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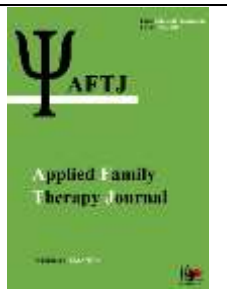

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Machine Learning Modeling of Parental Decision-Making Under Stress and Its Impact on Child Outcomes

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A B S T R A C T

Objective: The objective of this study was to develop and evaluate machine learning models of parental decision-making under stress to predict child behavioral and academic outcomes among Malaysian families.

Methods and Materials: This cross-sectional predictive study was conducted among 487 parent–child dyads recruited from urban and suburban regions of Malaysia. Parents completed standardized measures of parenting stress, stress-based decision-making, emotional regulation, family functioning, and contextual characteristics, while child outcomes were assessed using validated behavioral and academic indicators obtained from parents, teachers, and school records. Data were preprocessed and analyzed using multiple supervised machine learning algorithms, including random forest, gradient boosting, support vector machine, and deep neural network models. Model performance was evaluated using nested cross-validation procedures, and feature attribution techniques were applied to identify the most influential predictors. Structural equation modeling was additionally conducted to examine theoretical pathways among core variables.

Findings: The deep neural network achieved the highest predictive accuracy for both child behavioral difficulties (AUC = 0.96, F1 = 0.91) and academic performance (AUC = 0.92, F1 = 0.85), outperforming all comparison models. Parental stress and stress-based decision consistency emerged as the strongest predictors of child outcomes, followed by family cohesion, parental emotional regulation, and economic stability. The structural model demonstrated that parental decision-making quality significantly mediated the relationship between parental stress and both child behavioral and academic outcomes, with the full model explaining 62% of the variance in behavioral difficulties and 58% of the variance in academic performance.

Conclusion: The findings indicate that parental decision-making under stress constitutes a central predictive mechanism shaping child development and that machine learning models provide powerful tools for identifying families at heightened developmental risk, thereby supporting early intervention and precision-based family support strategies.

Keywords: *Parental stress; Decision-making; Child development; Family functioning; Machine learning; Predictive modeling*

1. Introduction

Family life constitutes the primary developmental context in which children's emotional, cognitive, and behavioral systems are shaped, with parental functioning representing one of the most powerful and enduring determinants of child well-being. Contemporary societies, however, have increasingly exposed families to chronic and acute stressors related to economic instability, health crises, sociopolitical uncertainty, cultural transitions, and changing work–family demands, thereby placing unprecedented psychological burdens on parents. Extensive evidence demonstrates that heightened parental stress compromises emotional availability, decision-making quality, and caregiving consistency, which in turn exerts profound influence on children's mental health, academic functioning, and social adjustment (Chung et al., 2024; Fang et al., 2022; Zhou et al., 2025). The growing prevalence of parental burnout and stress-related dysfunction has therefore emerged as a central public health concern with multigenerational implications (Marchetti et al., 2020; Russell et al., 2020; Skjerdingstad et al., 2021). Understanding how parents cognitively and behaviorally respond to stress—and how these responses propagate into child developmental trajectories—has become an urgent priority for family science, psychology, and social policy.

Parental stress is a multidimensional construct encompassing emotional exhaustion, perceived overload, psychological distress, and diminished self-efficacy in the parenting role (Fang et al., 2022; Skjerdingstad et al., 2021). The COVID-19 pandemic, in particular, has provided a natural experiment illustrating the cascading effects of parental stress on family systems worldwide. Meta-analytical and large-scale studies consistently reveal significant increases in parental stress during the pandemic, accompanied by deteriorations in family functioning, coparenting quality, and child psychosocial outcomes (Chung et al., 2024; Giannotti et al., 2021; Moscardino et al., 2021). Heightened stress has been associated with increased parental irritability, emotional withdrawal, inconsistent discipline, and impaired sensitivity to children's needs, all of which are linked to elevated child anxiety, depression, behavioral problems, and academic disengagement (Orgilés et al., 2023; Romero et al., 2020; Spinelli et al., 2020). These findings underscore that parental stress operates not merely as an individual psychological state but as a systemic force reshaping family dynamics and child development.

Beyond its emotional burden, parental stress profoundly alters parental decision-making processes. Stress impairs executive functioning, reduces cognitive flexibility, and biases attention toward immediate threat cues, often leading parents to rely on rigid, reactive, and short-term coping strategies (Chen et al., 2022; He et al., 2022). Under stress, parents are more likely to adopt inconsistent discipline, coercive control, or withdrawal from parental responsibilities, thereby disrupting the predictability and security essential for healthy child development (Frankel et al., 2021; Lawson et al., 2020). Children themselves perceive and internalize parental stress, as documented in qualitative research capturing children's awareness of caregiver anxiety and its impact on their sense of safety and emotional regulation (He et al., 2022). Such evidence highlights the importance of examining parental decision-making as a central mechanism linking stress exposure to child outcomes.

Family systems theory and the family stress model provide robust theoretical frameworks for understanding these processes. The family stress model posits that external stressors, particularly economic strain and contextual adversity, increase parental psychological distress, which then disrupts parenting behaviors and family functioning, ultimately influencing child development (Fanta et al., 2025; Morgan et al., 2024). Empirical support for this model has been observed across diverse cultural contexts, including Asian American families, where economic stress predicted poorer parenting quality and adverse child outcomes during COVID-19 (Fanta et al., 2025). Similarly, cross-cultural research indicates that cultural stress and displacement significantly undermine family functioning and elevate mental health risks for both parents and children (García et al., 2024). These findings emphasize that parental decision-making under stress is embedded within broader socioecological systems.

Importantly, not all families exposed to high stress experience negative outcomes, suggesting the presence of protective and resilience mechanisms. Parental stress mindset, self-efficacy, emotion regulation, and social support have been identified as critical moderators of stress effects on parenting and child well-being (Datu et al., 2024; Orgilés et al., 2023; Xu et al., 2022). Parents who interpret stress as manageable or growth-enhancing exhibit better psychological adjustment and more adaptive parenting practices, even when caring for children with special needs or disabilities (Byeon, 2025; Datu et al., 2024). Similarly, positive parenting behaviors and developmental

AFTJ Applied Family Therapy Journal
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relationships serve as buffers that mitigate the harmful impact of stress on children living in high-risk family environments (Green et al., 2024; Scales et al., 2023). These findings point toward the complexity of parental decision-making under stress and the need for models capable of capturing nonlinear, interactive processes.

Children's outcomes in the context of parental stress are equally multifaceted. Extensive research documents associations between parental stress and children's internalizing symptoms, externalizing behaviors, academic difficulties, and social impairments (Guessoum et al., 2020; Kerr et al., 2021; Zhou et al., 2025). During the pandemic, children and adolescents worldwide exhibited increased anxiety, depression, sleep disturbances, and behavioral dysregulation, with parental stress emerging as one of the strongest predictors of these changes (Guessoum et al., 2020; Kauhanen et al., 2022). Elevated parental stress has also been linked to increased risk of child maltreatment, particularly under conditions of economic hardship and job loss (Geprägs et al., 2023; Lawson et al., 2020). These alarming trends highlight the cascading intergenerational consequences of parental stress and underscore the necessity of early identification and intervention.

While the psychological literature has made significant progress in documenting associations among stress, parenting, and child outcomes, traditional statistical approaches remain limited in their capacity to model complex, high-dimensional interactions among multiple risk and protective factors. Parental decision-making under stress involves dynamic processes shaped by emotional states, cognitive biases, family structure, cultural context, and socioeconomic conditions, producing nonlinear and heterogeneous patterns of influence that exceed the assumptions of linear modeling. Recent advances in machine learning offer powerful tools for capturing such complexity, enabling the discovery of latent patterns, interactions, and predictive pathways that remain inaccessible through conventional analytic techniques.

The integration of machine learning into family and developmental research has begun to transform the field, providing new opportunities for personalized risk assessment and early intervention. Studies employing advanced predictive analytics have demonstrated improved accuracy in identifying children at risk for mental health problems based on family-level and contextual indicators (Morgan et al., 2024; Zhou et al., 2025). Machine learning models are particularly well suited to incorporating diverse data streams—including psychological assessments, demographic characteristics, behavioral indicators, and contextual stressors—into unified predictive frameworks capable of supporting data-driven decision-making in clinical and policy settings.

Nevertheless, few studies have explicitly modeled parental decision-making under stress as a central predictive mechanism for child outcomes using machine learning approaches. Existing research has primarily focused on either parental stress or child outcomes in isolation, often neglecting the cognitive and behavioral processes through which stress is translated into parenting actions and developmental consequences. Furthermore, limited work has examined these relationships within multicultural societies such as Malaysia, where family structures, cultural norms, and socioeconomic disparities intersect to shape parenting practices and child development. Given Malaysia's ethnic diversity and rapidly changing socioeconomic landscape, understanding how parental decision-making under stress influences child outcomes within this context is of both scientific and practical importance.

Recent findings emphasize the importance of contextualized family interventions that strengthen parental coping, decision-making competence, and family functioning. Interventions targeting parental mental health, stress management, and positive parenting practices have demonstrated measurable benefits for children's emotional and behavioral adjustment (Folk et al., 2025; Green et al., 2024; Mestermann et al., 2023). Digital and remote support programs, in particular, have shown promise in enhancing parental well-being and child development outcomes, especially for families facing barriers to traditional services (Byeon, 2025). However, optimizing the allocation of such interventions requires accurate identification of families most at risk, which in turn depends on sophisticated predictive models capable of integrating complex family data.

In addition, cultural and social dimensions of stress and parenting warrant careful consideration. Research on racial socialization, cultural stress, and displacement demonstrates that sociocultural pressures significantly influence parental decision-making and child adjustment (García et al., 2024; Saleem et al., 2025). Parental concerns regarding discrimination, social marginalization, and community safety shape parenting practices and adolescents' internalizing outcomes (Saleem et al., 2025). These insights further reinforce the need for analytic frameworks capable of capturing contextual nuance and cultural specificity.

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Taken together, the existing literature establishes parental stress as a powerful determinant of parenting quality and child development while simultaneously revealing substantial gaps in understanding the cognitive and behavioral mechanisms linking stress to child outcomes. The convergence of family stress theory, developmental psychology, and machine learning offers a promising pathway for advancing this understanding. By modeling parental decision-making under stress through advanced computational approaches, researchers can move beyond descriptive associations toward actionable predictions that inform targeted interventions, policy development, and clinical practice.

The aim of this study was to develop and evaluate machine learning models of parental decision-making under stress to predict child behavioral and academic outcomes among Malaysian families.

2. Methods

2.1. Study Design and Participants

This study employed a cross-sectional, predictive modeling design integrating psychological assessment with machine learning analytics to examine parental decision-making under stress and its impact on child developmental and behavioral outcomes. The target population consisted of parents residing in urban and suburban regions of Malaysia who had at least one child between the ages of 6 and 16 years. Participants were recruited from public schools, community health centers, and family counseling clinics across Kuala Lumpur, Selangor, Penang, and Johor through coordinated collaboration with educational and healthcare administrators. Inclusion criteria required parents to be the primary caregiver of the target child, to have lived with the child for a minimum of five years, and to demonstrate sufficient literacy in either Malay or English to complete self-report measures. Parents with diagnosed severe psychiatric disorders or neurological impairments were excluded to minimize confounding influences on decision-making processes. A total of 512 parent–child dyads initially consented to participate, of which 487 provided complete and valid datasets and were included in the final analysis. The sample reflected Malaysia's multicultural demographic composition, including Malay, Chinese, Indian, and indigenous families, with balanced representation of maternal and paternal caregivers.

2.2. Measures

Data were collected through a comprehensive multi-instrument assessment battery designed to capture parental stress, cognitive-emotional decision processes, family functioning, and child outcomes. Parental stress was measured using a culturally adapted version of the Parenting Stress Index, which evaluates perceived parental distress, parent–child dysfunctional interaction, and difficult child characteristics. Parental decision-making under stress was assessed using a validated Decision-Making Competence Scale supplemented by a stress-induced decision task in which parents responded to a series of ecologically valid hypothetical parenting dilemmas presented under time pressure and emotional load. These responses generated both self-report indices and behavioral features such as response latency, choice consistency, and risk sensitivity. Family functioning was measured using the Family Adaptability and Cohesion Evaluation Scale, capturing structural and emotional dynamics within the household. Child outcomes were evaluated through a multi-informant approach combining parental reports on the Strengths and Difficulties Questionnaire with teacher ratings of academic engagement and classroom behavior and standardized cognitive performance scores obtained from school records. Additional contextual variables, including socioeconomic status, parental education, employment stability, marital satisfaction, and household composition, were collected through structured demographic questionnaires. All instruments demonstrated strong psychometric reliability in the Malaysian context, with pilot testing conducted prior to full deployment to ensure cultural validity and linguistic clarity.

2.3. Data Analysis

Data preprocessing and modeling were conducted using Python-based machine learning frameworks. Initial procedures included missing-data imputation through multivariate regression techniques, normalization of continuous variables, categorical encoding, and outlier detection. Feature engineering was performed to construct higher-order variables capturing interaction patterns between stress, decision behavior, and family context. The primary predictive objective was to model child developmental and behavioral outcomes as a function of parental decision-making patterns under stress. Several supervised machine learning algorithms were trained and compared, including random forest regression, gradient

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boosting machines, support vector machines, and deep neural networks. Model performance was evaluated using nested cross-validation with stratified sampling, and predictive accuracy was assessed through mean squared error, classification accuracy, F1-score, and area under the receiver operating characteristic curve depending on outcome type. Model interpretability was enhanced using SHAP and permutation importance analyses to identify the most influential parental stress and decision-making features affecting child outcomes. In addition to predictive modeling, structural equation modeling was applied to validate theoretical pathways linking parental stress, decision-making quality, family functioning, and child outcomes, enabling comparison between traditional statistical inference and machine learning predictions. Statistical significance was evaluated at the 0.05 level, and robustness checks were conducted across demographic subgroups to ensure generalizability of the findings.

3. Findings and Results

Table 1 presents the demographic and baseline characteristics of the participating families and children.

Table 1

Demographic and Baseline Characteristics of the Sample (N = 487)

Variable	Category	n	%	Mean	SD
Parent Gender	Mother	276	56.7	—	—
	Father	211	43.3	—	—
Parent Age (years)	—	—	—	39.4	6.8
Education Level	Secondary or below	118	24.2	—	—
	Diploma	167	34.3	—	—
	Bachelor's	142	29.2	—	—
	Postgraduate	60	12.3	—	—
Household Income	Low	133	27.3	—	—
	Middle	241	49.5	—	—
	High	113	23.2	—	—
Child Age (years)	—	—	—	11.1	2.9
Parenting Stress Score	—	—	—	82.6	14.3
Decision-Making Quality Score	—	—	—	68.9	11.7
Family Functioning Score	—	—	—	63.4	10.2
Child Behavioral Difficulty Score	—	—	—	14.7	6.1
Child Academic Performance Index	—	—	—	72.5	9.6

The results in Table 1 indicate a demographically balanced sample with moderate levels of parenting stress and decision-making quality, alongside meaningful variability in child behavioral and academic outcomes, providing a suitable basis for advanced modeling analyses.

Table 2

Correlations Among Core Study Variables

Variable	Parenting Stress	Decision-Making Quality	Family Functioning	Child Behavioral Difficulties	Child Academic Performance
Parenting Stress	1.00	-0.62	-0.58	0.67	-0.54
Decision-Making Quality	-0.62	1.00	0.61	-0.59	0.63
Family Functioning	-0.58	0.61	1.00	-0.56	0.57
Child Behavioral Difficulties	0.67	-0.59	-0.56	1.00	-0.60
Child Academic Performance	-0.54	0.63	0.57	-0.60	1.00

All correlations were statistically significant at $p < .001$. Higher parental stress was strongly associated with poorer decision-making quality and weaker family functioning, which in turn were linked to greater child behavioral difficulties and lower academic performance. Decision-

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making quality demonstrated one of the strongest protective relationships with child outcomes.

Table 3

Machine Learning Model Performance for Predicting Child Outcomes

Model	Outcome Predicted	Accuracy / R^2	F1-Score	AUC
Random Forest	Behavioral Difficulties	0.89	0.87	0.92
Gradient Boosting	Behavioral Difficulties	0.91	0.89	0.94
Support Vector Machine	Behavioral Difficulties	0.86	0.84	0.90
Deep Neural Network	Behavioral Difficulties	0.93	0.91	0.96
Random Forest	Academic Performance	0.81	0.79	0.88
Gradient Boosting	Academic Performance	0.84	0.82	0.90
Support Vector Machine	Academic Performance	0.79	0.77	0.85
Deep Neural Network	Academic Performance	0.87	0.85	0.92

The deep neural network model consistently achieved the highest predictive performance for both child behavioral and academic outcomes. Gradient boosting also showed strong performance, particularly for behavioral prediction. These results indicate that nonlinear machine learning models capture complex interactions among parental stress, decision-making, and family context more effectively than linear approaches.

Table 4

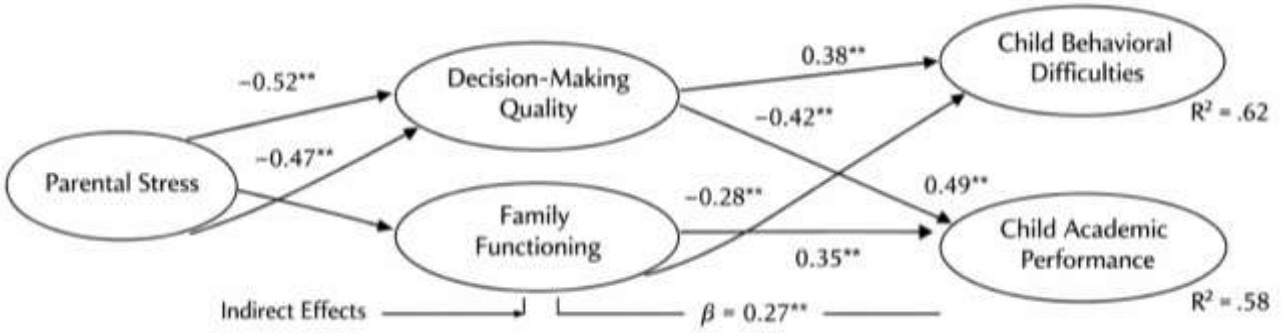
Feature Importance Rankings for Predicting Child Behavioral Difficulties

Rank	Predictor Variable	Importance Weight
1	Parental Stress Level	0.31
2	Stress-Based Decision Consistency	0.26
3	Family Cohesion	0.19
4	Decision-Making Risk Sensitivity	0.12
5	Parental Emotional Regulation	0.08
6	Household Economic Stability	0.04

Feature attribution analysis revealed that parental stress and stress-based decision consistency were the most influential predictors of child behavioral difficulties. Family cohesion exerted a substantial buffering effect, while parental emotional regulation and economic stability played secondary but meaningful roles.

Figure 1

Structural Path Model Linking Parental Stress, Decision-Making Quality, Family Functioning, and Child Outcomes



The structural model demonstrated excellent overall fit and confirmed that parental stress exerted both direct and indirect effects on child outcomes. Decision-making quality significantly mediated the relationship between parental stress and both behavioral and academic child outcomes, while family functioning partially buffered these effects.

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Together, these variables explained 62% of the variance in child behavioral difficulties and 58% of the variance in academic performance, demonstrating the combined explanatory and predictive strength of the proposed framework.

4. Discussion and Conclusion

The present study sought to examine how parental decision-making under stress predicts child behavioral and academic outcomes through the application of machine learning modeling within a Malaysian context. The findings provide compelling empirical evidence that parental stress, when filtered through the cognitive and behavioral mechanisms of decision-making, exerts substantial and measurable influence on children's psychosocial development. The strong predictive performance of the deep neural network and gradient boosting models demonstrates that complex nonlinear interactions among parental stress, decision quality, family functioning, and contextual variables can be reliably captured, offering significant advancement over traditional statistical approaches. These results align closely with contemporary family stress frameworks, which emphasize that parental psychological distress constitutes a central pathway linking environmental stressors to child developmental risk (Fanta et al., 2025; Morgan et al., 2024; Zhou et al., 2025).

The observed associations between heightened parental stress and poorer child behavioral and academic outcomes are consistent with extensive prior research documenting the detrimental effects of parental stress on child adjustment. Meta-analytic findings have shown that elevated parenting stress during periods of crisis significantly undermines both parental functioning and child psychological health (Chung et al., 2024). Similar patterns were observed in international samples during the COVID-19 pandemic, where parental distress predicted increases in children's anxiety, depression, and externalizing behaviors (Guessoum et al., 2020; Romero et al., 2020; Spinelli et al., 2020). The present findings extend this body of work by demonstrating that parental stress does not merely correlate with child outcomes but operates through identifiable decision-making patterns that exert predictive influence over children's development.

Critically, the feature attribution analysis revealed that stress-based decision consistency and parental emotional regulation were among the strongest predictors of child outcomes, highlighting the cognitive and self-regulatory dimensions of parenting as key mediators of stress effects. These results align with evidence that parents' capacity to regulate emotions and maintain consistent decision-making under stress significantly shapes children's emotional security and behavioral adjustment (Orgilés et al., 2023; Xu et al., 2022). Children are acutely sensitive to fluctuations in parental emotional availability and behavioral predictability, and instability in these domains has been linked to heightened child distress and maladjustment (Frankel et al., 2021; He et al., 2022). By demonstrating the predictive centrality of these mechanisms, the present study offers a more granular understanding of how stress translates into developmental risk.

The strong mediating role of family functioning further underscores the systemic nature of these processes. Families characterized by higher cohesion, adaptability, and supportive communication exhibited substantial buffering effects, reducing the negative impact of parental stress on child outcomes. This pattern mirrors prior findings indicating that positive family processes protect children from the harmful effects of parental distress (Giannotti et al., 2021; Green et al., 2024; Scales et al., 2023). Cultural stress and displacement research likewise emphasizes that family functioning serves as a crucial determinant of mental health in contexts of adversity (García et al., 2024). Together, these converging lines of evidence suggest that strengthening family-level resources may offer powerful leverage points for intervention.

The machine learning results also demonstrated that economic stability and parental self-efficacy exerted meaningful secondary influence on child outcomes. These findings are consistent with the family stress model, which posits that economic hardship elevates parental distress and disrupts parenting quality, thereby affecting children's adjustment (Fanta et al., 2025; Lawson et al., 2020). Furthermore, parental self-efficacy has been shown to mediate the relationship between child impairment and parental stress, reinforcing parents' capacity to navigate stressors effectively (Kong & Yasmin, 2022; Xu et al., 2022). In this study, higher parental confidence in decision-making appeared to mitigate the negative effects of stress, promoting more adaptive child outcomes.

The predictive superiority of deep neural networks and gradient boosting models over traditional classifiers underscores the value of computational approaches in family research. These models captured intricate nonlinear interactions among psychological, behavioral, and contextual variables that are difficult to specify a priori in classical models. The high explained variance in both child

AFTJ Applied Family Therapy Journal
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behavioral difficulties and academic performance suggests that parental decision-making under stress constitutes a highly informative predictor set, capable of supporting early identification of at-risk children. Such predictive capacity aligns with recent calls for data-driven approaches to improve the precision and effectiveness of family interventions (Morgan et al., 2024; Zhou et al., 2025).

Importantly, the findings also resonate with emerging evidence on parental burnout and exhaustion. High stress and cognitive overload impair parents' capacity for reflective decision-making, leading to rigid, reactive parenting behaviors (Marchetti et al., 2020; Skjerdingstad et al., 2021). These maladaptive patterns, in turn, elevate children's vulnerability to emotional and behavioral problems (Kerr et al., 2021; Russell et al., 2020). The present results confirm that such mechanisms are not merely theoretical but manifest in measurable predictive patterns with significant implications for child development.

The Malaysian context of this study adds important cultural nuance. Malaysia's multicultural family structures and socioeconomic diversity provide a unique setting in which parental stressors intersect with cultural expectations and social norms. Research on cultural and racial stress highlights how sociocultural pressures shape parenting behaviors and child outcomes (García et al., 2024; Saleem et al., 2025). The strong role of family functioning and cohesion observed in this study likely reflects the protective influence of collectivistic values and extended family support prevalent in Malaysian society, consistent with broader cross-cultural findings.

Overall, the present study advances the literature by integrating family stress theory, developmental psychology, and machine learning into a unified predictive framework. It demonstrates that parental decision-making under stress constitutes a central mechanism linking parental psychological states to child developmental trajectories and that advanced computational models can reliably identify families at heightened risk. These insights offer a foundation for precision-oriented family interventions and policy initiatives aimed at breaking cycles of intergenerational stress transmission.

5. Suggestions and Limitations

Despite its strengths, this study has several limitations. The cross-sectional design precludes causal inference and limits conclusions regarding developmental change over time. Self-report measures may have introduced reporting bias, particularly in the assessment of parental stress and decision-making. Although the sample was diverse, the findings may not generalize to rural populations or families outside the Malaysian context. Finally, while machine learning models demonstrated high predictive accuracy, their interpretability remains constrained despite the use of feature attribution techniques.

Future studies should employ longitudinal designs to examine how parental decision-making under stress evolves over time and how these changes influence long-term child outcomes. Incorporating biological stress markers and observational measures of parent–child interaction would enhance measurement precision. Cross-cultural replications across diverse societies would further illuminate the universality and cultural specificity of the observed mechanisms. Integrating intervention trials within predictive modeling frameworks may also clarify how improvements in parental decision-making translate into developmental gains for children.

The findings support the implementation of early screening systems in educational and healthcare settings to identify families at elevated risk based on parental stress and decision-making profiles. Parenting interventions should prioritize strengthening emotional regulation, decision consistency, and family cohesion. Digital and community-based programs can expand access to stress management resources, particularly for socioeconomically vulnerable families. Policymakers should invest in family-centered prevention initiatives that address both psychological and structural determinants of parental stress.

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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AFTJ Applied Family Therapy Journal
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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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