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Predicting Cognitive Distortions in Youth Using Advanced Machine Learning Algorithms

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A B S T R A C T

Objective: This study aimed to predict cognitive distortions among undergraduate students using advanced machine learning algorithms and to compare their predictive performance with traditional statistical approaches.

Methods and Materials: The study employed a quantitative, cross-sectional predictive design involving undergraduate students enrolled at universities in Yazd, Iran. Participants completed a battery of standardized self-report instruments assessing cognitive distortions and related psychological variables, including perceived stress, emotional distress, coping styles, and demographic characteristics. Data were preprocessed through screening for missing values, normalization, and partitioning into training, validation, and testing subsets. Multiple machine learning algorithms, including linear, nonlinear, and ensemble-based models, were implemented to predict overall cognitive distortion scores. Hyperparameter tuning and cross-validation procedures were applied to optimize model performance, and feature importance analyses were conducted to enhance interpretability. Model evaluation relied on multiple error-based and variance-explained indices to ensure robust and generalizable prediction.

Findings: Advanced machine learning models demonstrated substantially higher predictive accuracy than traditional linear regression, with ensemble-based algorithms achieving the strongest performance. The optimal model explained a large proportion of variance in cognitive distortion scores and maintained stable accuracy across training, validation, and testing datasets, indicating minimal overfitting. Perceived stress, emotional distress, and maladaptive coping emerged as the most influential predictors, while demographic variables contributed comparatively little to model performance. The results confirmed that nonlinear interactions among psychological variables play a critical role in predicting cognitive distortions in youth.

Conclusion: The findings indicate that cognitive distortions in university students can be accurately predicted using advanced machine learning approaches, highlighting the complex and multidimensional nature of distorted cognition.

Keywords: *Cognitive distortions; machine learning; university students; stress; emotional distress; predictive modeling*

1. Introduction

Cognitive distortions are systematically biased patterns of thinking that lead individuals to interpret internal experiences and external events in inaccurate, maladaptive, or exaggerated ways. These distorted cognitions play a central role in the onset, maintenance, and exacerbation of a wide range of psychological difficulties, particularly during youth and early adulthood, when cognitive schemas are still consolidating and vulnerability to emotional dysregulation is heightened. Contemporary psychological research increasingly recognizes cognitive distortions not merely as symptoms of psychopathology, but as transdiagnostic mechanisms that cut across emotional, behavioral, and interpersonal disorders (Topalalioğlu, 2025; Zimmerman et al., 2022). Understanding how cognitive distortions emerge, interact with psychosocial variables, and predict maladaptive outcomes in youth is therefore essential for both theoretical advancement and preventive intervention.

University students represent a particularly relevant population for studying cognitive distortions. This developmental stage is characterized by increased academic demands, identity exploration, interpersonal challenges, and exposure to stressors that may activate maladaptive cognitive patterns. Empirical evidence consistently demonstrates elevated levels of cognitive distortions among university students, especially in relation to anxiety, depression, interpersonal sensitivity, and academic stress (Haryadi et al., 2022; Sibarani et al., 2024). Cognitive distortions such as catastrophizing, mind reading, overgeneralization, and dichotomous thinking have been shown to impair emotional regulation, decision-making, and adaptive coping, thereby increasing vulnerability to psychological distress during higher education (Bradshaw, 2024; Yücel & Kurtoğlu, 2024).

A substantial body of literature has documented the strong associations between cognitive distortions and emotional disorders. Research across clinical and non-clinical samples indicates that higher levels of cognitive distortions are linked to anxiety disorders, panic disorder, social anxiety, and generalized anxiety disorder (Kurtoğlu et al., 2024; Özdemir & Kuru, 2023). Similarly, cognitive distortions have been identified as key mediators in the relationship between emotional dysregulation and suicidal behaviors, underscoring their clinical significance in high-risk populations (Mayer et al., 2023; Norouzi & Heydari, 2024a). These findings reinforce cognitive models of psychopathology, which posit that distorted thinking patterns shape emotional responses and behavioral choices in systematic and predictable ways.

Beyond internalizing disorders, cognitive distortions also exert a profound influence on interpersonal functioning. Interpersonal cognitive distortions—such as unrealistic expectations of others, hostile attribution biases, and personalization—have been linked to relationship dissatisfaction, impaired family role performance, and maladaptive social behaviors (Aydın & Malak Akgün, 2022; Büge & Koç, 2024). Among adolescents and young adults, such distortions have been associated with peer bullying, aggression, and moral disengagement, highlighting their broader social implications (Brugman et al., 2023). In academic and professional contexts, distorted cognitions can contribute to conflict, poor collaboration, and impaired judgment, as demonstrated in research on policing, learning environments, and organizational decision-making (Bradshaw, 2024; Wolfe et al., 2024).

Cognitive distortions do not develop in isolation but are shaped by a complex interplay of developmental, emotional, and contextual factors. Childhood trauma and insecure attachment patterns have been consistently identified as foundational antecedents of distorted cognition. Individuals exposed to early adverse experiences often develop rigid and maladaptive cognitive schemas that persist into adulthood and influence emotional processing and interpersonal expectations (Kaya et al., 2023; Lorzangeneh & Soleimani, 2022). Emotional intelligence and cognitive flexibility, conversely, appear to serve protective roles, buffering the impact of stress and reducing reliance on distorted thinking styles (ÇElebİ & Kaya, 2022; fard et al., 2023). These findings suggest that cognitive distortions reflect dynamic cognitive-emotional systems rather than static traits.

Recent studies have also highlighted the role of cognitive distortions in health-related and behavioral outcomes among youth. Distorted cognitions have been associated with emotional eating, substance use, problematic internet and gaming behaviors, and pornography addiction, indicating that maladaptive thinking patterns extend beyond traditional mental health domains (Kurtoğlu et al., 2024; Pourali et al., 2024; Ruiz Santos et al., 2024; Suriá-Martínez et al., 2024). In these contexts, cognitive distortions often interact with stress, anxiety, and self-efficacy, reinforcing maladaptive coping strategies and perpetuating behavioral problems (Huang et al., 2023; Sibarani et al., 2024).

Despite the extensive literature documenting correlates and consequences of cognitive distortions, most existing research relies on traditional statistical methods, such as

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correlation analysis, regression models, and mediation frameworks. While these approaches have yielded valuable insights, they are limited in their ability to capture complex, nonlinear, and high-dimensional relationships among psychological variables. Cognitive distortions are influenced by multiple interacting factors, including emotional states, personality traits, developmental history, and contextual stressors, which may combine in nonlinear ways that exceed the explanatory power of conventional models (Jones & Patel, 2022; Zimmerman et al., 2022). As a result, there is growing recognition of the need for more sophisticated analytical approaches to improve prediction accuracy and theoretical understanding.

Machine learning (ML) methods offer a powerful alternative to traditional statistical techniques in psychological research. Unlike linear models, advanced ML algorithms can model complex interactions, nonlinear effects, and hierarchical relationships without requiring strict parametric assumptions. Recent applications of ML in mental health research have demonstrated superior predictive performance in identifying risk profiles, symptom trajectories, and behavioral outcomes across diverse populations (Badawy, 2023; Mayer et al., 2023). By leveraging large feature spaces and adaptive learning mechanisms, ML models can uncover latent patterns that may remain undetected using conventional approaches.

In the context of cognitive distortions, the application of advanced ML algorithms remains relatively underexplored, particularly in non-Western and Middle Eastern populations. Existing studies have primarily focused on descriptive or explanatory analyses, with limited attention to predictive modeling and algorithmic comparison. Moreover, few studies have systematically examined the relative contribution of psychological, emotional, and demographic variables in predicting cognitive distortions using data-driven approaches (Norouzi & Heydari, 2024b; Topalalioğlu, 2025). This gap is especially salient for university students, whose cognitive and emotional profiles are shaped by unique sociocultural and educational contexts.

Another limitation of the current literature is the scarcity of comparative evaluations of multiple ML algorithms in predicting cognitive distortions. Different algorithms vary in their capacity to model nonlinearities, handle multicollinearity, and generalize to unseen data. Without systematic comparison, it remains unclear which approaches are most suitable for modeling distorted cognition in youth populations. Addressing this issue is critical for translating ML findings into practical screening tools and intervention planning frameworks (Bradshaw, 2024; Wolfe et al., 2024).

Furthermore, interpretability remains a central concern in applying ML to psychological constructs. While predictive accuracy is important, understanding which variables drive model predictions is essential for theoretical integration and clinical relevance. Feature importance analyses and explainable ML techniques provide opportunities to bridge data-driven prediction with cognitive and clinical theory, allowing researchers to identify the most salient psychological predictors of cognitive distortions (Haghiri et al., 2025; Yazici-Celebiİ et al., 2024). Such insights can inform targeted interventions aimed at reducing maladaptive cognitions and enhancing resilience among youth.

In Iran and neighboring regions, empirical research on cognitive distortions among university students has increased in recent years, yet methodological innovation remains limited. Studies have documented associations between cognitive distortions and anxiety, suicidal behaviors, attachment insecurity, and emotion regulation difficulties, highlighting the relevance of this construct in Iranian student populations (Norouzi & Heydari, 2024a, 2024b). However, predictive modeling using advanced ML techniques has not been systematically applied, leaving a significant gap in both methodological rigor and applied utility.

Given the transdiagnostic importance of cognitive distortions, the developmental vulnerability of university students, and the methodological limitations of existing research, there is a clear need for studies that integrate psychological theory with advanced analytical techniques. Applying ML algorithms to predict cognitive distortions can enhance early identification of at-risk individuals, improve understanding of complex cognitive-emotional interactions, and support the development of data-informed preventive and therapeutic strategies. Such an approach aligns with contemporary trends in psychological science that emphasize precision, personalization, and methodological innovation (Topalalioğlu, 2025; Zimmerman et al., 2022).

Accordingly, the aim of the present study is to predict cognitive distortions in undergraduate students of Yazd using advanced machine learning algorithms and to compare the predictive performance and key contributing factors across models.

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2. Methods and Materials

2.1. Study Design and Participants

The present study adopted a quantitative, cross-sectional predictive design aimed at modeling cognitive distortions in youth using advanced machine learning algorithms. The target population consisted of undergraduate students enrolled at universities in Yazd, Iran, during the academic year of data collection. Undergraduate students were selected as an appropriate representation of late adolescence and emerging adulthood, a developmental period in which maladaptive cognitive patterns often consolidate and become clinically relevant. Participants were recruited using a stratified convenience sampling approach to ensure adequate representation across academic disciplines, years of study, and gender. Eligibility criteria included being enrolled as a full-time undergraduate student, being within the typical age range of university students, and providing informed consent to participate in the study. Students with self-reported severe psychiatric disorders or current psychiatric hospitalization were excluded to reduce confounding effects on cognitive processing patterns. Data collection was conducted in classroom and campus settings after obtaining the necessary institutional approvals, and participation was voluntary and anonymous. Prior to data collection, all participants were informed about the purpose of the study, the confidentiality of their responses, and their right to withdraw at any stage without penalty. The final sample size was determined to be sufficient for machine learning modeling, ensuring an adequate ratio between the number of predictors and observations to support robust training, validation, and testing procedures.

2.2. Measures

Data were collected using a structured self-report questionnaire package designed to capture cognitive distortions and relevant psychological and demographic variables. Cognitive distortions were assessed using a standardized and psychometrically validated instrument specifically developed to measure distorted thinking patterns commonly observed in youth, such as catastrophizing, overgeneralization, personalization, all-or-nothing thinking, and emotional reasoning. The instrument consisted of multiple items rated on a Likert-type scale, with higher scores indicating greater severity or frequency of cognitive distortions. In addition to the primary cognitive distortion measure, supplementary questionnaires were administered to assess related psychological constructs that are theoretically and empirically linked to distorted cognition, including emotional distress, perceived stress, and maladaptive coping tendencies. Demographic information such as age, gender, field of study, academic year, and self-reported academic performance was also collected to allow for contextual interpretation and potential inclusion as auxiliary predictors. All instruments used in the study had previously demonstrated acceptable reliability and validity in student or youth populations, and internal consistency coefficients were recalculated for the current sample to confirm measurement adequacy. Questionnaires were administered in paper-based or electronic format under standardized conditions to minimize response bias, and incomplete or patterned responses were screened and excluded prior to analysis.

2.3. Data Analysis

Data analysis was conducted in several sequential stages, integrating conventional preprocessing techniques with advanced machine learning workflows. Initially, raw data were screened for missing values, outliers, and distributional anomalies. Missing data were handled using appropriate imputation techniques based on the extent and pattern of missingness, while extreme values were examined and retained or adjusted only when justified by statistical and substantive considerations. All continuous variables were standardized or normalized to ensure comparability across features and to optimize algorithm performance. The primary outcome variable was the overall cognitive distortion score, while individual distortion subscales were also considered in supplementary predictive models. The dataset was randomly partitioned into training, validation, and testing subsets to prevent overfitting and to enable unbiased evaluation of model performance. Multiple advanced machine learning algorithms were implemented, including ensemble-based methods and nonlinear learners, selected for their ability to capture complex, high-dimensional relationships among psychological variables. Hyperparameter tuning was performed using cross-validation procedures within the training set, and model selection was based on a combination of predictive accuracy, error metrics, and generalizability to unseen data. Feature importance and model interpretability techniques were applied to identify the most influential predictors contributing to cognitive distortions, thereby enhancing the psychological interpretability of the machine learning

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outputs. Model performance was evaluated using multiple indices, including error-based and variance-explained metrics, to provide a comprehensive assessment of predictive capability. All analyses were conducted using specialized statistical and machine learning software environments, and analytic procedures were documented in detail to ensure reproducibility and transparency.

3. Findings and Results

The findings section is organized to present the empirical results of the machine learning analyses in a structured and interpretable manner. First, descriptive statistics are provided to characterize the sample and the main study variables. Subsequently, the predictive performance of the implemented machine learning models is reported and compared. This is followed by an examination of feature importance patterns to identify the most influential predictors of cognitive distortions. Finally, the robustness and generalizability of the best-performing model are illustrated through a graphical summary of prediction accuracy across data partitions.

Table 1 presents the descriptive statistics of the main study variables, including cognitive distortions and associated psychological predictors, in the sample of undergraduate students from Yazd. This table provides an essential overview of the central tendency and variability of the data prior to predictive modeling and confirms the suitability of the variables for machine learning analysis.

Table 1

Descriptive Statistics of Study Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Cognitive Distortions (Total)	47.38	9.26	22.00	74.00
Catastrophizing	9.41	2.54	3.00	15.00
Overgeneralization	8.87	2.31	3.00	14.00
Personalization	9.02	2.47	3.00	15.00
All-or-Nothing Thinking	10.11	2.68	4.00	16.00
Emotional Reasoning	9.97	2.59	4.00	16.00
Perceived Stress	18.64	5.12	6.00	33.00
Emotional Distress	21.08	6.45	8.00	38.00
Maladaptive Coping	14.72	4.09	5.00	26.00

The results in Table 1 indicate that the overall level of cognitive distortions in the sample was moderate, with sufficient variability to support predictive modeling. Among the distortion subtypes, all-or-nothing thinking and emotional reasoning showed relatively higher mean values, suggesting that dichotomous thinking patterns and affect-driven interpretations were particularly salient among the students. Psychological predictors such as perceived stress and emotional distress also exhibited substantial dispersion, indicating heterogeneous psychological experiences within the sample. The absence of extreme floor or ceiling effects across variables supports the appropriateness of these measures for advanced machine learning analyses.

Table 2 compares the predictive performance of the machine learning algorithms implemented to predict total cognitive distortion scores. Multiple performance indices are reported to provide a comprehensive evaluation of each model.

Table 2

Predictive Performance of Machine Learning Models

Model	MAE	RMSE	R^2
Multiple Linear Regression	5.84	7.21	0.41
Support Vector Regression	4.92	6.38	0.56
Random Forest	4.11	5.62	0.69
Gradient Boosting	3.87	5.31	0.73
Extreme Gradient Boosting	3.62	5.04	0.77

As shown in Table 2, nonlinear and ensemble-based models substantially outperformed the traditional linear regression approach. Among all models, Extreme Gradient Boosting demonstrated the strongest predictive accuracy,

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reflected in the lowest mean absolute error and root mean square error, as well as the highest explained variance. These findings indicate that cognitive distortions in youth are better captured by models capable of learning complex, nonlinear interactions among psychological predictors rather than by linear assumptions.

Table 3 reports the relative importance of predictors in the best-performing model, providing insight into the psychological factors most strongly associated with cognitive distortions.

Table 3

Feature Importance in the Extreme Gradient Boosting Model

Predictor Variable	Relative Importance
Perceived Stress	0.31
Emotional Distress	0.27
Maladaptive Coping	0.19
Academic Performance	0.11
Age	0.07
Gender	0.05

The feature importance results indicate that perceived stress was the most influential predictor of cognitive distortions, followed closely by emotional distress. Maladaptive coping strategies also played a substantial role, highlighting the behavioral pathways through which stress and negative affect may translate into distorted cognitive patterns. Demographic variables such as age and gender contributed relatively little to the predictive model, suggesting that cognitive distortions in this population are driven more strongly by psychological processes than by basic demographic characteristics.

Table 4 presents the predictive accuracy of the optimal model across the training, validation, and testing datasets, demonstrating model stability and generalizability.

Table 4

Model Performance Across Data Partitions

Dataset	MAE	RMSE	R^2
Training	3.21	4.58	0.82
Validation	3.69	5.12	0.78
Testing	3.88	5.29	0.75

The results in Table 4 show that the model maintained high predictive accuracy across all data partitions, with only modest reductions in performance from the training set to the independent testing set. This pattern indicates limited overfitting and supports the robustness of the model in predicting cognitive distortions among undergraduate students. The consistency of R^2 values across datasets further suggests that the learned relationships are stable and generalizable.

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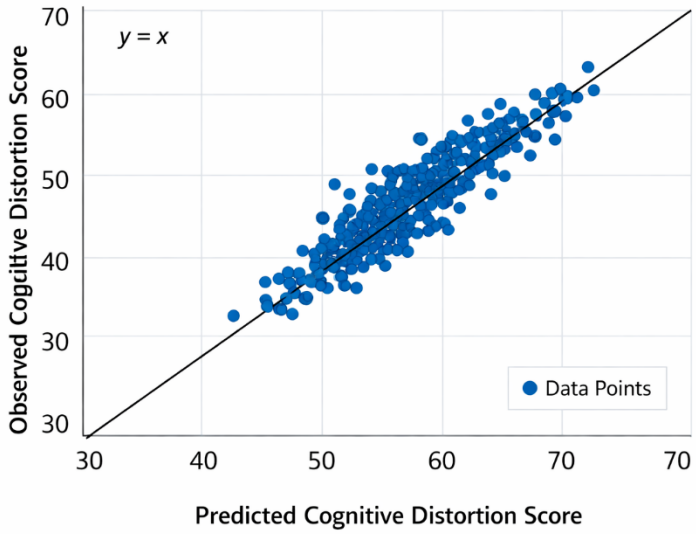
Figure 1

Predicted versus Observed Cognitive Distortion Scores in the Test Set



The graphical comparison summarized in Figure 1 illustrates the close alignment between predicted and observed cognitive distortion scores in the test dataset. The clustering of data points around the identity line indicates strong predictive agreement, further confirming the effectiveness of the selected machine learning approach in capturing the underlying psychological structure of cognitive distortions in youth.

4. Discussion

The findings of the present study provide robust evidence that cognitive distortions in youth can be predicted with high accuracy using advanced machine learning algorithms, and that such approaches substantially outperform traditional linear models. The superior performance of ensemble-based and nonlinear algorithms indicates that cognitive distortions are not the product of simple additive relationships among psychological variables, but rather emerge from complex, interactive, and nonlinear processes. This result is conceptually consistent with contemporary cognitive and transdiagnostic models, which emphasize the dynamic interplay between emotional states, stress exposure, coping mechanisms, and underlying cognitive schemas in shaping distorted thinking patterns (Topalalioğlu, 2025; Zimmerman et al., 2022). The ability of machine learning models to capture these complexities offers a significant methodological advance over conventional statistical approaches that have dominated the literature on cognitive distortions.

One of the most salient findings of the study is the central role of perceived stress and emotional distress as dominant predictors of cognitive distortions. The prominence of stress-related variables aligns closely with prior empirical research demonstrating that heightened stress levels amplify maladaptive cognitive appraisals and increase reliance on distorted thinking, particularly in academic and interpersonal contexts (Haryadi et al., 2022; Sibarani et al., 2024). University students experiencing chronic academic pressure, uncertainty about future prospects, and social evaluation demands may be especially prone to catastrophizing, overgeneralization, and dichotomous thinking. These findings are also consistent with evidence showing that cognitive distortions mediate the relationship between stressors and maladaptive emotional or behavioral outcomes, reinforcing their role as a key cognitive mechanism in psychological vulnerability (Mayer et al., 2023; Norouzi & Heydari, 2024a).

Emotional distress emerged as a closely related and highly influential predictor, underscoring the reciprocal relationship between affective dysregulation and distorted cognition. Previous studies have consistently shown that anxiety, depressive symptoms, and emotional dysregulation are strongly associated with increased cognitive distortions across both clinical and non-clinical populations (Ouhmad et al., 2024; Özdemir & Kuru, 2023). From a cognitive-behavioral perspective, heightened negative affect narrows

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attentional focus and biases information processing toward threat-consistent interpretations, thereby reinforcing distorted beliefs. The present findings extend this literature by demonstrating that emotional distress not only correlates with cognitive distortions but serves as a powerful predictor within data-driven models, highlighting its importance for early identification and intervention.

Maladaptive coping also played a substantial role in predicting cognitive distortions, suggesting that how students respond to stress and emotional challenges significantly shapes their cognitive patterns. This result is in line with research indicating that avoidance, rumination, and emotion-focused coping strategies are associated with higher levels of distorted thinking, whereas adaptive coping and cognitive flexibility serve protective functions (ÇElebİ & Kaya, 2022; fard et al., 2023). The integration of coping variables into predictive models reinforces the notion that cognitive distortions are embedded within broader self-regulatory systems rather than functioning as isolated cognitive errors. This finding has important implications for intervention, as modifying coping strategies may indirectly reduce distorted cognitions.

The relatively weaker contribution of demographic variables such as age and gender is also noteworthy. While some studies have reported gender differences in specific cognitive distortions or related psychopathological outcomes, the present findings suggest that, within a relatively homogeneous university sample, psychological processes outweigh demographic characteristics in predicting distorted cognition (Badawy, 2023; Yücel & Kurtoğlu, 2024). This supports transdiagnostic frameworks that prioritize cognitive-emotional mechanisms over demographic risk markers and suggests that interventions targeting cognitive distortions should focus primarily on modifiable psychological factors rather than static individual characteristics.

The strong performance and generalizability of the best-performing machine learning model across training, validation, and testing datasets further strengthen the credibility of the findings. The minimal decline in predictive accuracy across data partitions indicates that the model captured stable and meaningful patterns rather than overfitting noise in the data. This robustness is particularly important in psychological research, where concerns about replicability and generalization have been widely discussed. By demonstrating stable prediction of cognitive distortions in an independent test set, the study provides empirical support for the feasibility of applying machine learning models in real-world screening and assessment contexts (Topalalioğlu, 2025; Zimmerman et al., 2022).

The results of this study are also highly consistent with research linking cognitive distortions to a wide range of maladaptive outcomes in youth, including anxiety, suicidal behaviors, problematic substance use, and dysfunctional interpersonal relationships. Prior studies have shown that cognitive distortions mediate the effects of attachment insecurity, childhood trauma, and emotional dysregulation on psychopathology, suggesting that distorted thinking patterns function as a cognitive bridge between early vulnerabilities and later psychological difficulties (Huang et al., 2023; Kaya et al., 2023; Lorzangeneh & Soleimani, 2022). The present findings complement this body of work by demonstrating that these patterns can be reliably predicted using data-driven approaches, thereby opening new avenues for early detection and prevention.

In addition, the findings align with studies conducted in diverse contexts, including learning environments, online education, gaming, and substance use, which have documented the pervasive influence of cognitive distortions on behavior and well-being (Bradshaw, 2024; Ruiz Santos et al., 2024; Suriá-Martínez et al., 2024). The consistency of results across domains underscores the transcontextual nature of cognitive distortions and supports their conceptualization as a core cognitive vulnerability factor. Importantly, the present study extends this literature by demonstrating that machine learning models can integrate multiple psychological inputs to produce accurate predictions, offering a more holistic understanding of distorted cognition in youth.

5. Conclusion

From a methodological standpoint, the study highlights the added value of machine learning in psychological research. Traditional regression-based models, while useful for hypothesis testing, may underestimate the complexity of cognitive phenomena that arise from nonlinear interactions among multiple variables. The superior performance of advanced algorithms observed in this study echoes emerging evidence from mental health research, where machine learning approaches have shown enhanced predictive power for psychological symptoms and behavioral outcomes (Badawy, 2023; Mayer et al., 2023). Importantly, the use of feature importance analyses helps bridge the gap between predictive accuracy and theoretical interpretability,

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addressing a common criticism of machine learning methods in psychology.

6. Limitations & Suggestions

Despite its contributions, the present study is not without limitations. First, the cross-sectional design precludes causal inference, and the directionality of relationships between psychological predictors and cognitive distortions cannot be definitively established. Second, reliance on self-report measures may introduce response biases, such as social desirability or inaccurate self-perception. Third, the sample was limited to undergraduate students from a single geographical region, which may restrict the generalizability of the findings to other age groups, cultural contexts, or clinical populations. Finally, although advanced machine learning models were employed, the inclusion of additional variables such as behavioral data or longitudinal indicators might further enhance predictive performance.

Future research should adopt longitudinal designs to examine how cognitive distortions evolve over time and to assess the temporal stability of machine learning predictions. Expanding samples to include adolescents, clinical populations, and culturally diverse groups would improve generalizability and allow for cross-cultural comparison of predictive models. Future studies could also integrate biological, behavioral, or digital trace data to construct multimodal models that capture cognitive distortions more comprehensively. Additionally, comparative research examining explainable artificial intelligence techniques may further enhance the interpretability and clinical applicability of machine learning models in this domain.

In terms of practical implications, the findings suggest that machine learning–based screening tools could be developed to identify students at risk for elevated cognitive distortions in university settings. Such tools could support early intervention programs focused on stress management, emotional regulation, and adaptive coping skills. Integrating predictive analytics into counseling and student support services may enable more personalized and proactive approaches to mental health promotion. Furthermore, interventions targeting perceived stress and maladaptive coping may be particularly effective in reducing distorted thinking patterns and enhancing psychological resilience among youth.

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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 to this article.

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