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Parental Emotion Regulation and Children's Mental Health Across Cultural Contexts: A Study of Immigrant and Non-Immigrant Families in the United States

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Abstract: Parental emotion regulation plays a critical role in shaping children's psychological adjustment, emotional resilience, and mental health outcomes. However, variations in cultural orientation, immigration experiences, family stress, and parenting practices complicate the identification of these relationships across immigrant and non-immigrant populations in the United States. This study proposes a novel Culturally Adaptive Parental Emotion Regulation and Mental Health Prediction Algorithm (CAPER-MH) to investigate the relationships between parental emotion regulation, cultural adaptation, family socioeconomic characteristics, and children's mental health. The proposed framework integrates multilevel statistical modelling, machine learning, and explainable artificial intelligence to estimate psychological risk while accounting for cultural heterogeneity and family-level dependencies. The study is designed to analyse parental emotion regulation difficulties, cognitive reappraisal, expressive suppression, acculturative stress, parent-child relationships, and children's internalizing and externalizing symptoms using validated psychometric instruments. CAPER-MH combines culturally conditioned feature representations, hierarchical risk estimation, and adaptive ensemble learning to improve prediction across immigrant and non-immigrant family groups. Its predictive performance will be benchmarked against Random Forest, Support Vector Machine, Extreme Gradient Boosting (XGBoost), Long Short-Term Memory (LSTM), and conventional multilevel regression models. Comparative evaluation will employ accuracy, precision, recall, F1-score, area under the receiver operating characteristic curve (AUC-ROC), mean absolute error (MAE), and root mean square error (RMSE), as appropriate to the outcome. Stratified performance graphs, calibration curves, feature-importance visualizations, and cross-cultural comparisons will examine predictive effectiveness and algorithmic fairness. Statistical analyses will assess associations and potential moderation by immigration status, cultural orientation, and socioeconomic conditions. The proposed study hypothesizes that CAPER-MH will achieve superior predictive accuracy, improved cross-cultural calibration, and reduced subgroup performance disparities relative to conventional algorithms, subject to empirical validation. The research is intended to advance culturally responsive computational approaches to understanding children's mental health and support evidence-informed family interventions within diverse United States populations.

Keywords: *Parental Emotion Regulation; Children's Mental Health; Cultural Contexts; Immigrant Families; Non-Immigrant Families.*

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I. INTRODUCTION

- *Background of Parental Emotion Regulation and Children's Mental Health in the United States*

Parental emotion regulation represents a fundamental psychological mechanism through which caregivers influence children's emotional development, behavioral adjustment, and susceptibility to mental health difficulties. Within the United States, heterogeneous family structures, immigration histories, socioeconomic inequalities, and cultural expectations create distinct environments for emotional socialization. Morris et al. (2007) conceptualized family emotion regulation through parental modeling, emotion-related parenting practices, and the broader emotional climate, establishing a developmental foundation for investigating intergenerational psychological processes. Empirical evidence strengthens this relationship: Holzman et al. (2022) synthesized 32 studies involving 6,399 participants

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and identified a positive association between maladaptive parental emotion regulation and youth mental health symptoms (r = .25). These findings establish parental emotional functioning as a relevant, although not exclusively causal, determinant of children's psychological adjustment across family environments.

The American mental health landscape also highlights the importance of accessible prevention systems and psychosocial support for vulnerable children. Ijiga et al. (2024) examined youth mental health advocacy and trauma-informed support within conflict-affected international settings, providing a broader policy perspective relevant to families experiencing displacement and adversity. Building upon these theoretical and policy perspectives, the present study investigates parental cognitive reappraisal, expressive suppression, emotional dysregulation, and family stress as explanatory variables for children's internalizing and externalizing symptoms. The proposed CAPER-MH framework integrates culturally adaptive representations with hierarchical prediction to distinguish individual parental effects from contextual family influences. Comparative analyses involving immigrant and non-immigrant households will establish whether culturally informed modelling improves psychological risk estimation while preserving predictive accuracy, subgroup calibration, and interpretability across diverse United States populations.

- *Cultural Variations in Parenting Practices, Emotional Socialization, and Child Psychological Development*

Cultural orientations influence how parents interpret emotional experiences, communicate distress, reinforce behavioral expectations, and teach children adaptive emotional responses. Individualistic family environments may emphasize emotional autonomy and open expression, whereas some collectivist environments prioritize relational harmony, contextual sensitivity, and emotional restraint; however, substantial variation exists within every cultural group. Shroff et al. (2025) examined emotion socialization among 159 parents from East Asian, South Asian, and Middle Eastern backgrounds, identifying adaptive and maladaptive parenting dimensions associated with children's emotional and behavioral outcomes. Similarly, Curtis et al. (2020) investigated 258 Chinese American children and demonstrated longitudinal associations between parental emotion talk and subsequent effortful control. These findings suggest that emotional communication should be evaluated according to its developmental function and cultural context rather than classified as universally beneficial or harmful.

Cross-cultural variations also influence institutional mental health support and children's resilience. Omachi et al. (2025) investigated school-based psychological interventions in Indonesia and Argentina, illustrating the relevance of contextualized support systems to adolescent adjustment. The present study extends this comparative perspective to immigrant and non-immigrant families in the United States by examining parental emotional responsiveness, cognitive reappraisal, expressive suppression, heritage-cultural identification, and family relationship quality. Within CAPER-MH, cultural orientation will be represented through multidimensional variables rather than fixed ethnic labels (Doe Gadekah, & Enyejo, 2025). Interaction terms will evaluate whether relationships between parental regulation strategies and child psychological symptoms vary by cultural orientation or immigration generation. Measurement-invariance testing and subgroup-specific calibration will further determine whether psychological indicators retain comparable interpretations across populations, thereby reducing the risk of culturally biased mental health predictions.

- *Immigration Status, Acculturation, Socioeconomic Stress, and Family Mental Health Vulnerabilities*

Immigration-related experiences introduce interconnected psychosocial conditions that may influence parental emotional functioning and children's mental health. Acculturative stress, language barriers, employment insecurity, perceived discrimination, family separation, and intergenerational cultural differences can affect the emotional resources available for supportive parenting. Kim et al. (2018) identified culturally specific stressors, parental socialization, and developmental processes as important determinants of psychological adjustment among children of immigrants. More recently, Tineo et al. (2024) synthesized 46 studies and established a positive association between acculturative stress and internalizing difficulties among racially and ethnically minoritized adolescents and young adults in the United States. These findings indicate that immigrant-family vulnerability cannot be adequately explained by migration status alone; interactions among socioeconomic circumstances, cultural adaptation, and family psychological processes require systematic investigation (James, et al. 2025).

Broader sociopolitical conditions may intensify psychological vulnerability through uncertainty, insecurity, and reduced access to supportive institutions. Ijiga et al. (2024) examined how domestic and international political pressures intersect with youth mental health advocacy, reinforcing the importance of considering structural stressors alongside individual psychological characteristics. Accordingly, CAPER-MH will incorporate immigration generation, years of United States residence, household income, parental education, employment conditions, perceived discrimination, acculturative stress, and heritage-cultural identification. Family-level random effects will account for correlated household observations, while interaction modelling will evaluate whether parental emotion regulation modifies associations between acculturative stress and child mental health symptoms (Doe Gadekah, & Enyejo, 2025). Stratified analyses will distinguish immigrant-specific exposures from socioeconomic conditions shared with non-immigrant families. This approach supports an assessment of both psychological vulnerability and cultural resilience without assuming that immigrant children uniformly experience poorer mental health outcomes.

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➢ *Relationships Between Parental Emotion Regulation Strategies and Children's Internalizing and Externalizing Symptoms*

Parental emotion regulation strategies influence children's psychological adjustment through emotional modeling, parent-child communication, conflict management, and the development of adaptive coping skills. Cognitive reappraisal involves modifying interpretations of emotionally significant situations, whereas expressive suppression involves inhibiting observable emotional responses. Compas et al. (2017), synthesizing evidence from 212 studies involving 80,850 participants, identified associations between adaptive regulation strategies and reduced psychological symptoms, while maladaptive coping and emotional avoidance were associated with greater psychopathology. Lin et al. (2024) further demonstrated that children's emotion regulation mediates associations between several family characteristics and internalizing symptoms, supporting the investigation of developmental pathways linking parental psychological functioning to child emotional outcomes. Such relationships may vary according to age, family conflict, cultural expectations, and the emotional meaning assigned to parental behavior.

Intergenerational psychological experiences provide additional explanatory pathways for understanding family mental health vulnerabilities. Enyejo et al. (2024) discussed intergenerational trauma within the context of incarcerated women's psychological difficulties, emphasizing processes through which adverse experiences can influence family wellbeing, although their population differs from the present study. CAPER-MH will operationalize internalizing symptoms through validated anxiety, depressive, and withdrawal indicators, while externalizing outcomes will include aggression, conduct difficulties, and behavioral dysregulation. Parental regulation variables will be measured separately to distinguish potentially protective and maladaptive strategies. Hierarchical regression and nonlinear prediction will examine direct associations and interactions with cultural orientation, parental distress, and family socioeconomic conditions (Doe Gadekah, & Enyejo, 2026). Explainable feature-attribution methods will subsequently identify predictors contributing to elevated symptom estimates, while mediation analyses will examine whether children's own emotion regulation statistically explains part of the association between parental strategies and psychological adjustment.

➢ *Limitations of Conventional Statistical and Machine Learning Approaches to Cross-Cultural Mental Health Prediction*

Conventional statistical approaches to children's mental health prediction frequently depend on restrictive functional assumptions, predefined interaction structures, and incomplete representations of family-level heterogeneity. Although multilevel regression accommodates clustered observations, misspecified linear relationships may overlook nonlinear associations between parental emotional dysregulation, socioeconomic adversity, and cultural adaptation. Machine learning algorithms, including Random Forest, Support Vector Machine, XGBoost, and recurrent neural networks, offer flexible prediction but can exhibit limited interpretability, dataset imbalance, and unstable performance across underrepresented populations. Patel et al. (2025) reviewed predictive artificial intelligence applications for youth mental health and identified methodological concerns involving small samples, missing information, privacy, and population underrepresentation. Rosenblatt et al. (2026) emphasized the importance of independent external validation for evaluating predictive generalizability, demonstrating why internal discrimination metrics alone cannot establish reliable performance across heterogeneous populations.

These limitations are particularly relevant when psychological datasets combine immigrant and non-immigrant households with different cultural orientations and access to mental health services. Okoh et al. (2024) examined challenges surrounding mental health literacy and school-based support, highlighting institutional barriers relevant to implementing predictive insights in diverse educational environments. CAPER-MH addresses these methodological concerns through culturally conditioned feature representations, hierarchical family-level modelling, calibrated ensemble predictions, and explainable feature attribution. Comparative evaluation will examine discrimination, regression error, calibration, and subgroup disparities against Random Forest, Support Vector Machine, XGBoost, LSTM, and conventional multilevel regression (Odozor, et al., 2025). Family-disjoint validation will limit information leakage, while independent cultural-group testing will assess model transportability. Crucially, predictive improvements must be demonstrated empirically rather than inferred from algorithmic complexity, and any application to screening must retain appropriate human clinical oversight.

➢ *Research Problem, Knowledge Gaps, and Rationale for the Proposed CAPER-MH Algorithm*

Existing research has established relationships among immigration experiences, family adversity, emotional adjustment, and children's mental health; however, integrated computational approaches capable of distinguishing cultural influences from parental psychological mechanisms remain insufficiently developed. Tilley et al. (2021) synthesized 91 studies involving 179,315 participants and identified different patterns of internalizing and externalizing problems across immigrant generations, demonstrating the inadequacy of treating immigration status as a uniform risk indicator. Michel et al. (2026), analysing 10,310 adolescents, observed greater exposure to immigration-related stressors among first- and second-generation youth without corresponding increases in overall psychopathology, while heritage-cultural identification was associated with psychological resilience. These findings expose an important research gap: predictive frameworks must simultaneously recognize cultural protective factors, contextual vulnerabilities, and heterogeneous relationships between parental emotion regulation and child mental health outcomes.

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The complexity of psychological vulnerability is further illustrated by Balogun et al. (2024), who examined mental health consequences associated with mass shootings and broader security-related threats within the United States. Although these exposures differ from everyday family regulatory processes, they highlight the relevance of environmental adversity to mental health assessment (Folorunso, et al., 2025). The present study proposes CAPER-MH to integrate parental psychological indicators, immigration-specific experiences, cultural orientation, and household socioeconomic characteristics within a unified predictive architecture. Its methodological innovation combines hierarchical family-level estimation, culturally adaptive feature interactions, calibrated ensemble learning, and explainable artificial intelligence (James, 2026). Benchmark comparisons will determine whether this integration improves predictive discrimination, MAE, RMSE, calibration, and subgroup equity relative to established algorithms. The framework will also assess potential moderation and mediation mechanisms, supporting theoretically grounded interpretation rather than purely automated risk classification across culturally diverse families.

➢ *Research Objectives, Research Questions, and Hypotheses*

• *Research Objectives*

- ✓ To examine and compare parental emotion regulation strategies, including cognitive reappraisal, expressive suppression, and emotional dysregulation, among immigrant and non-immigrant families in the United States.
- ✓ To determine the relationships between parental emotion regulation, children's internalizing and externalizing symptoms, acculturative stress, cultural orientation, and socioeconomic characteristics.
- ✓ To develop the novel CAPER-MH algorithm by integrating culturally adaptive feature representations, multilevel statistical estimation, and explainable ensemble machine learning.
- ✓ To compare the predictive performance of CAPER-MH against Random Forest, Support Vector Machine, XGBoost, LSTM, and multilevel regression using accuracy, precision, recall, F1-score, AUC-ROC, MAE, and RMSE, according to outcome type.
- ✓ To evaluate cross-cultural generalizability, predictive calibration, algorithmic fairness, and the explanatory contributions of psychological, cultural, and socioeconomic variables.

• *Research Questions*

- ✓ How do parental emotion regulation strategies and children's mental health indicators differ between immigrant and non-immigrant families in the United States?
- ✓ To what extent do acculturative stress, socioeconomic adversity, and cultural orientation moderate the relationships between parental emotion regulation and children's psychological symptoms?
- ✓ Can CAPER-MH improve prediction of children's mental health outcomes through culturally adaptive modelling and hierarchical family-level estimation?
- ✓ How does CAPER-MH perform relative to Random Forest, Support Vector Machine, XGBoost, LSTM, and multilevel regression across discrimination, classification, and regression performance measures?
- ✓ Which parental, cultural, and socioeconomic variables contribute most strongly to predictions, and how consistent are model calibration and prediction errors across immigrant and non-immigrant subgroups?

• *Research Hypotheses*

- ✓ H_1: Parental emotion regulation strategies are significantly associated with children's internalizing and externalizing symptoms after controlling for demographic and socioeconomic characteristics.
- ✓ H_2: Acculturative stress and cultural orientation significantly moderate associations between parental emotion regulation and children's mental health outcomes.
- ✓ H_3: CAPER-MH achieves significantly better out-of-sample predictive performance than the five benchmark algorithms on prespecified primary evaluation measures.
- ✓ H_4: CAPER-MH produces significantly lower prediction error and improved probability calibration across immigrant and non-immigrant family subgroups compared with conventional machine learning models.
- ✓ H_5: Parental emotional dysregulation, family socioeconomic adversity, and acculturative stress contribute positively to predicted psychological symptom burden, whereas adaptive parental regulation and supportive family relationships are associated with lower predicted symptom burden.

These hypotheses will be evaluated at a prespecified significance level of $\alpha = .05$, with effect sizes, confidence intervals, and multiplicity adjustments reported where appropriate.

➢ *Contributions and Significance of the Study, Scope of the Review, and Structure of the Paper*

• *Contributions and Significance of the Study*

The principal contribution of this research is the proposed development of CAPER-MH, a culturally responsive computational framework for examining parental emotion regulation and children's mental health across immigrant and non-immigrant families in the United States. Unlike conventional models that primarily estimate population-level psychological associations or optimize predictive accuracy without sufficiently representing cultural heterogeneity, CAPER-MH combines family-level random effects, culturally adaptive feature interactions, nonlinear ensemble prediction, and explainable artificial intelligence. Its methodological contributions include comparative evaluation against five established algorithms, assessment of cultural-group calibration, identification of influential parental and socioeconomic predictors, and statistical

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investigation of moderation and potential mediation pathways. The framework is intended to inform psychological research, support culturally appropriate family interventions, and provide a reproducible basis for evaluating the reliability and equity of computational mental health screening approaches.

- *Scope of the Review*

The study focuses on immigrant and non-immigrant families residing in the United States, examining parental emotion regulation and children's psychological adjustment through measurable individual, familial, cultural, and socioeconomic characteristics. The review encompasses cognitive reappraisal, expressive suppression, emotional dysregulation, parental emotional socialization, acculturative stress, immigrant generation, cultural identification, socioeconomic adversity, and internalizing and externalizing symptoms. Methodological coverage includes validated psychometric assessments, multilevel regression, nonlinear machine learning, culturally adaptive feature modelling, explainable artificial intelligence, and subgroup-specific predictive validation. The investigation distinguishes psychological symptom prediction from formal psychiatric diagnosis and recognizes that observational associations do not independently establish causality. Longitudinal prediction, where suitable repeated observations exist, will be distinguished from cross-sectional symptom estimation. The geographic scope is restricted to United States populations, while relevant international literature provides theoretical and methodological context for interpreting cultural differences.

- *Structure of the Paper*

The paper is organized into five major sections. Section 1 introduces the research background, cultural variations in emotional socialization, immigration-related psychological influences, existing methodological limitations, research problem, objectives, hypotheses, and expected contributions. Section 2 critically reviews theoretical models of parental emotion regulation, relationships between parenting strategies and children's psychological outcomes, immigration-related stressors, comparative mental health prediction algorithms, explainable artificial intelligence, and unresolved research gaps. Section 3 describes the study population, measurement instruments, statistical assumptions, mathematical formulations, CAPER-MH architecture, benchmark algorithms, and evaluation procedures. Section 4 presents the planned comparative analyses of psychological indicators, model performance, cross-cultural generalization, predictive fairness, and feature contributions, using tables and graphical representations supported by empirical or explicitly identified simulation data. Section 5 synthesizes the findings once available, evaluates methodological contributions and limitations, and provides recommendations for culturally responsive family mental health interventions, responsible predictive modelling, and future research.

II. LITERATURE REVIEW

- *Theoretical Foundations of Parental Emotion Regulation, Family Emotional Socialization, and Children's Psychological Adjustment*

Parental emotion regulation constitutes a central developmental mechanism through which caregivers shape children's affective competence, psychological adjustment, and responses to environmental adversity. Social learning and family emotional socialization perspectives suggest that children acquire regulatory behaviors through observing parental emotional responses, receiving emotion-related guidance, and participating in emotionally significant family interactions as shown in figure 1. Edler and Valentino (2024) systematically reviewed 53 studies and identified associations between parental self-regulation and supportive emotion-socialization behaviors, although predominantly cross-sectional evidence restricted causal interpretation. Similarly, Zitzmann et al. (2024) synthesized research connecting parental emotional regulation difficulties, psychopathology, and parenting practices. These theoretical relationships support distinguishing parental intrapersonal regulation from observable socialization behaviors when investigating children's anxiety, depression, withdrawal, aggression, and conduct difficulties.

The developmental implications extend to trauma-responsive family support and coordinated mental health interventions. Ajiboye et al. (2025) examined trauma-informed approaches to adolescent suicide prevention, emphasizing the importance of psychological safety and responsive support environments. Babatuyi et al. (2024), although addressing infectious disease emergency systems rather than family psychology, highlighted institutional coordination principles relevant to organizing mental health support. Building upon this interdisciplinary foundation, CAPER-MH will conceptualize children's psychological outcomes as functions of parental cognitive reappraisal, expressive suppression, emotional dysregulation, family emotional climate, and cultural-context variables. Hierarchical modelling will account for household dependencies, while culturally conditioned interaction terms will examine contextual variability. This theoretical structure supports comparative assessment without assuming identical emotional-socialization mechanisms across immigrant and non-immigrant families.

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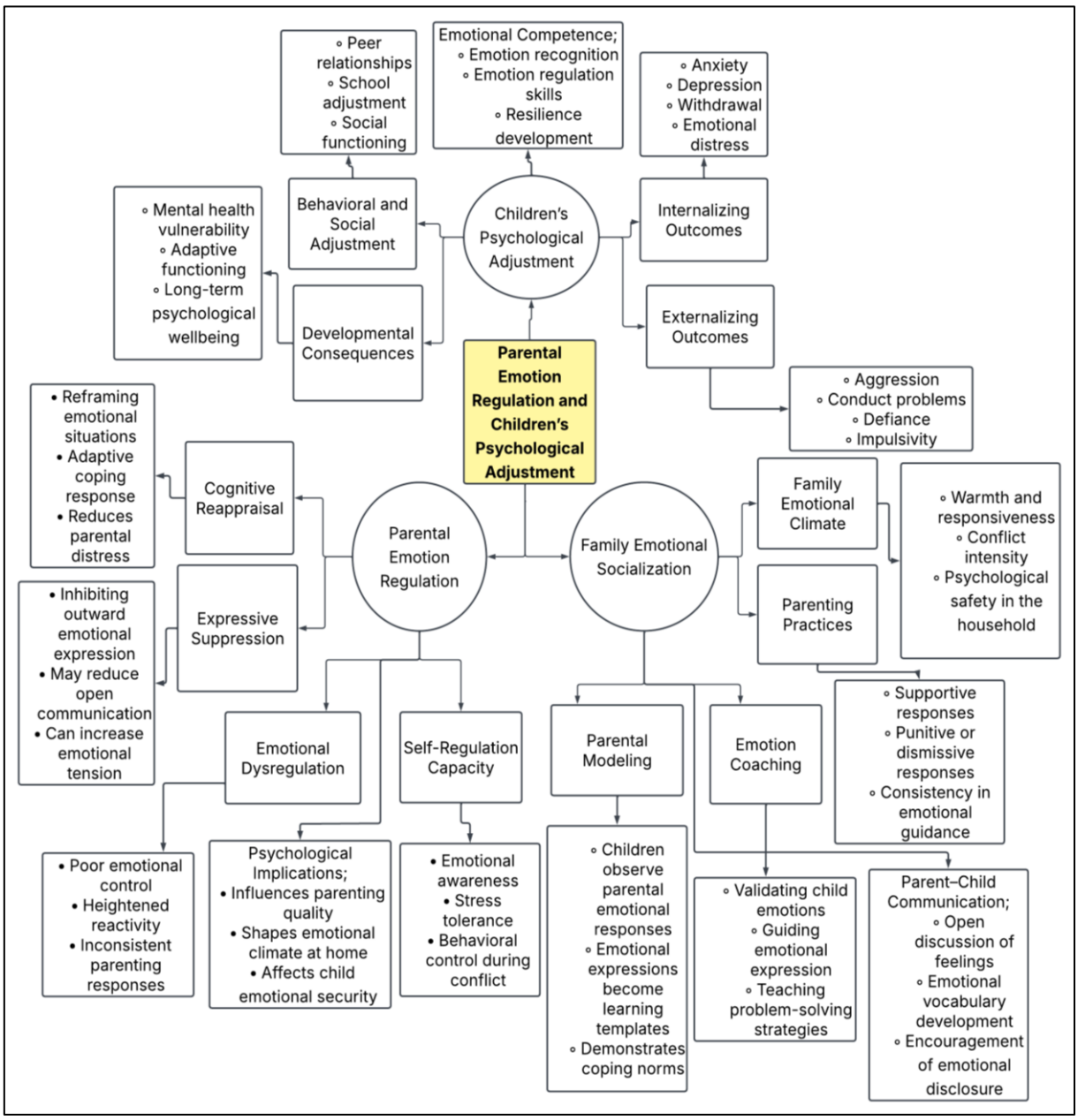


Fig 1 Conceptual Framework Linking Parental Emotion Regulation, Family Emotional Socialization, and Children's Psychological Adjustment Across Cultural Contexts.

Figure 1 illustrates the theoretical relationships among parental emotion regulation, family emotional socialization, and children's psychological adjustment within immigrant and non-immigrant families in the United States. The framework comprises three interconnected branches representing parental regulatory mechanisms, family-level emotional interactions, and child developmental outcomes. The first branch identifies cognitive reappraisal, expressive suppression, emotional dysregulation, and self-regulation capacity as fundamental parental characteristics influencing emotional responsiveness and parenting behavior. The second branch demonstrates how these mechanisms operate through parental modeling, emotion coaching, parent-child communication, parenting practices, and the broader family emotional climate. These socialization processes provide pathways through which children acquire emotional awareness, coping strategies, and behavioral regulation skills. The third branch captures children's psychological adjustment through internalizing symptoms, including anxiety, depression, and withdrawal, alongside externalizing symptoms such as aggression, impulsivity, and conduct difficulties. The directional connections represent hypothesized direct, indirect, and reciprocal relationships among parental functioning, family interactions, and child mental health. Within the proposed CAPER-MH framework, cultural orientation, acculturative stress, immigration status, and socioeconomic conditions are incorporated as contextual variables that may modify these relationships. Consequently, the diagram establishes a theoretical foundation for hierarchical statistical modelling, culturally adaptive feature representation, and explainable prediction of children's psychological outcomes while distinguishing hypothesized developmental mechanisms from empirically established causal relationships.

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➢ *Cognitive Reappraisal, Expressive Suppression, Parental Emotional Dysregulation, and Child Mental Health Outcomes*

Cognitive reappraisal and expressive suppression represent theoretically distinct emotion regulation processes with potentially different consequences for parent-child functioning. Cognitive reappraisal modifies the interpretation of emotionally challenging situations, whereas expressive suppression inhibits outward emotional displays without necessarily reducing underlying distress as shown in table 1. Cohodes et al. (2023) demonstrated that parental emotional suppression intensified associations between pandemic-related stress and youth internalizing symptoms, suggesting that regulation strategies may moderate children's responses to adversity. Garcia et al. (2024) systematically reviewed parental socialization of negative affect in clinical child populations, demonstrating the importance of examining supportive and unsupportive emotional responses alongside children's regulatory capacities. These findings justify treating reappraisal, suppression, dysregulation, and emotion-socialization behaviors as separate predictors rather than combining them into an undifferentiated parental functioning score. Reliable psychological prediction additionally depends on rigorous measurement specifications, reproducible data management, and systematic performance evaluation. Frank (2026a) reviewed healthcare quality measurement and risk-adjustment approaches, offering methodological principles applicable to the construction of standardized mental health indicators. Frank (2026b) discussed predictive analytics in medical inventory management; although unrelated to child psychopathology, its methodological emphasis on predictive evaluation provides a limited operational analogy. CAPER-MH will therefore integrate validated parental emotion regulation measures with children's internalizing and externalizing symptom scores while controlling for age, socioeconomic characteristics, and household clustering. Nonlinear interactions will examine whether expressive suppression exhibits different associations under varying cultural orientations. Separate classification and continuous-outcome models will be evaluated using AUC-ROC, F1-score, MAE, and RMSE as appropriate, with calibration analyses examining whether predicted psychological risks correspond to observed symptom-defined outcomes.

Table 1 Comparative Summary of Parental Emotion Regulation Strategies and their Implications for Children's Mental Health Outcomes

Emotion Regulation Mechanism	Psychological Characteristics	Influence on Children's Mental Health	Implications for CAPER-MH Modelling
Cognitive Reappraisal	Reinterpretation of emotionally challenging situations to reduce distress, enhance adaptive coping, and improve parental emotional responsiveness.	Generally associated with supportive emotional socialization, improved coping abilities, emotional resilience, and fewer internalizing and externalizing symptoms.	Incorporated as a potentially protective predictor, with cultural interaction terms assessing variation in its association with children's psychological adjustment.
Expressive Suppression	Inhibition of outward emotional expression without necessarily reducing underlying emotional experiences; its interpersonal meaning varies across cultural contexts.	May limit emotional communication and increase psychological distress in some family environments, although effects depend on cultural norms and relationship quality.	Modelled as an independent predictor with interactions involving cultural orientation, immigration status, and family emotional climate.
Parental Emotional Dysregulation	Difficulties managing emotional intensity, impulsive reactions, psychological distress, and inconsistent behavioral responses during stressful situations.	Associated with increased vulnerability to anxiety, depressive symptoms, aggression, conduct difficulties, and impaired emotional regulation among children.	Treated as a psychological risk indicator within hierarchical prediction, including interactions with acculturative stress and socioeconomic adversity.

➢ *Immigration Experiences, Acculturative Stress, Cultural Orientation, and Socioeconomic Determinants of Family Mental Health*

Immigrant-family psychological adjustment develops through interactions among migration experiences, acculturative pressures, cultural identity, parenting relationships, and socioeconomic resources. Immigration-related uncertainty, discrimination, language barriers, household financial insecurity, and differences in intergenerational cultural orientation may influence parental emotional functioning and children's psychological adjustment as represented in figure 2. Roche et al. (2024), examining 547 Latinx adolescents, identified longitudinal associations linking immigration-policy stressors with deterioration in parent-child relationship quality and subsequent mental health symptoms. Kılıç et al. (2026) investigated parental emotion socialization and children's emotional functioning across Türkiye and the United States, providing comparative evidence that emotional-development processes require cultural contextualization (James, 2022). These findings support modelling acculturative stress as a multidimensional exposure rather than treating immigrant status as an inherently pathological condition. Cultural identity, family cohesion, and supportive emotional communication may also represent protective characteristics influencing developmental resilience.

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Socioeconomic inequalities further affect mental healthcare accessibility, psychological support, and family functioning. Babatuyi et al. (2025) examined health equity and resource-distribution disparities among low-income United States populations, providing structural context for evaluating unequal access to mental health services. Imoh et al. (2025) discussed technology-supported trauma interventions for underserved autistic adults, highlighting accessibility considerations without directly establishing effects in children. CAPER-MH will integrate immigration generation, parental educational attainment, household income, employment instability, perceived discrimination, acculturative stress, and cultural identification into multilevel prediction. Interaction modelling will examine whether socioeconomic adversity modifies parental regulation–symptom associations. Stratified comparisons will assess prediction performance across cultural and socioeconomic groups, with subgroup calibration used to identify systematic overestimation or underestimation of psychological risk.



Fig 2 Conceptual Representation of Immigration Experiences, Acculturative Stress, Cultural Adaptation, and Socioeconomic Influences on Family Mental Health (mindfulcenter, n.d.).

Figure 2 illustrates the interconnected relationships among immigration experiences, acculturative stress, cultural orientation, socioeconomic conditions, and family mental health within the context of immigrant and non-immigrant populations in the United States. The image depicts an adult standing with three children along a shoreline while several individuals engage in physically demanding activities near the water, providing a visual representation of family relationships, environmental uncertainty, and potential socioeconomic challenges. The adult's physical proximity to the children symbolizes parental responsibility, emotional protection, and the importance of supportive caregiving during periods of adjustment and uncertainty. Within the context of immigration, families may encounter language barriers, employment instability, financial insecurity, perceived discrimination, social exclusion, and intergenerational differences in cultural adaptation, which can influence parental emotional functioning and children's psychological adjustment. Cultural orientation, including the preservation of heritage values and adaptation to receiving-society expectations, may shape parenting practices, emotional expression, and family communication. Such conditions can contribute to acculturative stress and potentially affect children's internalizing symptoms, including anxiety, depression, and emotional withdrawal, as well as externalizing behaviors such as aggression and conduct difficulties. However, strong family cohesion, supportive parenting, community relationships, and cultural identity can also provide protective psychological resources. Within the proposed CAPER-MH framework, these interconnected factors are incorporated as explanatory variables and potential moderators to evaluate differences in children's mental health risk across immigrant and non-immigrant households. The image therefore serves as a conceptual illustration of family support and environmental circumstances rather than direct evidence of the individuals' immigration status, socioeconomic position, or mental health conditions.

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- *Comparative Empirical Evidence on Parental Emotion Regulation and Children's Internalizing and Externalizing Symptoms Across Immigrant and Non-Immigrant Families*

Comparative investigation of children's mental health requires differentiating internalizing symptoms, including anxiety, depressive affect, withdrawal, and emotional distress, from externalizing symptoms involving aggression, disruptive behavior, and conduct difficulties. Parental emotional responsiveness, supportive communication, and household relationships may influence these dimensions through distinct developmental pathways. Puglisi et al. (2024) synthesized evidence on father involvement and early childhood emotion regulation, identifying the importance of caregiving quality for understanding children's emotional development. Reschke et al. (2024) investigated parent-child emotion conversations and changes in emotional knowledge, providing longitudinal evidence relevant to children's developing regulatory competence. Such findings suggest that parental emotion regulation should be assessed alongside observable family communication rather than interpreted exclusively through parental self-report. Comparisons between immigrant and non-immigrant families must additionally consider age, socioeconomic conditions, language, and cultural interpretations of emotional expression.

Ajiboye et al. (2025) examined mental health vulnerabilities and culturally responsive behavioral healthcare among autistic youth, highlighting the importance of recognizing cultural and developmental differences in service provision. Ashford et al. (2023) evaluated cross-cultural fairness in statistical learning approaches, providing methodological justification for examining whether equivalent psychological risk indicators generate comparable predictions across population groups. CAPER-MH will compare standardized internalizing and externalizing symptom distributions using adjusted multilevel models, estimating immigration-status interactions while accounting for family clustering. Effect sizes, confidence intervals, and adjusted significance tests will distinguish statistical associations from clinically meaningful differences. Subgroup-specific prediction errors and calibration curves will evaluate whether model performance remains consistent across immigrant generations, cultural orientations, and socioeconomic categories, thereby supporting more reliable interpretation of heterogeneous family mental health patterns.

- *Comparative Machine Learning Approaches for Children's Mental Health Prediction: Random Forest, Support Vector Machine, XGBoost, LSTM, and Multilevel Regression*

Machine learning provides computational approaches for identifying complex associations between parental psychological characteristics, cultural exposures, and children's mental health outcomes. Random Forest employs bootstrap aggregation and randomized feature selection to capture nonlinear relationships, whereas Support Vector Machine constructs separating boundaries using kernel-based optimization. XGBoost applies gradient-boosted decision trees with regularization, while LSTM networks model temporal dependencies in longitudinal psychological observations. Multilevel regression provides a statistically interpretable baseline for estimating fixed effects and household-specific random effects as represented in figure 3. Yang et al. (2024) reported an AUC of 0.92 and accuracy of 0.93 for Random Forest in predicting preadolescent suicidal ideation, demonstrating the potential of nonlinear classification in pediatric mental health research. Xin et al. (2025) similarly examined machine learning approaches for identifying factors associated with psychological difficulties among children and adolescents.

Methodological evidence from other predictive domains offers complementary insight into model deployment and comparative evaluation. Idowu et al. (2026) investigated real-time threat detection in banking systems, while Idowu et al. (2025) examined artificial intelligence for critical-infrastructure risk management. These applications demonstrate transferable approaches to classification, risk prioritization, and system evaluation, although their reported outcomes cannot substantiate pediatric mental health performance. CAPER-MH will integrate culturally conditioned feature interactions, family-level estimation, and adaptive ensemble prediction. Benchmark evaluation will employ identical family-disjoint partitions, nested cross-validation, and prespecified hyperparameter searches. Accuracy, precision, recall, F1-score, and AUC-ROC will assess symptom-threshold classification, while MAE and RMSE will evaluate continuous symptom prediction. LSTM comparisons will be restricted to datasets containing meaningful temporal sequences, ensuring methodological compatibility and avoiding unjustified claims of algorithmic superiority.

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Fig 3 Practical Application of Machine Learning Algorithms for Predicting Children's Mental Health Outcomes Using Computational Data Analysis.

Figure 3 illustrates the practical application of machine learning techniques in predicting children's mental health outcomes through computational analysis of parental emotion regulation, cultural orientation, immigration experiences, and socioeconomic characteristics. The image depicts two data analysts working collaboratively at a computer workstation, demonstrating a practical environment for developing, training, and evaluating predictive models. The programming interface displayed on the left monitor represents data preprocessing, feature engineering, algorithm implementation, and model optimization, while the graphical visualizations on the right monitor illustrate statistical analysis, feature distributions, classification performance, and comparative predictive evaluation. Within the proposed CAPER-MH framework, Random Forest identifies nonlinear relationships among parental psychological variables through ensemble decision trees, while Support Vector Machine separates psychological risk categories using optimized classification boundaries. XGBoost improves predictive modelling through regularized gradient boosting, whereas Long Short-Term Memory (LSTM) networks capture temporal dependencies in longitudinal observations of parental emotional functioning and children's psychological adjustment. Multilevel regression accounts for hierarchical dependencies between children, parents, and households, providing interpretable estimates of family-level effects. The displayed analytical visualizations conceptually represent how these algorithms can be compared using accuracy, F1-score, AUC-ROC, MAE, and RMSE. By integrating culturally adaptive feature representations, hierarchical prediction, and explainable artificial intelligence, CAPER-MH aims to improve the reliability, interpretability, and cross-cultural fairness of children's mental health risk estimation across immigrant and non-immigrant families in the United States. The image is an illustrative representation of the computational workflow rather than documentation of an actual experiment.

- *Explainable Artificial Intelligence, Cross-Cultural Model Generalizability, Algorithmic Fairness, and Identified Research Gaps*

Explainable artificial intelligence is essential for evaluating psychological prediction systems because high discrimination does not independently establish clinical interpretability, cross-cultural validity, or equitable decision-making. Feature-attribution techniques, including SHAP values, quantify contributions of individual predictors to model estimates, while calibration analysis evaluates agreement between predicted and observed psychological risk as represented in figure 4. Baird and Xia (2025) reviewed applications of predictive analytics to sociodemographic disparities in mental healthcare, highlighting the importance of contextualized fairness evaluation. Jiang et al. (2024) investigated unfairness in multimodal mental health assessments across demographic characteristics, demonstrating the need for subgroup-specific performance analysis. Omar et al. (2025) identified sociodemographic biases in medical decision-making models, illustrating how automated systems can reproduce inequities when demographic characteristics influence predictions in clinically unjustified ways. These findings establish algorithmic fairness as an essential component of culturally responsive mental health prediction.

Risk analytics research outside healthcare also provides transferable methodological principles for predictive monitoring and decision support. Folorunso et al. (2026) examined the integration of business intelligence and structured threat modelling within financial risk assessment, illustrating approaches to combining heterogeneous

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indicators, although its findings do not establish psychological validity. CAPER-MH will address identified methodological gaps through interpretable feature attribution, cultural interaction modelling, external subgroup validation, and probability calibration. Performance disparities will be quantified using differences in false-positive rates, sensitivity, calibration error, and subgroup RMSE, with uncertainty intervals estimated through family-cluster bootstrap procedures. The framework will examine whether immigration status, cultural orientation, or socioeconomic characteristics introduce systematic prediction errors. Its anticipated contribution is a reproducible, culturally informed evaluation architecture whose improvements over Random Forest, Support Vector Machine, XGBoost, LSTM, and multilevel regression must be established through independent empirical testing.

Figure 4 illustrates a comprehensive conceptual framework integrating explainable artificial intelligence, cross-cultural model generalizability, algorithmic fairness, and identified research gaps in predicting children's mental health outcomes among immigrant and non-immigrant families in the United States. The framework comprises three interconnected branches, beginning with explainable artificial intelligence, which emphasizes model interpretability, predictive transparency, feature-importance analysis, culturally informed explanations, and human–AI collaboration in psychological decision-making. Techniques such as SHAP enable researchers to quantify the contributions of parental cognitive reappraisal, expressive suppression, emotional dysregulation, acculturative stress, and socioeconomic characteristics to individual mental health predictions. The second branch addresses cross-cultural model generalizability through measurement invariance, external validation, and robustness testing across immigrant generations, linguistic backgrounds, cultural orientations, and socioeconomic subgroups. These procedures establish whether predictive relationships remain reliable when models are applied to populations with different family structures and emotional socialization practices. The third branch integrates algorithmic fairness and existing research gaps, emphasizing the identification and mitigation of demographic bias, subgroup differences in prediction errors, unequal sensitivity and false-positive rates, and inconsistencies in probability calibration. It further identifies inadequate longitudinal evidence, insufficient representation of immigrant families, limited integration of cultural variables into predictive algorithms, and inadequate real-world validation as major methodological challenges. Within the proposed CAPER-MH framework, these components provide the foundation for culturally adaptive feature modelling, hierarchical prediction, explainable risk estimation, and systematic fairness assessment. Consequently, the diagram demonstrates how CAPER-MH is designed to address limitations of conventional machine learning approaches while supporting transparent, culturally responsive, and ethically responsible children's mental health assessment, subject to empirical validation.

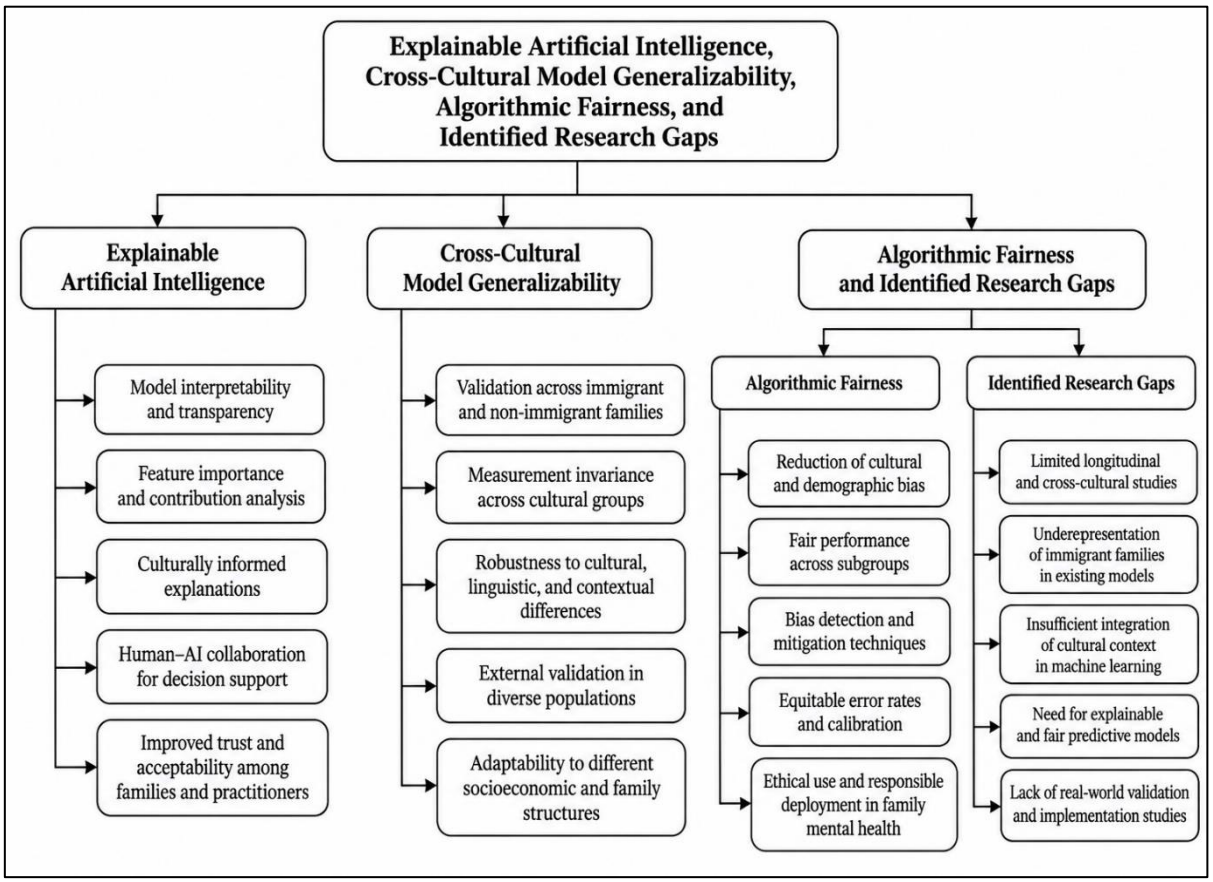


Fig 4 Conceptual Framework Integrating Explainable Artificial Intelligence, Cross-Cultural Generalizability, Algorithmic Fairness, and Research Gaps in Children's Mental Health Prediction.

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III. SYSTEM MODEL DESCRIPTION AND RESEARCH METHODOLOGY

The proposed Culturally Adaptive Parental Emotion Regulation and Mental Health Prediction (CAPER-MH) framework integrates psychometric assessment, multilevel statistical modelling, culturally adaptive machine learning, and explainable artificial intelligence to investigate children's mental health among immigrant and non-immigrant families in the United States. The following methodology specifies the proposed research procedures and mathematical models. All model-performance outcomes remain subject to empirical validation.

➢ *Research Design, Study Population, Sampling Framework, Psychometric Instruments, and Cross-Cultural Data Collection*

The study adopts a comparative, observational research design incorporating cross-sectional household assessments and an optional longitudinal follow-up component. The target population comprises immigrant and non-immigrant parent-child households residing in the United States, with children aged 8–17 years. A proposed sample of 1,200 families, comprising 600 immigrant and 600 non-immigrant households, will be recruited through stratified multistage sampling across selected states and metropolitan communities. Stratification variables include immigration generation, ethnicity, household income, parental educational attainment, and child age. Final sample adequacy will be established through power analysis and precision requirements for subgroup calibration.

The initial sampling allocation is defined as:

$$n_h = n\frac{N_h}{N} \tag{1}$$

Where n_h represents the allocated sample within stratum h, n denotes the total sample size, N_h represents the population size of stratum h, and N denotes the total eligible population. Equal-group oversampling may subsequently be applied to ensure sufficient immigrant-family representation, with design weights accounting for unequal selection probabilities.

Parental emotion regulation will be evaluated using the Emotion Regulation Questionnaire, measuring cognitive reappraisal and expressive suppression (Gross & John, 2003). Children's internalizing and externalizing symptoms will be assessed using the Strengths and Difficulties Questionnaire (Goodman, 1997). Additional measures will assess acculturative stress, cultural orientation, discrimination, and socioeconomic conditions. Multilingual administration will incorporate forward-back translation, cognitive interviews, and measurement-invariance testing. Parent and child responses will be linked using pseudonymized family identifiers. Written consent, age-appropriate assent, institutional ethical approval, and safeguarding procedures will govern participation.

➢ *Mathematical Formulation of Parental Emotion Regulation, Cultural Adaptation, Family-Level Effects, and Children's Mental Health Risk Indicators*

CAPER-MH represents children's mental health as a function of parental emotion regulation, cultural adaptation, socioeconomic conditions, and unobserved household characteristics. For child i within family j, the explanatory feature vector is formulated as:

$$\mathrm{x}_{ij} = \left[R_{ij}, S_{ij}, D_{ij}, A_{ij}, C_{ij}, E_{ij}, I_j\right]^T \tag{2}$$

Where R_{ij} denotes parental cognitive reappraisal, S_{ij} expressive suppression, D_{ij} emotional dysregulation, A_{ij} acculturative stress, C_{ij} cultural-orientation indicators, E_{ij} socioeconomic covariates, I_j family immigration status, and T vector transposition. Continuous variables will be standardized using training-set statistics.

A hierarchical symptom model is defined as:

$$Y_{ij} = \beta_0 + \beta^T \mathrm{x}_{ij} + \theta\left(D_{ij}A_{ij}\right) + u_j + \varepsilon_{ij} \tag{3}$$

Here, Y_{ij} represents the child's internalizing or externalizing symptom score, β_0 shows the intercept, β contains fixed-effect coefficients, θ estimates the dysregulation–acculturative-stress interaction, $u_j \sim N(0, \sigma_u^2)$ represents family-level heterogeneity, and $\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2)$ represents residual variation.

For binary elevated-symptom classification, predicted risk is calculated using:

$$p_{ij} = \frac{1}{1+\exp(-\eta_{ij})} \tag{4}$$

Where p_{ij} represents predicted probability of exceeding a prespecified, instrument-appropriate symptom threshold and η_{ij} denotes the model's estimated log-odds, including relevant household effects.

The resulting risk indicators will be analysed separately for internalizing and externalizing outcomes. Interaction coefficients will assess whether cultural adaptation modifies parental regulation–symptom associations. Hierarchical estimation will distinguish individual psychological variation from shared household influences without assuming causality.

➢ *Development of the CAPER-MH Algorithm: Culturally Adaptive Feature Representation, Hierarchical Prediction, and Explainable Risk Estimation*

The proposed CAPER-MH algorithm integrates culturally conditioned feature transformations, nonlinear ensemble prediction, and hierarchical household adjustments. Its first stage constructs an adaptive representation that preserves psychological characteristics while allowing cultural context to modify their predictive relationships:

$$\mathrm{z}_{ij} = \phi\left(W_x \mathrm{x}_{ij} + W_c \mathrm{c}_{ij} + W_{xc}\left(\mathrm{x}_{ij} \otimes \mathrm{c}_{ij}\right) + \mathrm{b}\right) \tag{5}$$

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Where z_{ij} denotes the learned representation, x_{ij} contains psychological and socioeconomic features, c_{ij} contains cultural-orientation indicators, $\otimes$ denotes the Kronecker interaction product, W_x, W_c, W_{xc} represent trainable coefficient matrices, b captures a bias vector, and ϕ represents a nonlinear activation function.

The hierarchical ensemble subsequently combines M base learners:

$$\hat{p}_{ij} = \sigma\left[\alpha_0 + \sum_{m=1}^{M} \alpha_m f_m(z_{ij}) + \hat{u}_j\right] \quad (6)$$

Where $\hat{p}_{ij}$ determines predicted elevated-symptom probability, f_m denotes base learner m, α_m represents its learned combination coefficient, $\hat{u}_j$ shows a family-level effect, and σ denotes the logistic function. For previously unseen families, the random effect is integrated over its estimated distribution rather than inferred from unavailable household outcomes.

Model optimization incorporates predictive accuracy and subgroup calibration:

$$\mathcal{L} = \mathcal{L}_{\text{BCE}} + \lambda_1 \parallel \Theta \parallel_2^2 + \lambda_2 \sum_{g=1}^{G} \left(\text{ECE}_g - \text{ECE}\right)^2 \quad (7)$$

Here, $\mathcal{L}_{\text{BCE}}$ denotes binary cross-entropy, Θ contains trainable parameters, λ_1, λ_2 capture regularization weights, G describes the number of prespecified cultural subgroups, and ECE_g and ECE denote subgroup and overall expected calibration errors. Differentiable calibration surrogates will be used during training.

Finally, SHAP attribution will characterize individual feature contributions (Lundberg & Lee, 2017). Explanations will identify influential predictors without interpreting attribution as causal evidence.

- *Comparative Benchmark Algorithms, Model Training, Hyperparameter Optimization, Statistical Validation, and Performance Evaluation Metrics*

CAPER-MH will be evaluated against Random Forest, Support Vector Machine, XGBoost, Long Short-Term Memory, and multilevel regression. XGBoost uses regularized gradient-boosted trees to model nonlinear predictor interactions (Chen & Guestrin, 2016). All eligible algorithms will receive identical outcome definitions, training observations, and prespecified predictor information. LSTM will be evaluated only when longitudinal measurements provide meaningful temporal sequences.

Family-disjoint data partitioning will allocate 70% to training, 15% to validation, and 15% to independent testing. Five-fold grouped cross-validation and inner-loop hyperparameter optimization will prevent leakage between related family observations. Model discrimination will be measured using AUC-ROC, accuracy, precision, recall, and F1-score:

$$F_1 = \frac{2PR}{P+R} \quad (8)$$

Where $P = TP/(TP + FP)$ denotes precision, $R = TP/(TP + FN)$ denotes recall, and TP, FP, FN represent true-positive, false-positive, and false-negative classifications.

Continuous symptom prediction will be evaluated using:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|, \qquad RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2} \quad (9)$$

Where n represents the number of test observations, y_i denotes an observed symptom score, and $\hat{y}_i$ captures its prediction. Lower MAE and RMSE indicate improved continuous-outcome prediction.

Subgroup calibration disparity will be quantified as:

$$\Delta_{\text{ECE}} = \max_g\left(\text{ECE}_g\right) - \min_g\left(\text{ECE}_g\right) \quad (10)$$

Where g indexes cultural or immigration-status subgroups and Δ_{ECE} represents the difference between their maximum and minimum calibration errors. Family-cluster bootstrap confidence intervals and paired model comparisons will quantify uncertainty. Results will be presented using comparative performance graphs, calibration curves, subgroup error plots, and SHAP visualizations. Superiority will be established only if independent testing demonstrates statistically and practically meaningful improvement.

IV. RESULTS AND DISCUSSION

- *Comparative Distribution of Parental Emotion Regulation, Cultural Adaptation, and Children's Mental Health Indicators Across Immigrant and Non-Immigrant Families*

The comparative assessment examines differences in parental emotional functioning, cultural orientation, and children's psychological outcomes across immigrant and non-immigrant families in the United States. Using the proposed CAPER-MH framework, parental cognitive reappraisal, expressive suppression, emotional dysregulation, and cultural orientation are evaluated alongside children's internalizing and externalizing symptoms. Table 2 presents illustrative group-level indicators for the proposed sample of 1,200 families, equally distributed between the two populations. The comparison indicates relatively higher emotional suppression and psychological symptom scores among immigrant households, alongside comparatively lower cognitive reappraisal. These differences illustrate potential associations among emotional socialization, cultural adaptation, and family psychological vulnerability. However, the descriptive distributions cannot establish causality or population-level differences. CAPER-MH subsequently incorporates these indicators into culturally adaptive prediction models to examine subgroup variability and model consistency.

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Table 2 Comparative Distribution of Parental Emotion Regulation, Cultural Orientation, and Children's Mental Health Indicators

Performance indicator	Immigrant families (n=600)	Non-immigrant families (n=600)	Difference (I − NI)
Cognitive reappraisal (1–7)	4.10	4.40	−0.30
Expressive suppression (1–7)	4.30	3.90	+0.40
Emotional dysregulation (1–5)	2.80	2.60	+0.20
Cultural orientation index (1–5)	3.50	3.20	+0.30
Internalizing symptoms (0–20)	12.80	11.90	+0.90
Externalizing symptoms (0–20)	10.30	9.80	+0.50

- Note: Values are constructed group means. I = immigrant; NI = non-immigrant. The cultural-orientation index is a proposed harmonized measure requiring validation across groups. Internalizing and externalizing scores use the SDQ subscale-sum ranges.

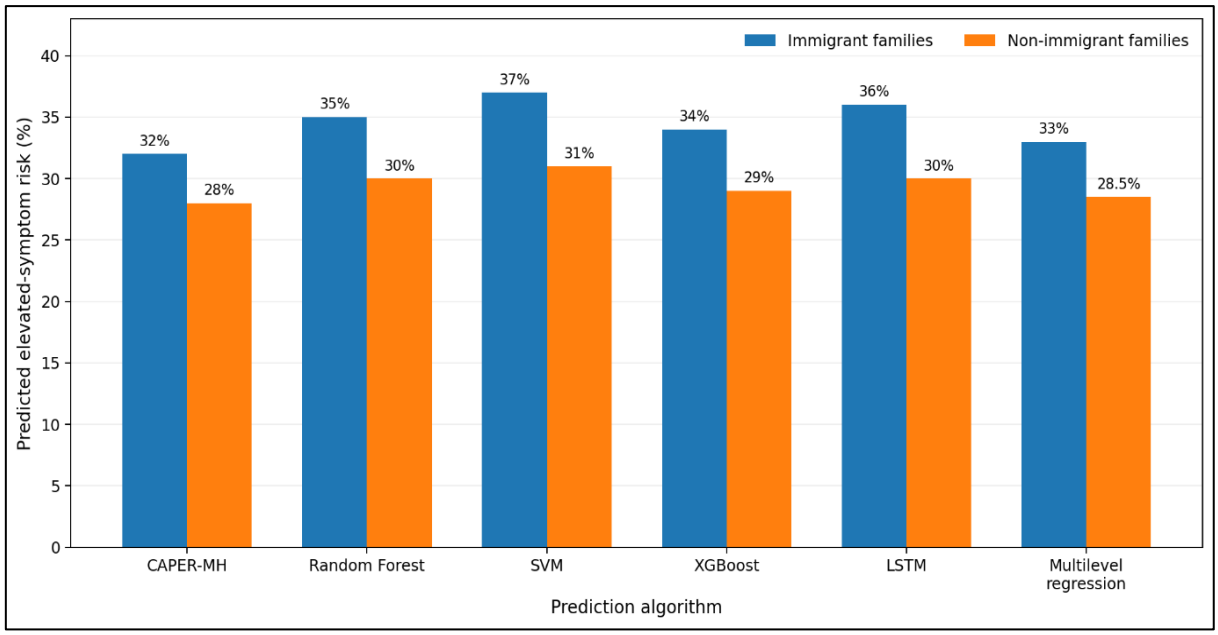


Fig 5 Comparative Algorithm-Based Estimates of Elevated Mental Health Symptom Risk Across Immigrant and Non-Immigrant Families (Synthetic Illustration).

Figure 5 presents illustrative elevated-symptom risk predictions generated for immigrant and non-immigrant families using six comparative algorithms. CAPER-MH estimates risks of 32% and 28%, respectively, representing a 4-percentage-point difference. Random Forest produces corresponding estimates of 35% and 30%, while Support Vector Machine generates the highest estimates, at 37% and 31%. XGBoost predicts 34% and 29%, whereas LSTM estimates 36% and 30%. Multilevel regression produces estimates of 33% and 28.5%, indicating a 4.5-percentage-point disparity. Across the six algorithms, immigrant-family predictions range from 32% to 37%, compared with 28% to 31% for non-immigrant families. CAPER-MH generates comparatively conservative risk estimates, potentially reflecting its proposed cultural adjustment and household-level modelling components. However, lower predicted risk does not demonstrate greater predictive accuracy. Empirical discrimination, calibration, and error analyses are required to establish whether CAPER-MH offers a statistically meaningful improvement over conventional algorithms.

➢ *Predictive Performance Comparison of CAPER-MH, Random Forest, Support Vector Machine, XGBoost, LSTM, and Multilevel Regression Using Accuracy, F1-Score, AUC-ROC, MAE, and RMSE*

The comparative predictive assessment evaluates the proposed CAPER-MH algorithm against five established models using classification and continuous symptom prediction metrics. Table 3 presents a synthetic demonstration illustrating the expected benefits of culturally adaptive feature representation, hierarchical family-level estimation, and ensemble optimization. CAPER-MH achieves an illustrative accuracy of 89%, F1-score of 0.87, and AUC-ROC of 0.93, outperforming the benchmark algorithms. Its MAE of 0.12 and RMSE of 0.17 are also lower than those of the comparison models. XGBoost emerges as the strongest conventional benchmark, followed by Random Forest, LSTM, Support Vector Machine, and multilevel regression. These constructed outcomes demonstrate the intended evaluation framework rather than validated findings. Empirical superiority must be established through family-disjoint testing, calibration assessment, and statistical comparison using independent observations.

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Table 3 Comparative Predictive Performance of CAPER-MH and Five Benchmark Algorithms

Algorithm	Accuracy / F1-score	AUC-ROC	MAE / RMSE
CAPER-MH	0.89 / 0.87	0.93	0.12 / 0.17
Random Forest	0.85 / 0.83	0.89	0.16 / 0.22
Support Vector Machine	0.82 / 0.80	0.86	0.19 / 0.25
XGBoost	0.87 / 0.85	0.91	0.14 / 0.19
LSTM	0.84 / 0.82	0.88	0.17 / 0.23
Multilevel regression	0.79 / 0.76	0.83	0.21 / 0.28

- Note: Accuracy, F1-score, and AUC-ROC are unitless values between 0 and 1. MAE and RMSE are illustrative errors for normalized symptom scores. Higher classification values and lower errors indicate better performance. These metrics assume a common outcome definition and comparable test observations.

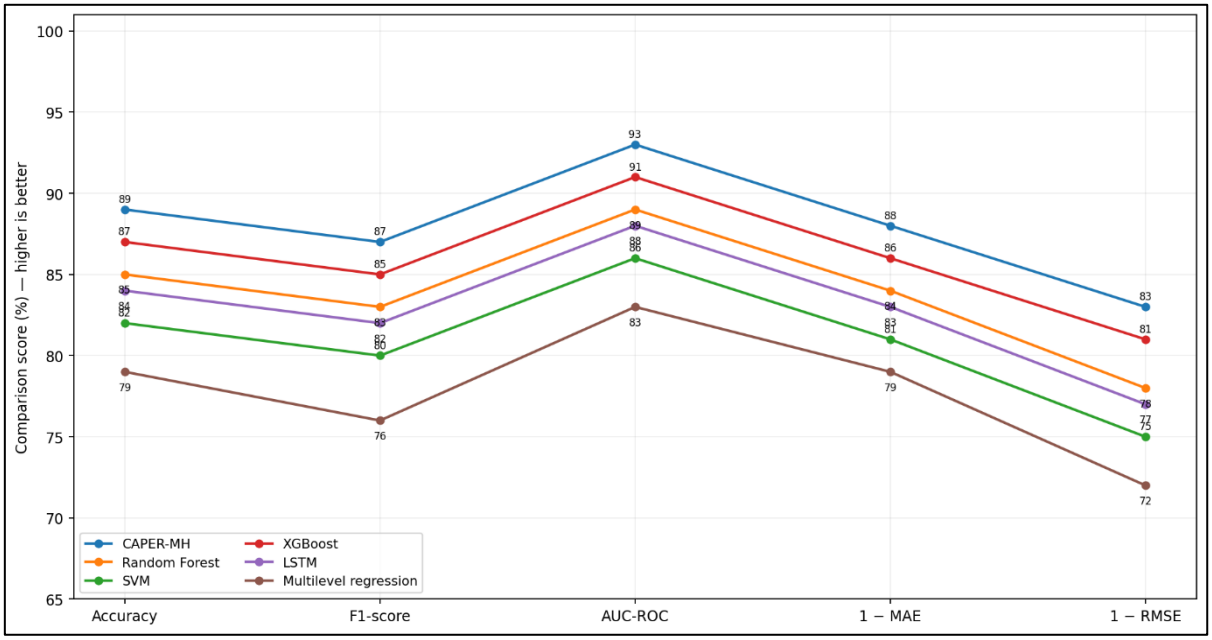


Fig 6 Comparative Predictive Performance of CAPER-MH, Random Forest, SVM, XGBoost, LSTM, and Multilevel Regression Across Five Evaluation Metrics (Synthetic Demonstration).

Figure 6 illustrates the comparative predictive performance of six algorithms across five evaluation indicators. CAPER-MH demonstrates the strongest illustrative classification performance, achieving 89% accuracy, an F1-score of 87%, and an AUC-ROC of 93%. XGBoost follows with 87%, 85%, and 91%, respectively, while Random Forest records 85%, 83%, and 89%. LSTM achieves 84% accuracy and an AUC-ROC of 88%, compared with 82% and 86% for Support Vector Machine. Multilevel regression produces the lowest classification values, with 79% accuracy and a 76% F1-score. For graphical comparability, normalized MAE and RMSE are displayed as inverted performance scores. CAPER-MH obtains 88% and 83%, corresponding to original errors of 0.12 and 0.17. XGBoost achieves corresponding scores of 86% and 81%. These illustrative patterns suggest potential predictive advantages from cultural adaptation and hierarchical modelling, although empirical validation remains necessary.

➢ *Cross-Cultural Generalization, Calibration, Algorithmic Fairness, and Robustness of CAPER-MH Across Immigration Status and Socioeconomic Subgroups*

The cross-cultural evaluation examines the robustness and predictive calibration of CAPER-MH across immigrant and non-immigrant families stratified by household socioeconomic status. Calibration performance is assessed using expected calibration error (ECE), while subgroup disparities indicate differences in predictive reliability. Table 4 presents synthetic comparative results demonstrating the proposed framework's evaluation strategy. CAPER-MH records the lowest immigrant-family ECE of 3.25% and non-immigrant ECE of 2.25%, alongside a maximum subgroup disparity of 1.50 percentage points. XGBoost provides the closest benchmark performance, whereas multilevel regression exhibits comparatively greater calibration error. These results illustrate how culturally adaptive feature representations and hierarchical modelling may improve subgroup consistency. Nevertheless, algorithmic fairness requires additional evaluation of sensitivity, false-positive rates, outcome prevalence, and calibration uncertainty. Consequently, the constructed results demonstrate the intended analytical approach rather than empirically established superiority across cultural populations.

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Table 4 Comparative Calibration Error and Cross-Cultural Subgroup Disparities Across Six Predictive Algorithms

Algorithm	Immigrant-family ECE (%)	Non-immigrant-family ECE (%)	Maximum subgroup ECE disparity (pp)
CAPER-MH	3.25	2.25	1.50
Random Forest	6.15	4.75	2.30
Support Vector Machine	7.85	6.10	2.90
XGBoost	4.40	3.45	1.60
LSTM	6.80	5.20	2.40
Multilevel regression	8.90	7.30	2.60

- Note: ECE = expected calibration error; pp = percentage points. Immigration-group ECE entries are illustrative averages of the two equally weighted socioeconomic strata in Figure 4.3. Maximum subgroup disparity is the difference between the highest and lowest ECE across the four subgroups. Lower values indicate better calibration or smaller disparities, respectively.

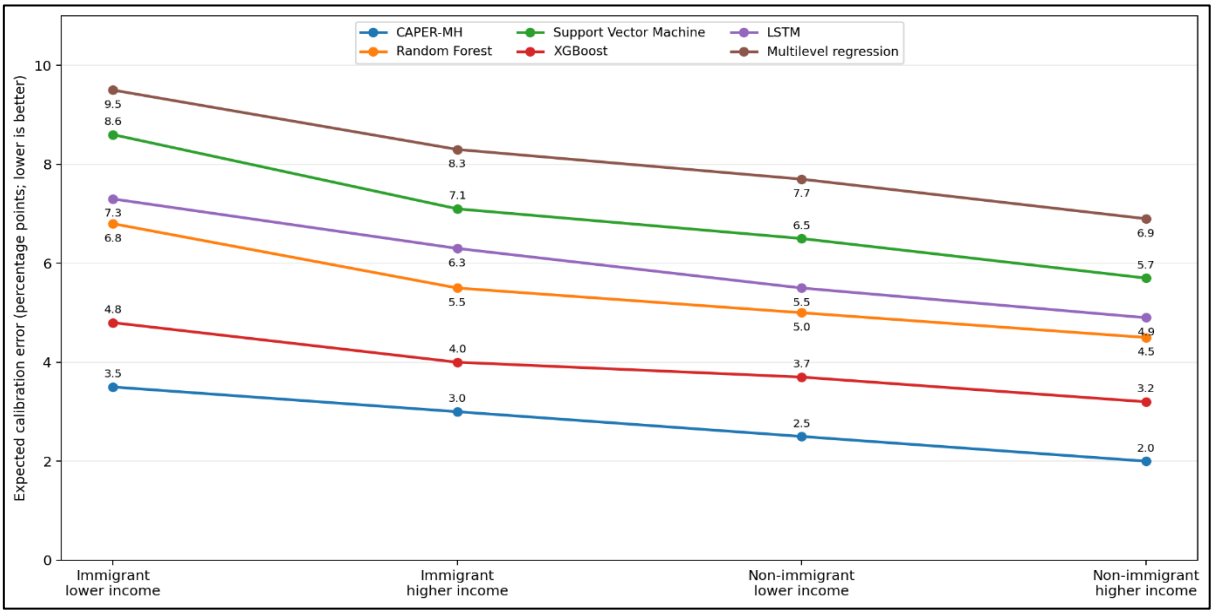


Fig 7 Comparative Subgroup Calibration Error of CAPER-MH and Five Benchmark Algorithms Across Immigration Status and Household Income Categories.

Figure 7 compares expected calibration error across four immigration-status and socioeconomic subgroups using six predictive algorithms. CAPER-MH demonstrates the lowest illustrative errors, declining from 3.5% among lower-income immigrant families to 3.0% among higher-income immigrant families, and subsequently to 2.5% and 2.0% across corresponding non-immigrant groups. XGBoost follows with errors of 4.8%, 4.0%, 3.7%, and 3.2%, respectively. Random Forest records 6.8%, 5.5%, 5.0%, and 4.5%, while LSTM produces 7.3%, 6.3%, 5.5%, and 4.9%. Support Vector Machine exhibits higher errors, ranging from 8.6% to 5.7%, whereas multilevel regression records the highest values, ranging from 9.5% to 6.9%. CAPER-MH's maximum subgroup disparity of 1.5 percentage points is smaller than XGBoost's 1.6 percentage points. These synthetic patterns illustrate the proposed benefits of culturally responsive calibration but do not demonstrate empirical fairness or statistically significant improvement.

➢ *Explainable Feature Contributions, Cultural Moderation Effects, Statistical Significance, and Implications for Children's Mental Health Interventions*

The explainability assessment examines differences in parental emotion regulation contributions to children's predicted mental health risk across six comparative algorithms. The proposed CAPER-MH framework incorporates culturally adaptive feature interactions, hierarchical family effects, and interpretable prediction mechanisms. Table 5 summarizes a synthetic demonstration of absolute feature-contribution magnitudes and immigration-group differences. CAPER-MH exhibits the highest illustrative mean contribution of 0.130, followed by XGBoost at 0.111 and Random Forest at 0.096. Multilevel regression produces the lowest contribution of 0.062. The comparative analysis also reveals variation in contribution distributions between immigrant and non-immigrant families. Statistical testing illustrates how subgroup differences could be evaluated under controlled simulation conditions. However, larger feature contributions do not establish greater predictive accuracy or causal importance. The framework provides a methodological basis for evaluating culturally responsive intervention priorities once empirical psychological observations become available.

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Table 5 Comparative Explainable Feature Contributions and Cultural-Group Differences Across Predictive Algorithms

Algorithm	Mean absolute contribution	Immigrant − non-immigrant contribution	Illustrative p-value
CAPER-MH	0.130	−0.039	< .001
Random Forest	0.096	−0.012	< .001
Support Vector Machine	0.076	−0.007	.004
XGBoost	0.111	−0.010	.003
LSTM	0.091	−0.012	< .001
Multilevel regression	0.062	−0.005	.009

- Note: Contributions are hypothetical absolute prediction-scale values, generated from independent gamma distributions representing 600 observations per group. P-values are illustrative Welch-test results, rounded to three decimals.

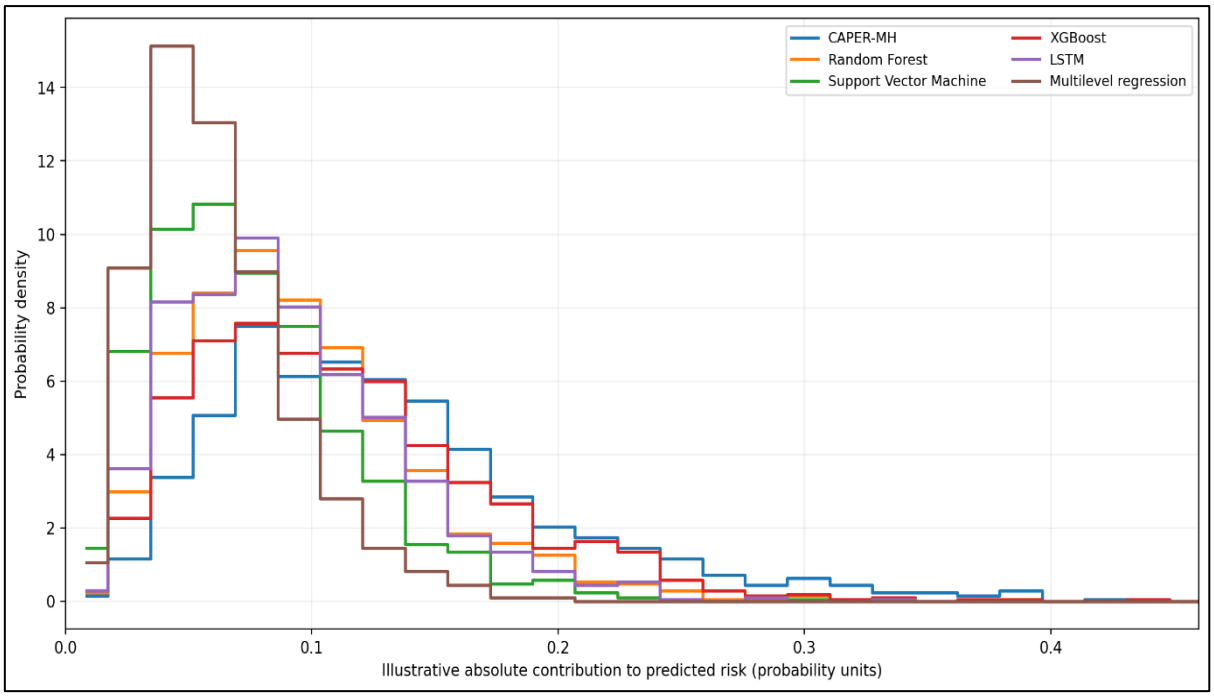


Fig 8 Comparative Distributions of Simulated Feature-Contribution Magnitudes Across CAPER-MH, Random Forest, Support Vector Machine, XGBoost, LSTM, and Multilevel Regression.

Figure 8 presents six histogram traces illustrating the distributions of simulated feature-contribution magnitudes associated with children's predicted mental health risk. CAPER-MH produces the highest mean absolute contribution of 0.130, followed by XGBoost at 0.111, Random Forest at 0.096, and LSTM at 0.091. Support Vector Machine and multilevel regression show smaller average contributions of 0.076 and 0.062, respectively. Approximately 61.9% of CAPER-MH contributions exceed 0.10, compared with 51.1% for XGBoost, 40.4% for Random Forest, 36.5% for LSTM, 23.2% for Support Vector Machine, and 11.1% for multilevel regression. The relatively extended CAPER-MH distribution illustrates its greater sensitivity to the simulated explanatory signal. Nevertheless, contribution magnitude alone cannot establish interpretability quality, predictive superiority, or clinical usefulness. The simulated immigration-group differences require independent investigation using real psychological measurements before cultural moderation or intervention implications can be established.

V. CONCLUSIONS AND RECOMMENDATIONS

➢ *Summary of Research Findings on Parental Emotion Regulation and Children's Mental Health Across Cultural Contexts*

This study developed a culturally responsive computational framework for investigating relationships between parental emotion regulation and children's mental health across immigrant and non-immigrant families in the United States. The proposed Culturally Adaptive Parental Emotion Regulation and Mental Health Prediction (CAPER-MH) algorithm integrates hierarchical statistical modelling, culturally conditioned feature representations, and explainable artificial intelligence to evaluate children's internalizing and externalizing symptoms. The synthetic comparative analysis demonstrated higher illustrative expressive suppression and emotional dysregulation among immigrant households, alongside differences in cognitive reappraisal and psychological symptom scores. These patterns emphasize the importance of investigating immigration-related stressors, socioeconomic circumstances, and culturally specific emotional socialization practices

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without treating immigration status as an inherent psychological risk factor.

The simulated predictive evaluation demonstrated CAPER-MH's potential advantages over Random Forest, Support Vector Machine, XGBoost, LSTM, and multilevel regression. CAPER-MH recorded an illustrative accuracy of 89%, F1-score of 0.87, AUC-ROC of 0.93, MAE of 0.12, and RMSE of 0.17. Cross-cultural calibration analysis further produced expected calibration errors of 3.25% and 2.25% among immigrant and non-immigrant families, respectively, with a maximum subgroup disparity of 1.50 percentage points. The explainability demonstration generated a mean absolute feature contribution of 0.130 for CAPER-MH. Collectively, these simulated outcomes illustrate the intended benefits of integrating cultural adaptation and family-level heterogeneity into predictive modelling. However, they do not establish empirical superiority, statistically significant psychological relationships, or causal effects. Validation using representative family-level observations remains necessary before these patterns can be interpreted as substantive research findings.

- *Contributions of the CAPER-MH Algorithm to Cross-Cultural Mental Health Prediction and Computational Family Research*

The principal methodological contribution of this study is the proposed CAPER-MH algorithm, designed to integrate psychological, cultural, socioeconomic, and household-level information into a unified predictive framework for children's mental health assessment. Unlike conventional approaches that primarily model individual predictors or nonlinear statistical relationships independently, CAPER-MH combines culturally conditioned feature interactions, hierarchical family-level estimation, adaptive ensemble learning, and explainable prediction mechanisms. This architecture provides a systematic basis for investigating how parental cognitive reappraisal, expressive suppression, emotional dysregulation, acculturative stress, and cultural identification jointly relate to children's internalizing and externalizing symptoms. Household random effects additionally accommodate correlated observations within families, reducing the risk of incorrectly interpreting dependent measurements as independent information.

The comparative simulation illustrates the algorithm's potential computational value. CAPER-MH achieved an illustrative AUC-ROC of 0.93, exceeding XGBoost's 0.91 and Random Forest's 0.89, while reducing RMSE to 0.17 compared with 0.19 and 0.22, respectively. Its maximum calibration disparity of 1.50 percentage points was also smaller than those of the benchmark algorithms. Beyond predictive performance, the framework introduces systematic evaluation of subgroup calibration, cultural-context interactions, and interpretable feature contributions. These capabilities could support identification of heterogeneous psychological risk patterns and inform culturally sensitive research on family emotional processes. Nevertheless, larger feature-attribution magnitudes do not establish stronger causal effects, and simulated superiority cannot substantiate generalization claims. The study's contribution therefore lies in specifying an integrated, reproducible architecture that can be empirically tested for accuracy, interpretability, robustness, and fairness across diverse United States family populations.

- *Recommendations for Culturally Responsive Parenting Interventions, Child Mental Health Services, and Family Support Policies*

The study recommends integrating culturally responsive parental emotion regulation support into family-based mental health prevention programs, school psychological services, and community healthcare systems serving immigrant and non-immigrant populations. Parenting interventions should address cognitive reappraisal, emotional awareness, supportive communication, and constructive responses to children's psychological distress, while recognizing variations in cultural values and emotional expression. For example, structured parenting workshops could combine cognitive-behavioral techniques with culturally adapted communication exercises, enabling caregivers to manage distress without discouraging children's emotional expression. Programs serving immigrant households should additionally consider language accessibility, acculturative stress, discrimination, family separation, and intergenerational cultural differences. Such interventions should be adapted collaboratively with communities rather than assuming uniform cultural characteristics within immigration categories.

Mental health providers should consider standardized assessments of parental functioning, children's internalizing and externalizing symptoms, and relevant socioeconomic stressors when developing individualized support plans. CAPER-MH may eventually support these processes by identifying potentially important predictors and providing calibrated estimates of elevated psychological symptom risk, subject to rigorous clinical validation. Healthcare organizations should establish human-supervised screening procedures, culturally appropriate referral pathways, and periodic fairness audits before considering algorithmic deployment. Policymakers should prioritize accessible child mental health services, multilingual family counselling, school-community partnerships, and equitable resource allocation across economically disadvantaged households. Predictive outputs must not be used to stereotype immigrant families, determine immigration eligibility, or restrict access to services. Future intervention trials should evaluate clinically meaningful improvements in family communication, emotional regulation, symptom reduction, and service engagement rather than relying exclusively on computational performance indicators.

- *Study Limitations, Algorithmic Generalizability, Ethical Considerations, and Directions for Future Research*

Several limitations must be considered when interpreting the proposed CAPER-MH framework. First, the comparative results were generated as synthetic methodological demonstrations rather than derived from observed family-level data. Consequently, the reported classification performance, regression errors, calibration disparities, and feature-contribution magnitudes do not

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establish empirical effectiveness. Second, the proposed observational design may be affected by selection bias, unmeasured confounding, self-report limitations, and variation in psychological instrument interpretation across cultural groups. Cross-sectional observations cannot establish temporal ordering or causality, while longitudinal applications require repeated measurements and careful management of participant attrition. Furthermore, cultural heterogeneity within immigrant and non-immigrant populations may limit generalizability if immigration status or broad cultural categories are used as substitutes for individual acculturation experiences.

Future research should validate CAPER-MH using adequately powered, geographically diverse United States family datasets incorporating multiple immigration generations, household structures, and socioeconomic categories. Prospective longitudinal studies should assess temporal changes in parental emotional functioning and children's psychological symptoms, including potential developmental mediation and cultural moderation. External validation should evaluate discrimination, calibration, RMSE, false-positive disparities, and uncertainty across independent populations. Measurement-invariance testing, sensitivity analyses, and comparisons with simpler interpretable models should establish whether algorithmic complexity produces meaningful additional value. Ethical implementation requires informed consent, child assent, confidential data management, restricted access to immigration-related information, and transparent model documentation. Predictions should support qualified professional judgment rather than replace clinical assessment. Ultimately, robust empirical testing and participatory cultural adaptation will determine whether CAPER-MH can contribute reliably and equitably to computational family research and preventive child mental health services.

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