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ORIGINAL RESEARCH

Mind Matters: Exploring the Intersection of Psychological Factors and Cognitive Abilities of University Students by Using ANN Model

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Purpose: While previous studies have suggested close association of psychological variables of students withtheir higher-order cognitive abilities, such studies have largely been lacking for third world countries like India, with their unique socio-economic-cultural set of challenges. We aimed to investigate the relationship between psychological variables (depression, anxiety and stress) and cognitive functions among Indian students, and to predict cognitive performance as a function of these variables.

Patients and Methods: Four hundred and thirteen university students were systematically selected using purposive sampling. Widely used and validated offline questionnaires were used to assess their psychological and cognitive statuses. Correlational analyses were conducted to examine the associations between these variables. An Artificial Neural Network (ANN) model was applied to predict cognitive levels based on the scores of psychological variables.

Results: Correlational analyses revealed negative correlations between emotional distress and cognitive functioning. Principal Component Analysis (PCA) reduced the dimensionality of the input data, effectively capturing the variance with fewer features. The feature weight analysis indicated a balanced contribution of each mental health symptom, with particular emphasis on one of the symptoms. The ANN model demonstrated moderate predictive performance, explaining a portion of the variance in cognitive levels based on the psychological variables.

Conclusion: The study confirms significant associations between emotional statuses of university students with their cognitive abilities. Specifically, we provide evidence for the first time that in Indian students, self-reported higher levels of stress, anxiety, and depression are linked to lower performance in cognitive tests. The application of PCA and feature weight analysis provided deeper insights into the structure of the predictive model. Notably, use of the ANN model provided insights into predicting these cognitive domains as a function of the emotional attributes. Our results emphasize the importance of addressing mental health concerns and implementing interventions for the enhancement of cognitive functions in university students.

Keywords: depression anxiety stress score, DASS, Montreal Cognitive Assessment, MoCA, college students, artificial neural network, predictive performance, Indian, developing economies, feature reduction, feature weights

Introduction

College life is a period of significant transition and development, characterized by new experiences, academic challenges, and increased responsibilities. Indeed, the pursuit of higher education is a critical phase in an individual's life, marked by significant academic and personal challenges. University students often face various stressors, including academic

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pressures, social adjustments, and increased responsibilities.[1,2] These stressors can impact their emotional health and cognitive functioning, ultimately influencing their overall well-being and academic performance.[3,4] Numerous studies have demonstrated high prevalence of mental health problems among university students globally.[5–7] Indeed, Çelik et al (2019)[8] reported that approximately one in three college students experiences significant symptoms of depression. Understanding the complex interplay between psychological and cognitive variables among university students is crucial for promoting their holistic development and providing effective support.

In the context of developing economies (eg, India), college students face specific challenges that may act as specific emotional stressors.[5,6] India, with its diverse cultural landscape and rapidly growing higher education sector, presents a unique context to explore this relationship. Indian college and university students encounter a wide range of socio-cultural factors, such as familial expectations, societal pressures, and cultural norms, which can significantly impact their mental health experiences and cognitive functioning.[9,10] While research on emotional health and cognition in university students has gained attention globally, there is a need for context-specific investigations that consider the unique challenges and cultural influences faced by Indian students. Indeed, a study by Li et al, (2022)[11] found that the prevalence of mental health disorders, including depression and anxiety, was significantly higher among Indian college students compared to the general population. These findings highlight the importance of examining the emotional status within the specific socio-economic-cultural context of Indian university students and its relevance. Moreover, prediction of cognitive attributes of students as a function of their psychological statuses is warrantied in order to increase the opportunities for evaluation, assessment and establishment of novel and effective corrective strategies and regimens.

This study aims to bridge this research gap by investigating the relationship between psychological variables, viz. depression, anxiety, and stress, and cognition among Indian university students. To this end, we have employed two well-established, reliable and validated assessment tools with excellent internal consistency as well as tremendous temporal stability; namely, the Depression Anxiety Stress Scales (DASS[12,13]) and the Montreal Cognitive Assessment (MoCA[14,15]) in a sample of Indian university students. DASS is a widely used self-report questionnaire designed to assess the severity of psychological distress (depression, anxiety, and stress symptoms) experienced by individuals developed by Lovibond and Lovibond,[16] and has been previously applied for the evaluation of emotional well-being of student and adolescent populations,[17,18] including Indian adolescents.[19] On the other hand, MoCA is a widely utilized cognitive assessment tool that measures various cognitive domains, including attention, memory, language, visuospatial skills, and executive functions. While originally designed for diagnosis of mild and severe cognitive impairments in the aged population by Nasreddine and colleagues,[20] MoCA and its vernacular versions have been efficiently extended to young adult and adolescent student populations in several studies.[21–24] Use of MoCA has also been undertaken specifically in Indian students.[25] Using these questionnaire-based instruments, in this study, we investigated the emotional status and cognitive functioning in university students for the exploration of any potential associations.

Further, using the ANN model, we sought to predict the relationship between the emotional and cognitive attributes of university students. It is important to note here that the data for the various variables pertaining to emotional health of the students can be easily obtained, particularly for vulnerable students from internal cells, such as the psychological counselling divisions at the universities and institutes. This makes emotional health attributes as a suitable target for prediction of cognitive functioning in students. Understanding and predicting the interplay between psychological factors and cognitive functioning is essential for several reasons. First, it can contribute to the identification of individuals who may be at an elevated risk of experiencing cognitive impairments because of difficulties in emotional processing. Early detection may facilitate timely support and prevent potential negative consequences.[26] Second, such predictions may allow development of targeted personalized interventions and support services tailored to the specific needs of university students. Such interventions may be implemented in order to enhance the effectiveness of mental health and educational programs, leading to improvements in overall well-being and academic success of the students.[27,28]

It should be noted that our findings may have implications for the broader field of mental health research and clinical practice. Investigating the linkages between higher-order cognitive functions and pyscho-emotional factors in the context of Indian university students, for example, can provide insights into cultural factors that influence these domains across multiple age groups. Since cultural nuances shape the experience, expression, and perception of emotional and cognitive

cues, exploring these factors can lead to development of culturally sensitive assessment tools, interventions, and policies that are more aligned with the needs and experiences of the middle- and low-income countries, including India.[29,30]

In summary, this study aims to examine the relationship between emotional processing and cognitive functioning among Indian university students using DASS and MoCA scales. By investigating the multiple attributes of these dimensions, the study seeks to contribute to the existing literature on mental health and cognition while addressing the unique context of Indian higher education. The findings of this study may have implications for the development of targeted interventions and support services, ultimately fostering the well-being and academic success of university students in developing economies.

Materials and Methods

Participants

The participants in this study were 413 college students from different institutes in India. The students who were selected initially were all well-versed in the English language and agreed to respond to all aspects of the assessment questionnaires. The selection of participants was done using purposive sampling, where students were chosen based on specific criteria, such as being enrolled in a college or university in India. Summarization of the demographic, socio-economic, and general information of the students, including their universities/colleges is provided in Table 1. It is important to note here that the sample may not be fully representative of the entire population of Indian college students. The selection of students and data articulation were performed in a systematic manner (Figure 1). Only students between the age brackets of 17 to 22 (19.65 ± 1.75; mean ± SD) years were selected. Exclusion criteria included students with chronic diseases such as heart conditions, asthma, diabetes, and any underlying neurological conditions. Further, students with physical disabilities were excluded. Responses of the students with self-reported "abnormal" nocturnal activity were not considered for analyses. Lastly, students at both extremes of the socio-economic statuses were disregarded. Assessment of the socio-economic status was carried using the Revised Kuppuswamy scale, which has been shown to be suitable for division of Indian subjects into five socio-economic classes, and cover a range of attributes, including monthly income, level of education, social participation, occupation, type of residence, etc.[31] Responses from the students falling in the topmost (upper class) and bottommost (lower class) categories of the cumulative socio-economic status score were excluded from our analyses. Informed consent was obtained from all participants, with the agreement to store, organize and utilize individual data anonymously. The study was conducted in accordance with the principles stated in the Declaration of Helsinki and approved by the Institutional Ethical Committee for Studies on Human Subjects (IECH), Vellore Institute of Technology (VIT), Vellore, India (Ref. No. VIT/IECH/XIV/2023/24).

Data Collection

Data for this study were collected using a supervised offline questionnaire. The questionnaire consisted of several sections, including measures of emotional status of the students using the DASS questionnaire[16] and cognitive function domains using the MoCA scale.[20] These are well established and validated questionnaires with standardized scoring schemes. Using the DASS questionnaire, we extracted features that quantify the severity of psychological symptoms, such as scores for depression, anxiety, and stress. On the other hand, MoCA was used to obtain the global cognition scores in students. Cumulative cognitive scores were considered as they provide better comprehension of overall cognitive abilities of students, as opposed to the individual domain scores, as observed in previous studies for adolescent subjects.[22,32] The questionnaire was administered to the participants in a controlled setting, ensuring standardized conditions for data collection for all participants.

Data Analysis

The collected data was analysed using an Artificial Neural Network (ANN) model for regression analysis. The theoretical underpinnings for employing the ANN model in our study stem from its inherent ability to model non-linear and complex relationships that are characteristic of mental health data. Unlike traditional statistical methods, which may assume linearity among variables, ANNs are particularly suited for the multifaceted patterns present in mental health indicators

Table 1 Demographic, Socio-Economic and General Details of the Students Selected for the Study

Demographic Factors		Frequency	Percentage
Gender	**Male**	216	52.3
	Female	197	47.7
Age (years)	**17–18**	115	27.8
	19–20	193	46.7
	21–22	105	25.4
Institution	**Vellore Institute of Technology, Vellore**	142	34.4
	BSA Crescent Institute of Science and Technology, Chennai	84	20.3
	Presidency University, Bangalore	47	11.4
	Jain university, Bangalore	34	8.2
	Anna University, Chennai	33	8.0
	Bharath Institute of Higher Education and Research, Chennai	26	6.3
	Noorul Islam College of Arts and Science, Kumaracoil	17	4.1
	Madras University, Chennai	12	2.9
	Bharathidasan University, Trichy	10	2.4
	Sastra University, Thanjavur	8	1.9
Smoking habit	**Current smoker**	42	10.2
	Never	362	87.7
	Ex-smoker	9	2.2
Upbringing	**Rural**	133	32.2
	Urban	280	67.8
High school	**Private**	291	70.5
	Public	122	29.5
Socio-economic status (According to the Revised Kuppuswamy scale)	**Upper middle class (Total score 16–25)**	101	24.4
	Middle class (Total score 11–15)	165	40
	Lower middle class (Total score 5–10)	147	35.6

due to their flexibility in model architecture and capacity to learn from the data iteratively. This makes ANNs adept at detecting subtle interactions and hidden patterns within the diverse and nuanced spectrum of mental health symptoms and their impact on cognitive functions. By leveraging this modelling approach, we aimed to capture the intricacies of mental health data more effectively, providing a more accurate and insightful analysis of the factors influencing cognitive performance among college students.

To enhance the analysis, we incorporated feature reduction using Principal Component Analysis (PCA). PCA was employed to reduce the dimensionality of the input features, focusing on those that explained a significant portion of the

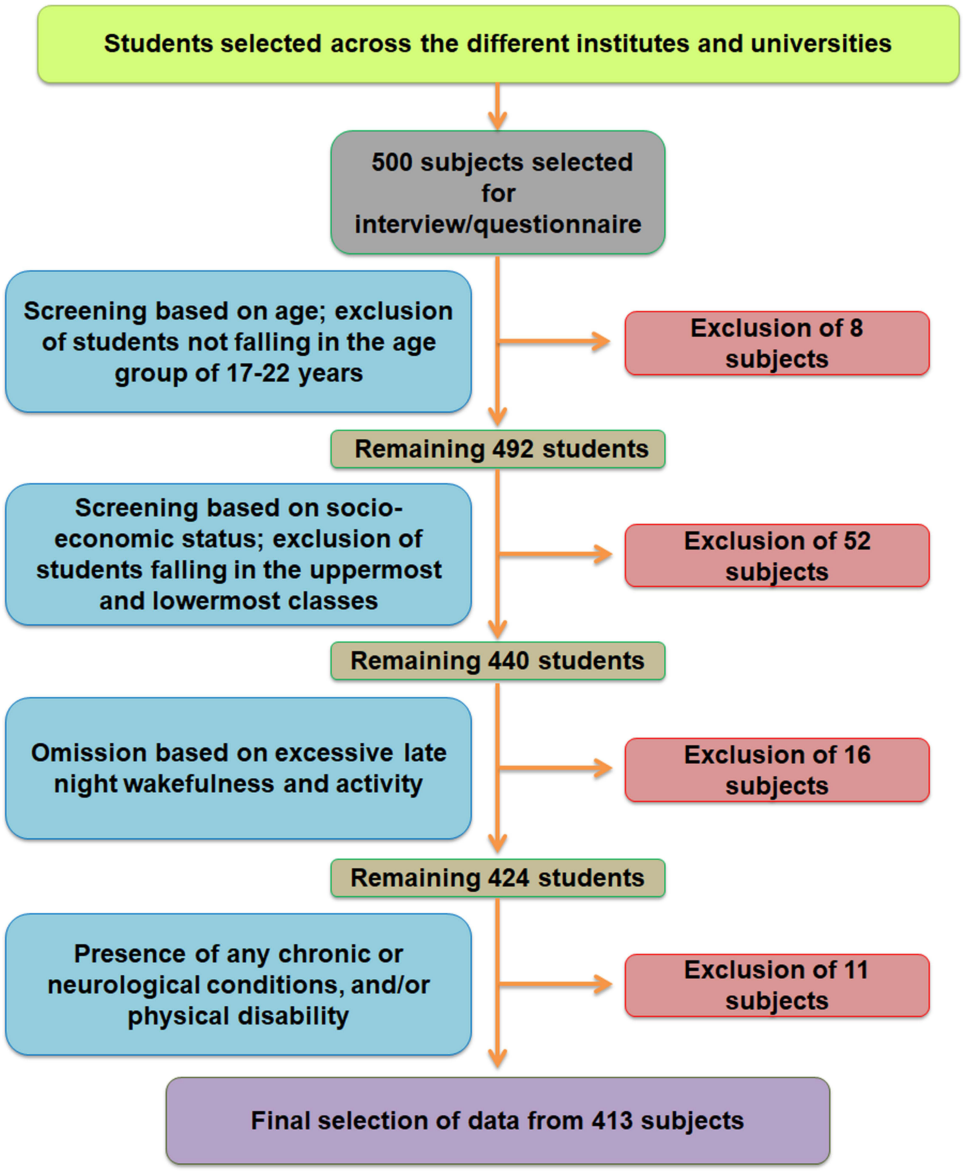

Figure 1 Flow chart showing the systematic methodology for the selection of primary data from subjects.

variance in the dataset. First, the data was pre-processed by importing the necessary libraries (numpy, pandas, scikit-learn, keras) and performing data scaling using the Standard-scaler. The psychological variables of depression, anxiety and stress scores were selected as the input features (X), while cognitive functioning (MoCA scores) was considered the target variable (Y). Additionally, we analysed the weight of features by examining the aggregate absolute weights of each feature in the neural network, providing insight into their relative influence on the model's predictions.

The data was then split into training and testing sets using the train_test_split function from scikit-learn. The training set, which comprised 70% of the data, was used to train the ANN model, while the remaining 30% served as the testing set for evaluating the model's performance.

Following the feature reduction, an MLPRegressor model from the scikit-learn library was employed as the ANN model, with a refined architecture that incorporated the reduced feature set. As shown in Figure 2, the model architecture consisted of a single hidden layer with 780 neurons, and the Adam optimizer was used for training. The model was fitted to the training data, and predictions were made for both the training and testing sets.

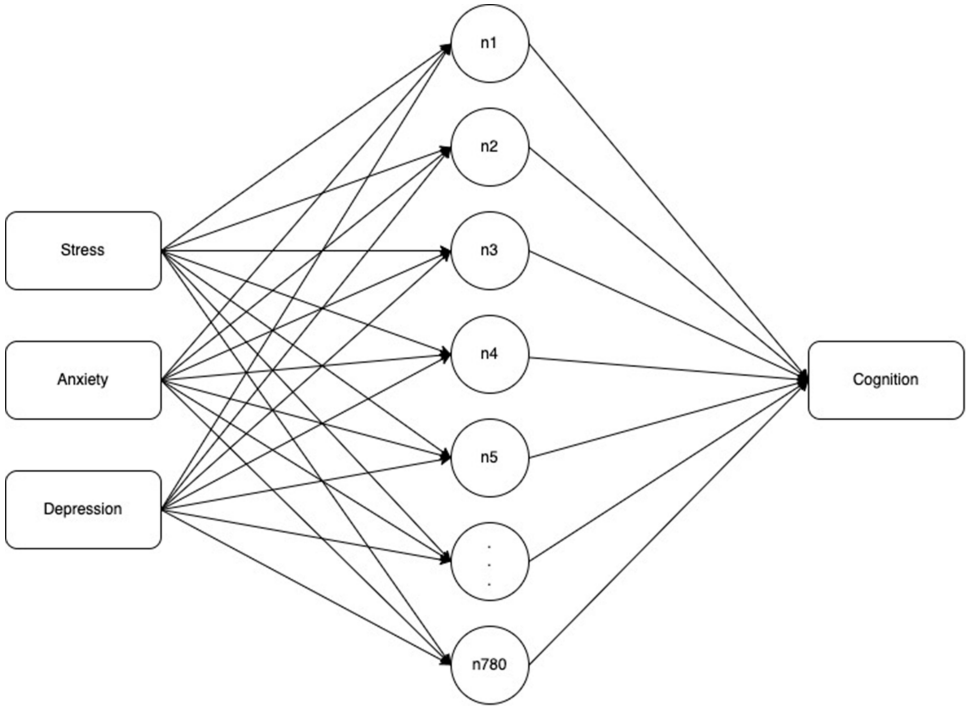

Figure 2 Prediction of the relationship between psychological variables and cognitive performance was performed using ANN using the depicted topology.

To assess the performance of the model, several metrics were calculated. These included the mean squared error (MSE), mean absolute error (MAE), and the coefficient of determination (R-squared or r^2). The R-squared value indicates the proportion of variance in the target variable that can be explained by the input features.

Additionally, a correlation analysis was performed using the pandas library to examine the relationships between the psychological variables and cognitive functioning. A correlation matrix was generated, and a heatmap visualization was created using the Seaborn and Matplotlib libraries.

Results

As depicted in Figure 3, the correlation coefficient between stress and anxiety was 0.4706, indicating a moderately positive correlation between these variables. The correlation coefficient between stress and depression was 0.4748, indicating a moderately positive correlation between these variables. The correlation coefficient between anxiety and

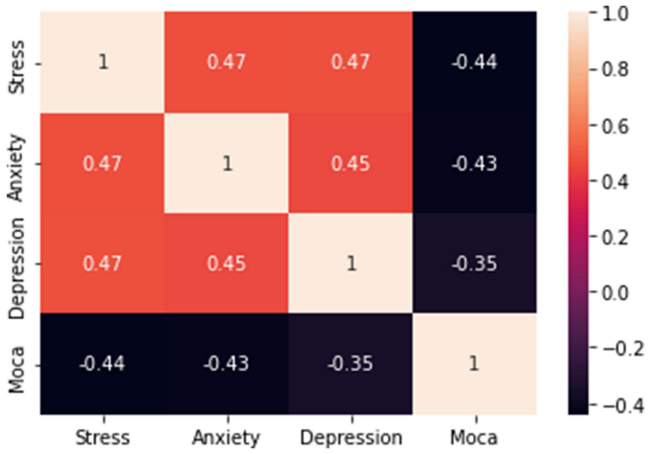

Figure 3 Heat map for the correlation analyses among the psychological variables and cognitive functions.

depression was 0.4496, indicating a moderately positive correlation between these variables. The correlation coefficient between stress and cognitive functioning (MoCA) was −0.4405, indicating a moderate negative correlation. This suggests that higher levels of stress were associated with lower cognitive performance. The correlation coefficient between anxiety and MoCA score was −0.4288, indicating a moderate negative correlation. Higher levels of anxiety were associated with lower cognitive performance. The correlation coefficient between depression and cognitive performance was −0.3506, indicating a weaker negative correlation.

To further refine our understanding of the data, feature reduction was applied using Principal Component Analysis (PCA), which resulted in two principal components. These components explained 64.07% and 20.65% of the variance, respectively, indicating that a significant portion of the dataset's variability was captured in these reduced dimensions. In examining the feature weights through the ANN model, the aggregate absolute weights for the three input features were 16.81, 16.98, and 17.64, respectively. This analysis provided a preliminary indication of each feature's influence on the model's predictions, suggesting that while all features contribute to the model's performance, the third feature had a slightly more substantial influence.

These correlation coefficients provide insights into the relationships between the different emotional attributes and cognitive functions of the university students. The positive correlations between stress, anxiety, and depression suggest that these mental health symptoms tend to co-occur among the participants. Furthermore, the negative correlations between emotional status (depression, anxiety and stress scores) and cognitive levels (MoCA scores) indicate that higher levels of association of elevated psychological distress and poor cognitive performance. The magnitude of the correlations suggests that stress and anxiety may have a slightly stronger association with cognitive functions compared to depression.

It is important to note that these correlation coefficients provide statistical evidence of associations, but they do not imply causation. Other factors and variables (e.g., socio-economic statuses) not included in this study could also contribute to the observed correlations. Overall, the correlation analyses highlight the significant relationships between the emotional statuses of Indian university students with their cognitive performances. The findings suggest that addressing mental health concerns, particularly stress, anxiety, and depression, may be crucial for promoting optimal cognitive functioning in educational settings.

The ANN model was applied to both the training and testing sets to predict cognitive levels (MoCA scores) as a function of emotional attributes of depression, anxiety and stress. As shown in Table 2, in the training set, the ANN model performed reasonably well. The mean squared error (MSE) was 1.6143, indicating the average squared difference between the predicted and actual values of cognitive scores. The mean absolute error (MAE) was 0.9841, which represents the average absolute difference between the predicted and actual values. The coefficient of determination (R-squared or r^2) was 0.3624, suggesting that the ANN model explained approximately 36.24% of the variance in cognitive scores based on the DASS scores in the training set.

In the testing set, performance of the ANN model was slightly better than in the training set. The MSE was 1.3405, indicating a slightly lower average squared difference between the predicted and actual values compared to the training set. The MAE was 0.8632, representing a lower average absolute difference. The r^2 value was 0.4158, indicating that the ANN model explained approximately 41.58% of the variance in cognitive functioning based on the mental health symptoms in the testing set.

Table 2 Correlational Analyses for Psychological Variables and Cognitive Performance

	Testing Set	Training Set
MSE	1.34046347	1.61427129
MAE	0.86322784	0.98407955
r^2	0.41575944	0.3624352

Abbreviations: MSE, mean squared error; MAE, mean absolute error; r^2, r-squared (coefficient of determination).

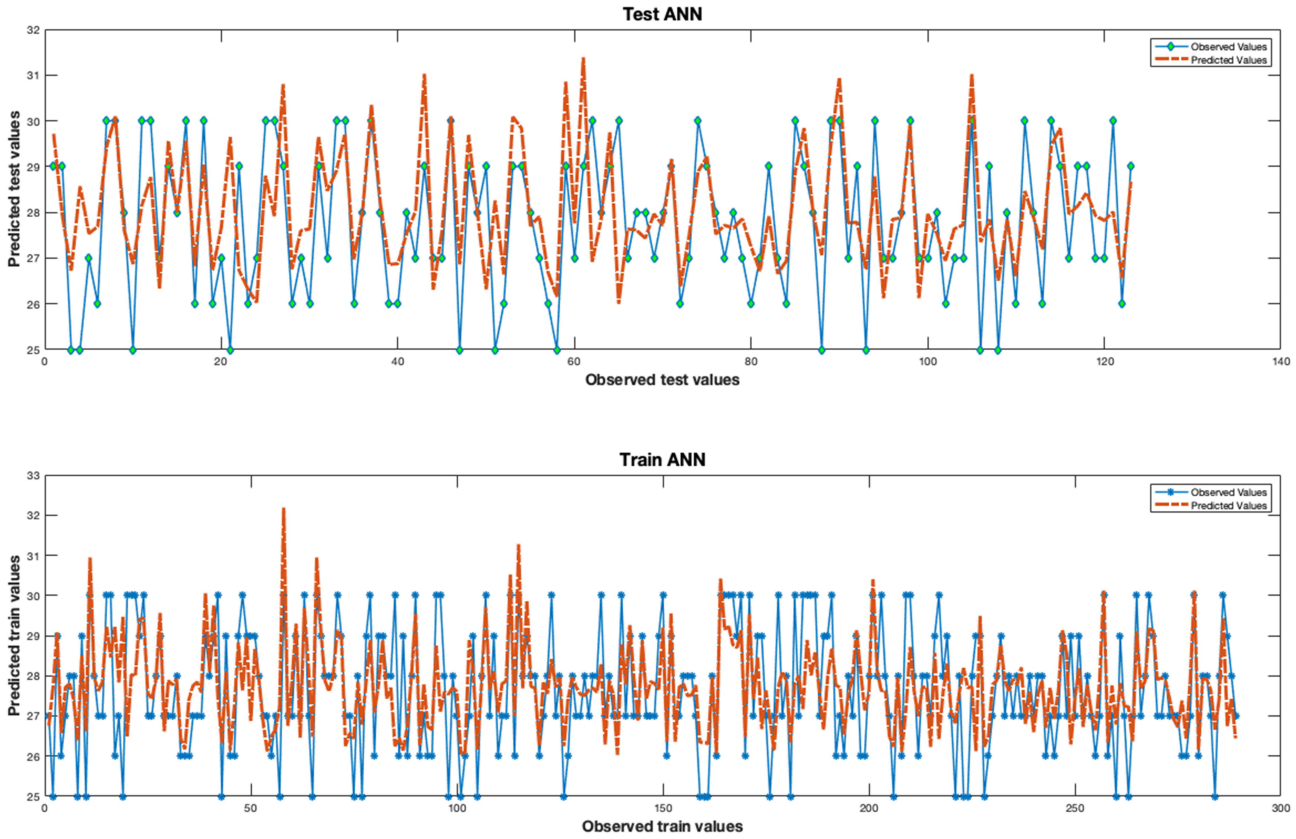

Figure 4 Correlation and prediction strength for psychological variables of depression, anxiety and stress and cognitive performance are depicted below for the test (top) and train (bottom) sets.

As depicted in Figure 4, the ANN model demonstrated some ability to predict cognitive performance based on the psychological status. However, the relatively low r^2 values suggest that there may be other factors influencing cognitive functioning which were not captured by the model. It is important to interpret these results with caution, as the ANN model may have limitations and the predictive power may be influenced by the specific characteristics of the data and model configuration.

Further research and refinement of the ANN model are recommended to improve its performance in predicting cognitive functioning based on mental health symptoms. Additionally, the inclusion of additional variables and features in the model may enhance its accuracy and ability to capture the complexity of the relationship between mental health and cognitive functioning.

Discussion

Cognitive attributes, such as attention, memory, executive functions, and problem-solving skills, are essential for learning, decision-making, and adaptation to new environments. These play a crucial role in the academic performance and overall mental health of university students. Several studies have investigated cognitive functioning of students and its association with academic outcomes.[33–36] In particular, high cognitive abilities in the domains of working memory and attention have been found to be significantly associated with better academic performance.[37–39] Understanding the relationship between psychological attributes and cognitive functioning is crucial for comprehensively assessing the overall well-being and academic performance of university students. Past research studies have shown that emotional distress can robustly and detrimentally impact various cognitive domains. For instance, depression has been associated with impairments in cognitive domains of attention, memory, and executive functions.[40–43] Similarly, anxiety has been linked to difficulties in attentional control and working memory.[44–46] Stress has also been found to negatively affect multiple spheres of cognitive performances.[47–49]

While several studies have explored the relationship between psychological status and cognitive functioning of students on the global stage and particularly in developed countries,[50–52] there is a scarcity of research specific to the low- and middle-income economies like India. Investigating this relationship among Indian university students is important due to the specific set of socio-economic and cultural factors characterized by collectivism, economic challenges, academic pressure, and societal expectations, which influence the manifestation and impact of psychological attributes and cognitive abilities in a manner which is significantly different compared to cultural contexts of students from developed countries.[53,54] Research directed to bridge this research gap may allow developing targeted interventions and support services that cater to the specific needs of this population. Additionally, understanding the associations between mental health symptoms and cognitive functioning can inform educational institutions, policymakers, and mental health professionals in implementing strategies that promote the well-being and academic success of Indian college students. Further, we extended our objective to prediction of overall performances of Indian university students in cognitive domains of attention, memory, language, visuospatial skills, and executive functions as a function of their emotional status, as adjudged by questionnaire-based self-reported scores for depression, anxiety and stress.

For the purpose of this study, we investigated the relationship between mental health status (depression, anxiety and stress) and cognitive abilities among college students in India using an ANN model for regression analysis. The findings revealed significant associations between the psychological variables and cognitive functions, with negative correlations between depression, anxiety and stress scores and performances on the cognitive assessment tests. While this was expected, we further employed the ANN model for insights into suitability of using these psychological variables for prediction of the cognitive abilities of university students. Although the predictive power was modest in the Indian academic context, future studies are warrantied to ascertain the predictive value of this strategy using population datasets from other medium-to-low income economies. Nevertheless, the present study highlights the importance of addressing mental health concerns among college students to support their cognitive and academic abilities and overall well-being. Interventions aimed at reducing depression, anxiety and stress may potentially improve cognitive performance in educational settings.

Relationship between mental health symptoms and cognitive functioning among Indian college students provides critical insights with direct implications for youth mental health strategies. The established correlations between stress, anxiety, depression, and cognitive performance not only underscore the interconnected nature of these mental health challenges but also highlight the potential for cognitive impairments associated with psychological distress.

The deployment of an ANN model in this research offers a sophisticated analytical tool that accounts for complex, non-linear interactions between mental health variables and cognitive outcomes. The moderate predictive power of the ANN model emphasizes its utility in identifying students at risk for cognitive difficulties due to mental health issues. It suggests the potential for developing predictive tools that can be used in educational and clinical settings to monitor and support students' mental health. There are multiple practical implications for youth mental health: (1) Early identification and intervention: The ANN model's ability to predict cognitive functioning based on mental health symptoms can facilitate early identification of students who may benefit from mental health interventions. Of note, psychological counselling cells at academic institutions and universities implement regular screening and these data can be used for identification of emotionally vulnerable youth who can be targeted for timely cognition-enhancing interventions such as therapeutic regimens and programs, before escalation of the cognitive deficits. (2) Tailored support programs: Understanding the specific mental health symptoms that correlate strongly with cognitive impairment allows for the development of targeted support and intervention programs. Resources can be allocated efficiently to address the symptoms with the greatest impact on students' cognitive abilities, such as stress and anxiety management workshops. (3) Mental health education: Educational campaigns can be designed to raise awareness among students about the impact of stress, anxiety, and depression on cognitive functions. Empowering students with knowledge and coping strategies can play a pivotal role in mitigating the negative effects of these symptoms. (4) Curriculum and policy development: Our study suggests necessitation of educational institutions to consider integrating findings from studies like this into the curriculum and policy development. Policies that promote mental well-being, such as providing access to personalized counselling services and creating a supportive learning environment, can in turn help enhance cognitive functioning and academic performance. (5) Collaboration with mental health professionals: Another key implication of our study is need

for enhanced collaboration between academic institutions and mental health professionals to create comprehensive programs that address both the psychological and cognitive needs of students. Such collaboration can ensure that interventions are evidence-based and tailored to the specific context of the educational institution.

Several limitations should be considered when interpreting the findings of this study. First, the study utilized self-reported measures, which may be subject to response bias and may not capture the full complexity of mental health symptoms and cognitive functioning. Additionally, the cross-sectional design of the study limits the establishment of causal relationships. Furthermore, the sample was selected using purposive sampling, which may introduce sampling bias and restrict the generalizability of the findings to the broader population of Indian university students. The exclusive focus on ANN as a predictive model without comparing its efficacy against other statistical or machine learning methods may limit the interpretability of the predictive outcomes. In addition, the absence of demographic variables such as socioeconomic status, which could significantly influence both mental health and cognitive functioning, presents a limitation. The inclusion of such variables in future research could provide a more comprehensive understanding of the underlying factors that contribute to the observed associations.

To address these limitations, future research may consider employing objective measures of mental health status and cognitive abilities, such as clinical assessments or neuropsychological tests. Further, longitudinal studies may be conducted to examine the temporal dynamics and causal relationships between the psychological attributes and cognitive performance over time. Additionally, expanding the sample size, utilizing random sampling methods and including a more diverse population can improve the representativeness of the findings. Future investigations should be directed to explore the potential mediating or moderating variables (eg, demographic factors, socio-economic status, physical and mental activities, etc.) which may influence the relationship between psychological and cognitive attributes of the students. Indeed, these studies are on-going in our laboratory. Lastly, exploring the effectiveness of various interventions, such as cognitive-behavioural therapy or mindfulness-based interventions, in improving mental health and cognitive performance among university students can provide valuable insights for future interventions, which is the ultimate goal of our research.

Conclusion

In this study, we delved into the dynamics between mental health symptoms (stress, anxiety, and depression) and cognitive functioning among Indian college students. Utilizing an ANN model for regression analysis, augmented with PCA for feature reduction, our research has illuminated significant associations that delineate the influence of mental health on cognitive abilities. The adoption of PCA enabled us to refine our dataset, ensuring the ANN model honed in on the most salient features with maximum variance, thus optimizing the interpretability of the model. Our findings reveal a consistent pattern: positive correlations among mental health symptoms themselves and inverse correlations between these symptoms and cognitive performance. This suggests a detrimental impact of exacerbated mental health symptoms on cognitive functioning. While the ANN model provided modest predictive power, it showcased the potential of machine learning techniques in identifying and predicting the cognitive impacts of mental health symptoms.

The practical implications of our findings are clear: addressing mental health concerns is not just crucial for the psychological well-being of college students but also for their cognitive and academic performance. Further, prediction of global cognitive abilities of students from their psychological data is particularly suited for educational institutions which have presence of well-established psychological counselling cells with the ability to identify emotionally vulnerable youth. Interventions specifically designed to alleviate stress, anxiety, and depression could play a pivotal role in not only enhancing mental health but also in potentially boosting cognitive functions in academic settings. By integrating advanced analytical techniques such as feature reduction and weight analysis into mental health research, this study paves the way for developing more nuanced predictive models. Such models could inform the creation of targeted mental health interventions, ultimately contributing to the improved cognitive functioning and overall well-being of college students.

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Disclosure

The authors reports no conflicts of interest in this work.

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