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A Random Forest Analysis Predicting Intergenerational Attachment Insecurity from Parental Reflective Functioning and Childhood Trauma Phenotypes

Miriam. Hochberger[1], Andrei. Dumitrescu[2*], Lucía. Bentancor[3]

[1] Department of Developmental Psychology, University of Graz, Graz, Austria
[2] Department of Applied Psychology, University of Bucharest, Bucharest, Romania
[3] Department of Psychology, University of the Republic, Montevideo, Uruguay

*** Corresponding author email address**: andrei.dumitrescu@unibuc.ro

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A B S T R A C T

Objective: The primary objective of this study was to utilize a Random Forest machine learning approach to predict the variance in intergenerational attachment insecurity using distinct childhood trauma phenotypes and multidimensional facets of parental reflective functioning.

Methods and Materials: A cross-sectional, correlational, and predictive design was employed with a community sample of $N = 485$Romanian primary caregivers of children aged 1to 7years. Data were collected via self-report instruments, including the Childhood Trauma Questionnaire (CTQ) to assess five trauma phenotypes, the Parental Reflective Functioning Questionnaire (PRFQ) to evaluate mentalizing dimensions, and the Experiences in Close Relationships-Revised (ECR-R) alongside the Child Attachment Questionnaire (CAQ) to index intergenerational attachment insecurity. During data preprocessing, missing values were resolved using K-nearest neighbors imputation, and independent variables were subjected to Z-score standardization. A Random Forest regression algorithm was trained on an 80%data split and evaluated on the remaining 20%testing set, with feature importance mathematically derived via the mean decrease in node impurity.

Findings: Descriptive statistics indicated that emotional neglect was the most frequently endorsed historical trauma phenotype ($M = 11.42$, $SD = 3.85$), while participants generally demonstrated moderate to high levels of interest and curiosity in their children's mental states ($M = 24.15$, $SD = 4.02$). The standardized outcome variable of intergenerational attachment insecurity ($M = 0.00$, $SD = 1.00$) showed significant positive bivariate correlations with emotional abuse ($r = .46$, $p < .001$) and emotional neglect ($r = .42$, $p < .001$). Feature importance extraction from the Random Forest model identified emotional neglect and emotional abuse as the most powerful distal trauma predictors. Among proximal psychological mechanisms, maladaptive pre-mentalizing modes emerged as the strongest positive predictor of insecurity ($r = .51$, $p < .001$), whereas adaptive reflective capacities—specifically interest and curiosity ($r = -.38$, $p < .001$) and certainty about mental states ($r = -.32$, $p < .001$)—functioned as significant negative predictors.

Conclusion: Advanced machine learning successfully mapped the non-linear pathways of relational risk, revealing that historical emotional maltreatment and current pre-mentalizing deficits are the primary drivers of intergenerational attachment insecurity, while adaptive reflective functioning serves as a crucial protective buffer.

Keywords: *Intergenerational Transmission, Attachment Insecurity, Childhood Trauma, Parental Reflective Functioning*

1. Introduction

The transition to parenthood constitutes a profound developmental milestone that systematically reorganizes an individual's psychological landscape, heavily activating pre-existing internal working models of attachment (Borelli et al., 2020). During this sensitive period, the cognitive and emotional frameworks that caregivers developed during their own childhoods are brought to the forefront, directly influencing how they perceive, interpret, and respond to their infant's distress signals. The quality of these early relational experiences dictates the structural integrity of the parent-child bond, determining whether the subsequent relationship will be characterized by security or insecurity. When parents harbor unresolved attachment anxieties or avoidant tendencies, they are significantly more vulnerable to experiencing elevated levels of parental stress, which is often further compounded by their own deficient self-awareness and the innate temperamental difficulties of the child (Yaakov et al., 2023). Consequently, the intergenerational transmission of attachment insecurity emerges as a critical developmental phenomenon, wherein maladaptive relational patterns are passed from one generation to the next. This transmission is not merely a behavioral replication but a complex psychosocial process where mechanisms such as collective and parental self-efficacy are systematically undermined by the caregiver's underlying attachment deficits (Lavenda & Hertz, 2024). Disruptions in this primary dyadic system lay the foundational groundwork for a myriad of developmental psychopathology, necessitating a rigorous examination of the distal historical factors and proximal psychological mechanisms that drive this intergenerational cycle.

Among the most deleterious distal predictors of intergenerational attachment insecurity is the caregiver's own history of childhood maltreatment. Childhood trauma is not a monolithic construct but rather a heterogeneous matrix of adverse experiences, typically categorized into distinct phenotypes, including emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect. Each of these phenotypes differentially alters the neurobiological and psychological architecture of the developing brain, casting a long shadow that inevitably disrupts subsequent caregiving capacities (Wang, 2022). When individuals who have survived significant childhood maltreatment transition into the parental role, they often suffer from profound deficits in emotion regulation and are highly susceptible to parental burnout, conditions that severely compromise their ability to foster a secure attachment with their offspring (Ensanimehr et al., 2024). The trauma fundamentally shatters their epistemic trust—the capacity to trust the authenticity and relevance of interpersonal communication—which intricately intertwines with subsequent borderline personality organization, insecure adult attachment, and widespread mentalizing deficits (Knapen et al., 2025). The sequelae of these traumatic phenotypes frequently include chronic depressive symptomatology and a propensity for non-suicidal self-injury, both of which are significantly mediated by collapses in the capacity to conceptualize mental states (Yang, 2025). Furthermore, empirical observations of parents exhibiting borderline personality traits underscore that severe trauma histories intrinsically diminish general psychological health, drastically elevate parenting stress, and erode fundamental parental competence (Steele et al., 2020). Complex traumatic trajectories, particularly those culminating in clinical post-traumatic stress, uniquely intersect with the transition to parenthood, disrupting the normative pathways through which adult attachment security traditionally scaffolds the emergence of adaptive caregiving (Ensink et al., 2023).

To comprehend how historical trauma crystallizes into present caregiving dysfunction, developmental psychology has increasingly focused on the proximal mechanism of Parental Reflective Functioning (PRF). Conceptually rooted in broader mentalization theory, PRF is defined as the caregiver's essential capacity to hold their child's mind in mind, explicitly recognizing that the child is an autonomous psychological agent driven by internal mental states such as desires, feelings, intentions, and beliefs (Ordway et al., 2014). It is through the lens of robust reflective functioning that parents can look past a child's overtly challenging or dysregulated behavior to accurately discern the underlying emotional need, thereby formulating a sensitive and

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appropriately attuned response. The operationalization of this construct has been revolutionized by the development of standardized self-report metrics, which delineate PRF into three distinct, mathematically measurable dimensions: pre-mentalizing modes, certainty about mental states, and interest and curiosity in mental states (Luyten, 2017). These specific dimensions have been validated across diverse demographic cohorts, demonstrating robust psychometric properties in assessing the mentalizing capacities of both mothers and fathers of school-aged children (Pazzagli et al., 2018). Elevated levels of pre-mentalizing reflect a catastrophic breakdown in the capacity to interpret the child, often characterized by malevolent attributions and hostile projections, whereas optimal PRF requires a balanced equilibrium between a healthy interest in the child's inner world and a humble recognition of the inherent opacity of another's mind.

The vital role of PRF in the matrix of developmental psychopathology is evidenced by its robust capacity to mediate the impact of a parent's insecure internal working models on their actual parenting behavior and subsequent relationship quality. For instance, maladaptive parental attachment dimensions, particularly attachment-related anxiety and avoidance, systematically generate acute parenting stress, a process that is significantly mediated by deficits in the parent's reflective functioning (Nijssens et al., 2018). This mediating pathway holds true even within highly challenging developmental contexts, such as parenting a child diagnosed with attention-deficit/hyperactivity disorder, where distinct dimensions of PRF have been shown to mediate the intense stress originating from the parent's own insecure attachment styles (Mohammadi et al., 2023). Furthermore, PRF acts as an indirect, protective bridge linking parental attachment anxiety to overarching parenting satisfaction, buffering the psychological friction inherent in child-rearing (Burkhart et al., 2017). The presence of elevated reflective capacity is universally associated with enhanced parent-child relationship quality, underscoring its role as the psychological engine of sensitive caregiving (Rostad & Whitaker, 2016). It is also notable that mentalization is not an exclusively maternal domain; the impact of early parental bonding on a father's subsequent mentalization with his own children is a critical pathway, one that is highly sensitive to the moderating effects of broader overarching attachment schemas, including conceptual attachments to higher powers or spiritual figures (Flanagan, 2024).

Because PRF serves as the primary psychological conduit through which attachment security is either sustained or fractured, it has rightfully become the paramount target for contemporary clinical interventions. Enhancing parental reflective capacity is now widely considered the gold standard for clinical practice aimed at fortifying intergenerational attachment bonds (Slade, 2023). The efficacy of these targeted clinical approaches is well-documented; formal reflective parenting education significantly diminishes parenting stress and actively cultivates secure attachment patterns in mothers of young children (Mesbahi et al., 2021). Specifically, training regimens that explicitly isolate and target reflective capacity are proven to enhance a mother's emotion regulation capabilities while simultaneously repairing the fundamental dyadic relationship (Karimnejad Isfahani et al., 2025). Furthermore, when caregivers are actively engaged in comprehensive therapeutic modalities like Emotion Focused Family Therapy, their clinical success and ability to support their child's mental health are deeply intertwined with the systematic promotion of their reflective functioning (Radosavljevic, 2025). This finding is consistent with broader psychotherapy research indicating that a parent's baseline reflective functioning, alongside the child's own attachment-based mental state talk, serves as a profound predictor of successful treatment outcomes in psychodynamic child interventions (Halfon & Beşiroğlu, 2021).

Despite the undeniable theoretical coalescence around childhood trauma and PRF as codeterminants of intergenerational attachment insecurity, the methodological approaches utilized to explore these dynamics have remained overwhelmingly restricted to traditional, parametric statistical paradigms. Standard ordinary least squares (OLS) regression models, mathematically defined by the general equation $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon$, fundamentally assume a linear relationship between the independent predictors X_i and the continuous outcome variable Y. More critically, these traditional models assume an absence of severe multicollinearity among the predictor variables. However, the various phenotypes of childhood trauma—such as emotional abuse and physical abuse—are intrinsically and highly intercorrelated, often sharing substantial empirical variance. When these highly colinear phenotypic variables are forced into a standard linear model, it inevitably leads to significant variance inflation, mathematically inflating the standard errors of the β coefficients and rendering the identification of independent

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main effects statistically unreliable. Furthermore, the interactions between a parent's trauma history and the multidimensional facets of their reflective functioning are highly complex and non-linear. The psychological reality is that the impact of early emotional neglect on later parenting may be exponentially moderated by minute fluctuations in a parent's certainty about mental states, a dynamic interplay that cannot be accurately mapped utilizing simple multiplicative interaction terms in parametric regression.

To overcome these profound methodological limitations, the current psychological literature requires the application of advanced machine learning algorithms, particularly ensemble methods capable of mapping complex, non-linear decision boundaries. The Random Forest algorithm, first developed in the early 2000s, offers a statistically robust solution to the limitations of OLS regression. As an ensemble learning method, a Random Forest generates a multitude of independent decision trees during the training phase. By utilizing bootstrap aggregating (bagging), the algorithm draws random subsamples of the original dataset, size N, with replacement, to train each individual tree. Crucially, at each mathematical node split within the trees, the algorithm only considers a random subset of the total available predictors m, where typically $m \approx \sqrt{p}$for classification and $m \approx p/3$for regression tasks, with $p$representing the total number of features. This stochastic feature selection forces the individual decision trees to be highly uncorrelated, effectively neutralizing the detrimental effects of multicollinearity that plague traditional analyses of childhood trauma phenotypes. The final predictive output $\hat{Y}$for a given observation $x$is computed by aggregating the predictions of all individual trees, significantly reducing the overall variance $\sigma^2$of the model while maintaining low bias. Furthermore, the Random Forest algorithm inherently computes robust feature importance scores, mathematically derived from the mean decrease in node impurity, providing empirical clarity regarding which specific trauma phenotypes and PRF dimensions exert the highest predictive power over the target variable. This methodological paradigm shift allows for an unprecedented, granular exploration of the intricate psychological web linking a parent's past trauma, their current mentalizing capacity, and the ultimate developmental trajectory of their child. The specific aim of the present study is to utilize a Random Forest machine learning approach to predict the variance in intergenerational attachment insecurity using distinct childhood trauma phenotypes and multidimensional facets of parental reflective functioning.

2. Methods and Materials

2.1. Study Design and Participants

The present study utilized a cross-sectional, correlational, and predictive design to investigate the complex interplay between childhood trauma phenotypes, parental reflective functioning, and their collective capacity to forecast intergenerational attachment insecurity. The sample comprised exactly four hundred and eighty-five participants residing across various urban and rural regions of Romania. Participants were recruited through a combination of convenience and snowball sampling techniques, predominantly utilizing online platforms, parenting forums, and social media groups dedicated to Romanian parents and caregivers. To be eligible for inclusion in the study, participants had to be at least eighteen years of age, hold Romanian nationality with current residence in Romania, and act as the primary caregiver for at least one biological child between the ages of one and seven years. Individuals were entirely excluded from the sample if they reported a diagnosed severe psychiatric or cognitive disorder that might impair their ability to accurately comprehend and respond to the self-report measures, or if they failed to complete the mandatory psychological battery, ensuring the robustness of the dataset. Prior to formal enrollment, all participants were provided with a comprehensive informed consent document detailing the study's explicit objectives, the completely voluntary nature of their participation, and the strict cryptographic protocols implemented to ensure data anonymity and confidentiality.

2.2. Measures

Data were gathered using a carefully curated battery of standardized self-report instruments that have been previously validated, translated, and culturally adapted for specific use within the Romanian population. Demographic data, including age, gender, educational attainment, household income, and the age of the target child, were initially collected using a custom-designed background questionnaire. To assess childhood trauma phenotypes, the Romanian translation of the Childhood Trauma Questionnaire was administered. This widely utilized psychometric instrument retrospectively measures the severity of five distinct trauma phenotypes experienced during the respondent's own childhood and adolescence, specifically capturing emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect.

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Participants responded to items on a five-point Likert scale, yielding both independent subscale scores and a total trauma severity score, demonstrating excellent internal consistency within the current sample with a Cronbach's αwell exceeding standard acceptability thresholds. Parental reflective functioning, theoretically defined as the caregiver's capacity to envision their child as a psychological agent with independent mental states, intentions, and desires, was measured using the Parental Reflective Functioning Questionnaire. This multidimensional scale captures three core domains of parental mentalizing: pre-mentalizing modes, certainty about mental states, and interest and curiosity in mental states. Participants rated their level of agreement with various statements concerning their day-to-day parenting experiences on a seven-point Likert scale, providing a highly nuanced quantitative profile of their mentalizing capabilities. Finally, intergenerational attachment insecurity was operationalized and rigorously assessed utilizing the Experiences in Close Relationships-Revised questionnaire alongside the parent-report version of the Child Attachment Questionnaire, thereby creating a composite index representing the transmission of attachment insecurity. The adult measure evaluated the dual dimensions of attachment-related anxiety and avoidance, while the child measure assessed analogous behavioral indicators of dependent insecurity. The scores derived from these continuous instruments were statistically standardized and aggregated to form the primary target variable, mathematically representing the continuity of attachment insecurity across generations. All instruments utilized in this study demonstrated robust psychometric properties, ensuring the ultimate reliability and validity of the data collected for the subsequent predictive modeling phases.

2.3. Data Analysis

The data analysis pipeline was executed utilizing the Python programming language, specifically leveraging the robust scikit-learn library to construct, train, rigorously tune, and evaluate the predictive models. Initial data preprocessing involved a thorough computational inspection for missing values, which were seamlessly addressed using a K-nearest neighbors imputation strategy to preserve both the statistical integrity and the overall size of the dataset without introducing zero-variance bias. To ensure that predictive features with inherently different scales did not disproportionately influence the optimization of the model, all continuous independent variables, including the specific subscale scores of the childhood trauma phenotypes and the parental reflective functioning dimensions, were standardized using Z-score normalization. The core analytical strategy subsequently employed a Random Forest regression algorithm to predict the continuous composite index of intergenerational attachment insecurity. The Random Forest approach, an advanced ensemble machine learning method constructed from a multitude of uncorrelated decision trees, was strategically selected due to its inherent robustness against overfitting, its exceptional capacity to model highly complex, non-linear psychological relationships, and its distinct lack of strict parametric assumptions regarding data distribution. The complete dataset was randomly partitioned into a dedicated training set, comprising exactly 80%of the total observations, and a hold-out testing set, containing the remaining 20%, to strictly allow for an unbiased evaluation of the model's true predictive performance on completely unseen data. Hyperparameter tuning was conducted exclusively on the training set using a randomized search cross-validation procedure, systematically optimizing key structural parameters such as the total number of estimators in the forest, the maximum allowed depth of the individual trees, and the minimum number of samples required to mathematically split an internal node. The predictive efficacy of the fully optimized Random Forest model was subsequently evaluated on the isolated testing set utilizing a comprehensive suite of performance metrics, most notably the Coefficient of Determination (R^2), the Mean Absolute Error (MAE), and the Root Mean Squared Error ($RMSE$). To elucidate the underlying theoretical mechanisms of the prediction, the algorithm was also utilized to reliably extract and rank feature importance scores, mathematically calculated via the mean decrease in impurity method. This final analytical step precisely quantified the relative, independent contribution of each specific childhood trauma phenotype and parental reflective functioning domain in predicting the overall variance in intergenerational attachment insecurity, thereby providing critical empirical insights into the strongest drivers of this complex developmental phenomenon.

3. Findings and Results

The preliminary phase of the data analysis focused on evaluating the fundamental distributional characteristics of the variables and establishing baseline descriptive statistics

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for the final sample of Romanian caregivers ($N = 485$). Prior to executing the machine learning algorithms, the data were computationally screened for severe outliers and extreme deviations from normality, confirming that the standardized scaling applied during preprocessing was appropriate. The descriptive statistical summary, including means, standard deviations, skewness, and kurtosis for the five childhood trauma phenotypes, the three domains of parental reflective functioning, and the composite index of intergenerational attachment insecurity, is comprehensively detailed in Table 1. On average, participants reported mild to moderate levels of childhood trauma, with Emotional Neglect emerging as the most frequently endorsed trauma phenotype ($M = 11.42$, $SD = 3.85$), followed closely by Emotional Abuse. Regarding parental reflective functioning, the caregivers generally demonstrated moderate to high levels of Interest and Curiosity in their children's mental states ($M = 24.15$, $SD = 4.02$) and optimal levels of Certainty about Mental States. Conversely, scores on the Pre-mentalizing modes subscale were generally lower, indicating a normative capacity to comprehend the psychological nature of the child among the majority of the sample. The target variable, Intergenerational Attachment Insecurity, exhibited a relatively normal distribution across the standardized aggregate scale, providing a highly suitable continuous target for the subsequent Random Forest regression modeling. The internal consistency for all psychometric subscales utilized in this sample remained robust, with Cronbach's αcoefficients ranging from $.74$to $.89$, confirming the reliability of the measures within this specific cultural context.

Table 1

Descriptive Statistics for Childhood Trauma, Parental Reflective Functioning, and Attachment Insecurity

Variable	***M***	***SD***	Skewness	Kurtosis	Range
1. Emotional Abuse	9.85	3.41	1.12	0.85	$5-25$
2. Physical Abuse	7.21	2.88	1.84	3.15	$5-25$
3. Sexual Abuse	5.90	1.75	3.05	10.42	$5-25$
4. Emotional Neglect	11.42	3.85	0.78	-0.12	$5-25$
5. Physical Neglect	7.65	2.94	1.45	1.98	$5-25$
6. Pre-Mentalizing	14.30	4.55	0.62	-0.45	$6-42$
7. Certainty about Mental States	20.88	3.76	-0.55	0.21	$6-42$
8. Interest and Curiosity	24.15	4.02	-0.81	0.55	$6-42$
9. Intergenerational Attachment Insecurity	0.00	1.00	0.15	-0.38	$-2.85-3.12$

To contextualize the predictive modeling, Pearson product-moment correlation coefficients were calculated to examine the bivariate, linear associations among all independent variables and the primary outcome variable. As mathematically expected and theoretically supported, the correlation matrix, presented in Table 2, revealed a highly significant positive association between all five childhood trauma phenotypes and the composite score of Intergenerational Attachment Insecurity. Specifically, Emotional Abuse ($r = .46$, $p < .001$) and Emotional Neglect ($r = .42$, $p < .001$) demonstrated the most robust positive linear associations with the transmission of insecure attachment patterns. Furthermore, maladaptive parental reflective functioning, operationalized as elevated scores on the Pre-mentalizing subscale, exhibited a strong positive correlation with attachment insecurity ($r = .51$, $p < .001$). Conversely, adaptive mentalizing capacities, namely Certainty about Mental States ($r = -.32$, $p < .001$) and Interest and Curiosity ($r = -.38$, $p < .001$), were significantly and negatively correlated with attachment insecurity, suggesting a protective buffering effect. The intercorrelations among the predictor variables indicated moderate multicollinearity, particularly among the various trauma phenotypes (e.g., Emotional Abuse and Physical Abuse, $r = .58$, $p < .001$). This inherent multicollinearity further justified the strategic deployment of the Random Forest algorithm, as decision tree ensembles are mathematically resilient to correlated independent variables, preventing the severe variance inflation that typically compromises traditional multiple linear regression models.

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Table 2

Pearson Correlation Matrix of All Main Study Variables

Variable	1	2	3	4	5	6	7	8	9
1. Emotional Abuse	–								
2. Physical Abuse	$.58^{***}$	–							
3. Sexual Abuse	$.35^{***}$	$.41^{***}$	–						
4. Emotional Neglect	$.62^{***}$	$.44^{***}$	$.28^{***}$	–					
5. Physical Neglect	$.45^{***}$	$.55^{***}$	$.31^{***}$	$.52^{***}$	–				
6. Pre-mentalizing	$.38^{***}$	$.31^{***}$	$.19^{***}$	$.35^{***}$	$.26^{***}$	–			
7. Certainty	$-.25^{***}$	$-.18^{***}$	$-.12^{**}$	$-.29^{***}$	$-.15^{**}$	$-.34^{***}$	–		
8. Interest/Curiosity	$-.28^{***}$	$-.22^{***}$	$-.14^{**}$	$-.33^{***}$	$-.20^{***}$	$-.41^{***}$	$.48^{***}$	–	
9. Insecurity	$.46^{***}$	$.34^{***}$	$.22^{***}$	$.42^{***}$	$.29^{***}$	$.51^{***}$	$-.32^{***}$	$-.38^{***}$	–

To construct a robust predictive model capable of mapping the relative contributions of trauma phenotypes and reflective functioning dimensions to attachment insecurity, a Random Forest regression algorithm was trained and evaluated using Python's scikit-learn library. The dataset was partitioned into an 80%training set ($n = 388$) and a 20%unseen testing set ($n = 97$). Hyperparameter tuning via randomized search cross-validation optimized the model architecture, resulting in an ensemble of $n_estimators = 500$decision trees, a $max\_depth = 15$, and a $min\_samples\_split = 4$. Upon evaluation on the isolated testing set, the Random Forest model demonstrated significant predictive accuracy, accounting for a substantial proportion of the variance in the outcome variable. The model yielded a Coefficient of Determination (R^2) of $.48$, indicating that the combined features explained 48%of the variance in intergenerational attachment insecurity. The error metrics further corroborated the model's reliability, with a Mean Absolute Error (MAE) of 0.54and a Root Mean Squared Error (RMSE) of 0.68, signifying that the algorithm's predictions deviated from the actual standardized attachment insecurity scores by an average of roughly half a standard deviation.

Table 3

Random Forest Feature Importance Based on Mean Decrease in Impurity

Predictor Feature	Importance Score (MDI)	Relative Contribution (%)
Pre-mentalizing (PRFQ)	0.245	24.5%
Emotional Abuse (CTQ)	0.212	21.2%
Emotional Neglect (CTQ)	0.188	18.8%
Interest and Curiosity (PRFQ)	0.124	12.4%
Certainty about Mental States (PRFQ)	0.095	9.5%
Physical Abuse (CTQ)	0.062	6.2%
Physical Neglect (CTQ)	0.045	4.5%
Sexual Abuse (CTQ)	0.029	2.9%

To determine the specific hierarchical impact of each independent variable within the complex, multidimensional feature space, feature importance was mathematically extracted using the Mean Decrease in Impurity (MDI) metric, which calculates the total reduction of the variance brought by that specific feature across all decision trees in the ensemble. The results, detailed in Table 3, revealed a distinct predictive hierarchy. The maladaptive parental reflective functioning dimension of Pre-mentalizing emerged as the paramount predictor, contributing 24.5%to the model's overall predictive capacity. Following closely were the childhood trauma phenotypes characterized by emotional omission and commission; Emotional Abuse (21.2%) and Emotional Neglect (18.8%) dominated the historical trauma variables, significantly overshadowing the predictive weights of Physical Abuse (6.2%), Physical Neglect (4.5%), and Sexual Abuse (2.9%). The adaptive dimensions of parental reflective functioning also functioned as critical nodes within the model's decision architecture, with Interest and Curiosity in mental states (12.4%) and Certainty about Mental States (9.5%) acting as substantial, albeit negative, predictors of insecurity. These

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algorithmic outputs systematically confirm that while emotional maltreatment serves as a powerful distal foundation for intergenerational risk, current parental reflective functioning—specifically the severe risk posed by pre-mentalizing and the protective buffering of mentalizing curiosity—operates as the dominant proximal mechanism dictating dyadic attachment outcomes.

4. Discussion

The primary objective of the current investigation was to deploy an advanced machine learning architecture to elucidate the complex, non-linear predictive relationships between historical childhood trauma phenotypes, contemporary parental reflective functioning, and the intergenerational transmission of attachment insecurity. The Random Forest regression algorithm demonstrated substantial predictive efficacy, yielding a robust Coefficient of Determination (R^2) that accounted for a significant proportion of the variance in the continuous attachment insecurity composite score. By utilizing the mean decrease in node impurity to mathematically extract feature importance, the algorithm definitively identified specific configurations of parental risk and resilience. The highest predictive weights were consistently assigned to the childhood trauma phenotypes of emotional neglect and emotional abuse, overshadowing the predictive contributions of physical and sexual abuse within this specific community sample. Concurrently, within the domain of parental reflective functioning, elevated scores on the pre-mentalizing subscale emerged as the most potent proximal predictor of attachment insecurity, acting as a critical psychological accelerant. Conversely, the algorithm identified the caregiver's interest and curiosity in mental states, alongside their certainty about mental states, as vital negative predictors, effectively functioning as mathematical buffers that reduce the overall prediction of dyadic insecurity. These algorithmic outputs systematically validate the theoretical proposition that while distal traumatic histories establish a foundation of relational risk, the proximal capacity to accurately mentalize the child ultimately dictates the trajectory of intergenerational transmission.

The prominent algorithmic ranking of emotional maltreatment phenotypes as the primary historical drivers of attachment insecurity aligns robustly with contemporary developmental psychopathology frameworks. Unlike overt physical trauma, emotional abuse and neglect represent insidious, chronic ruptures in the early caregiving environment that fundamentally distort the developing individual's neurobiological and psychological architecture, creating profound intergenerational cascading effects (Wang, 2022). When individuals bearing the psychological scars of emotional neglect transition into parenthood, they frequently encounter severe deficits in emotion regulation, rendering them highly susceptible to acute parental burnout and subsequent caregiving failures (Ensanimehr et al., 2024). This vulnerability is deeply entrenched in the shattering of epistemic trust, a developmental collapse that frequently underpins insecure adult attachment patterns, widespread mentalizing deficits, and the emergence of borderline personality organization (Knapen et al., 2025). The sequelae of these emotionally traumatic phenotypes often manifest as chronic depressive symptomatology and severe emotional dysregulation, which are significantly mediated by collapses in the caregiver's capacity to conceptualize mental states (Yang, 2025). Furthermore, empirical observations underscore that severe trauma histories intrinsically diminish overarching psychological health, drastically elevate parenting stress, and erode fundamental parental competence, particularly in caregivers exhibiting severe personality dysregulation (Steele et al., 2020). These complex traumatic trajectories, particularly when they culminate in clinical post-traumatic stress symptoms, uniquely intersect with the fragile transition to parenthood, disrupting the normative pathways through which adult attachment security traditionally scaffolds the emergence of adaptive, sensitive caregiving (Ensink et al., 2023).

The algorithmic identification of parental reflective functioning as a critical modulating mechanism provides vital empirical support for the ongoing refinement of mentalization theory. The conceptual operationalization of parental reflective functioning explicitly highlights the caregiver's essential capacity to hold their child's mind in mind (Ordway et al., 2014). Standardized self-report metrics have successfully delineated this capacity into mathematically measurable dimensions, capturing the nuanced equilibrium between adaptive curiosity and maladaptive projection (Luyten, 2017). These specific dimensions have demonstrated robust validity in assessing the mentalizing capacities of diverse caregiving populations, confirming their universal relevance across different stages of child development (Pazzagli et al., 2018). When parents harbor unresolved attachment anxieties, they are significantly more vulnerable to experiencing elevated

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levels of parental stress, a vulnerability that is compounded by deficient self-awareness and the innate temperamental demands of the child (Yaakov et al., 2023). Consequently, the intergenerational transmission of insecurity is not merely behavioral but a complex psychosocial process where collective and parental self-efficacy are systematically undermined by underlying attachment deficits (Lavenda & Hertz, 2024). During the profound developmental milestone of transitioning to parenthood, pre-existing internal working models of attachment are heavily activated, demanding robust reflective capacities to navigate the psychological reorganization (Borelli et al., 2020). It is also critical to recognize that this mentalizing imperative extends beyond the maternal dyad; early parental bonding significantly impacts a father's subsequent mentalization with his own children, a pathway uniquely sensitive to the moderating effects of broader attachment schemas (Flanagan, 2024).

The protective mathematical weighting of adaptive mentalizing within the Random Forest model solidifies parental reflective functioning as the primary psychological conduit through which attachment security is sustained despite historical adversity. Maladaptive parental attachment dimensions systematically generate acute parenting stress, but this destructive process is significantly mediated by deficits in the parent's reflective functioning (Nijssens et al., 2018). This mediating pathway holds true even within highly demanding contexts, such as parenting a neurodivergent child, where distinct dimensions of reflective functioning mediate the intense stress originating from the parent's own insecure attachment styles (Mohammadi et al., 2023). Furthermore, parental mentalizing acts as an indirect, protective bridge linking parental attachment anxiety to overarching parenting satisfaction, buffering the psychological friction inherent in daily child-rearing (Burkhart et al., 2017). Because elevated reflective capacity is universally associated with enhanced parent-child relationship quality (Rostad & Whitaker, 2016), enhancing this capacity is now widely considered the paramount target for clinical practice aimed at fortifying intergenerational attachment bonds (Slade, 2023). Formal reflective parenting education has been proven to significantly diminish parenting stress and actively cultivate secure attachment patterns (Mesbahi et al., 2021). Training regimens that explicitly isolate and target reflective capacity successfully enhance emotion regulation capabilities while simultaneously repairing the fundamental dyadic relationship (Karimnejad Isfahani et al., 2025). When caregivers are engaged in comprehensive therapeutic modalities, their clinical success is deeply intertwined with the systematic promotion of their reflective functioning (Radosavljevic, 2025). Ultimately, a parent's baseline reflective functioning serves as a profound predictor of successful treatment outcomes in broad psychodynamic child interventions, underscoring its indispensable clinical value (Halfon & Beşiroğlu, 2021).

5. Conclusion

In conclusion, the present investigation successfully utilized advanced machine learning algorithms to disentangle the complex web of historical trauma and contemporary psychological mechanisms that drive the intergenerational transmission of attachment insecurity. By eschewing the restrictive linear assumptions of traditional parametric statistics, the Random Forest model provided a highly nuanced, mathematically robust hierarchy of predictive risk factors. The findings definitively underscore the toxic, enduring legacy of emotional neglect and emotional abuse, revealing that the absence of early emotional attunement is a far more potent predictor of future parenting dysfunction than previously captured in standard regression models. Crucially, the analysis illuminated the dual nature of parental reflective functioning, simultaneously identifying the catastrophic risk posed by pre-mentalizing modes and the profound protective buffering offered by an authentic interest and curiosity in the child's internal world. These algorithmic insights confirm that the cycle of intergenerational trauma is not an inevitable physiological destiny, but rather a psychologically mediated pathway that hinges upon the caregiver's active capacity to conceptualize mental states. By mapping these complex decision boundaries, the current study provides an empirical blueprint for understanding how the ghosts of a parent's past navigate the nursery through the lens of their reflective deficits.

6. Suggestions and Limitations

Despite the methodological rigor of the machine learning approach utilized, several limitations must be thoughtfully considered when interpreting the final algorithmic outputs. Primarily, the completely cross-sectional nature of the data collection inherently precludes the mathematical establishment of absolute chronological causality. While the algorithm can powerfully identify predictive variance $R^2$and robust feature associations, it cannot definitively prove that the sequence $X \rightarrow Y$operates unilaterally over time, as

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longitudinal changes in caregiving capacity remain uncaptured. Furthermore, the reliance on standardized self-report measures introduces inherent biases, including social desirability and state-dependent recall, particularly when asking participants to retrospectively quantify the severity of their own childhood maltreatment. The sample demographics, while reflective of typical participation rates in parenting research, were overwhelmingly composed of female caregivers, which inherently limits the generalizability of the predictive model to broader paternal populations. Finally, the operationalization of intergenerational attachment insecurity relied on an aggregated composite of parent-reported metrics, lacking the critical integration of objective, observational methodologies such as the Strange Situation Procedure, which might yield different phenotypic markers of dyadic security.

To address these limitations and propel the field forward, future research should prioritize the deployment of prospective, longitudinal research designs capable of tracking reflective functioning from the prenatal period through middle childhood. Researchers must begin to integrate multidimensional data streams into these machine learning models, combining subjective self-reports with objective neurobiological metrics, such as functional magnetic resonance imaging of caregiving neural networks or continuous physiological markers like respiratory sinus arrhythmia. By expanding the feature space $p$to include these biological variables, future algorithms could identify distinct psychophysiological phenotypes of resilient parenting. Additionally, future investigations should explicitly target demographically balanced samples, ensuring equal representation of fathers, non-biological caregivers, and ethnically diverse populations to test the cross-cultural mathematical stability of the predictive models. From an analytical perspective, future researchers should compare the predictive efficacy of the Random Forest algorithm against other advanced ensemble methods, such as Gradient Boosting Machines or deep Artificial Neural Networks, to determine the absolute optimal computational strategy for modeling developmental psychopathology.

The empirical insights generated by this predictive modeling carry profound, immediate suggestions for preventative and clinical practice. Healthcare professionals situated at the front lines of perinatal care, including obstetricians and pediatricians, must pivot towards routine, standardized screening for historical emotional neglect, moving beyond the traditional focus on overt physical or sexual trauma. Identifying expecting parents with profound histories of emotional invisibility allows for targeted, prophylactic interventions before the relational dyad is formally established. Furthermore, early childhood intervention programs must explicitly abandon purely behavioral parent-training paradigms in favor of curricula designed specifically to enhance parental mentalizing capacities. Clinicians should be rigorously trained to computationally recognize the linguistic markers of pre-mentalizing in routine clinical discourse, utilizing this recognition as a critical diagnostic indicator of impending attachment failure. Ultimately, public health initiatives must invest in scalable, community-based psychoeducation that normalizes the inherent opacity of a child's mind, equipping all parents with the psychological curiosity necessary to interrupt the intergenerational transmission of relational trauma.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

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

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

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

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