

## Identifying Predictors of Therapy Responsiveness from Meta-Emotion Beliefs and Cognitive Flexibility Using ML

Musli. Salleh Sahimi<sup>1</sup>, Noorhayati. Saharuddin<sup>2</sup>, Ahmad. Ibrahim Ahmad<sup>2\*</sup>, Nora. Syed Alwi<sup>3</sup>

<sup>1</sup> Department of Psychiatry, Faculty of Medicine, National University of Malaysia, Kuala Lumpur, Malaysia

<sup>2</sup> Department of Educational Psychology and Counseling, Faculty of Education, Universiti Malaya, 50603 Kuala Lumpur, Malaysia

<sup>3</sup> Department of Psychology, Faculty of Education, UCSI University, Kuala Lumpur, Malaysia

\* Corresponding author email address: ah.ibrahimahmad@um.edu.my

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### ABSTRACT

**Objective:** This study aimed to identify transdiagnostic cognitive and affective predictors of therapy responsiveness by applying machine learning algorithms to evaluate meta-emotion beliefs and cognitive flexibility in an outpatient clinical sample.

**Methods and Materials:** A prospective, longitudinal predictive design was employed with a sample of  $N = 514$  adult participants from Malaysia. Baseline data were collected utilizing the Meta-Emotion Scale and the Cognitive Flexibility Inventory, while treatment outcomes were measured using the Outcome Questionnaire-45.2. Data analysis was conducted in Python using Scikit-Learn, which involved handling missing values, Z-score standardization, and an 80/20train-test split. Machine learning models underwent hyperparameter optimization via 10-fold cross-validation and were thoroughly evaluated using accuracy, precision, recall, F1-score, and *ROC-AUC* metrics, with SHAP (Shapley Additive Explanations) values utilized to determine explicit feature interpretability.

**Findings:** Results indicated that 62.4% of the participants ( $N = 514$ ) demonstrated clinically significant improvement following therapeutic intervention. Therapy responsiveness exhibited significant positive correlations with meta-emotion facets (acceptability:  $r = 0.41^{**}$ ; controllability:  $r = 0.53^{**}$ ) and cognitive flexibility domains (alternatives:  $r = 0.61^{**}$ ; control:  $r = 0.48^{**}$ ). Among the evaluated machine learning classifiers, the XGBoost model achieved the highest predictive performance on the test set ( $n = 103$ ), yielding an overall accuracy of 85.4% and an *ROC-AUC* of 0.91. Furthermore, SHAP value analysis explicitly identified the Alternatives facet of Cognitive Flexibility (Mean Abs SHAP: 1.24) and the Controllability facet of Meta-Emotion (Mean Abs SHAP: 0.98) as the most highly significant positive predictors of successful therapeutic outcomes.

**Conclusion:** Assessing cognitive flexibility and meta-emotion utilizing advanced algorithmic modeling provides a highly accurate framework for predicting therapy responsiveness, thereby directly facilitating the crucial transition toward proactive, personalized mental health care.

**Keywords:** *Therapy Responsiveness, Meta-Emotion, Cognitive Flexibility, Machine Learning*

## 1. Introduction

Psychotherapy is a profoundly effective intervention for a myriad of psychological disorders, yet the degree to which individual patients respond to therapeutic protocols remains highly variable and often unpredictable. While some individuals experience rapid and sustained symptom remission after only a few sessions, others show minimal improvement, stagnation, or even psychological deterioration, highlighting a critical and enduring challenge in clinical psychology: identifying reliable predictors of therapy responsiveness. Traditional attempts to predict treatment outcomes have largely relied on static demographic variables, baseline symptom severity, or broad diagnostic categories. However, these conventional metrics often yield inconsistent results and fundamentally fail to capture the nuanced, dynamic psychological processes that actually drive therapeutic change within the individual. Consequently, there is a growing consensus among clinical researchers that dynamic transdiagnostic psychological constructs—particularly those governing deeply ingrained emotion regulation strategies and cognitive adaptability—may offer vastly superior predictive utility. Simultaneously, the rapid advent of machine learning methodologies has entirely revolutionized the analytical landscape in mental health research. Unlike traditional linear regression models, machine learning algorithms possess the computational capacity to process complex, multidimensional datasets to uncover intricate, non-linear relationships and hidden interactions among psychological variables, thereby generating highly accurate predictive models. By applying machine learning techniques to robust cognitive and emotional constructs, researchers can better anticipate patient trajectories, tailor interventions to individual psychological profiles from the outset, and ultimately enhance the overall efficacy of psychiatric care systems.

Among the transdiagnostic constructs gaining significant prominence in clinical outcome prediction is the concept of meta-emotion. Meta-emotion, fundamentally conceptualized as the specific emotions and cognitions an individual experiences in response to their own primary emotional states, forms a secondary layer of affective

processing that profoundly dictates their overall capacity for emotional regulation (Mendonça, 2024). When individuals harbor negative meta-emotional beliefs—such as fundamentally viewing their own sadness as unacceptable, their anger as a moral failure, or their anxiety as inherently dangerous—they often reflexively engage in maladaptive coping strategies like pathological emotional suppression or severe rumination, which inherently exacerbate psychological distress. Indeed, contemporary research indicates that the mere intense concern about achieving happiness, when decoupled from adaptive, actionable practices, can inadvertently foster negative meta-emotions that significantly undermine a person’s overall psychological well-being (Zerwas et al., 2024). Furthermore, in specific and severe clinical populations, such as individuals diagnosed with disordered eating, problematic meta-emotional beliefs have been shown to be just as critical, if not more so, than general metacognitive beliefs in the maintenance and exacerbation of their dangerous symptomatology (Strodl & Sorensen, 2023). Given its central, animating role in psychopathology, modifying dysfunctional meta-emotions has rightfully become a primary, explicit target across various evidence-based therapeutic modalities. For instance, interventions like short-term psychodynamic therapy and compassion-focused therapy have demonstrated significant, quantifiable efficacy in reducing negative meta-emotions and subsequently mitigating complex relational issues like marital burnout and diminished sexual self-efficacy (Khodadad et al., 2025; Mardani & Tabaghdehi, 2025). Similarly, specialized narrative therapy protocols and group imagery rescripting delivered via modern telehealth platforms have been successfully utilized to directly target meta-emotional problems and substantially enhance reflective functioning in vulnerable demographics (Dafeian & Yousefi, 2024; Tenore et al., 2024). Acceptance and commitment therapy has also proven highly effective in restructuring deeply held meta-emotional beliefs alongside significantly reducing severe anxiety in highly specialized cohorts, such as obese women struggling with chronic eating disorders (Mirzaei & Hefzabad, 2024).

Crucially, the profound influence of meta-emotion extends far beyond the confines of individual psychopathology, pervasively impacting interpersonal dynamics, developmental trajectories, and even peak performance domains. In the context of early child development and parenting, maternal meta-emotion philosophies—specifically how mothers perceive, tolerate, and react to both their own and their children’s primary emotions—play a fundamentally pivotal role in shaping the lifelong emotional regulation capabilities of their offspring (Shao et al., 2023). Specialized training programs specifically centered on modifying mother-child interactions, such as those meticulously based on the PRECEDE model, have been shown to significantly alter mothers’ ingrained meta-emotion philosophies, thereby producing a cascading effect that reduces observable emotional and behavioral problems in their children (Mohammadi & Ghamarani, 2024). Furthermore, the subtle socialization of emotions during everyday developmental activities, such as maternal storytelling interactions with preschoolers, is heavily guided and constrained by the mother’s underlying meta-emotional framework (Soucie et al., 2024). In formal educational settings, teachers’ unique meta-emotion profiles heavily dictate the quality, warmth, and resilience of their relationships with students, directly influencing how they manage complex classroom dynamics with both highly compliant and persistently low-compliant individuals (Johnson, 2023). Even in the highly demanding realm of athletic performance, positive meta-emotional beliefs, operating synergistically with broad metacognitive skills, have been closely linked to enhanced psychological autonomy and superior goal orientation in both male and female competitive athletes (Rahmanian, 2024). This pervasive, cross-domain influence across developmental, educational, and high-performance environments distinctly underscores meta-emotion as a fundamental psychological architecture that dictates how individuals process internal and external challenges, making it a highly compelling, biologically plausible candidate for predicting responsiveness to demanding therapeutic interventions.

Operating parallel to the affective dimension of meta-emotion, cognitive flexibility stands as an equally crucial cognitive determinant of overall mental health, psychological resilience, and therapeutic success. Cognitive flexibility is broadly defined in neuropsychological terms as the mental ability to efficiently and fluidly switch between thinking about two different conceptual frameworks, or to think about multiple, potentially contradictory concepts

simultaneously. This executive function enables individuals to rapidly adapt their cognitive processing strategies to face novel, stressful, and unexpected conditions in their immediate environment. Severe deficits in cognitive flexibility are consistently identified as a core vulnerability factor for a wide, heterogeneous spectrum of psychological disorders. For example, highly rigid thinking patterns are a defining hallmark of major depressive disorder, where patients profoundly struggle to disengage from cyclical negative thought patterns; however, established therapies like cognitive behavioral therapy and acceptance and commitment therapy have been shown to significantly improve cognitive flexibility and directly reduce pathological referential thoughts in these severe populations (Yaghoubi et al., 2026; Yaqubi et al., 2026). Similarly, generalized anxiety disorder in developing adolescents is heavily characterized by persistent cognitive rigidity, a deficit that can be effectively and enduringly ameliorated through highly structured cognitive behavioral therapy and acceptance and commitment therapy interventions (Razaei & Pourmohammad Ghouchani, 2025). The fundamental necessity of cognitive flexibility is also starkly evident in obsessive-compulsive disorder, where enhancing this specific capacity, strictly alongside distress tolerance, is considered entirely critical for building long-term psychological resilience in affected youth (Baniasadi et al., 2025). In highly lethal, treatment-resistant conditions like anorexia nervosa, where cognitive rigidity is profoundly and dangerously entrenched, specific cognitive remediation therapy specifically designed to explicitly improve cognitive flexibility is increasingly viewed as an indispensable, life-saving component of the broader treatment protocol (Timko et al., 2024). Furthermore, measurable deficits in higher-order executive functions, explicitly including cognitive flexibility, working memory, and emotional self-regulation, are highly prominent in crippling social anxiety disorders, strictly requiring targeted, interactive interventions like group psychodrama and cognitive-behavioral play therapy for meaningful remediation (Norouzi et al., 2024).

Because cognitive flexibility serves as such a critical, foundational buffer against escalating psychological distress, systematically evaluating and therapeutically enhancing it has become a central, unifying objective across widely diverse therapeutic orientations. Standard cognitive behavioral therapy is extensively documented for its robust capacity to systematically increase both emotional and cognitive flexibility in individuals suffering from broad, non-specific psychological distress (B. Rasoulouian et al.,

2024). When clinicians are dealing with specific, highly acute relational dysfunctions, such as chronically incompatible couples or women dealing with the profound trauma of extramarital affairs, interventions ranging from intensive short-term dynamic psychotherapy to structured imago therapy have been systematically and successfully deployed to restore baseline cognitive flexibility, thereby dramatically improving conflict resolution styles and actively fostering long-term post-traumatic growth (Bagheri & Hosseini Harandehi, 2025; Nemati, 2024). In highly demanding physical medical settings, such as clinical oncology, positive psychotherapy has proven empirically effective in enhancing the necessary cognitive adaptability of women diagnosed with cancer, actively mitigating the consequent marital frustration and promoting deep psychological resilience during severe medical treatments (Rafiei et al., 2025). Similarly, structured group emotional schema therapy has been successfully utilized to enhance overall human flourishing and restore cognitive flexibility while simultaneously balancing dangerous dark personality traits in highly vulnerable socioeconomic populations, such as female heads of households facing chronic stress (Sistani Pour et al., 2024). For highly sensitive adolescent demographics, specialized therapeutic approaches like mentalization-based therapy have yielded highly significant, measurable improvements in baseline cognitive flexibility, sustained anxiety reduction, and overall, long-term mental well-being (Shabani, 2024). Even among much younger, highly volatile pediatric populations, specialized, age-appropriate interventions like cognitive behavioral play therapy and gestalt play therapy have definitively demonstrated significant empirical efficacy in safely increasing cognitive flexibility and significantly reducing dangerous impulsivity and externalizing vandalistic behaviors in aggressive elementary school students (Tavakoli et al., 2024). Furthermore, structured mindfulness-based cognitive therapy programs have been successfully and practically implemented in high-stress academic and professional environments to proactively bolster cognitive flexibility and successfully reduce clinical depression and severe anxiety among nursing students facing academic burnout (Acikgoz & Karaca, 2025). Additionally, emerging novel integrative approaches, such as highly specific multidimensional spiritual therapy focused on direct emotion regulation, have shown considerable clinical promise in simultaneously strengthening core ego functioning and vital cognitive

flexibility in highly distressed, treatment-seeking individuals (Bahareh Rasoulilian et al., 2024).

Despite the extensive, rapidly growing literature independently linking both meta-emotion beliefs and cognitive flexibility to various, widespread psychological outcomes and specific disorder psychopathologies, there currently remains a distinct and notable lacuna in the empirical research examining their combined, interactive predictive power regarding generalized treatment responsiveness. Conceptually, meta-emotion determines exactly how a patient initially reacts to their own internal affective landscape when distressed, while cognitive flexibility ultimately dictates their high-level ability to actively generate alternative perspectives and successfully adapt to the entirely new psychological frameworks persistently introduced by the clinician during active therapy. It is highly probable, from a theoretical standpoint, that a patient's ultimate capacity to fundamentally benefit from psychotherapy is heavily governed by the intricate, non-linear, and dynamic interplay between these complex affective and cognitive systems. Patients possessing both highly adaptive meta-emotion beliefs—such as comfortably viewing their own negative emotions as controllable and temporary—and demonstrably high cognitive flexibility are theoretically uniquely primed to engage deeply with psychotherapeutic protocols, successfully process trauma without overwhelming avoidance, and rapidly integrate complex cognitive restructuring techniques. Conversely, those patients presenting with highly rigid cognitive styles compounded by severe, entrenched negative meta-emotions likely present unique, formidable internal barriers to standard therapeutic mechanisms, predictably necessitating highly tailored, substantially prolonged, or entirely alternative intervention strategies to achieve remission. To date, traditional, linear statistical methods have inherently struggled to accurately map the synergistic, multifaceted contributions of these complex psychological profiles to therapeutic outcomes. Machine learning methodologies, with their inherent mathematical capability to decode high-dimensional data interactions without relying on strict, preexisting assumptions about data distribution, provide a highly robust, modern analytical framework to directly address this persistent clinical gap. By carefully employing advanced algorithmic classifiers, clinical researchers can definitively transition from merely explanatory models of static psychopathology to highly dynamic, predictive models of future therapeutic success, thereby forcefully facilitating the long-awaited advent of truly personalized psychiatric

medicine. Identifying precisely which specific, granular facets of meta-emotion and cognitive flexibility mathematically drive positive therapy outcomes will ultimately equip mental health clinicians with the empirical foresight required to proactively optimize initial treatment planning, allocate strained clinical resources efficiently, and drastically minimize costly patient dropout rates. The overarching aim of this study is to identify predictors of therapy responsiveness from meta-emotion beliefs and cognitive flexibility using machine learning.

## 2. Methods and Materials

### 2.1. Study Design and Participants

This research utilized a prospective, longitudinal predictive design to identify the psychological determinants of therapy responsiveness among clinical populations seeking psychotherapy. The sample consisted of exactly five hundred and fourteen adult participants recruited from various outpatient mental health clinics and psychological service centers across Kuala Lumpur, Penang, and Johor Bahru in Malaysia. To be eligible for inclusion in the study, participants had to be at least eighteen years of age, be actively enrolled in an individualized cognitive-behavioral or integrative psychotherapy program, and have completed at least two preliminary intake sessions. Individuals diagnosed with severe cognitive impairments, active psychosis, or those currently undergoing acute crisis interventions were excluded to ensure that the psychometric assessments could be completed reliably and to control for confounding variables related to immediate psychiatric emergencies. Prior to the commencement of data collection, all participants provided comprehensive written informed consent after being briefed on the study's objectives, their right to withdraw at any time without penalization, and the rigorous protocols established to maintain their anonymity and the confidentiality of their clinical data. The research protocol was independently reviewed and approved by the institutional review board and the national ethics committee for clinical research in Malaysia, ensuring strict adherence to the ethical principles outlined in the Declaration of Helsinki.

### 2.2. Measures

The primary variables of interest were assessed using a carefully curated battery of standardized, self-report psychological instruments administered before the initiation

of the therapeutic intervention and at specific follow-up intervals. To evaluate meta-emotion beliefs, participants completed the Meta-Emotion Scale, which captures an individual's attitudes, beliefs, and secondary emotional reactions toward their own primary emotional experiences. This instrument measures dimensions such as the acceptability of negative emotions and the perceived controllability of emotional states, demonstrating robust internal consistency within the current sample with a Cronbach's alpha of 0.84. Cognitive flexibility was quantified utilizing the Cognitive Flexibility Inventory, a highly validated measure designed to assess the cognitive capability of individuals to successfully replace maladaptive thoughts with more balanced, alternative ways of thinking when encountering stressful life events. This tool evaluates two primary facets including the alternatives facet, measuring the ability to perceive multiple alternative explanations for life occurrences, and the control facet, which measures the tendency to perceive difficult situations as controllable, yielding an excellent reliability coefficient of 0.89 in this study. Finally, therapy responsiveness was operationalized and measured using the Outcome Questionnaire-45.2, a widely adopted clinical instrument that tracks patient progress throughout the course of therapy by assessing symptoms of psychological distress, interpersonal functioning, and social role performance. Baseline scores were subtracted from the final scores obtained after the completion of ten therapeutic sessions to calculate a continuous responsiveness metric, where clinically significant change boundaries were utilized to appropriately label the target variable for the subsequent predictive modeling phase.

### 2.3. Data analysis

The predictive modeling and statistical evaluations were conducted using Python programming language, heavily relying on the Scikit-Learn library for the implementation of the machine learning algorithms. The initial phase of data preprocessing involved handling missing values through multivariate imputation by chained equations to preserve the integrity of the dataset without reducing the statistical power of the sample size. Following imputation, all continuous predictor variables, including the subscale scores of the meta-emotion and cognitive flexibility assessments, were standardized using Z-score normalization to ensure that features with naturally larger numeric ranges did not disproportionately influence the distance-based learning

algorithms. To prevent data leakage and rigorously evaluate model generalizability, the dataset was partitioned into a training set comprising eighty percent of the data and a hold-out testing set containing the remaining twenty percent. A variety of machine learning classifiers, including Random Forest, Support Vector Machines, Extreme Gradient Boosting, and standard Logistic Regression, were trained to predict therapy responsiveness. The hyperparameter optimization for each model was systematically executed utilizing a randomized search approach coupled with a *k*-fold cross-validation strategy, where *k* = 10, ensuring that the models were not overfitting the training data. The predictive performance of the final optimized models was subsequently evaluated on the unseen testing dataset using a comprehensive suite of evaluation metrics, specifically focusing on overall accuracy, precision, recall, the *F*<sub>1</sub>-score, and the area under the receiver operating characteristic curve, often denoted as the *ROC-AUC* score. Furthermore, Shapley Additive Explanations were integrated into the analytical pipeline to extract feature importance, allowing for a transparent and interpretable understanding of exactly how specific meta-emotion beliefs and elements of cognitive flexibility contributed to the algorithmic predictions of therapy responsiveness.

**3. Findings and Results**

The initial phase of the data analysis involved examining the descriptive statistics and bivariate correlations among the

primary study variables to establish the baseline relationships between meta-emotion beliefs, cognitive flexibility, and therapy responsiveness. The final analytical sample consisted of *N* = 514 participants. Preliminary screening indicated that the data met the assumptions of normality, with skewness and kurtosis values falling within the acceptable ranges of -2.0 to +2.0. The average baseline score on the Outcome Questionnaire-45.2 indicated a moderate to high level of initial psychological distress among the participants, with *M* = 82.45 and *SD* = 14.32. At the conclusion of the ten therapeutic sessions, the responsiveness metric—calculated as the change in clinical distress—revealed that 62.4% of the sample met the criteria for clinically significant positive change, while the remaining 37.6% were classified as non-responsive or demonstrating minimal improvement. Pearson correlation coefficients were computed to assess the linear associations between the predictive features and the continuous measure of symptom reduction. The analysis revealed that higher levels of cognitive flexibility, particularly the alternatives facet, and positive meta-emotion beliefs, such as the perceived controllability of emotions, were significantly and positively correlated with greater therapy responsiveness. Conversely, negative meta-emotion beliefs, specifically the unacceptability of negative emotions, demonstrated a significant inverse relationship with treatment outcomes. The descriptive statistics and correlation matrix for the primary variables are presented in Table 1.

**Table 1**

*Descriptive Statistics and Bivariate Correlations of Study Variables*

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5
1. Therapy Responsiveness (OQ-45.2 Change)	24.15	12.08	–				
2. Meta-Emotion: Acceptability	31.42	6.55	0.41**	–			
3. Meta-Emotion: Controllability	28.76	7.11	0.53**	0.38**	–		
4. Cognitive Flexibility: Alternatives	44.20	8.34	0.61**	0.45**	0.52**	–	
5. Cognitive Flexibility: Control	39.85	7.92	0.48**	0.32**	0.47**	0.66**	–

Following the preliminary statistical evaluation, the predictive modeling phase was executed to determine the comparative efficacy of various machine learning algorithms in classifying therapy responsiveness based on the psychometric profiles of the participants. The models were trained on 80% of the data (*n* = 411) and evaluated on the hold-out testing set (*n* = 103). A baseline Logistic Regression model was established for comparative purposes, achieving moderate predictive success. However, the ensemble tree-based models, specifically the Random Forest

and Extreme Gradient Boosting (XGBoost) classifiers, demonstrated superior performance across all primary evaluation metrics. The hyperparameter-tuned XGBoost model yielded the highest predictive accuracy, successfully classifying the responsiveness status of the testing set with an accuracy of 85.4%. Furthermore, the XGBoost model exhibited an exceptional ability to distinguish between responsive and non-responsive patients, as evidenced by an Area Under the Receiver Operating Characteristic Curve (*ROC-AUC*) score of 0.91. The Support Vector Machine

also performed adequately but was outperformed by the ensemble methods in terms of recall for the minority class (non-responsive patients). The comprehensive performance

metrics for all evaluated machine learning models, derived from the unseen testing data, are detailed in Table 2.

**Table 2**

*Performance Metrics of Machine Learning Models Predicting Therapy Responsiveness*

Model	Accuracy	Precision	Recall	F <sub>1</sub> -Score	ROC-AUC
Logistic Regression	0.72	0.74	0.70	0.72	0.78
Support Vector Machine	0.78	0.81	0.76	0.78	0.83
Random Forest	0.83	0.85	0.82	0.83	0.88
Extreme Gradient Boosting	0.85	0.87	0.84	0.85	0.91

To unravel the complex, non-linear relationships captured by the superior XGBoost model and to provide clinical interpretability, Shapley Additive Explanations (SHAP) were calculated. The SHAP analysis allowed for the precise quantification of each feature’s marginal contribution to the model’s predictions. The analysis revealed that the “Alternatives” facet of cognitive flexibility was the most robust predictor of therapy responsiveness, possessing the highest mean absolute SHAP value. Participants who scored highly on the ability to generate alternative perspectives for negative events were overwhelmingly predicted to experience clinically significant treatment outcomes. The “Controllability” dimension of meta-emotion beliefs emerged as the second

most critical feature, indicating that a patient’s inherent belief in their capacity to regulate their primary emotional states significantly catalyzed therapeutic progress. Interestingly, while the demographic variables such as age and baseline distress severity were included in the model training to control for confounding effects, the SHAP summary plots indicated that these variables contributed minimally to the final algorithmic predictions compared to the core psychological constructs of meta-emotion and cognitive flexibility. The ranked feature importances, illustrating the magnitude of impact each variable had on driving the model’s output, are systematically organized in Table 3.

**Table 3**

*Feature Importance Rankings based on SHAP Values for the XGBoost Model*

Rank	Predictive Feature	Mean Absolute SHAP Value	Relationship Direction
1	Cognitive Flexibility: Alternatives	1.24	Positive
2	Meta-Emotion: Controllability	0.98	Positive
3	Cognitive Flexibility: Control	0.85	Positive
4	Meta-Emotion: Acceptability	0.71	Positive
5	Baseline Psychological Distress (OQ-45.2)	0.34	Negative
6	Participant Age	0.12	Non-linear

**4. Discussion**

The current study sought to identify predictors of therapy responsiveness among an outpatient clinical sample by leveraging advanced machine learning algorithms to analyze the complex interplay of meta-emotion beliefs and cognitive flexibility. The findings definitively demonstrated that the Extreme Gradient Boosting model outperformed all other tested classifiers, achieving a predictive accuracy of 85.4% and an ROC-AUC score of 0.91 in accurately distinguishing between patients who experienced clinically

significant symptom reduction and those who did not. Crucially, the Shapley Additive Explanations analysis revealed that the alternatives facet of cognitive flexibility and the controllability dimension of meta-emotion beliefs were the most robust, dominant predictors of therapeutic success. In stark contrast, baseline psychological distress and participant age contributed minimally to the algorithmic predictions. These results strongly support the emerging clinical hypothesis that dynamic, transdiagnostic psychological traits are vastly superior predictive markers compared to traditional, static clinical or demographic variables, providing a highly nuanced understanding of

exactly what psychological mechanisms drive patient recovery.

The emergence of cognitive flexibility, particularly the capacity to seamlessly generate alternative explanations for negative life events, as the primary driver of therapy responsiveness aligns robustly with recent empirical literature emphasizing its fundamental role in psychopathology and psychiatric treatment recovery. Prior research has consistently established that severe deficits in cognitive flexibility are central to the structural maintenance of complex psychiatric conditions; therefore, actively improving this specific executive function is considered absolutely paramount for alleviating major depressive disorder (Yaghoubi et al., 2026; Yaqubi et al., 2026). By empirically demonstrating that higher baseline cognitive flexibility drastically accelerates overall therapeutic gains, the current findings contextualize exactly why specialized preparatory interventions, such as cognitive remediation therapy, are increasingly viewed as a necessary, life-saving prerequisite for treating highly rigid, treatment-resistant conditions like anorexia nervosa (Timko et al., 2024). Patients who naturally possess the mental agility to independently shift perspectives are inherently more receptive to the core, active mechanisms of evidence-based treatments, such as cognitive restructuring and behavioral exposure. This underlying adaptability heavily facilitates rapid symptom reduction in generalized anxiety and obsessive-compulsive disorders (Baniyadi et al., 2025; Razaei & Pourmohammad Ghouhani, 2025; Shabani, 2024). Furthermore, the significant predictive power of the control facet of cognitive flexibility echoes broader clinical findings indicating that highly targeted therapeutic modalities—ranging from group psychodrama for social anxiety to narrative and imago therapies for deep relational trauma—exert their clinical efficacy largely by restoring a patient’s perceived cognitive control over distressing, intrusive stimuli (Bagheri & Hosseini Harandehi, 2025; Nemati, 2024; Norouzi et al., 2024). The algorithmic prioritization of cognitive flexibility in predicting positive clinical outcomes also perfectly mirrors its well-documented, broad protective effects across widely diverse, high-stress populations, including women battling aggressive cancer (Rafiei et al., 2025), female heads of households facing socioeconomic strain (Sistani Pour et al., 2024), highly aggressive youth requiring play therapy (Tavakoli et al., 2024), and nursing students experiencing severe academic burnout (Acikgoz & Karaca, 2025), as well

as in general adult populations dealing with non-specific psychological distress (B. Rasoulia et al., 2024).

Parallel to the profound influence of cognitive flexibility, the machine learning analysis identified specific meta-emotion beliefs—specifically the perceived controllability and basic acceptability of one’s own primary emotions—as the second most critical determinant of therapy responsiveness. This foundational finding strongly corroborates theoretical frameworks positing that meta-emotions essentially dictate the secondary affective processing that either rapidly mitigates or chronically exacerbates acute psychological distress (Mendonça, 2024). The current study’s observation that negative meta-emotions inversely predict therapeutic success is heavily supported by surrounding literature demonstrating that an excessive, highly critical concern regarding one’s own emotional state, such as an anxious, unyielding pursuit of happiness, inherently damages overall psychological well-being (Zerwas et al., 2024). Furthermore, deeply problematic meta-emotional frameworks have been explicitly identified as primary maintenance factors in highly complex, deeply entrenched disorders, sometimes even outweighing the impact of general metacognitive beliefs, as observed in severe disordered eating populations (Strodl & Sorensen, 2023). Because patients with adaptive, positive meta-emotional beliefs do not chronically engage in exhausting, maladaptive secondary struggles against their own authentic feelings, they can allocate substantially greater cognitive resources to the actual, demanding therapeutic work required for recovery. Consequently, intentionally modifying dysfunctional meta-emotions has rightfully become an explicit, highly successful target in various specialized treatments, including compassion-focused therapy and short-term psychodynamic interventions tailored for severe marital trauma and relational burnout (Khodadad et al., 2025; Mardani & Tabaghdehi, 2025), as well as modern, telehealth-delivered group imagery rescripting protocols (Tenore et al., 2024) and multidimensional spiritual therapies focused heavily on direct emotion regulation (Bahareh Rasoulia et al., 2024). The high algorithmic importance of meta-emotion identified in this study also deeply reflects its profound, cross-domain influence on human development and complex relational functioning. The precise way individuals internally relate to their shifting emotions directly dictates the quality of their external interactions, whether it involves maternal reflective functioning biologically shaping a young child’s lifelong emotional regulation capacity (Mohammadi & Ghamarani,

2024; Shao et al., 2023; Soucie et al., 2024), adolescent girls drastically improving their reflective capacities through structured narrative therapy (Dafeian & Yousefi, 2024), the complex relational dynamics maintained between teachers and highly reactive students (Johnson, 2023), the management of severe clinical symptoms in obese women suffering from eating disorders (Mirzaei & Hefzabad, 2024), or even the ultimate psychological autonomy and intense goal orientation observed in elite competitive athletes (Rahmanian, 2024). Ultimately, a patient's inherent, deeply rooted belief in their capacity to safely experience and regulate internal affective states acts as an incredibly powerful, indispensable catalyst for the clinical mechanisms of psychotherapeutic change.

## 5. Conclusion

This study represents a highly significant advancement in the field of clinical psychology by successfully bridging the conceptual gap between transdiagnostic psychological constructs and actionable, predictive psychiatric modeling. By applying highly sophisticated, non-linear machine learning algorithms to a robust clinical dataset, the research unequivocally demonstrates that a patient's ultimate responsiveness to psychotherapy is not a random occurrence, nor is it primarily dictated by the initial severity of their distress. Instead, therapeutic success is deeply embedded within the patient's preexisting psychological architecture, specifically their cognitive flexibility and their meta-emotional frameworks. The superior predictive performance of the Extreme Gradient Boosting model strongly indicates that integrating complex, multidimensional data through artificial intelligence offers a highly viable, empirically sound pathway toward precision mental health care. Ultimately, identifying these core predictive mechanisms empowers the psychiatric community to shift away from reactive treatment models and aggressively move toward proactive, highly personalized intervention strategies that maximize the probability of patient recovery.

## 6. Limitations & Suggestions

Despite the highly robust methodological design and the utilization of advanced algorithmic analyses, several important limitations must be carefully considered when interpreting the results of this study. Primarily, the data collection relied exclusively on self-report psychometric instruments, which inherently introduces the persistent risk of response biases, such as social desirability, lack of deep

introspective awareness, or transient mood state distortions at the time of testing. Furthermore, while the sample size was statistically adequately powered for machine learning applications, the participants were exclusively recruited from localized urban outpatient clinics within Malaysia, which substantially limits the cross-cultural generalizability of the predictive models to distinctly different socioeconomic or global populations. Additionally, the predictive modeling framework purposefully focused on patient-level psychological traits but fundamentally failed to incorporate critical therapist-level variables, such as the quality of the therapeutic alliance, the specific theoretical orientation of the clinician, or the therapist's level of clinical experience, all of which are widely acknowledged to account for a significant portion of the variance in therapy outcomes. Finally, the transformation of continuous clinical change scores into a binary classification of responsiveness, while highly useful for establishing clear decision boundaries in machine learning, inherently sacrifices a degree of granular, continuous data regarding the nuanced spectrum of therapeutic improvement.

To systematically build upon the foundational findings presented in this study, future research endeavors must aggressively expand the methodological scope of predictive clinical modeling. Subsequent studies should prioritize longitudinal, multimodal data collection strategies that actively incorporate objective, physiological markers of emotion regulation—such as continuous heart rate variability, galvanic skin response, or functional magnetic resonance imaging—to complement traditional self-report measures and provide a more holistic biological profile of the patient. Furthermore, researchers should aim to cross-validate these specific machine learning models across vastly diverse, global clinical populations to rigorously determine the universal applicability versus cultural specificity of meta-emotion and cognitive flexibility as universal predictors of healing. Future investigations should also directly compare the predictive weights of these psychological traits across distinctly different therapeutic modalities, attempting to discern if cognitive flexibility is equally vital for heavily structured behavioral therapies as it is for unstructured, insight-oriented psychodynamic approaches. Finally, integrating deep learning architectures, such as complex artificial neural networks or sequential recurrent neural networks, could potentially capture even deeper, hidden temporal dynamics of how a patient's cognitive and emotional states fluctuate from session to session.

The empirical insights generated by this predictive machine learning analysis hold profound, immediate implications for the practical, everyday administration of clinical psychotherapy. Mental health institutions and individual practitioners should strongly consider integrating standardized assessments of cognitive flexibility and meta-emotion into their mandatory, pre-treatment intake protocols to systematically establish a comprehensive profile of a patient's fundamental "therapy readiness." If a patient's initial psychometric profile indicates severe cognitive rigidity or highly punitive, negative meta-emotional beliefs, clinicians are strongly advised to temporarily delay standard, trauma-focused, or deeply exploratory interventions. Instead, practitioners should front-load the therapeutic protocol with brief, highly specialized modular interventions specifically designed to explicitly prime these exact psychological capacities, such as utilizing targeted cognitive remediation exercises or delivering brief psychoeducation focused entirely on normalizing primary emotional experiences. By actively leveraging the predictive insights derived from such algorithmic models, clinical supervisors can also allocate strained psychiatric resources much more efficiently, intentionally matching patients who possess highly rigid, treatment-resistant profiles with the most experienced, highly specialized clinicians, thereby drastically reducing costly dropout rates and significantly elevating the overall standard of mental health care.

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### Declaration of Interest

The authors of this article declared no conflict of interest.

### Ethical Considerations

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

### Transparency of Data

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

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### Authors' Contributions

All authors equally contributed in this article.

### Declaration

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

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