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A Predictive ML Model of Self-Compassion, Shame-Proneness, and Emotion Regulation Strategies in Counseling Outcomes

Padma. Dolderer[1], Lilit. Hayrapetyan[1], Nathan C. Mathewson[2*], Andrea. Campostrini[3]

[1] Campbell Family Mental Health Institute, Centre for Addiction and Mental Health, Toronto, Canada
[2] Department of Educational and Counselling Psychology, McGill University, Montreal, QC H3A 1Y2, Canada
[3] Department of Psychology, Iowa State University, Ames, Iowa, US

*** Corresponding author email address**: nathan.c.mathewson@mcgill.ca

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A B S T R A C T

Objective: The primary objective of this study was to construct and validate a predictive machine learning model to determine the relative mathematical feature importance and prognostic capacity of baseline self-compassion, shame-proneness, and emotion regulation strategies on outpatient clinical counseling outcomes.

Methods and Materials: A prospective observational cohort design was utilized with $n = 452$ Canadian adult outpatients attending a minimum of 6 psychotherapy sessions. Baseline psychological variables were assessed using the 26-item Self-Compassion Scale (SCS), the Test of Self-Conscious Affect (TOSCA) shame-proneness subscale, and the 10-item Emotion Regulation Questionnaire (ERQ). Ultimate treatment outcomes were quantified at termination using the 34-item Clinical Outcomes in Routine Evaluation-Outcome Measure (CORE-OM). Data preprocessing incorporated K-Nearest Neighbors imputation for missing values and Z-score normalization ($z = \frac{x-\mu}{\sigma}$) for all psychometric features. Following dimensionality reduction, a Random Forest regressor was trained on an 80%training split ($n = 361$) employing 10-fold cross-validation for hyperparameter tuning, and subsequently evaluated on a 20%testing split ($n = 91$).

Findings: The optimized Random Forest model ($n\_estimators = 200$, $max\_depth = 10$) demonstrated robust predictive generalization on the independent testing set, accounting for 61%of the variance in counseling outcomes ($R^2 = .61$) with a Root Mean Square Error ($RMSE$) of 3.45and a Mean Absolute Percentage Error ($MAPE$) of 16.5%. The algorithmic extraction of Gini importance scores revealed a definitive predictive hierarchy: baseline self-compassion emerged as the paramount prognostic indicator (score $= .385$), followed sequentially by shame-proneness ($.312$), cognitive reappraisal ($.195$), and expressive suppression ($.108$).

Conclusion: Baseline self-compassion and shame-proneness serve as the most critical transdiagnostic determinants of psychotherapeutic success, demonstrating that the application of machine learning algorithms to intake assessments can revolutionize personalized prognostic modeling and clinical treatment planning.
Keywords: *Machine Learning; Self-Compassion; Shame-Proneness; Emotion Regulation*

1. Introduction

The efficacy of psychotherapeutic interventions and the accurate prediction of counseling outcomes remain central imperatives within the domains of clinical psychology and psychiatric research. Anticipating how a patient will respond to counseling before the intervention actually begins allows for highly personalized treatment planning, optimal resource allocation, and the prevention of therapeutic dropout. Over the past 2decades, psychological researchers have increasingly recognized that baseline psychological characteristics—specifically enduring transdiagnostic constructs rather than mere surface-level symptom severity—are the most robust predictors of psychotherapeutic success. Among these foundational psychometric elements, the synergistic triad of self-compassion, shame-proneness, and emotion regulation strategies has garnered unprecedented clinical attention. These underlying variables collectively orchestrate how individuals process severe psychological distress, internalize life adversity, and ultimately engage with the therapeutic process. Therefore, identifying the exact predictive hierarchy and complex interactive effects of these constructs utilizing advanced computational paradigms holds immense potential for revolutionizing contemporary counseling frameworks and elevating patient care standards.

Shame-proneness stands as a highly destructive, deeply internalized psychological barrier to therapeutic progress. Shame is a ubiquitous and intensely painful social emotion characterized by a global negative evaluation of the self. Unlike guilt, which focuses outward on a specific negative behavior, shame involves the pervasive perception that one's core identity is fundamentally flawed, inadequate, or entirely unworthy of human connection. The highly toxic nature of shame-proneness has been intimately linked to a myriad of severe psychological distress markers across highly diverse and profoundly vulnerable populations. For instance, trauma-related shame deeply exacerbates generalized psychological distress and actively inhibits recovery among individuals subjected to severe interpersonal violations, such as ongoing peer victimization and school-based bullying (Xu et al., 2024; Yaghoubi et al., 2021). Similarly, profound feelings of both external and internalized shame present critical barriers to psychological healing and cognitive flexibility for survivors of sexual violence, embedding a deep sense of unworthiness that clinical counseling must systematically dismantle (Bhuptani & Messman, 2021). Furthermore, the devastating psychological impact of shame is not strictly limited to interpersonal trauma; it also severely complicates the psychosocial trajectory of individuals navigating chronic and life-threatening medical illnesses. Elevated levels of profound shame and guilt have been identified as primary drivers of severe depressive symptomatology in patients grappling with complex oncological conditions, such as lung cancer (Siwik et al., 2022), as well as among those managing the profound historical stigmatization and social isolation associated with living with HIV/AIDS (Skelton et al., 2021).

Beyond acute trauma and chronic illness, internalized shame heavily dictates functional outcomes in everyday psychosocial contexts, severely impairing interpersonal relationships, identity formation, and behavioral regulation. Internalized shame fosters profound maladaptive self-concealment, driving individuals to hide their perceived internal flaws due to a paralyzing fear of both negative and positive external evaluation (Jeon & Park, 2023). This pervasive sense of personal inadequacy frequently mediates the highly destructive relationship between persistent cognitive rumination and severe interpersonal dissatisfaction (Sim & Choi, 2023). Additionally, it has been empirically modeled as a core sequential mediator driving severe relationship addiction and dependency among university and graduate student populations (Park & Lee, 2024). In the contemporary digital era, the profound burden of appearance-based and social-comparative shame has been radically amplified by technology. The relentless societal pursuit of idealized body norms and resulting appearance shame heavily undermines positive body image and holistic mental well-being (Mills et al., 2022). This algorithmic phenomenon is particularly evident on modern social media platforms, where appearance-focused content directly catalyzes acute appearance shame, severe anxiety, and highly maladaptive comparison processes among young women (Seekis & Kennedy, 2023), while broader social comparison tendencies critically fuel comprehensive social networking site addiction through the direct mediation of internalized shame (Kang & Jo, 2024). In rigorous academic and professional training environments, mental health shame

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poses a significant threat to systemic psychological stability, uniquely interacting with developing caregiver identities to severely undermine the well-being of educational students (Kotera et al., 2022). Furthermore, early onset shame during crucial developmental years continues to serve as a critical overarching vulnerability factor, with traditional predictive models successfully estimating adolescent shame based heavily on core emotional deficits (Moradmand et al., 2023).

In stark contrast to the destructive, self-isolating pathology of shame-proneness, self-compassion emerges as a profound protective mechanism and a critical psychological catalyst for positive therapeutic change. Rooted in traditional mindfulness and the acknowledgment of common humanity, self-compassion involves extending the exact same kindness, unwavering care, and non-judgmental understanding toward oneself during moments of perceived failure or suffering that one would naturally extend to a cherished friend. The systematic cultivation of self-compassion is widely recognized as a cornerstone for enhancing broad psychological flourishing, directly mediating positive psychosocial constructs like enduring hope among diverse college populations (Liu et al., 2024). Furthermore, self-compassion acts as a foundational cognitive pillar for students' overall subjective well-being, securely anchoring highly adaptive attachment styles and preserving a high quality of life within intensely stressful academic and competitive environments (Rezagholiyan et al., 2025).

The highly robust buffering effect of self-compassion against severe psychological distress has been rigorously validated across an extensive array of highly demanding clinical contexts and vulnerable socio-demographic cohorts. Among post-9/11 military veterans, baseline self-compassion functions as a paramount psychological predictor across multiple, highly distinct dimensions of overall quality of life, effectively mitigating the deep-seated psychological scars of intensive combat deployment and fostering long-term reintegration (Wild et al., 2025). In the exceptionally demanding realm of unpaid caregiving, self-compassion-focused therapeutic interventions have proven highly efficacious in permanently alleviating debilitating caregiver burden, severe major depression, and profound emotional dysregulation among individuals caring full-time for elderly family members suffering from advanced Alzheimer's disease (Sadeghi et al., 2024). The expansive protective umbrella of self-compassion also extends seamlessly to highly specific female medical populations, profoundly mitigating acute sexual distress and actively buffering the extensive psychological trauma of drastically altered body image in women navigating the difficult aftermath of radical mastectomy surgeries (Rasouli et al., 2024). Similarly, during global societal crises, high trait self-compassion significantly influenced and dramatically reduced the immense baseline burden of generalized anxiety, clinical depression, and severe social anxiety experienced by highly vulnerable perinatal women throughout the height of the COVID-19 pandemic (Cutajar & Bates, 2025).

While shame-proneness and self-compassion represent powerful, opposing internal valences of self-relation, emotion regulation strategies dictate the actual mechanical pathways and cognitive operations through which these internal relational states are processed, modulated, and behaviorally manifested in daily life. Emotion regulation refers to the highly complex intrinsic and extrinsic psychological processes by which individuals influence exactly which emotions they have, precisely when they have them, and exactly how they intimately experience and outwardly express these feelings. The adaptive capacity to effectively regulate emotional responses is inherently vital for establishing and maintaining baseline mental health, particularly during highly volatile transitional developmental phases; specifically, self-compassion has been shown to actively moderate the critical, life-altering relationship between functional emotion regulation strategies and broader longitudinal mental health trajectories in adolescents (Nguyen et al., 2025). Similarly, emotion regulation operates directly in tandem with self-compassion to foster essential psychological mental stability and emotional maturity in high school students (Syafitri et al., 2024), while simultaneously serving as a highly crucial mediating cognitive pathway definitively linking overarching psychological resilience to the functional daily mental health of adult working professionals, such as college educators navigating high-stress occupational environments (Rehman et al., 2024).

Conversely, chronic difficulties in emotion regulation, commonly identified as explicit emotional dysregulation, fundamentally bridge the dangerous psychological gap between underlying cognitive vulnerabilities and the onset of overt clinical psychiatric symptomatology. Dysfunctional emotional processing significantly and powerfully mediates the perilous cognitive transition from harsh internal self-criticism to overt, clinically diagnosable depressive symptoms (Vidal et al., 2024). It also heavily fuels systemic, trait-level psychological inflexibility, forming a dangerous serial mediating chain with deficits in mindfulness and low

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self-compassion that ultimately culminates in severe, generalized anxiety among broad adult populations (Büyüköksüz & Kayaalp-pehlivan, 2025). The highly destructive interaction between early maladaptive schemas, such as fundamentally insecure interpersonal attachment styles, and the profound experience of chronic loneliness is deeply mediated by the systemic failure to regulate emotions effectively alongside a critical deficit in baseline self-compassion (Ohadi Haeri et al., 2024). Recognizing this highly critical pathological mechanism, modern clinical counseling interventions explicitly target these exact self-regulatory pathways to induce therapeutic change. Targeted cognitive and emotional training programs strictly focused on teaching self-compassion alongside adaptive emotion regulation have successfully and permanently enhanced intrinsic motivational self-regulation and highly adaptive social functioning in severely anxious youth populations (Osareh et al., 2024). Likewise, targeted emotion regulation skills training has been proven to be just as effective as traditional mindfulness-based cognitive behavioral therapies in drastically reducing perceived physiological stress and directly fostering internal self-compassion in patients suffering from highly chronic psychosomatic conditions, such as irritable bowel syndrome (Omidi et al., 2024).

The intricate, highly multidimensional interplay between baseline shame-proneness, inherent self-compassion, and habitual emotion regulation forms a profoundly complex web of clinical causality that fundamentally determines psychotherapeutic success and ultimate counseling outcomes. Traditional statistical methodologies, which predominantly rely on basic linear regressions and highly restricted structural equation modeling, often fail catastrophically to capture the highly non-linear, dynamically interacting, and deeply hierarchical nature of these specific psychological constructs when attempting to predict real-world clinical counseling outcomes. To accurately and comprehensively map the complete psychological topography of a new patient at baseline and reliably forecast their unique longitudinal therapeutic trajectory, behavioral researchers must aggressively pivot toward highly advanced, data-driven computational techniques. Modern machine learning algorithms, particularly complex supervised ensemble decision trees, offer an entirely unprecedented capacity to process massive, high-dimensional psychometric datasets, explicitly identifying the complex, hidden feature importance hierarchies that traditional linear models inherently obscure. By algorithmically evaluating exactly how adaptive psychological strategies, such as cognitive reappraisal and high self-compassion, quantitatively interact with and mathematically neutralize deeply maladaptive internal vulnerabilities, such as expressive suppression and intense internalized shame, highly sophisticated machine learning methodologies can generate vastly more accurate and clinically actionable predictive tools for mental health practitioners.

Despite the overwhelming volume of empirical evidence individually linking self-compassion, shame, and emotion regulation to overarching mental health, there currently remains a highly critical dearth of quantitative research formally utilizing advanced artificial intelligence and machine learning to synthesize these specific variables into a unified, mathematically rigorous predictive prognostic model for general outpatient counseling. Bridging this specific methodological gap is absolutely essential for advancing the modern era of precision, personalized psychotherapy, wherein complex clinical interventions can be precisely and algorithmically tailored to a patient's completely unique baseline psychological and emotional profile. Therefore, the primary aim of this study was to construct, thoroughly train, and rigorously validate a highly accurate predictive machine learning model to explicitly determine the relative mathematical feature importance and precise predictive prognostic capacity of baseline self-compassion, shame-proneness, and diverse emotion regulation strategies on ultimate clinical counseling outcomes.

2. Methods and Materials

2.1. Study Design and Participants

This research utilized a prospective observational cohort design to investigate the predictive utility of specific psychological constructs on counseling outcomes using advanced machine learning algorithms. The study population comprised adults seeking outpatient psychotherapy at various community mental health centers and university counseling clinics across Canada. A purposive sampling strategy was employed to recruit eligible participants over a period of eighteen months. Informed consent was obtained electronically from all individuals prior to their inclusion in the clinical study. The final analytical sample consisted of exactly 452Canadian adults who successfully completed both the baseline psychological assessments and the comprehensive post-treatment outcome evaluations. To be included in the dataset, participants had

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to be at least 18years of age, fluent in the English language, and actively engaged in a minimum of 6sessions of individual counseling. Individuals presenting with active psychosis, acute suicidality requiring immediate hospitalization, or severe cognitive impairments that would preclude the accurate completion of self-report measures were systematically excluded from the analytical sample to ensure the reliability of the psychometric data. The demographic composition of the 452participants reflected a highly diverse cross-section of the Canadian treatment-seeking population, ensuring adequate variance and representativeness for the robust training and testing of the predictive computational models.

2.2. Measures

The empirical data required for building this predictive model were gathered utilizing a comprehensive battery of validated self-report psychometric instruments, which were administered digitally prior to the commencement of the first counseling session, alongside a standardized outcome measure administered at the clinical conclusion of the treatment protocol. Self-compassion was quantified using the Self-Compassion Scale, a widely utilized and rigorously validated instrument comprising 26items that assess primary components such as self-kindness, common humanity, and mindfulness on a 5-point Likert scale. Shame-proneness was measured via the Test of Self-Conscious Affect, specifically focusing on the core shame-proneness subscale, which presents respondents with brief, relatable scenarios and asks them to rate the absolute likelihood of experiencing shame-based reactions on a 5-point scale. Emotion regulation strategies were thoroughly evaluated using the Emotion Regulation Questionnaire, a 10-item inventory designed to capture the habitual use of cognitive reappraisal and expressive suppression, with responses scored on a 7-point scale ranging from strongly disagree to strongly agree. Finally, to establish the definitive target variable for the supervised machine learning model, counseling outcomes were operationalized and measured using the Clinical Outcomes in Routine Evaluation-Outcome Measure. This extensive 34-item questionnaire meticulously assesses global psychological distress spanning subjective well-being, reported problems or symptoms, general life functioning, and risk to self or others. This target measure was administered upon the formal termination of the counseling process to accurately determine the aggregate clinical improvement and establish the predictive target value for the algorithm.

2.3. Data analysis

The computational phase of the research employed sophisticated machine learning techniques to construct, tune, and validate a predictive model of counseling outcomes based entirely on the baseline psychological metrics. Initially, data preprocessing was conducted to handle missing values utilizing a K-Nearest Neighbors imputation strategy, ensuring the maximum preservation of the dataset's integrity without carelessly discarding valuable patient records. The continuous psychometric variables were subsequently standardized using a Z-score normalization process to ensure all input features shared a common scale, where the mean was centered at 0and the standard deviation was scaled to 1, denoted mathematically as $z = \frac{x-\mu}{\sigma}$. To identify the most salient predictors among the various self-compassion, shame-proneness, and emotion regulation facets, a recursive feature elimination protocol was implemented to reduce dimensionality and mitigate the risk of multicollinearity. The core predictive modeling was executed utilizing an ensemble learning approach, specifically a Random Forest regressor, chosen for its inherent robustness against overfitting and its superior capacity to capture complex, non-linear interactions between the measured psychological constructs. The complete dataset of 452participants was randomly partitioned into a training set comprising 80%of the data and a hold-out testing set containing the remaining 20%. Model hyperparameter tuning, including tree depth and estimator count, was optimized through a rigorous 10-fold cross-validation procedure on the training set. The ultimate predictive performance of the model was evaluated on the unseen testing data using standard regression metrics, primarily the Root Mean Square Error, denoted mathematically as $RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$, and the coefficient of determination, represented as R^2. Furthermore, Gini importance scores were systematically extracted from the trained ensemble model to explicitly delineate the relative hierarchical contribution of self-compassion, shame-proneness, and emotion regulation strategies in accurately forecasting the trajectory of therapeutic outcomes.

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3. Findings and Results

The findings of this study elucidate the predictive capacity of self-compassion, shame-proneness, and emotion regulation strategies on counseling outcomes using a machine learning framework. Preliminary data screening confirmed that the dataset of 452participants was free from severe outliers and met the fundamental assumptions required for the specified analytical techniques. Demographic analysis revealed that the participants had a mean age of 34.5years ($SD = 11.2$), with the sample identifying predominantly as female (68.4%), followed by male (29.2%), and non-binary or other gender identities (2.4%). The average duration of counseling was 12.4sessions ($SD = 3.6$). Table 1 presents the descriptive statistics and bivariate Pearson correlation coefficients for the primary psychological constructs and the target clinical outcome variable, the Clinical Outcomes in Routine Evaluation-Outcome Measure (CORE-OM) score at termination. The correlational matrix indicates that baseline shame-proneness and expressive suppression were significantly and positively correlated with higher psychological distress at termination, whereas self-compassion and cognitive reappraisal demonstrated strong negative correlations with the final CORE-OM scores, suggesting their protective role in therapeutic recovery.

Table 1

Descriptive Statistics and Bivariate Correlations of Primary Study Variables

Variable	M	SD	1	2	3	4	5
1. Self-Compassion	3.12	0.85	–				
2. Shame-Proneness	4.25	1.10	$-.54^{**}$	–			
3. Cognitive Reappraisal	4.88	1.24	$.41^{**}$	$-.32^{**}$	–		
4. Expressive Suppression	3.95	1.31	$-.28^{**}$	$.38^{**}$	$-.15^{*}$	–	
5. CORE-OM (Outcome)	12.45	5.62	$-.62^{**}$	$.58^{**}$	$-.47^{**}$	$.35^{**}$	–

Following the descriptive analysis, the predictive modeling phase was executed utilizing the Random Forest regressor. The hyperparameter tuning process, conducted via a rigorous 10-fold cross-validation grid search on the training dataset ($n = 361$), identified the optimal architectural parameters for the ensemble model. The tuning process systematically evaluated various combinations of decision trees and depth constraints to minimize the mean squared error while preventing algorithmic overfitting. The final selected parameters, which yielded the most robust predictive performance across the cross-validation folds, are detailed in Table 2. These optimized parameters were subsequently locked in for the final model training and evaluation on the hold-out testing set.

Table 2

Hyperparameter Tuning Results for the Random Forest Regressor

Hyperparameter	Evaluated Range/Options	Optimal Selected Value
Number of Estimators ($n\_estimators$)	50,100,200,500	200
Maximum Depth (max_depth)	5,10,20,None	10
Minimum Samples Split ($min\_samples\_split$)	2,5,10	5
Minimum Samples Leaf ($min\_samples\_leaf$)	1,2,4	2
Maximum Features ($max\_features$)	auto, sqrt, log2	sqrt

The overall predictive performance of the optimized Random Forest model was evaluated using the unseen hold-out testing dataset ($n = 91$). The model demonstrated strong predictive efficacy, successfully forecasting a significant proportion of the variance in the final counseling outcomes based solely on the baseline psychological assessments. Table 3 outlines the primary performance metrics, including the Root Mean Square Error ($RMSE$), Mean Absolute Error (MAE), and the Coefficient of Determination (R^2), for both the training and testing phases. The minimal degradation in performance metrics between the training and testing sets confirms that the model generalizes exceptionally well to novel patient data and did not suffer from excessive overfitting. The testing set $R^2$of $.61$indicates that approximately 61%of the variance in post-treatment psychological distress can be accurately predicted by the patient's initial levels of self-compassion, shame-proneness, and emotion regulation strategies.

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Table 3

Machine Learning Model Performance Metrics

Metric	Training Set ($\boldsymbol{n = 361}$)	Testing Set ($\boldsymbol{n = 91}$)
Root Mean Square Error ($\boldsymbol{RMSE}$)	3.12	3.45
Mean Absolute Error ($\boldsymbol{MAE}$)	2.41	2.68
Coefficient of Determination ($\boldsymbol{R^2}$)	.68	.61
Mean Absolute Percentage Error ($\boldsymbol{MAPE}$)	14.2%	16.5%

To achieve the primary research objective of identifying the most critical predictors of counseling outcomes, feature importance scores were extracted from the trained Random Forest model. The Gini importance scores, which quantify the total decrease in node impurity averaged across all decision trees in the ensemble, highlight the relative contribution of each psychological construct. Table 4 presents the normalized feature importance scores for the predictor variables. The algorithmic analysis identified baseline self-compassion as the paramount predictor of counseling outcomes, accounting for the highest feature importance score. This was closely followed by shame-proneness, which also emerged as a highly significant determinant of the therapeutic trajectory. Interestingly, within the domain of emotion regulation, cognitive reappraisal demonstrated substantially greater predictive utility compared to expressive suppression, suggesting that the presence of adaptive cognitive reframing skills at the onset of therapy is a vital prognostic indicator for ultimate treatment success.

Table 4

Relative Feature Importance Scores (Gini Importance) from the Random Forest Model

Predictor Variable	Gini Importance Score	Relative Rank
Self-Compassion	.385	1
Shame-Proneness	.312	2
Cognitive Reappraisal	.195	3
Expressive Suppression	.108	4

4. Discussion

The primary objective of the present study was to utilize advanced machine learning algorithms to elucidate the predictive capacity and hierarchical importance of baseline self-compassion, shame-proneness, and specific emotion regulation strategies on ultimate counseling outcomes. The application of a Random Forest regressor to our dataset of 452outpatient adults yielded a highly robust predictive model, successfully forecasting a substantial 61%of the variance in post-treatment psychological distress, denoted as $R^2 = .61$. The algorithmic extraction of feature importance scores revealed a definitive hierarchy among the psychological predictors: baseline self-compassion emerged as the paramount prognostic indicator with the highest Gini importance score of .385, closely followed by shame-proneness at .312. Within the domain of emotion regulation, cognitive reappraisal demonstrated significantly greater predictive utility (importance score of .195) compared to expressive suppression (importance score of .108). Furthermore, our correlational analyses indicated that high initial levels of self-compassion and cognitive reappraisal were strongly associated with lower psychological distress at termination, whereas elevated baseline shame-proneness and habitual expressive suppression accurately predicted higher enduring distress and poorer therapeutic responses.

The algorithmic identification of self-compassion as the single most critical baseline predictor of successful counseling outcomes aligns profoundly with an expanding corpus of contemporary clinical literature emphasizing its extensive protective mechanisms. Self-compassion inherently equips individuals with a non-judgmental, stabilizing internal framework that actively buffers against the acute emotional turbulence inevitably encountered during the psychotherapeutic process. By extending kindness toward oneself during moments of perceived failure, patients with high baseline self-compassion are fundamentally more resilient to the distress of unpacking clinical trauma. This finding is heavily supported by recent empirical investigations demonstrating that self-compassion

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acts as a foundational cognitive pillar for broader psychological flourishing and subjective well-being (Liu et al., 2024; Rezagholiyan et al., 2025). Furthermore, the robust predictive power of self-compassion observed in our model reflects its well-documented capacity to mitigate severe psychological distress across highly vulnerable populations, effectively serving as a primary determinant of treatment success and quality of life for military veterans (Wild et al., 2025), heavily burdened caregivers (Sadeghi et al., 2024), and perinatal women facing acute global crises (Cutajar & Bates, 2025). Because psychotherapy intrinsically requires patients to confront deeply uncomfortable realities and personal vulnerabilities, individuals who enter treatment already possessing a modicum of self-compassion are theoretically far less likely to experience treatment-interfering defensive reactions, thereby accelerating the cognitive restructuring necessary for lasting clinical improvement.

Conversely, our model's identification of shame-proneness as the second most powerful predictor—and a robust indicator of poor therapeutic outcomes—highlights the highly destructive, treatment-resistant nature of internalized shame. The strong positive correlation between baseline shame and high termination distress scores suggests that patients who enter counseling with a pervasive sense of core defectiveness encounter substantial barriers to therapeutic alliance and cognitive flexibility. This algorithmic finding perfectly mirrors extensive traditional research explicitly linking shame to severe, enduring psychiatric symptomatology and profound interpersonal dysfunction. Pervasive shame-proneness actively fuels maladaptive self-concealment, severely hindering the open self-disclosure that is absolutely necessary for efficacious counseling (Jeon & Park, 2023). Furthermore, shame fundamentally complicates and prolongs the psychological recovery trajectory for individuals navigating complex trauma, such as survivors of sexual violence (Bhuptani & Messman, 2021) and victims of chronic peer bullying (Xu et al., 2024; Yaghoubi et al., 2021). The prognostic severity of shame captured by our Random Forest model is also theoretically consistent with its recognized role as a core driver of profound clinical depression in patients grappling with chronic illness (Siwik et al., 2022; Skelton et al., 2021) and its insidious mediation of deep-seated behavioral addictions and interpersonal relationship dysfunctions (Park & Lee, 2024; Sim & Choi, 2023). In essence, patients highly prone to shame inherently interpret psychotherapeutic interventions—especially initial diagnostic assessments or gentle clinical challenges—as confirmations of their ultimate unworthiness, thereby drastically elevating the risk of therapeutic dropout and stalling clinical progress.

The differential predictive utility observed between the two specific emotion regulation strategies provides critical insight into the mechanical pathways of psychological recovery. The machine learning model explicitly ranked cognitive reappraisal as a vastly superior and highly beneficial predictor compared to expressive suppression. This mathematical delineation supports the theoretical consensus that adaptive cognitive reframing is essential for processing the therapeutic insights generated during counseling. Cognitive reappraisal directly facilitates the active neutralization of negative affect, functioning as a vital moderator that bridges underlying cognitive vulnerabilities to actual positive behavioral mental health outcomes, particularly in developing youth and stressed adult populations (Nguyen et al., 2025; Rehman et al., 2024; Syafitri et al., 2024). Conversely, expressive suppression, which involves the conscious inhibition of emotional expression, consistently proved to be maladaptive in our dataset, serving as a minor but significant predictor of elevated termination distress. Habitual suppression actively prevents the emotional processing required in therapy, thereby cementing psychological inflexibility and directly contributing to severe emotional dysregulation. This algorithmic finding is heavily corroborated by recent literature demonstrating that explicit emotional dysregulation critically mediates the dangerous transition from mere internal self-criticism to overt, diagnosable depressive and anxiety disorders (Büyüköksüz & Kayaalp-pehlivan, 2025; Vidal et al., 2024). It also perfectly explains why contemporary clinical interventions that explicitly focus on replacing expressive suppression with adaptive emotional regulation training consistently yield profound reductions in perceived stress and chronic physiological symptomatology (Omidi et al., 2024; Osareh et al., 2024).

Ultimately, our findings suggest a complex, highly interactive psychological triad where baseline self-compassion serves as the primary engine for therapeutic change, cognitive reappraisal acts as the functional steering mechanism, and shame-proneness functions as the primary resistance or brake. High self-compassion intrinsically affords the emotional safety required to deploy cognitive reappraisal, which in turn systematically dismantles the irrational, core defectiveness beliefs inherent in shame-proneness. When patients severely lack these regulatory and compassionate internal resources at the onset of counseling,

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as evidenced by chronic loneliness and fundamentally insecure attachment schemas (Ohadi Haeri et al., 2024), they are significantly predisposed to therapeutic stagnation. Furthermore, the pervasive modern exacerbation of shame via digital social comparisons and idealized appearance norms makes the presence of baseline self-compassion even more statistically critical for modern treatment-seeking populations (Kang & Jo, 2024; Mills et al., 2022; Seekis & Kennedy, 2023). By utilizing an ensemble machine learning approach, this study definitively quantifies exactly how these specific variables interact to dictate the ultimate trajectory of clinical counseling, securely placing self-compassion and targeted emotional regulation at the absolute forefront of prognostic psychiatric indicators (Moradmand et al., 2023).

5. Conclusion

The present investigation successfully constructed and validated a highly efficacious machine learning model capable of predicting clinical counseling outcomes based on baseline psychometric profiles. By leveraging the advanced computational capacity of a Random Forest regressor, the study definitively established that a patient's initial levels of self-compassion, shame-proneness, and specific emotion regulation strategies account for a substantial majority of the variance in their ultimate post-treatment psychological distress. Crucially, algorithmic feature importance analyses revealed a strict hierarchical prognostic value among these constructs, identifying self-compassion as the single most powerful predictor of therapeutic success, followed closely by the destructive presence of shame-proneness. Within the domain of emotional processing, adaptive cognitive reappraisal demonstrated significantly greater predictive utility than maladaptive expressive suppression. These algorithmic findings provide unequivocal, data-driven evidence that enduring, transdiagnostic psychological traits fundamentally govern a patient's capacity to engage with and benefit from outpatient psychotherapy. Ultimately, this research underscores the immense potential of integrating artificial intelligence into clinical psychology, offering a robust mathematical framework for forecasting treatment trajectories and validating the critical importance of intrinsic self-compassion in navigating the difficult process of psychological healing.

6. Limitations & Suggestions

Despite the methodological rigor and high predictive accuracy of the machine learning model, several inherent limitations must be acknowledged when interpreting the results of this study. First, the analytical sample was restricted exclusively to English-speaking adults residing in Canada, which inherently limits the broader cross-cultural generalizability of the findings, as the psychosocial manifestations of shame and self-compassion can vary significantly across different global cultural paradigms. Second, the entirety of the psychometric data utilized to train the computational algorithms was derived from self-report questionnaires, which are pervasively susceptible to systemic biases, including social desirability, retrospective recall errors, and a patient's potentially compromised baseline level of self-awareness. Third, while machine learning excels at identifying complex predictive patterns and non-linear associations, the fundamentally observational nature of the research design precludes the establishment of definitive causal relationships between the predictor variables and the ultimate clinical outcomes. Furthermore, counseling success was operationalized using a single, albeit comprehensive, global distress metric at the point of treatment termination, which may not fully capture the highly nuanced, multidimensional, and frequently non-linear realities of long-term psychotherapeutic recovery.

Future academic inquiries should build upon these foundational findings by adopting highly granular, longitudinal study designs that meticulously track dynamic fluctuations in self-compassion, shame, and emotion regulation on a session-by-session basis. Incorporating intensive longitudinal data would allow for the training of even more sophisticated recurrent neural networks capable of predicting exactly when a patient is at the highest risk for acute therapeutic rupture or imminent dropout. Additionally, future computational research must actively expand beyond self-report psychometrics by integrating objective, multimodal data streams, including continuous biometric stress indicators, natural language processing of transcribed therapy sessions, and real-time behavioral ecological momentary assessments. It is also imperative that subsequent predictive modeling efforts systematically validate these specific feature importance hierarchies across vastly more diverse demographic cohorts, specifically testing the algorithms on culturally distinct international populations and explicitly defined clinical diagnostic subgroups, such as individuals with severe personality

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disorders or treatment-resistant depression. Finally, experimental research should rigorously investigate whether targeted, pre-treatment psychoeducational modules designed explicitly to elevate baseline self-compassion can successfully alter the computational risk profile and artificially improve the ultimate trajectory of the counseling outcomes.

The definitive hierarchical predictive findings generated by this computational model offer highly actionable, immediate directives for modern clinical practice and psychological treatment planning. Mental health practitioners and intake coordinators should systematically mandate the explicit assessment of self-compassion and shame-proneness during the very first clinical encounter, treating these specific metrics as vital prognostic signs rather than secondary contextual variables. For patients whose baseline assessments flag them as highly shame-prone and severely lacking in self-compassion, clinicians must strategically delay traditional, emotionally intensive trauma-processing interventions. Instead, the initial phase of psychotherapy should be entirely reoriented toward foundational skills-building, explicitly utilizing compassion-focused therapy techniques and rigorous cognitive reappraisal training to construct the necessary emotional scaffolding required to withstand deeper clinical exploration. Furthermore, community mental health clinics can actively utilize similar predictive algorithms to achieve highly optimal resource allocation, selectively matching high-risk, low-compassion patients with specialized, highly experienced senior clinicians, or proactively approving extended counseling session limits to accommodate the significantly slower, more fragile therapeutic trajectory mathematically predicted by their initial psychometric profile.

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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 in this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

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