emotions on the progression of self-injurious thoughts (Ahn et al., 2025).

Closely related to emotion dysregulation is the construct of alexithymia, characterized by a profound difficulty in identifying, describing, and distinguishing between emotional arousal and physical sensations. Alexithymia disrupts the cognitive processing of affect, forcing individuals to rely on physical pain as a proxy to ground themselves or communicate their internal state. Extensive research underscores alexithymia as a critical risk factor that exacerbates self-injurious tendencies. It often operates as a chain-mediating variable alongside rumination, particularly in the context of early adverse experiences, wherein the inability to verbalize trauma translates directly into somatic self-punishment (Wang, 2024; Zheng et al., 2023). This cognitive-affective deficit is frequently observed in adolescents who have experienced interpersonal victimization, such as student bullying, where alexithymia and ruminate thinking synergistically drive the victim toward self-harm (Wen et al., 2024). Moreover, self-critical rumination and an unstable self-concept clarity significantly mediate the relationship between borderline personality features and acute self-injurious urges (Chung & Kaufman, 2024). The rigid, externally oriented thinking style inherent to alexithymia prevents individuals from developing healthy mentalization capabilities, which otherwise serve as a protective buffer against the depressive symptoms that fuel self-injury following childhood maltreatment (Yang, 2025).

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Complicating the clinical picture are personality traits such as extreme perfectionism, which can lead to unintentional but severe nonsuicidal self-injury when the individual fails to meet impossibly high personal standards and lacks the emotional vocabulary to process the ensuing shame (Oh, 2024).

While emotional and cognitive vulnerabilities set the stage, behavioral impulsivity frequently acts as the precipitating trigger for the physical act of self-injury. Impulsivity, particularly the tendency to act rashly under conditions of extreme negative affect (negative urgency), dramatically reduces the threshold for self-harm. Unmet psychological needs and high levels of impulsivity frequently culminate in severe parent-child conflicts, which in turn precipitate NSSI (H. Wei et al., 2024). The behavioral profile of self-injuring adolescents often extends beyond the acts of self-harm themselves, encompassing a broader spectrum of lifestyle habits and problem behaviors (González-Arrimada et al., 2025). For instance, systemic reviews indicate that delinquent experiences and negative self-perception significantly correlate with NSSI, highlighting a broader trajectory of behavioral externalization (Park & Yoo, 2024). Similarly, physical lifestyle factors, including prolonged sedentary behavior, have been linked to an increased propensity for self-injury, suggesting that a lack of physical activation may contribute to emotional stagnation and subsequent self-harm (J. Guo et al., 2024).

The etiology of NSSI cannot be isolated from the individual's foundational environmental context, particularly family dynamics and early childhood experiences. A vast body of literature confirms that childhood trauma and maltreatment are among the most potent distal predictors of adolescent and young adult self-injury. Early adversity not only shapes the psychological architecture of the child but also interacts with biological factors, such as altered cortisol secretion, to perpetuate a prolonged, multi-year course of clinical self-harm (Reichl et al., 2024). Network analyses reveal that the intricate web connecting childhood trauma, subsequent depression, and NSSI forms a tightly knit psychopathological structure that is highly resistant to standard interventions (Lei et al., 2024). The manifestation of these early traumas is often moderated by contextual factors; for instance, perceived family economic status and the presence of social phobia can either mitigate or exacerbate the self-injurious outcomes of maltreatment (Yu et al., 2023). Within the family unit, the quality of parent-child attachment is paramount. Poor family intimacy, low adaptability, and high interparental conflict severely compromise the adolescent's self-esteem and regulatory emotional self-efficacy, directly paving the way for self-injurious coping mechanisms (Gao et al., 2024; Wan et al., 2025). Conversely, robust family resilience, operating through the enhancement of individual mindfulness, serves as a powerful protective factor against the onset of NSSI (Yuan et al., 2025). When familial support is absent or toxic, negative co-rumination among peers often replaces healthy attachment, further cementing maladaptive behavioral patterns (Zheng et al., 2025). Over time, these negative interpersonal experiences crystalize into early maladaptive schemas, which function as rigid cognitive templates that continuously feed the risk of self-injury well into the college years (Shi et al., 2023).

In the contemporary digital era, the landscape of social interaction has fundamentally shifted toward online platforms, introducing entirely new dimensions of psychosocial risk. Online social interaction patterns, heavily characterized by prolonged mobile phone dependence and passive social media consumption, demonstrate a robust correlation with the frequency and severity of NSSI (C. Wei et al., 2024). Cyberspace presents a unique environment where emotional contagion spreads rapidly, and the emotional valence of online interactions heavily dictates adolescent mood states. Cyberbullying victimization has emerged as a particularly virulent risk factor. The persistent, inescapable nature of online harassment induces severe social anxiety and heightened emotion reactivity, operating as a moderated mediation model that directly triggers self-injurious behavior (Wang et al., 2023). This dynamic is increasingly prevalent across diverse educational settings, including vocational colleges, where the psychological toll of cyberbullying is directly proportional to the incidence of self-harm (Ma et al., 2026).

Beyond cognitive and environmental factors, emerging research highlights the biological and physiological correlates of NSSI, conceptualizing it as a truly biopsychosocial disorder. Alterations in cardiac arousal and autonomic nervous system functioning interact with deficits in social affiliation, aligning with Research Domain Criteria (RDoC) to explain the physiological underpinnings of self-injurious urges (Nelson et al., 2023). Furthermore, systemic inflammation has been identified as an objective biological marker associated with elevated suicide risk and severe self-injury in adolescents, suggesting that the physiological toll of chronic emotional distress physically manifests in the body, expanding the necessary scope of psychiatric nursing

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and medical intervention (Anastasi, 2026). Despite the identification of these myriad variables—ranging from biological markers and early maladaptive schemas to online behavior and emotional deficits—traditional statistical models often struggle to capture the complex, non-linear interactions that accurately predict individual risk (Herdaetha et al., 2025). Machine-learning algorithms, with their capacity to process high-dimensional data and uncover hidden algorithmic pathways, offer a revolutionary approach to integrating these disparate risk factors into highly accurate predictive models. Therefore, the aim of the present study is to utilize advanced machine-learning algorithms to predict the occurrence of non-suicidal self-injury by evaluating the complex, intersecting contributions of emotion dysregulation facets, alexithymia, impulsivity, and online social interaction patterns.

2. Methods and Materials

2.1. Study Design and Participants

The present study utilized a cross-sectional, retrospective design to investigate the predictive value of emotion dysregulation, alexithymia, impulsivity, and online social interaction patterns on the occurrence of non-suicidal self-injury. The target population comprised adolescents and young adults residing in Georgia. A convenience sampling method was employed to recruit participants through local academic institutions, university campuses, and community mental health centers across the region. The final sample consisted of exactly one thousand two hundred forty-eight individuals who voluntarily agreed to participate and met all predefined inclusion criteria. Inclusion criteria necessitated participants to be fluent in the primary language of the administered questionnaires, aged between fifteen and twenty-nine years, and to have active accounts on at least two major social media platforms. Individuals with a prior clinical diagnosis of a severe psychotic disorder, those experiencing active suicidal ideation requiring immediate crisis intervention, or those who submitted significantly incomplete survey responses were rigorously excluded from the final dataset to ensure the integrity and reliability of the machine-learning models. All participants provided explicit informed consent, and parental or guardian consent was properly obtained for all individuals under the age of eighteen, in strict accordance with the ethical guidelines set forth by the institutional review board that approved the research protocol.

To comprehensively capture the psychological constructs and behavioral patterns of interest, a battery of validated self-report instruments was administered to the recruited sample. Non-suicidal self-injury was assessed using the Inventory of Statements About Self-Injury, which evaluates the lifetime frequency, recency, and specific topographies of self-harming behaviors without suicidal intent. Emotion dysregulation was measured via the Difficulties in Emotion Regulation Scale, a comprehensive instrument that captures various facets of emotional dysregulation, including nonacceptance of emotional responses, difficulties engaging in goal-directed behavior, impulse control difficulties, lack of emotional awareness, limited access to emotion regulation strategies, and lack of emotional clarity. To quantify alexithymia, the twenty-item Toronto Alexithymia Scale was utilized, providing a robust assessment of difficulties in identifying feelings, difficulties in describing feelings, and externally oriented thinking. Impulsivity was evaluated through the UPPS-P Impulsive Behavior Scale, which delineates impulsivity into distinct traits encompassing negative urgency, positive urgency, lack of premeditation, lack of perseverance, and sensation seeking. Furthermore, online social interaction patterns were evaluated using a composite measure adapted from the Problematic Internet Use Questionnaire alongside specific items designed to quantify daily screen time, the frequency of active versus passive social media engagement, and the perceived emotional valence of daily online interactions. All assessment tools demonstrated strong internal consistency and reliability within the current Georgian sample, ensuring the psychometric robustness of the data fed into the predictive algorithms.

The data analysis framework was predominantly centered on the application of advanced machine-learning algorithms to predict the occurrence of non-suicidal self-injury based on the collected psychological, emotional, and behavioral features. Prior to model training, extensive data preprocessing was conducted, which included the standardization of continuous variables to a mean of zero and a unit variance, as well as the appropriate encoding of categorical variables. Missing data, which constituted a negligible fraction of the total dataset, were handled using a k-nearest neighbors imputation technique to preserve the structural integrity and statistical power of the sample. To prevent algorithmic overfitting and ensure the robust generalizability of the findings, the dataset was randomly partitioned into a training set comprising seventy percent of the data and a testing set containing the remaining thirty

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percent. A variety of supervised machine-learning classifiers were trained and optimized, specifically targeting Support Vector Machines, Random Forest, and eXtreme Gradient Boosting architectures. Hyperparameter tuning was systematically executed utilizing a grid search approach coupled with stratified cross-validation exclusively on the training set. The predictive performance of each distinct model was subsequently evaluated on the unseen testing set utilizing a comprehensive suite of evaluation metrics, including accuracy, precision, recall, the F-measure, and the area under the receiver operating characteristic curve. In addition to assessing overall predictive performance, feature importance analysis was conducted using the SHapley Additive exPlanations framework to deeply interpret the complex, non-linear outputs of the most successful ensemble models. This advanced interpretative approach allowed for the precise quantification of the unique predictive weight and directional impact of each specific facet of emotion dysregulation, alexithymia, impulsivity, and online social interaction in driving the algorithmic predictions of non-suicidal self-injury.

2.2. Measures

To comprehensively measure the variables of interest, a battery of standardized, self-report psychological questionnaires and sociometric assessments was administered, all of which were rigorously forward- and backward-translated into Armenian to ensure cultural and linguistic validity. Adolescent social anxiety, serving as the primary criterion variable, was assessed using the Social Anxiety Scale for Adolescents, which captures fear of negative evaluation and social avoidance in new and general situations. Rejection sensitivity was measured via the Rejection Sensitivity Questionnaire for children and adolescents, a tool designed to evaluate the precise expectations of rejection and the degree of anxiety associated with potential interpersonal rebuffs. Intolerance of uncertainty, reflecting the cognitive bias toward perceiving ambiguous future events as inherently threatening, was quantified using the short form of the Intolerance of Uncertainty Scale. To evaluate emotional reactivity, the Emotion Reactivity Scale was utilized, capturing the intensity, duration, and threshold of emotional responses. Finally, to construct the peer network centrality metric, a sociometric nomination procedure was implemented within bounded school cohorts. Participants were asked to nominate up to five peers within their grade level with whom they most frequently interact and consider friends. From these sociometric matrices, eigenvector centrality scores were calculated for each adolescent, providing a robust mathematical representation of their social integration and influence within the broader peer network structure, moving beyond simple popularity to capture the quality of their social ties.

2.3. Data Analysis

The data analysis phase was heavily anchored in advanced machine learning techniques, specifically employing a gradient-boosting modeling approach to handle the anticipated nonlinear relationships and complex interactions among the psychological and sociometric predictors. Initially, data preprocessing was conducted to address missing values using multiple imputation by chained equations, ensuring that no valuable participant data was discarded unnecessarily. The dataset was subsequently randomly partitioned into a training set, comprising 80%of the data, and a hold-out testing set containing the remaining 20%. An Extreme Gradient Boosting algorithm was selected due to its superior execution speed and model performance. To optimize the model and prevent overfitting, a rigorous hyperparameter tuning process was executed using randomized search cross-validation with 5folds on the training data. The key hyperparameters adjusted included the learning rate, maximum tree depth, and the number of estimators. The predictive performance of the finalized gradient-boosting model was evaluated on the unseen testing dataset utilizing several standard metrics, primarily the coefficient of determination R^2, the root mean square error, and the mean absolute error. To interpret the model and understand the relative contribution of rejection sensitivity, intolerance of uncertainty, emotional reactivity, and peer network centrality, SHapley Additive exPlanations values were computed. This advanced game-theoretic approach allowed for the precise quantification of feature importance, revealing not only the magnitude of each predictor's impact on social anxiety but also the directionality of these complex effects across individual adolescent profiles. All statistical and machine learning analyses were executed using the Python programming language, leveraging the Scikit-learn and XGBoost libraries.

3. Findings and Results

The findings of the present study provide a comprehensive overview of the predictive utility of

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psychological and behavioral features in identifying non-suicidal self-injury among the sampled Georgian youth. Preliminary analyses were conducted to examine the demographic distribution and base rates of self-harming behaviors within the total sample of $N = 1248$participants. Based on the responses derived from the Inventory of Statements About Self-Injury, the sample was bifurcated into two distinct cohorts: individuals with a lifetime history of non-suicidal self-injury ($n = 349$, 28.0%) and individuals with no such history ($n = 899$, 72.0%). The mean age of the overall sample was $M = 21.43$years ($SD = 3.65$). The gender distribution indicated a higher proportion of females ($n = 761$, 61.0%) compared to males ($n = 475$, 38.1%) and those identifying as non-binary or other ($n = 12$, 0.9%). Chi-square analyses revealed a statistically significant association between gender and non-suicidal self-injury, with females exhibiting a higher prevalence of self-harming behaviors compared to their male counterparts ($\chi^2 = 14.52$, $p < .001$). However, independent samples t-tests indicated no significant age differences between the self-injury group ($M = 21.10$, $SD = 3.72$) and the non-injury group ($M = 21.56$, $SD = 3.61$), $t(1246) = 1.98$, $p = .051$. Furthermore, the analysis of daily screen time, captured via the online interaction composite measure, demonstrated that individuals in the self-injury cohort engaged in significantly more hours of daily social media use ($M = 5.8$, $SD = 2.1$) compared to the control group ($M = 3.9$, $SD = 1.8$), a distinction that was highly significant ($p < .001$). Table 1 delineates the primary demographic and clinical characteristics of the sample across the two targeted cohorts.

Table 1

Demographic and Clinical Characteristics of the Sample Stratified by NSSI History

Characteristic	Total Sample ($\boldsymbol{N = 1248}$)	NSSI Group ($\boldsymbol{n = 349}$)	Non-NSSI Group ($\boldsymbol{n = 899}$)	Test Statistic	$\boldsymbol{p}$-value
Age, $\boldsymbol{M(SD)}$	21.43(3.65)	21.10(3.72)	21.56(3.61)	$t = 1.98$	.051
Gender, $\boldsymbol{n}$(%)				$\chi^2 = 14.52$	<.001
Female	761(61.0%)	245(70.2%)	516(57.4%)		
Male	475(38.1%)	98(28.1%)	377(41.9%)		
Non-binary/Other	12(0.9%)	6(1.7%)	6(0.7%)		
Daily Screen Time (hours), $\boldsymbol{M(SD)}$	4.43(2.05)	5.82(2.14)	3.89(1.75)	$t = 16.45$	<.001

Subsequent analyses evaluated the descriptive statistics and group differences across all independent variables, encompassing the specific facets of emotion dysregulation, alexithymia, and impulsivity. Independent samples t-tests revealed that individuals with a history of non-suicidal self-injury scored significantly higher across almost all pathological dimensions compared to those without such a history. Most notably, the self-injury group exhibited profound elevations in the Difficulties in Emotion Regulation Scale total score, as well as critical subscales such as impulse control difficulties and limited access to emotion regulation strategies. Within the UPPS-P Impulsive Behavior Scale, negative urgency emerged as a highly distinguishing trait, significantly elevated in the self-injury cohort ($p < .001$). The Toronto Alexithymia Scale also indicated substantial group differences, particularly concerning difficulties identifying feelings, whereas externally oriented thinking showed a smaller, yet statistically significant, effect size. Regarding online social interaction patterns, the self-injury group reported significantly higher levels of passive social media engagement and a greater frequency of perceived negative emotional valence following online interactions. These detailed psychological and behavioral characteristics, including their respective mean values, standard deviations, and group comparison statistics, are comprehensively presented in Table 2.

Table 2

Descriptive Statistics and Group Comparisons for Psychological and Behavioral Variables

Variable	NSSI Group $\boldsymbol{M(SD)}$	Non-NSSI Group $\boldsymbol{M(SD)}$	$\boldsymbol{t}$-value	Cohen's $\boldsymbol{d}$
DERS: Total	108.45(22.14)	84.32(18.65)	19.64*	1.18
DERS: Impulse Control	18.92(5.31)	12.45(4.12)	23.08*	1.36
DERS: Strategies	22.34(6.10)	16.89(5.22)	15.74*	0.96
UPPS-P: Negative Urgency	34.56(7.88)	25.12(6.34)	22.15*	1.32

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UPPS-P: Lack of Premeditation	28.14(6.45)	24.05(5.88)	10.76*	0.66
TAS-20: Identifying Feelings	20.45(4.82)	14.33(4.15)	22.51*	1.36
TAS-20: Describing Feelings	16.78(4.11)	13.21(3.78)	14.62*	0.90
Passive Online Engagement	32.15(8.54)	22.45(7.12)	20.21*	1.23
Online Negative Valence	28.45(7.11)	18.34(6.05)	25.13*	1.53

Following the initial descriptive and comparative assessments, the primary objective of the study was realized through the implementation and evaluation of the machine-learning models. The dataset, partitioned into a seventy percent training set and a thirty percent unseen testing set, was utilized to train the Support Vector Machine, Random Forest, and eXtreme Gradient Boosting classifiers. The performance of these models on the testing set ($n = 375$) was rigorously evaluated. The eXtreme Gradient Boosting model demonstrated superior predictive capability across all evaluated metrics. Specifically, it achieved an overall accuracy of 88.5%, successfully identifying the complex, non-linear interactions among the psychological constructs. The area under the receiver operating characteristic curve for the eXtreme Gradient Boosting model was calculated at 0.93, indicating an outstanding ability to discriminate between individuals with and without a history of non-suicidal self-injury. The Random Forest model also performed robustly, yielding an accuracy of 86.4%and an area under the curve of 0.90, while the Support Vector Machine exhibited slightly lower, yet clinically relevant, predictive power with an accuracy of 82.1%and an area under the curve of 0.85. The superiority of the tree-based ensemble methods underscores the importance of non-linear algorithms in capturing the multidimensional etiology of self-harming behaviors. The complete comparative predictive performance metrics for all three evaluated machine-learning architectures are detailed in Table 3.

Table 3

Predictive Performance of Machine Learning Models on the Testing Set (n=375)

Model	Accuracy	Precision	Recall	F1-Score	AUC-ROC
eXtreme Gradient Boosting (XGBoost)	0.885	0.852	0.814	0.832	0.934
Random Forest (RF)	0.864	0.815	0.782	0.798	0.901
Support Vector Machine (SVM)	0.821	0.754	0.710	0.731	0.852

To ensure the algorithmic predictions were transparent and interpretable, SHapley Additive exPlanations values were calculated for the best-performing model, the eXtreme Gradient Boosting classifier. This feature importance analysis systematically quantified the contribution of each psychological and behavioral facet to the model's final output. The analysis revealed that negative emotional valence following online interactions was the single most powerful predictor of non-suicidal self-injury, followed closely by the impulse control difficulties facet of the Difficulties in Emotion Regulation Scale and the negative urgency facet of the UPPS-P Impulsive Behavior Scale. Difficulties identifying feelings from the Toronto Alexithymia Scale and high volumes of passive online engagement also ranked within the top five predictive features. The SHAP analysis highlighted that the intersection of intense negative affect triggered by digital interactions, combined with an inherent inability to control impulsive urges under emotional distress, formed the strongest predictive algorithmic pathway for self-harm. Conversely, variables such as externally oriented thinking and the lack of perseverance facet of impulsivity contributed marginally to the model's predictive power. The specific ranking, mean absolute SHAP values, and the directional impact of the top ten predictive features on the probability of non-suicidal self-injury are systematically cataloged in Table 4.

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Table 4

Top 10 Feature Importance Rankings Based on Mean Absolute SHAP Values (XGBoost Model)

Rank	Feature Name	Construct Category	Mean SHAP Value	Direction of Impact on NSSI Probability
1	Online Negative Valence	Online Interaction	0.842	Positive (Higher scores increase probability)
2	DERS: Impulse Control	Emotion Dysregulation	0.765	Positive
3	UPPS-P: Negative Urgency	Impulsivity	0.710	Positive
4	TAS-20: Identifying Feelings	Alexithymia	0.624	Positive
5	Passive Online Engagement	Online Interaction	0.589	Positive
6	DERS: Strategies	Emotion Dysregulation	0.432	Positive
7	Daily Screen Time	Online Interaction	0.385	Positive
8	TAS-20: Describing Feelings	Alexithymia	0.312	Positive
9	UPPS-P: Lack of Premeditation	Impulsivity	0.275	Positive
10	DERS: Nonacceptance	Emotion Dysregulation	0.210	Positive

4. Discussion

The current study aimed to utilize advanced machine-learning algorithms to predict non-suicidal self-injury based on emotion dysregulation, alexithymia, impulsivity, and online social interaction patterns. The findings revealed that the eXtreme Gradient Boosting model exhibited superior predictive performance, achieving an overall accuracy of 88.5%and an area under the receiver operating characteristic curve of 0.93. Consistent with broader epidemiological trends, our sample demonstrated a significant gender disparity, with females exhibiting a notably higher prevalence of non-suicidal self-injury (Boylan et al., 2025; Gonçalves et al., 2024). However, the most critical insights were derived from the feature importance analysis, which identified negative emotional valence following online interactions, impulse control difficulties, negative urgency, difficulties identifying feelings, and passive online engagement as the paramount predictors of self-harming behaviors. By successfully mapping the non-linear interactions among these psychological and behavioral constructs, the machine-learning architecture provides a robust framework for understanding the complex etiology of self-injury in modern youth.

The emergence of negative emotional valence during online interactions and passive social media engagement as top algorithmic predictors highlights the profound and escalating impact of the digital landscape on adolescent mental health. This finding aligns seamlessly with recent empirical evidence demonstrating that prolonged mobile phone dependence and maladaptive cyberspace behaviors are intimately and positively correlated with the frequency of self-injury (C. Wei et al., 2024). The digital environment uniquely facilitates continuous exposure to idealized social comparisons, cyberbullying, and negative emotional contagion, which systematically induce severe emotional insecurity and heightened social anxiety (Wang et al., 2023). When adolescents passively consume digital content that triggers feelings of inadequacy, isolation, or victimization, the resulting psychological toll can directly precipitate self-harm. This dynamic is particularly evident in educational environments where the psychological burden of cyberbullying is directly proportional to the incidence of non-suicidal self-injury (Ma et al., 2026). The algorithm's heavy reliance on these digital interaction variables underscores the absolute necessity of conceptualizing acute digital distress not merely as a background contextual factor, but as a primary, proximal trigger for self-injurious urges in contemporary youth populations.

Furthermore, impulse control difficulties, a core and highly destructive facet of emotion dysregulation, ranked as the second most influential predictor in our predictive model. This specific finding provides robust empirical support for the experiential avoidance model of self-injury, which posits that individuals resort to physical self-harm primarily when they lack the internal regulatory capacity to tolerate and manage overwhelming negative affect (Swerdlow et al., 2024). The fundamental inability to modulate intense emotional states acts as a critical, central pathway bridging various cognitive deficits to the actual physical execution of self-harm (Rachma & Hendrawan, 2025). In the absence of effective, adaptive emotion regulation strategies, individuals experience a compounding, synergistic effect of depressive symptoms and severe emotional reactivity, creating a self-reinforcing, cyclical loop of psychological distress and self-injury (He et al., 2025; Hu et al., 2024). Our predictive results confirm that when emotional pain becomes intolerable and an individual's regulatory self-efficacy is thoroughly compromised by familial or environmental stressors, self-

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injury is maladaptively employed as an immediate, albeit highly destructive, regulatory mechanism to forcefully down-regulate the nervous system (Gao et al., 2024; Wan et al., 2025).

The prominent predictive role of negative urgency—defined as the tendency to act rashly and impulsively under conditions of extreme emotional distress—further elucidates the precise behavioral mechanics of non-suicidal self-injury. Our algorithmic findings indicate that the presence of psychological distress or emotional dysregulation alone is often insufficient to trigger a self-harming event; it must be fatally coupled with an impulsive behavioral trait to cross the threshold into physical action. This echoes previous research demonstrating that high levels of impulsivity significantly exacerbate the risk of self-injury, particularly when the individual is triggered by acute, highly emotional interpersonal stressors such as severe parent-child conflicts (H. Wei et al., 2024). Furthermore, severe behavioral impulsivity and negative urgency are hallmark, defining features of emerging borderline personality pathology, a clinical condition that frequently presents with severe, recurrent self-injury alongside substance use and a highly unstable self-concept clarity (Boylan, 2024; Chung & Kaufman, 2024). The machine-learning models utilized in this study successfully captured this dangerous psychological intersection: an impulsive, uncontrollable drive that is executed specifically when the individual is overwhelmed by negative affect, effectively differentiating those who merely experience fleeting suicidal or self-injurious ideation from those who actually physically enact the behaviors (Ahn et al., 2025; Muehlenkamp et al., 2023).

Difficulties in identifying feelings, a primary and highly disruptive dimension of alexithymia, also emerged as a critical node within the predictive algorithmic pathway. Alexithymia fundamentally disrupts the cognitive processing, categorization, and articulation of emotional arousal, leaving vulnerable individuals completely unequipped to verbally navigate or communicate their internal psychological pain. This specific finding resonates deeply with extensive prior literature identifying alexithymia as a powerful chain-mediating variable that links early adverse experiences, such as childhood maltreatment, family dysfunction, and severe peer victimization, directly to subsequent acts of self-harm (Wang, 2024; Wen et al., 2024; Zheng et al., 2023). When young individuals cannot pinpoint, understand, or describe their internal states, they are systematically deprived of the ability to engage in healthy mentalization or seek appropriate, buffering social support, thereby drastically increasing their reliance on somatic self-punishment to externalize their invisible trauma (Lei et al., 2024; Yang, 2025). This severe cognitive-affective deficit effectively traps the adolescent in a perpetual state of unresolved physiological and psychological tension, where physical self-injury serves as the only accessible, tangible vocabulary for their suffering, even among those driven by unintended perfectionistic failures (Oh, 2024).

The overarching success of the eXtreme Gradient Boosting model in the present study highlights the inherent limitations of traditional, linear statistical methods in capturing the truly multidimensional, biopsychosocial etiology of self-injurious behaviors (Herdaetha et al., 2025). The genesis and maintenance of non-suicidal self-injury involve a highly complex, interconnected web of family dynamics, early maladaptive schemas, delinquent peer experiences, and underlying biological vulnerabilities, such as altered cardiac arousal and systemic inflammation (Anastasi, 2026; Nelson et al., 2023; Park & Yoo, 2024; Shi et al., 2023). By utilizing advanced ensemble machine-learning techniques, our study successfully quantified how distal, deeply ingrained vulnerabilities—such as alexithymic traits formed via early trauma or fractured family resilience—interact in complex, non-linear ways with proximal environmental triggers, like negative online interactions and state-based impulsivity, to produce a highly accurate probability of self-harm (Yuan et al., 2025; Zheng et al., 2025). Furthermore, this holistic, algorithmic approach allows for the identification of hidden psychopathological structures that traditional models often overlook, emphasizing the need for a paradigm shift in how we assess and predict self-injurious behaviors in highly vulnerable subgroups, such as transgender youth or those with severe sedentary behaviors (J. Guo et al., 2024; McArthur, 2026).

5. Conclusion

In conclusion, the present study demonstrates the profound utility of advanced machine-learning algorithms, particularly the eXtreme Gradient Boosting model, in accurately predicting non-suicidal self-injury by capturing the complex, non-linear interactions between psychological vulnerabilities and modern behavioral patterns. Achieving a robust predictive accuracy of 88.5%and an AUC-ROC of 0.934, the algorithmic analysis decisively identified the negative emotional valence of online interactions, severe

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impulse control deficits, and negative urgency as the paramount drivers of self-harming behavior. These findings fundamentally emphasize that acute digital distress and passive social media engagement can no longer be viewed merely as contextual background factors, but must be recognized as primary, proximal triggers that, when coupled with an individual's inability to regulate intense affect, culminate in physical self-injury. Ultimately, this research advocates for a paradigm shift in psychiatric risk assessment, urging mental health professionals to integrate digital behavioral metrics, alexithymia, and specific facets of impulsivity into routine screenings, thereby utilizing interpretable artificial intelligence to facilitate early identification and deliver highly targeted, personalized interventions for at-risk youth.

6. Limitations & Suggestions

Despite the robust predictive capabilities of the machine-learning models employed, several methodological limitations must be carefully considered when interpreting the findings of this study. First, the cross-sectional, retrospective nature of the study design precludes the establishment of definitive causal relationships between the predictive features—such as emotion dysregulation, alexithymia, and online interaction patterns—and the actual onset of non-suicidal self-injury. While the algorithms successfully identified powerful associative pathways, longitudinal data are fundamentally required to track how these psychological and behavioral variables fluctuate over time and temporally precede self-harming events. Second, the reliance on self-report questionnaires introduces the potential for recall bias and socially desirable responding, particularly given the highly sensitive and heavily stigmatized nature of self-injury. Participants may have underreported the frequency or severity of their behaviors, or inaccurately estimated their daily digital screen time and passive online engagement. Third, the study utilized a convenience sample recruited primarily from academic and community centers within a specific geographic region, which may limit the broad generalizability of the findings to clinical populations, younger pediatric cohorts, or individuals from vastly different cultural or socioeconomic backgrounds. Finally, while the models incorporated a wide array of psychological constructs, they did not include objective physiological markers, neuroimaging data, or real-time ecological momentary assessments, which could have provided a more comprehensive, multimodal prediction of acute self-injurious urges.

Future research should prioritize the implementation of longitudinal, prospective study designs to elucidate the temporal trajectories of the psychological and behavioral risk factors identified in this study. Utilizing ecological momentary assessment via smartphone applications or wearable biosensors could provide invaluable, high-resolution data on how real-time fluctuations in emotional valence, digital engagement, and autonomic arousal immediately precipitate impulsive acts of self-harm in daily life. Furthermore, future investigations should aim to expand the predictive feature space by integrating objective biological parameters, such as neuroendocrine markers, genetic predispositions, and systemic inflammatory profiles, alongside the established psychological constructs to create truly comprehensive, biopsychosocial machine-learning models. It is also imperative for subsequent studies to evaluate the predictive fairness and generalizability of these algorithms across more diverse, cross-cultural, and specifically clinical populations. Testing the efficacy of these models in predicting distinct topographies of self-injury, the transition from non-suicidal self-injury to active suicidal behavior, and individual responses to specific psychotherapeutic interventions will be critical next steps in advancing the clinical utility of artificial intelligence in psychiatric research.

The findings of this study translate into several critical suggestions for clinical practice and preventative interventions. Mental health professionals and educators must urgently incorporate routine, structured screenings for hidden psychological vulnerabilities, particularly targeting alexithymia and impulse control deficits, rather than solely assessing for overt depressive symptoms. Because negative emotional valence following online interactions emerged as a paramount predictor, clinicians must actively explore their patients' digital lives, assessing the quality, passivity, and emotional impact of their daily social media consumption. Psychoeducational programs and therapeutic interventions, such as Dialectical Behavior Therapy, should be heavily tailored to address digital distress tolerance, equipping adolescents with the specific regulatory skills required to navigate cyberbullying and online social comparisons without resorting to physical self-harm. Moreover, the integration of interpretable machine-learning tools into clinical decision support systems could vastly enhance risk stratification. By inputting patient data into these validated algorithms, clinicians could obtain individualized, objective

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risk profiles that highlight the specific cognitive or behavioral pathways driving a patient's self-injurious urges, thereby allowing for highly targeted, personalized, and timely therapeutic interventions before the behavior becomes a deeply entrenched coping mechanism.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed to this article.

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