Predicting Mexican-origin Adolescent-Parent Depressive Symptom Profiles: Analysis of Cultural Factors Using Machine Learning Approach

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Introduction

Adolescent depression poses a significant challenge to positive youth development, with implications for long-term health outcomes (Thapar et al., 2012). Community and nationally-based samples have consistently demonstrated that Mexican-origin adolescents are at risk of experiencing depressive symptoms. Cultural factors, such as adolescent language brokering experiences and discrimination, play a significant role in shaping the experiences of Mexican-origin youth and may contribute to their vulnerability to depression (Kessler et al., 1999; Kim et al., 2017; Umaña-Taylor & Hill, 2020). While past literature has illustrated the effects of various cultural factors on depressive symptoms among Mexican-origin adolescents, the primary cultural factor with the greatest impact on adolescent depressive symptoms remains unknown. Guided by family system theory (Brown, 1999), which emphasizes the interdependency within the family system, it is essential to investigate the understudied phenomenon of depressive symptoms among Mexican-origin adolescents and their parents, who are simultaneously influenced by cultural factors. Considering adolescence is a phrase that demonstrates a lot of changes, such as cognitive and psychological changes, it is essential to investigate adolescent and parental depressive symptoms from a developmental perspective (Bámaca-Colbert et al., 2012). The current study aims to use machine learning to explore the most influential cultural factor that affects dyadic depressive symptoms among Mexican-origin adolescents and mothers, both concurrently and longitudinally

Cultural Influences on Mexican-origin Families

Adolescence is a phrase characterized by substantial changes and the influences of cultural factors may vary through early to late adolescence. Mexican-origin adolescents may have different cultural perceptions and identities in the process of adapting to the larger host society (Umaña-Taylor & Guimond, 2010). For instance, ethnic identity as an important cultural factor is manifested throughout adolescence. In the process of adjusting to new social

and cultural norms, Mexican-origin adolescents may start to expand the significance of their ethnic heritage and understand the meaning of their ethnic identity. The process of exploring, formatting, and retaining ethnic identity is a stressful process for immigrant-origin populations (Toomey et al., 2013). Previous literature has shown that high levels of ethnic centrality are associated with better adolescent developmental outcomes, such as a greater sense of belonging and life meaning (Rumbaut, 1994). Therefore, examining adolescent ethnic centrality from a developmental perspective is needed.

Furthermore, family obligation is considered a fundamental component of Mexican cultural values. Family obligation values refer to the psychological sense that one should help, support, and sacrifice for the family (e.g., it is important to treat parents with respect). Family obligation values are found to be a protective factor to buffer against the detrimental influence of family stress on adolescent delinquency (Wheeler et al., 2017). For instance, a study on Latino adolescents shows that adolescent family obligation values serve as a resilience factor to buffer the negative effect of parental alcohol use on adolescent alcohol use (Espinosa-Hernandez et al., 2022). Specially, Latino adolescents with a higher sense of family obligation report a low level of alcohol use even under the influence of their parents' high level of risky drinking behavior. Adolescents with a strong commitment to family obligation values often prioritize family support, leading them to consume less alcohol to maintain their role in supporting the family, especially when parents engage in risky drinking behaviors. However, previous research has shown that Mexican-origin adolescent family values decline from early to late adolescence and such decreased commitment to family obligation values may also be attributed to adolescents' development of emotional autonomy and acculturation to American culture (Kho et al., 2023).

Moreover, language brokering experiences, referring to the process by which adolescents provide translation for their English-limited parents, is a critical cultural factor

for Mexican-origin adolescents (Kim et al., 2017). Adolescent language brokering experiences can be a protective and risk factor for adolescent development (Shen et al., 2020). For instance, previous research has shown that language brokering stress diminishes adolescent mental health. Moreover, adolescents are more likely to have poor executive functioning if their parents are overly dependent on them for language brokering. the concept of dependency contradicts the emphasis in Mexican culture on parents as authoritative figures. This dynamic may lead to confusion among adolescents and impose additional burdens on them. On the other hand, when adolescents develop positive relationships with their parents by doing language brokering for their parents, adolescents are more likely to have higher high school grades. As adolescents gain proficiency in both English and Spanish through years of language brokering, their perception of this activity may change through adolescence.

In addition to the cultural factors previously discussed, Mexican-origin adolescents may encounter various other cultural stressors, such as discrimination, bicultural management difficulties, foreigner stress, etc. Given that adolescents' experiences of cultural factors may differ throughout adolescence due to the development of cognition and adaptation, it is crucial to examine adolescents' perceptions of cultural factors from early to late adolescence. This approach allows for a comprehensive understanding of the evolving nature of adolescents' perceptions of cultural influences over time.

Depressive Symptoms among Adolescent-Mother Dyads

Adolescence is marked by various developmental tasks, such as the formation of identity and the management of peer and romantic relationships (Cicchetti & Rogosch, 2002). Challenges in navigating those transitions may contribute to higher levels of depressive symptoms. Previous studies show that Mexican-origin adolescents experience a high risk of depressive symptoms due to the experience of different family, social, and cultural challenges

(Bámaca-Colbert et al., 2012). The family system theory (Brown, 1999) demonstrates that the family system is an interdependent system, which means that adolescents and mothers mutually influence each other. Previous research has illustrated that mental health is strongly associated with adolescent mental health (Ge et al., 1995). Specifically, adolescents with mothers who have higher levels of depressive symptoms are at higher risk of depressive symptoms than adolescents with mothers who do not have depressive symptoms. On the other hand, mothers who have adolescents with depressive symptoms have higher levels of psychological distress and are more vulnerable to depressive symptoms (Ge et al., 1995). Although previous research has examined the bidirectional association between mothers and adolescents, how adolescents' depressive symptoms development informs changes in parents' depressive symptoms, or if this process is parallel remains unknown. Therefore, the current study aims to investigate how depressive symptoms change across time in mother-adolescent dyads to inform future intervention efforts to reduce depressive symptoms among the Mexican-origin population.

Influences of Cultural Factors on Depressive Symptoms among Adolescent-Mother Dyads

In addition to exploring the developmental change in depressive symptoms among adolescent-mother dyads, it is important to understand how cultural contexts shape development. Previous studies have shown that cultural factors, such as language brokering experience, discrimination, acculturation, bicultural management difficulties, etc, may influence adolescents' and mothers' depressive symptoms (Donovan et al., 2013; Kim et al., 2017; Milan & Wortel, 2015). For instability, adolescents who experience language brokering stress are more likely to have depressive symptoms (Shen et al., 2020). Adolescents and mothers who experience higher levels of discrimination and bicultural management difficulties are also at higher risks of depressive symptoms and anxiety. Moreover,

adolescents and mothers with higher family obligation values tend to be resilient from contextual stress and have better mental health status (Milan & Wortel, 2015). While previous research has investigated the cultural influence on Mexican-origin adolescents and mothers from individual levels, examining the cultural contexts in the family dynamic is also critical to understand how cultural factors impact the family system as a whole.

As adolescence is a phrase that demonstrates a lot of changes, the cultural effects on mother-adolescent depressive symptoms may differ from early to late adolescence. For instance, adolescents tend to have stronger family obligation values in early adolescence than in late adolescence, so family obligation values may have a stronger impact on mother-adolescent depressive symptoms in an earlier stage than later (Padilla et al., 2016). Moreover, adolescent ethnic identity evolves throughout adolescence and adolescents tend to have a stronger sense of ethnic identity in late adolescence than early adolescence, subsequently leading to stronger influences on mother-adolescent depressive symptoms (Umaña-Taylor & Guimond, 2010). To capture the diverse influence of cultural factors on mother-adolescent depressive symptoms throughout adolescence, the current study investigates the concurrent and longitudinal influences of cultural factors on mother-adolescent depressive symptoms. Particularly, the current study aims to explore the most impactful cultural factor that can best predict depressive symptoms in adolescent-mother dyads concurrently and longitudinally.

Current study

Adapted family stress theory (Brown, 1999), the current study utilized a three-wave dataset to investigate the most impactful cultural factor that best predicts depressive symptoms in adolescent-mother dyads concurrently and longitudinally. It was hypothesized that the most influential factors for depressive symptoms in adolescent-mother dyads were different in early and late adolescence. Nevertheless, due to insufficient evidence from prior research regarding the dominant cultural factor affecting depressive symptoms among

Mexican-origin families, the most impactful factor remains undetermined.

Method

Participant

The data utilized in the current study were from a three-wave longitudinal dataset on Mexican immigrant families recruited from central Texas (Wave 1: 2012 – 2015; Wave 2: 2013 – 2016, Wave 3: 2017 – 2020). The larger study targeted families with at least one adolescent enrolled in middle school who served as a translator between Spanish and English for their parents. 604 adolescents (54% female, 46% male; M_{age} = 12.92, SD_{age} = 0.92) and 595 mothers (M_{age} = 38.89, SD_{age} = 5.74) participated in Wave 1. The majority of adolescents were born in the U.S. (75%), while almost all mothers (99%) were born in Mexico in Wave 1. Among adolescents born in Mexico, the mean age of permanent relocation to the U.S. was 3.99 years; for mothers born in Mexico, it was 23.31 years. Family income averaged between $20,001 to $30,000 in Wave 1. The average maternal education level was middle school (14.7% had less than an elementary school education, 30.5% had finished elementary but not middle school, 33% had finished middle school but not high school, and 21.8% had graduated from high school) in Wave 1.

Procedure

Participants' families were initially recruited through school presentations, community recruitment, and public records. Families were selected if parents were of Mexican heritage and their children had the experience of using English and Spanish to translate for at least one parent. Informed consent from parents and informed assent from adolescents were obtained. Research assistants read the questionnaires to mothers and adolescents and their responses were recorded on a laptop computer. All materials were available in both English and Spanish, with the questionnaires originally crafted in English. Bilingual and bicultural research assistants translated the materials into Spanish and then

back-translated them into English. Families received compensation of $60 at Wave 1, $90 at Wave 2, and $90 at Wave 3 for their participation. All procedures were approved by the Institutional Review Board at the University of Texas at Austin.

Measure

Language Brokering

Adolescents and mothers reported language brokering experiences including: adolescent language brokering stress at different places for mothers, adolescent language brokering frequency of different materials for mothers, adolescent language brokering stress of different materials for mothers, adolescent language brokering positive emotion for mothers, adolescent language brokering negative emotion for mothers, adolescent linguistic benefits of doing language brokering for mothers, adolescent socio-emotional benefits of doing language brokering for mothers, adolescent language brokering efficacy for mothers, positive mother-child relationship tied to language brokering, adolescent negative feelings of language brokering for mothers, adolescent language brokering centrality for mothers, and maternal language brokering dependency on adolescents, maternal perceived adolescent language brokering stress, maternal perceived adolescent language brokering frequency, maternal perceived adolescent language brokering positive emotion, maternal perceived adolescent language brokering negative emotion, maternal perceived adolescent linguistic benefits of doing language brokering, maternal perceived adolescent socio-emotional benefits of doing language brokering, maternal perceived positive mother-child relationship tied to language brokering. Measured items were adapted from a previous study (Kim et al., 2017). Sample items included “Because I translate for my mother, I have had to learn how to communicate effectively (people understand me well),” “My mother is not in control of the situation when she asks me to translate,” and “I become impatient when my mother asks me to translate for her.”

Acculturation and Enculturation

Adolescents and mothers reported acculturation and enculturation experiences including: adolescent and maternal acculturation, and adolescent and maternal enculturation. Measured items were adapted from a previous study (Ryder et al., 2000). Sample items included “I often follow traditions of the Mexican culture (way of living or doing things),” and “It is important for me to maintain or develop typical U.S American cultural practices (way of living or doing things).”

Discrimination

Adolescents and mothers reported discrimination experiences including: adolescent and maternal daily discrimination, adolescent and maternal group discrimination, adolescent and maternal racial discrimination, adolescent and maternal mistreatment due to being Mexican, and adolescent and maternal victimization. Measured items were adapted from previous studies (Kessler et al., 1999; Rigby, 2000). Sample items included “I am treated with less courtesy (politeness) than other people every day,” “People act like I am dishonest because I am Mexican,” and “People say mean or bad things about me to other people.”

Familism

Adolescents and mothers reported familism values including: adolescent family obligation values and maternal perceived adolescent family obligation values. Measured items were adapted from a previous study (Fuligni et al., 1999). A sample item included “How important it is to you that you treat your parents with respect?”

T*raditional Gender Belief*

Adolescents and mothers reported traditional gender beliefs including: adolescent and maternal perceived machismo, caballerismo, and marianismo. Measured items were adapted from a previous study (Castillo et al., 2010). Sample items included “A man need to be in control of his wife” and “A woman should meet the husband's needs without arguing.”

Racial Socialization

Adolescents and mothers reported racial socialization including: adolescent-reported maternal cultural socialization practices and adolescent-reported maternal socialization for bias preparation, maternal reported teaching adolescents about ethnic background, and maternal reported teaching adolescents about discrimination. Measured items were adapted from a previous study (Umaña-Taylor & Hill, 2020). Sample items included "My mother talks to me about what to do if someone insults or harasses me" and "My mother pushes me to work harder than others."

Bicultural Management

Adolescents and mothers reported bicultural management including: adolescent and maternal bicultural management difficulties. Measured items were adapted from a previous study (Kim et al., 2014). A sample item included "I am conflicted between the U.S American and Mexican ways of doing things."

Ethnic Identity

Adolescents and mothers reported ethnic identity affiliation including: adolescent and maternal ethnic centrality, adolescent and maternal ethnic exploration, and adolescent and maternal ethnic resolution. Measured items were adapted from previous studies (Sellers et al., 1997; Umaña-Taylor et al., 2004). Sample items included "I have a sense of belonging with other Mexican people" and "I have often done things that will help me understand my Mexican background better."

Foreigner Stress

Adolescents and mothers reported foreigner stress including: adolescent and maternal foreigner stress, and adolescent and maternal feelings of misfit. Measured items were adapted from a previous study (Benner & Kim, 2009). Sample items included "Because of how I speak, people sometimes assume I am not a U.S. American" and "I feel that somehow I don't

fit in with U.S. Americans."

Adolescent and Maternal Depressive Symptoms

Adolescents and mothers reported their own depressive symptoms by using 20 items from the Epidemiologic Studies of Depression Scale (CES-D). Sample items included, "I felt people disliked me" and "I thought my life had been a failure."

Analysis Plan

First, latent profile analysis (LPA) was conducted to identify distinct mother-adolescent depressive symptoms profiles at two waves based on raw scores of mothers- and adolescent-reported depressive symptoms. Six LPA models were conducted to identify one to six profiles, respectively. Then, the optimal profile number was selected separately based on model indices (i.e., Akaike information criteria (AIC), Bayesian information criteria (BIC), adjusted Bayesian information criteria (ABIC), and entropy) and by considering the substantive meanings of the profiles. Lower values of AIC, BIC, and ABIC indicates better fit, and entropy above 0.80 indicates acceptable model fit (Nylund et al., 2007).

Then, three classifiers: decision tree, random forest, and XGBoost was used to determine the effect of cultural factors on adolescent-mother depressive symptom profiles. Their performances was evaluated by calculating the accuracy defined as below:

$$Accuracy(y, \hat{y}) = \frac{1}{n_{samples}} \sum_{i=1}^{n_{samples}} 1(y = \hat{y})$$

The statistical meaning of accuracy is the proportion of the samples whose actual labels are equal to the predicted labels. Based on the comparison result, the best model was employed to analyze the feature importance by using SHAP (SHapley Additive exPlanations) to determine the directions of the cultural effects on adolescent-mother depressive symptom profiles. Regarding the validation, the dataset was split into the training set and testing set with a ratio of 0.67:0.33. The training set was used to train the models and the testing set was used to

calculate the accuracy.

Finally, to explore whether the cultural factors could be used to predict the depressive profile of a given dyad, a neural network model using the TensorFlow and Keras libraries was used. The neural network used was the Sequential model available in the Keras library consisting of alternating Dense and Dropout layers. We picked this architecture because a linear topology seemed sufficient for our classification problem; our goal is to produce just one output from a collection of inputs, and there is no temporal component or dependence on past results in our data. The activation function chosen was the ReLU function (Equation 1), to avoid the vanishing gradient problem presented by sigmoid functions and to capture more complex relationships than a linear function.[1] The last layer utilizes a softmax activation function (Equation 2) to match the multi-class classification task output required. The optimizer chosen was the Adam optimizer (Equation 3) due to its computational efficiency and its suitability for data with many parameters.[2] This makes the model well-equipped to handle potentially large numbers of samples efficiently in the future. The loss function chosen was the sparse categorical cross-entropy function (Equation 4), to match the multi-class, integer-encoded output required. Finally, dropout layers were added after initial testing showed that the model was overfitting the training data to the detriment of its validation performance. So, the final architecture of the neural network consists of a 128-node dense layer with a ReLU activation, a dropout layer with ratio 0.2, a 64-node dense layer with a ReLU activation, a dropout layer with ratio 0.2, and a 3-node dense output layer with a softmax activation. Wave 1 and wave 3 data were analyzed separately with the same network architecture to account for potential variability due to the different adolescent ages across the two groups.

$$g(z) = max(0, z)$$

Equation 1: ReLU activation function.

$$softmax(v_i) = \frac{e^{v_i}}{\sum_{j=1}^{N} e^{v_j}}$$

Equation 2: Softmax activation function with v representing the output vector and N representing the number of classes.

$$m_t = \beta_1 \cdot m_{t-1} + (1 - \beta_1) \cdot g_t$$

$$v_t = \beta_2 \cdot v_{t-1} + (1 - \beta_2) \cdot g_t^2$$

$$\widehat{m_t} = m_t \,/\, (1 - \beta_1^t)$$

$$\widehat{v_t} = v_t \,/\, (1 - \beta_2^t)$$

$$\theta = \theta - (\alpha \cdot \widehat{m_t}) \,/\, (\sqrt{\widehat{v_t} + \varepsilon})$$

Equation 3: Adam optimizer algorithm, where θ is the model parameters, g_t is the gradient at time t, m_t is the exponential average of the gradient, v_t is the exponential average of the square of the gradient, β_1 and β_2 are hyperparameters, α is the learning rate, and ε is a small term added to prevent division by 0.

$$L_{SCCE} = -\sum_{i=1}^{n} t_i log(p_i)$$

Equation 4: Sparse categorical cross-entropy function, where n is the number of classes, t_i is the truth label, and p_i is the probability for its class.

Results

Adolescent-mother Depressive Symptoms Profiles

Based on a holistic evaluation of model fit indices for latent profile analyses (Table 1) and evaluation of the substantive meaning of depressive symptom profiles (Spurk et al., 2020), the 3-profile solution was the optimal solution for mother-adolescent depressive symptom profiles both in Wave 1 and 3. Figure 1 displays the mean scores of mothers' and adolescents' depressive symptoms in various profiles at different waves, with one-way MANOVA testing assessing significant differences in the same indicator across the three profiles. According to the mean scores of different indicators, the three profiles were named as *mother higher than adolescents (MH)*, *mother lower than adolescents (ML),* and *mother and adolescents both low (MAL)*.

Concurrent Influences of Cultural Factors on Adolescent-mother Depressive Symptom

Profiles

We calculated the accuracy and compared the performance of the three models. The comparison result was shown in the Figure 2. From this result, one can clearly see that the performances of the random forest and XGBoost were much better than the performance of the decision tree. The optimal model among them was the random forest with the maximum depth equal to 3, so we used this model to extract the five most important features as shown in the

The five most important features were Mom Reported Discrimination, Teen Reported Daily Discrimination, Teen Reported Language Brokering Stress for Mother, Mom Reported Discrimination Because of Being Mexican, and Teen reported language brokering negative emotions for Mother. Although the important features can be easily extracted, this analysis included the combined information from all three profiles in the Wave 1 data.

Figure 4. shows the SHAP analysis of the feature importance for the Profile 1 (MAL) in Wave 1 data. The most important feature was “smits”, whose full name was Teen reported Language Brokering Stress for Mother. The SHAP result shows that adolescent language brokering stress for mothers was associated with a lower likelihood of being in the MAL profile. That is to say, when adolescents experienced a high level of stress when brokering for mothers, mothers and adolescents both have a higher tendency to have depressive symptoms (lower likelihood to be MAL).

The same principle can be applied to interpret the SHAP results for Profile 2 (MH) and Profile 3 (ML), as shown in Figure 5. and Figure 6., respectively. The most important feature in Figure 5 was “meds”, whose full name was Mom Reported Discrimination Because of Being Mexican. When the feature value increased, mothers had a higher likelihood than adolescents to have depressive symptoms. The most important feature in Figure 6 was Teen Reported Daily Discrimination. When the feature value increased, mothers had less likelihood than adolescents to have depressive symptoms.

Longitudinal Influences of Cultural Factors on Adolescent-mother Depressive Symptom Profiles

We calculated the accuracy and compared the performance of the three models. The comparison result is shown in the figure below. From this result, one can clearly see that the performances of the random forest and XGBoost were much better than the performance of the decision tree. The optimal model among them was the XGBoost with the maximum depth equal to 5, so we uses this model to extract the five most important features as shown in the bar chart below (Figure 8).

The five most important features were Teen Reported Poor Treatment because Mexican, Teen Reported American Acculturation, Mom Reported Discrimination, Mom Report Frequency of Translation for Mom for Different Things, Mom Reported Negative Feelings About Translating. To investigate the details of each profile, we used SHAP to do the feature importance analysis. Figure 9. shows the SHAP analysis of the feature importance for the Profile 1 (MAL) in Wave 3 data. The most important feature was “disc”, whose full name was Teen Reported Daily Discrimination. The more adolescents reported daily discrimination, the less likelihood of adolescents in the profile that mother-adolescent both have low depressive symptoms. That is to say, daily discrimination can be harmful to mother-adolescent dyad in terms of their depressive symptom profiles. The second most important feature was “accl”, whose full name was adolescent enculturation. When there was a higher level of adolescent enculturation (maintaining Mexican cultural tradition/norms), there was higher likelihood of adolescents in the profile that mother-adolescent both have low depressive symptoms, which referred that traditional cultural orientation can benefit mother and adolescent.

The same principle could be applied to interpret the SHAP results for Profile 2 (MH) and Profile 3 (ML), as shown in Figure 10. and Figure 11., respectively. The most important feature in Figure 10 was “tnemo”, whose full name was Mom Reported Own Negative Emotions When Child

Translates. When the feature value increased, mothers had a lower likelihood than adolescents to have depressive symptoms. The most important feature in Figure 11 was also “tnemo”, whose full name was Mom Reported Own Negative Emotions When Child Translates. When the feature value increased, mothers had a higher likelihood than adolescents to have depressive symptoms.

Neutral Network

When training this architecture with our available data, there were two main issues that affected the model performance. First, even with the dropout layers incorporated, the model overfit the data over fifty epochs, as evidenced by the training loss steeply decreasing while the validation loss increased as training progressed. This was an expected problem, as the available dataset for training and validation was relatively small (595 samples for wave 1 and 328 samples for wave 3). To reduce this overfitting, an early stopping callback parameter was added to the model training. This parameter monitored the validation loss, and stopped the training process if the validation loss did not improve by any amount in the last 5 epochs. While the small dataset fundamentally limited the validation performance, this addition produced decreasing training and validation loss curves, demonstrating that the model was training properly (Figure 12). Second, the confusion matrices produced at the end of training showed that the initial model skewed towards classifying almost all of the samples as 0, or the MAL profile. This was due to the profile imbalance in the dataset, with 82.9% and 89.3% MAL profiles in wave 1 and 3 respectively. So, the model optimized its classification accuracy by simply classifying almost all of the samples as MAL. To address this issue, a class weight parameter was added to the model training. This parameter assigns a class weight to each class that is inversely related to its prevalence in the dataset, so that under-represented classes are assigned a greater weight and emphasizes the smaller classes more during training. This somewhat improved the confusion matrix results, although the model still struggled to identify MH and ML profiles for wave 3, likely due to the even higher imbalance in that dataset. Computationally, there are limited strategies to combat this, so in the future, more MH and ML

samples will have to be included to improve the model's performance in classifying these profiles.

After implementing these improvements, the model produced a 61.34% validation accuracy for wave 1 data and an 86.36% validation accuracy for wave 3 data, with the corresponding confusion matrices shown in Figure 13. While we cannot say with full certainty why there is a significant difference in the accuracy between wave 1 and wave 3 data, this could be due to the previously mentioned class imbalances. Since wave 3 had a larger percentage of MAL samples, even with the class weights implemented, it could still be more heavily skewed towards classifying any sample as MAL and thus achieving an artificially high accuracy. The final results still have room for improvement, but as discussed above, the main way to improve the classifications is to collect a larger dataset to train on and to balance out the dataset with larger proportions of MH and ML samples. The current results show that it is feasible to predict the depressive profiles of mother-adolescent dyads from their cultural factors, even with a limited and unbalanced dataset.

Discussion

This study explored distinct profiles of mother-adolescent depressive symptoms and examined important antecedents of these profiles using machine learning methods. Overall, three mother-adolescent depressive symptom profiles were identified in both early and late adolescent stages. Congruent with previous research indicating intergenerational transmission of depressive symptoms, there were more mother-higher-than-adolescent dyads than adolescent-higher-than-mother dyads.

Model comparison and feature importance results suggest that factors concurrently differentiating mother-adolescent depressive symptom profiles differed from those exerting longitudinal influence. Concurrently, mother and adolescent reported daily discrimination were the most important cultural factors distinguishing profiles, while adolescent reported poor

treatment due to Mexican origin and acculturation were most important longitudinally. This aligns with prior studies indicating cultural factors' influence on mother-adolescent depressive symptoms may vary from early to late adolescence (Padilla et al., 2016; Umaña-Taylor & Guimond, 2010). Considering longitudinal and concurrent findings together, language brokering experiences and emotions (language brokering stress/negative emotions) emerged as salient in both timeframes. Consistent with past work identifying language brokering experiences and emotions as influential cultural factors for adolescent and maternal internalizing symptoms, both mothers' and adolescents' reports of language brokering impacted mother-adolescent depressive symptoms. This supports family systems theory (Brown, 1999) positing the family as an interdependent system wherein adolescents and mothers mutually influence each other.

Additionally, SHAP results suggest the factors most influential for individual profiles differed from those differentiating between profiles. For the mother-adolescent both low depressive symptom profile, adolescent-reported language brokering stress for mother and mother-reported racial discrimination were the most important contributing factors. Specifically, lower adolescent-reported language brokering stress and lower mother-reported racial discrimination related to higher probability of belonging to the both low profiles. This aligns with prior studies identifying higher language brokering stress and mother-reported racial discrimination as risk factors for adolescent and maternal depressive symptoms. Longitudinally, adolescent-reported daily discrimination and adolescent enculturation were most important for this profile. Greater adolescent-reported daily discrimination decreased likelihood of belonging to the both low depressive symptom profile, consistent with daily discrimination as a longitudinal risk factor for mother-adolescent depressive symptoms. Conversely, higher adolescent enculturation increased likelihood of the both low profiles, highlighting benefits of traditional cultural orientation for mother-adolescent depressive

symptoms. For the mother-higher-than-adolescent profile, mother-reported discrimination due to Mexican origin and mother-reported negative emotions during language brokering were most important concurrently and longitudinally. For the mother-lower-than-adolescent profile, adolescent-reported daily discrimination and mother-reported negative brokering emotions were most salient. However, interpretation of these latter two profiles warrants caution given small sample sizes.

For the neural network analyses, after implementing these improvements, the model produced a 61.34% validation accuracy for wave 1 data and an 86.36% validation accuracy for wave 3 data, with the corresponding confusion matrices shown in Figure 13, which might due to the previously mentioned class imbalances. Since wave 3 had a larger percentage of MAL samples, even with the class weights implemented, it could still be more heavily skewed towards classifying any sample as MAL and thus achieving an artificially high accuracy. The final results still have room for improvement, but as discussed above, the main way to improve the classifications is to collect a larger dataset to train on and to balance out the dataset with larger proportions of MH and ML samples. The current results show that it is feasible to predict the depressive profiles of mother-adolescent dyads from their cultural factors, even with a limited and unbalanced dataset.

The present study extends beyond an individual-centric approach to examine depressive symptoms through the lens of family systems dynamics. By using machine learning techniques, the current study contributes to the field by scrutinizing over 30 cultural factors that have demonstrated concurrent and longitudinal associations with depressive symptoms among adolescents and adults. Furthermore, we explore and compare these cultural factors between mothers and adolescents. Employing cutting-edge methods such as SHAP analysis, we aim to transcend conventional feature selection and elucidate how individual cultural factors intertwine within mother-adolescent profiles.

However, several limitations warrant consideration. Firstly, the study is constrained by a relatively small dataset, resulting in an overrepresentation of certain profiles, thereby limiting the predictive capacity of our findings. Secondly, the use of mean imputation to address missing data may introduce biases, suggesting the need for more sophisticated imputation methods in future research endeavors. Lastly, our focus solely on mother-adolescent dyads overlooks potential variations in depressive symptom patterns and cultural stressors within father-adolescent dyads. Future investigations should encompass father-adolescent dynamics to comprehensively explore their unique influences on depressive symptoms.

Conclusion

This study explored distinct profiles of mother-adolescent depressive symptoms and examined important antecedents of these profiles using machine learning methods. Overall, three mother-adolescent depressive symptom profiles were identified in both early and late adolescent stages. factors concurrently differentiating mother-adolescent depressive symptom profiles differed from those exerting longitudinal influence. The neural network analyses suggest that it is feasible to predict the depressive profiles of mother-adolescent dyads from their cultural factors, even with a limited and unbalanced dataset.

Team Contribution:

Tianlu Zhang: conceptualization, methodology, data cleaning, all data analyzing process with actual data (LPA, tree-based classifiers, feature analysis, SHAP, neural network), method part writing, results part writing, conclusion & discussion part writing, project administration. **Contribution score: 100**

Yayu Du: conceptualization, methodology, data cleaning, data analyzing, introduction and method part writing, results, discussion, and conclusion part editing, proofreading, and finalizing paper. **Contribution score: 100**

Rui-an Chang: Coding for the tree-based classifiers, conduct the feature analysis using

SHAP, writing for the methods and results. **Contribution score: 100**

Alexandra E Krylova: neural network coding, troubleshooting, and optimizing, methods and results part writing. **Contribution score: 100**

Table 1a

Latent profile analyses model fit indexes for mother-adolescent depressive symptom at Wave1

Model	AIC	BIC	aBIC	Entropy	Distribution
1-profile model	1230.064	1247.618	1234.919		595
2-profile model	1078.763	1109.483	1087.261	0.878	518-77
3-profile model	**968.706**	**1012.591**	**980.844**	**0.891**	**493-53-49**
4-profile model	950.405	1007.457	966.186	0.864	66-48-465-16
5-profile model	916.988	987.205	936.41	0.797	0-441-100-37-17
6-profile model	916.988	987.205	936.41	0.797	0-434-92-31-14-24

Note. Selected model is in bold

Table 1b

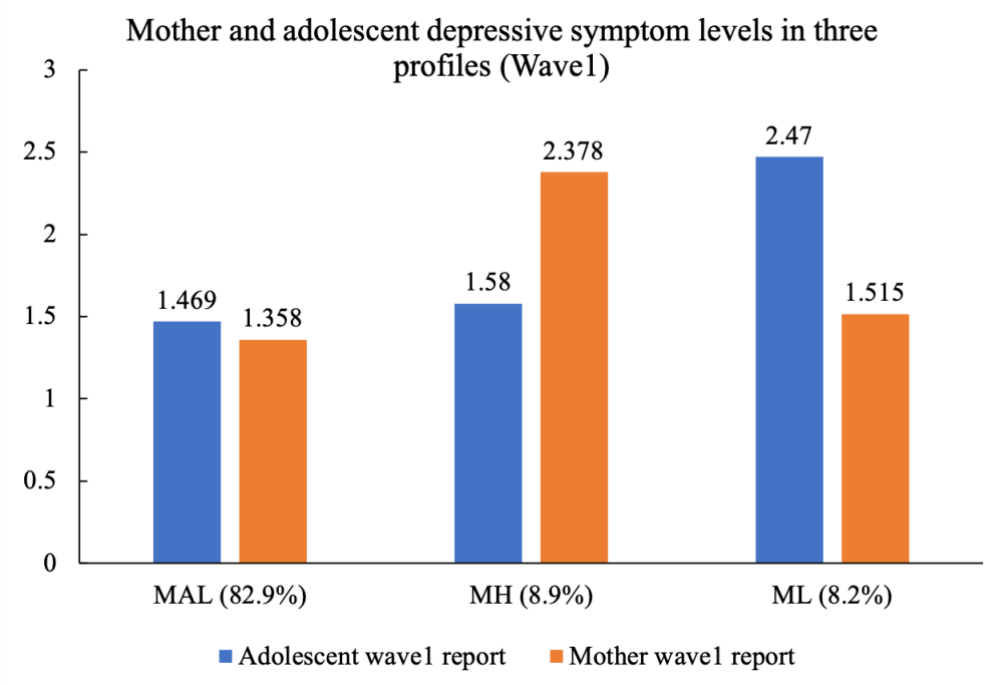
Latent profile analyses model fit indexes for mother-adolescent depressive symptom at Wave3

Model	AIC	BIC	aBIC	Entropy	Distribution
1-profile model	576.928	592.1	579.412		
2-profile model	493.494	520.046	497.842	0.984	9-319
3-profile model	**424.487**	**462.417**	**430.698**	**0.934**	**293-9-26**
4-profile model	409.228	458.537	417.302	0.874	33-28-5-262
5-profile model	394.367	455.055	404.304	0.856	5-24-245-7-47
6-profile model	400.367	472.434	412.167	0.871	0-245-47-24-7-5

Note. Selected model is in bold

Figure 1a

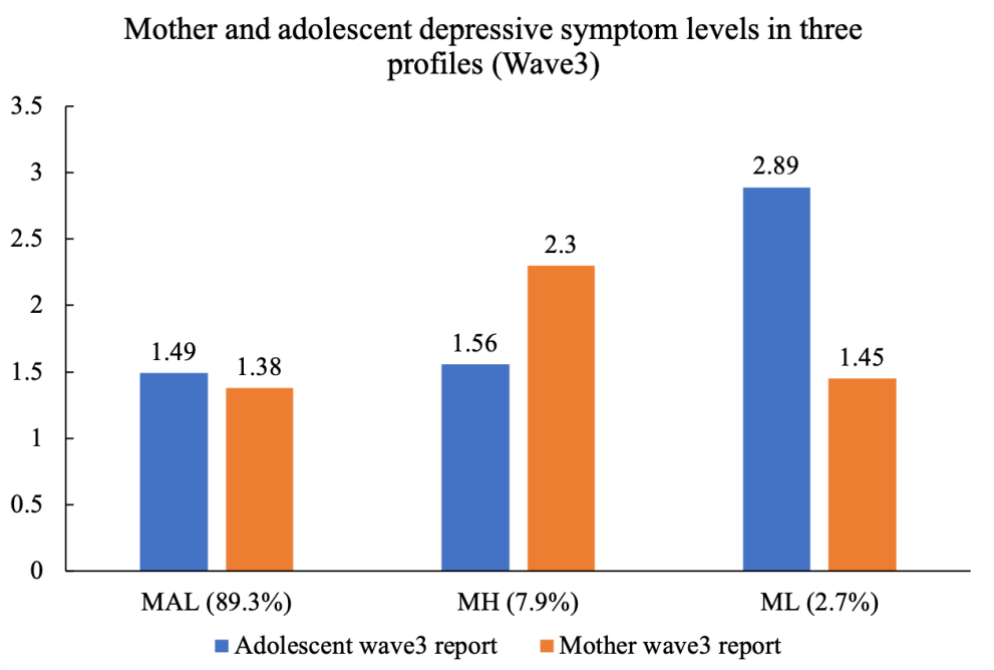
Wave 1 Mother-adolescent depressive symptom profiles



Note. Percentage of the profiles in all mother-adolescent dyads in parentheses

Figure 1b

Wave 3 Mother-adolescent depressive symptom profiles



Note. Percentage of the profiles in all mother-adolescent dyads in parentheses

Figure 2

Performances of the decision tree, random forest, and XGBoost

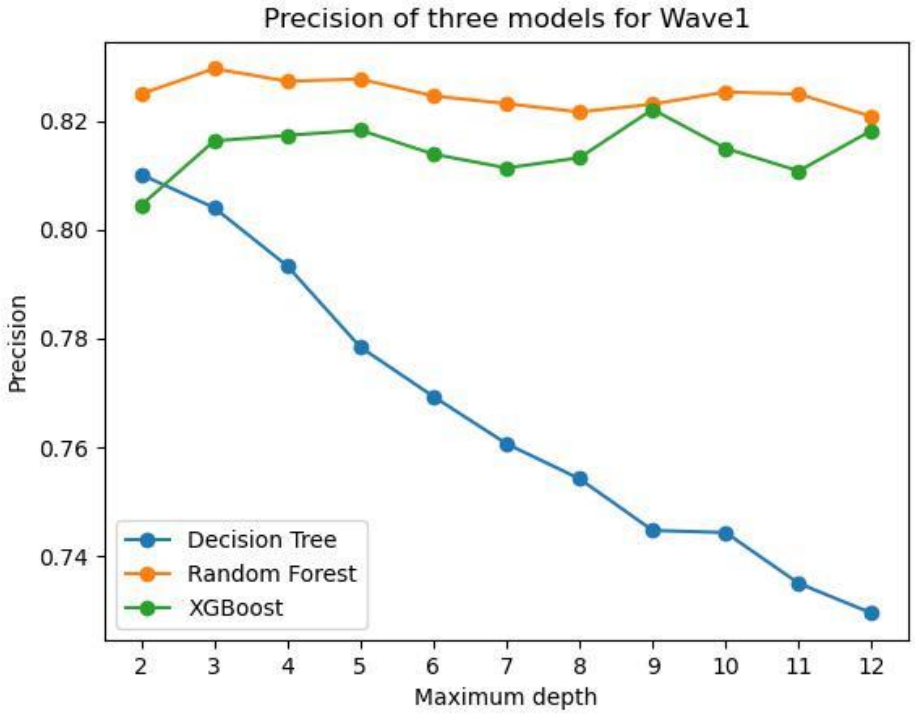


Figure 3

Feature importance for Wave 1 profiles

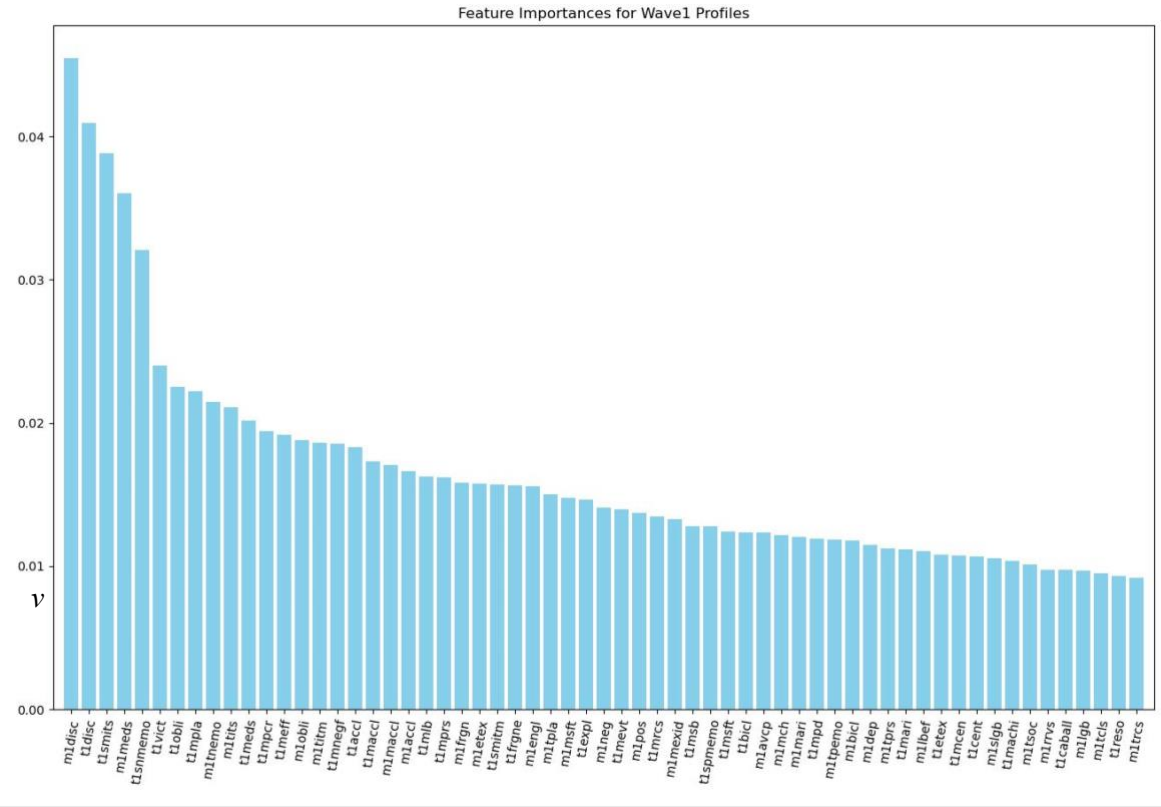


Figure 4

SHAP analysis for Profile 1 (MAL) in Wave 1

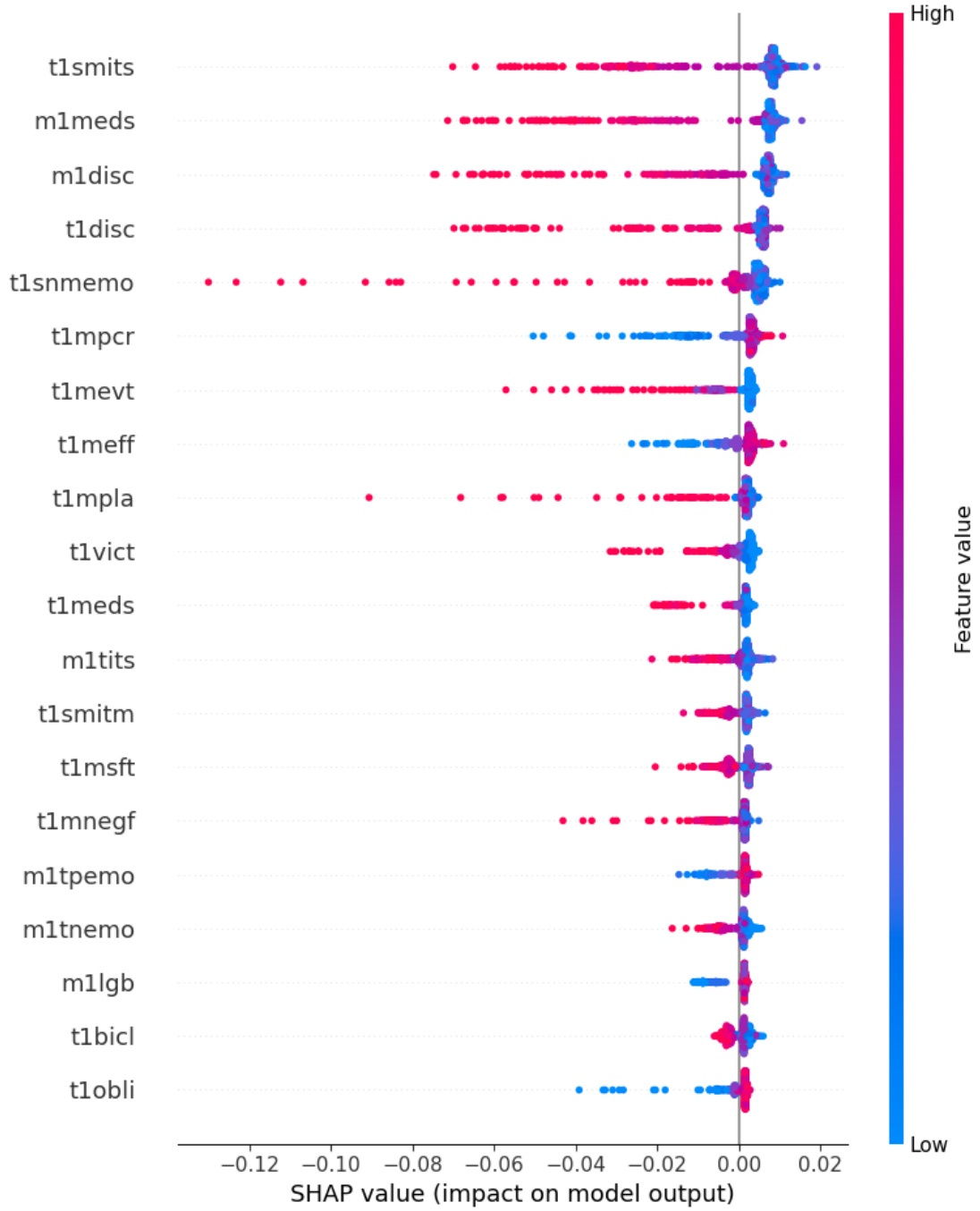


Figure 5

SHAP analysis for Profile 2 (MH) in Wave 1.

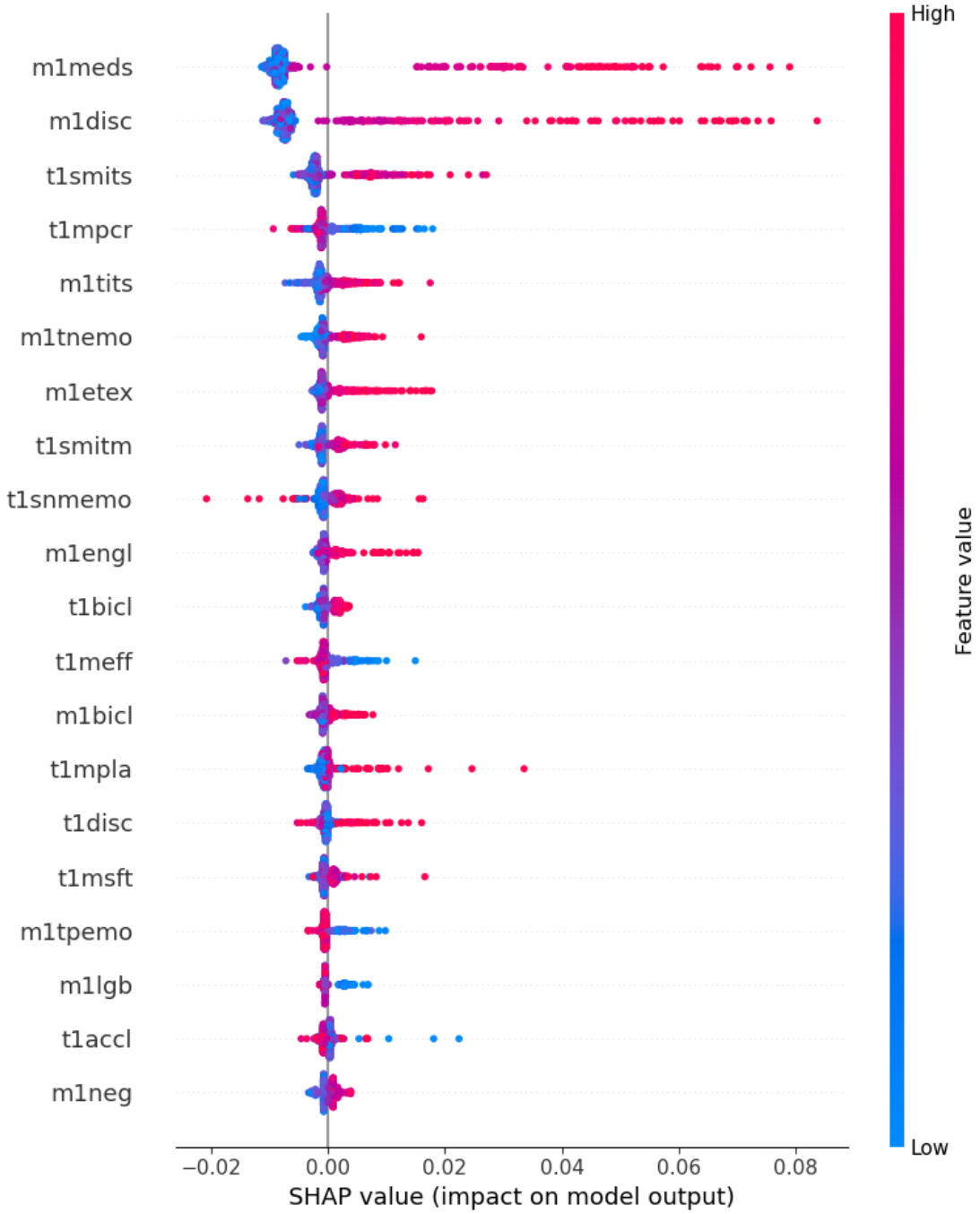


Figure 6

SHAP analysis for Profile 3 (ML) in Wave 1.

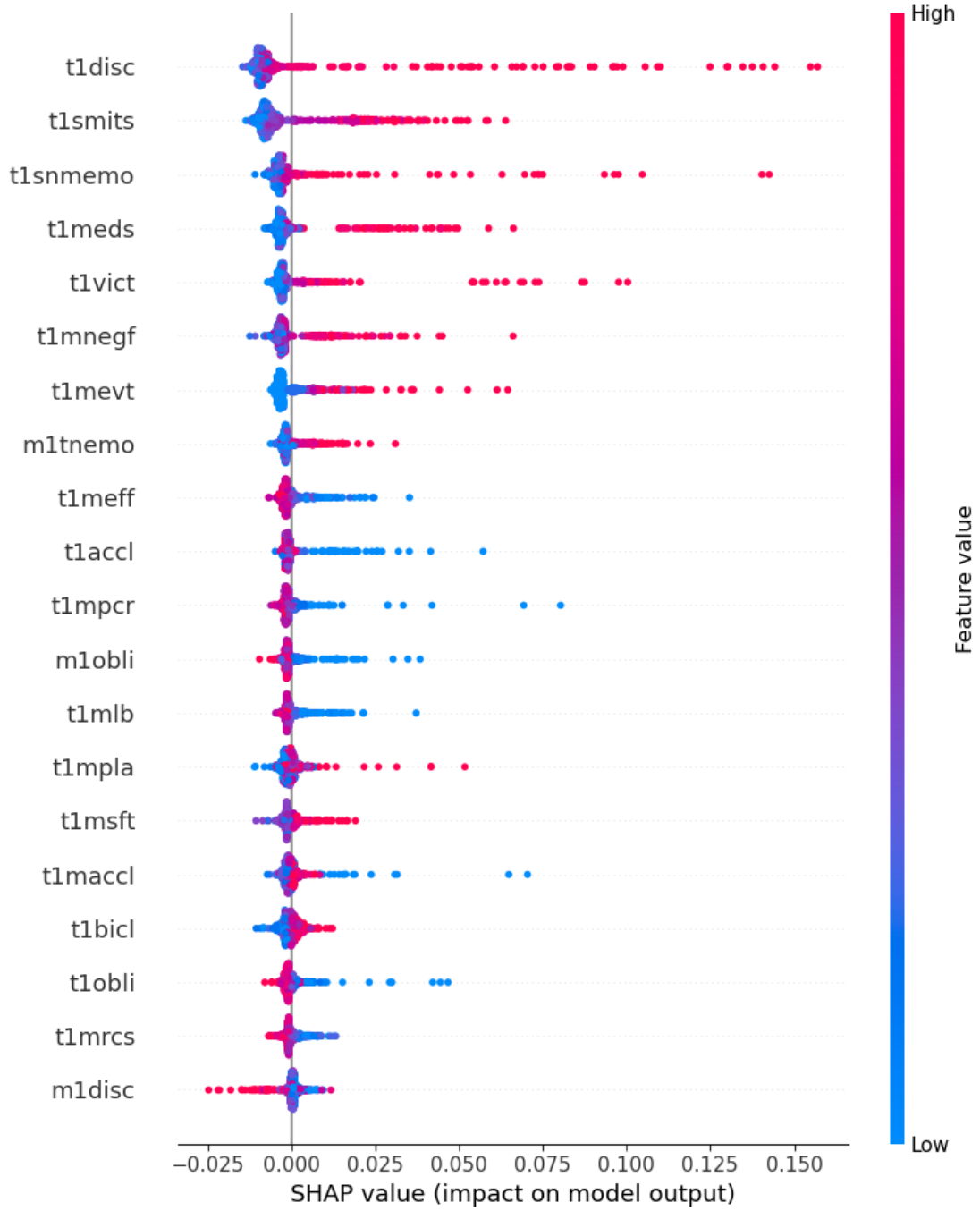


Figure 7

Performances of the decision tree, random forest, and XGBoost

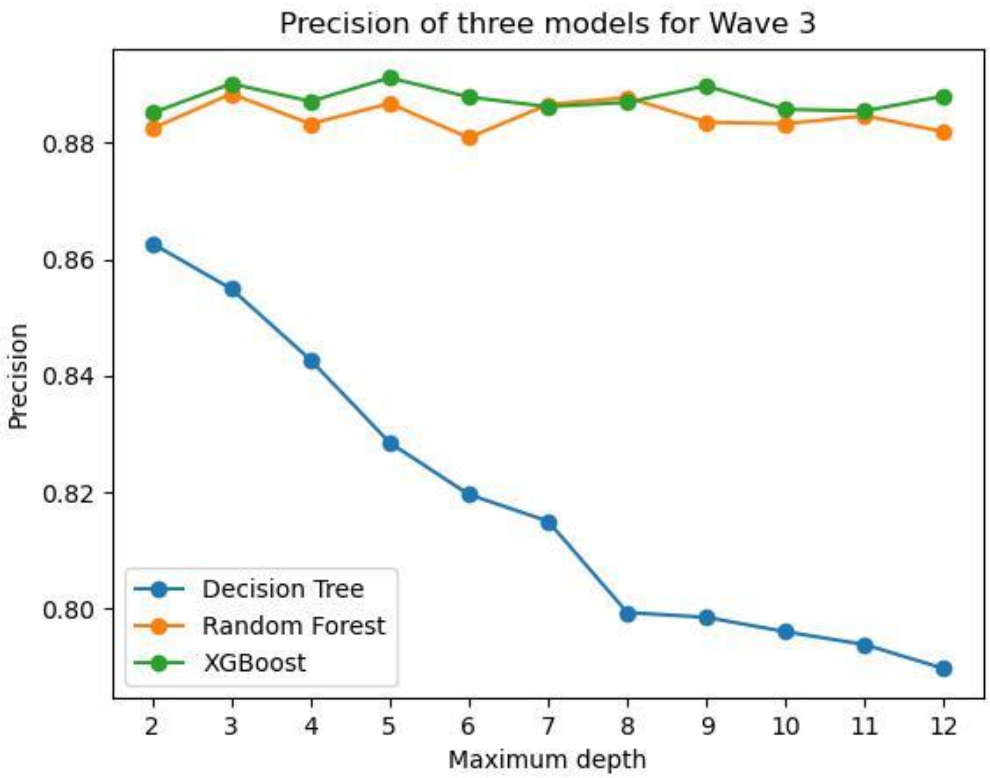


Figure 8

Feature importance for Wave 1 profiles

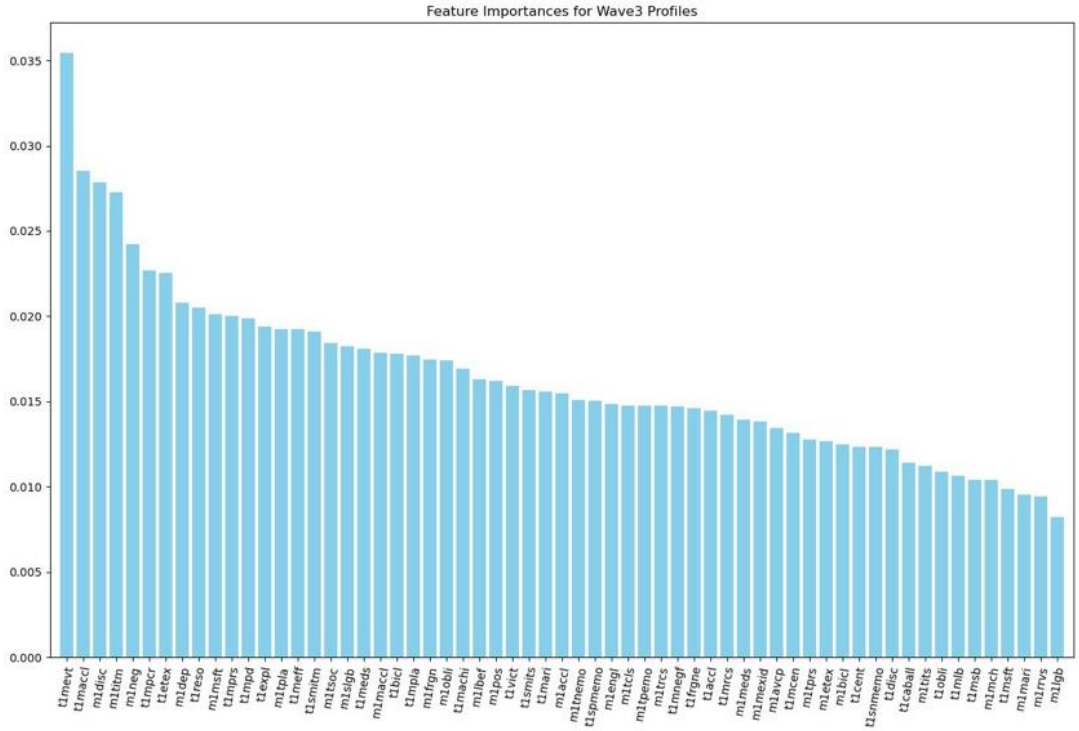


Figure 9

SHAP analysis for Profile 1 (MAL) in Wave 3

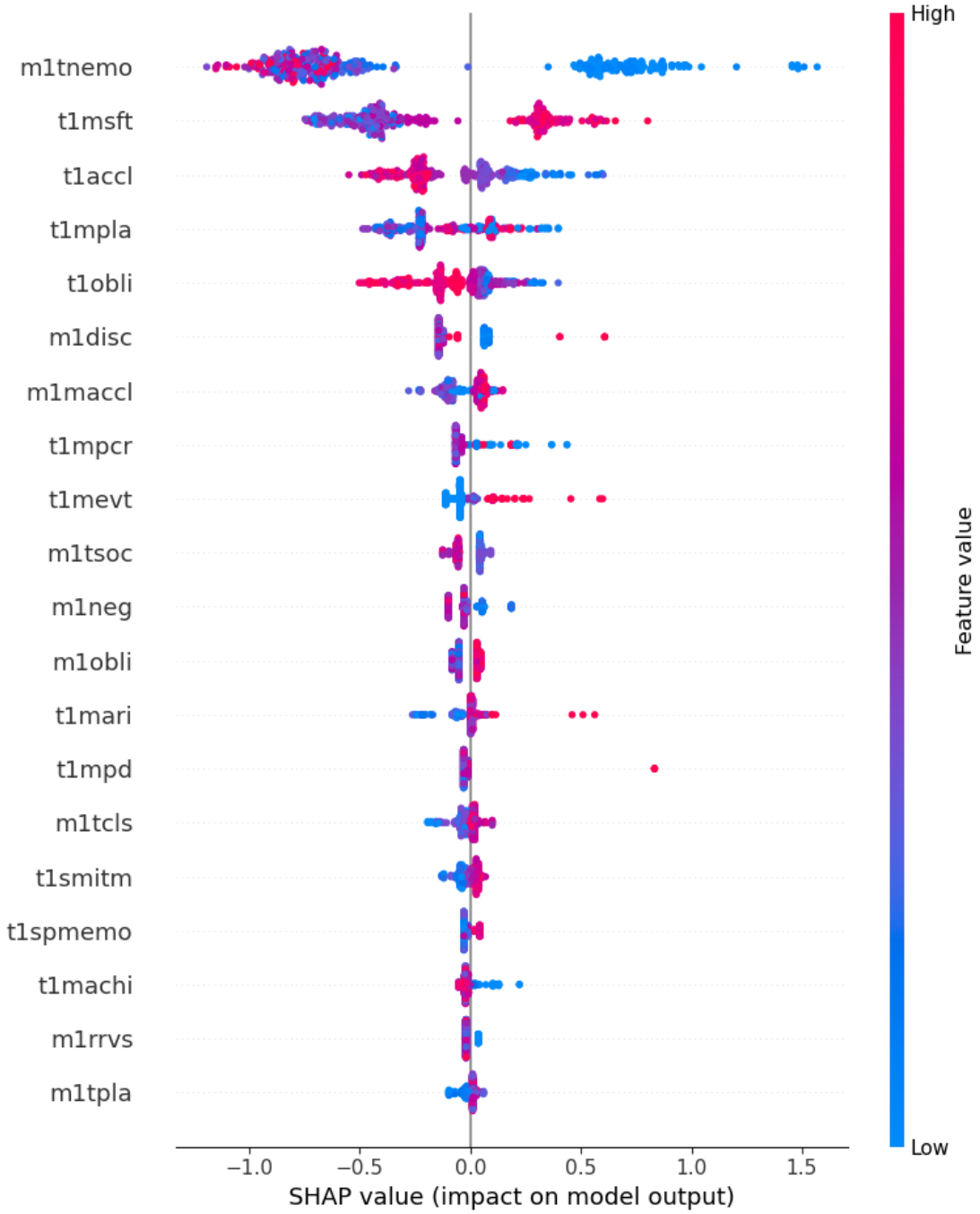


Figure 10

SHAP analysis for Profile 2 (MH) in Wave 3.

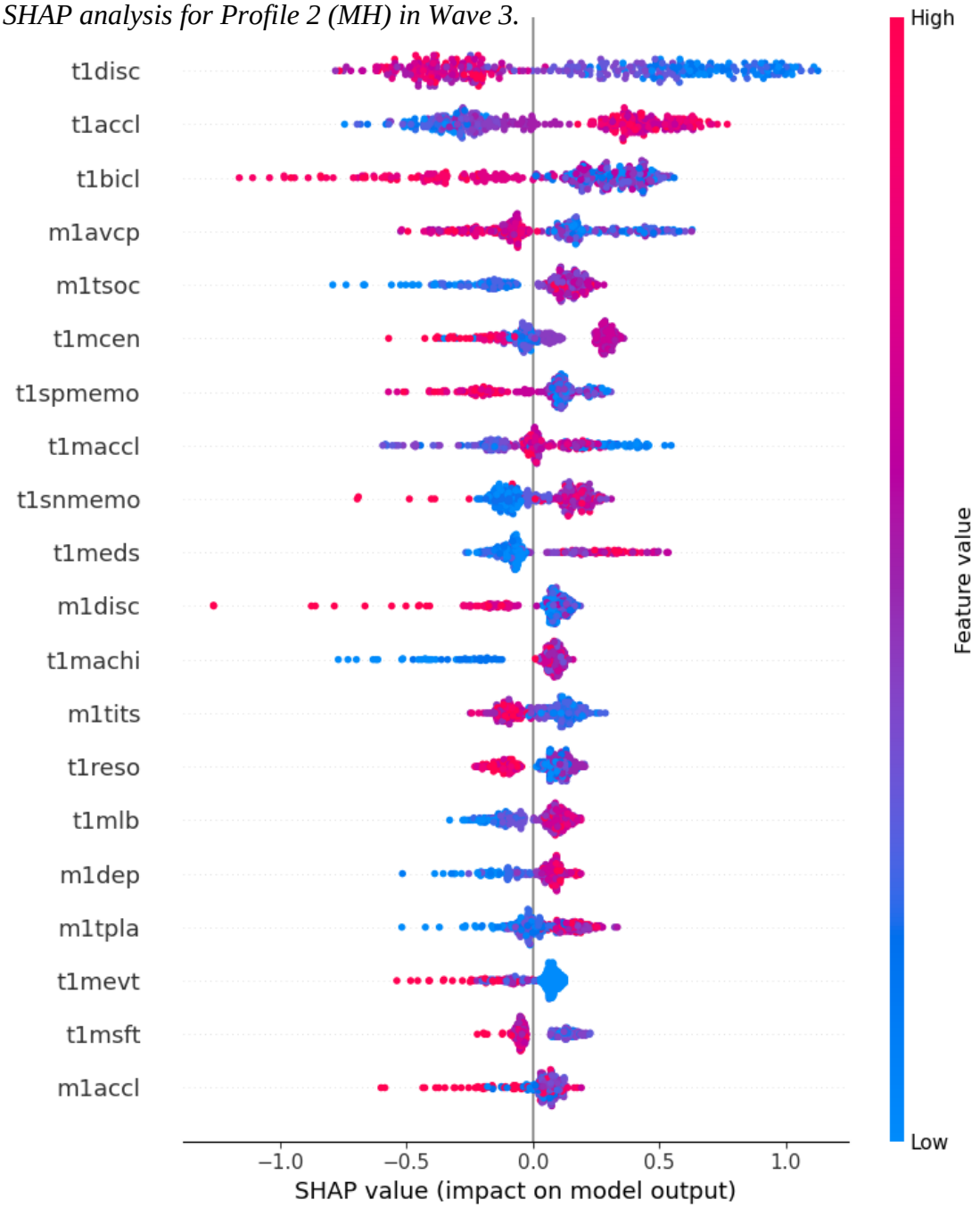


Figure 11

SHAP analysis for Profile 3 (ML) in Wave 3.

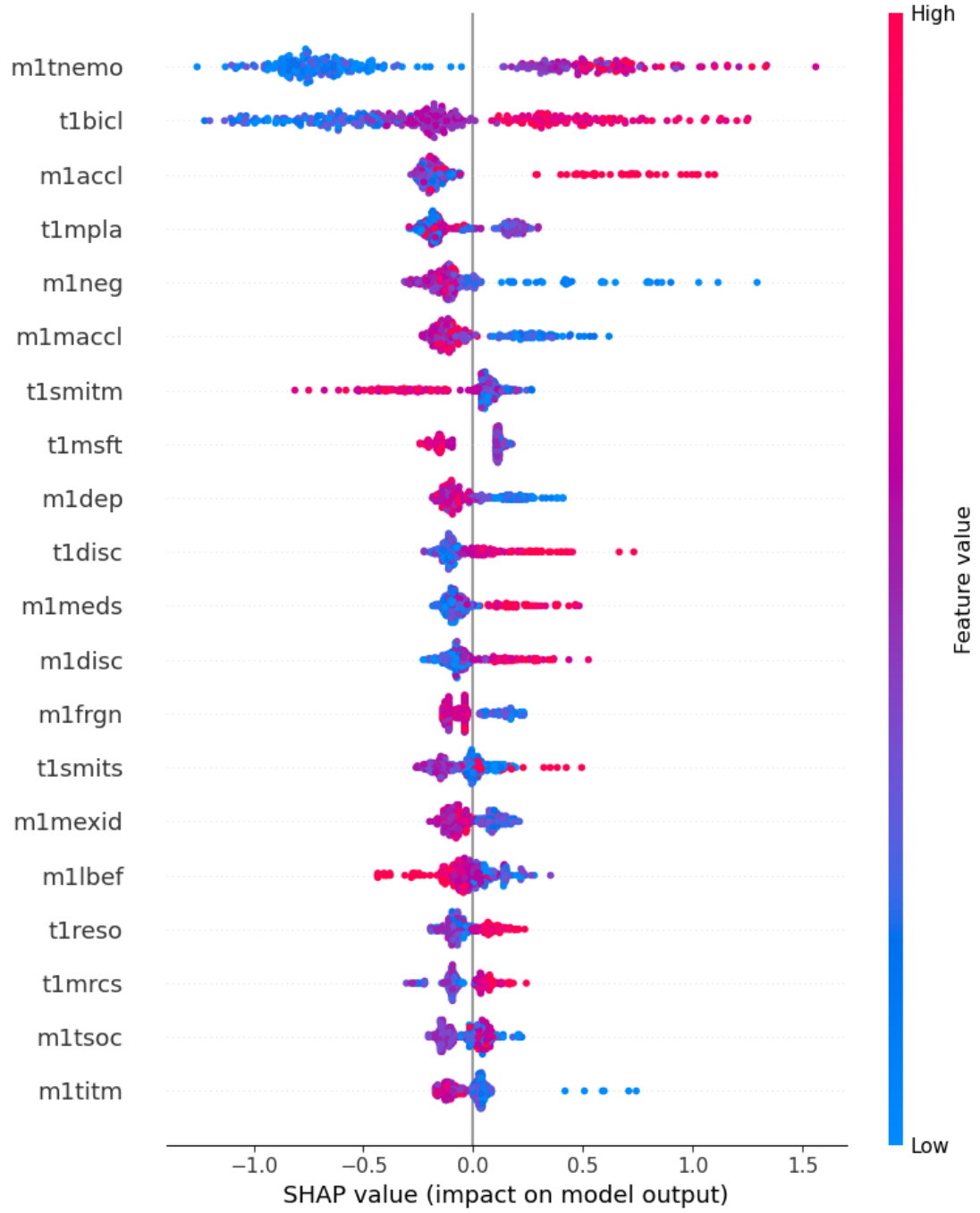


Figure 12

Training and validation loss for wave 1 data (Model1) and wave 3 data (Model3), plotted as loss vs epoch number

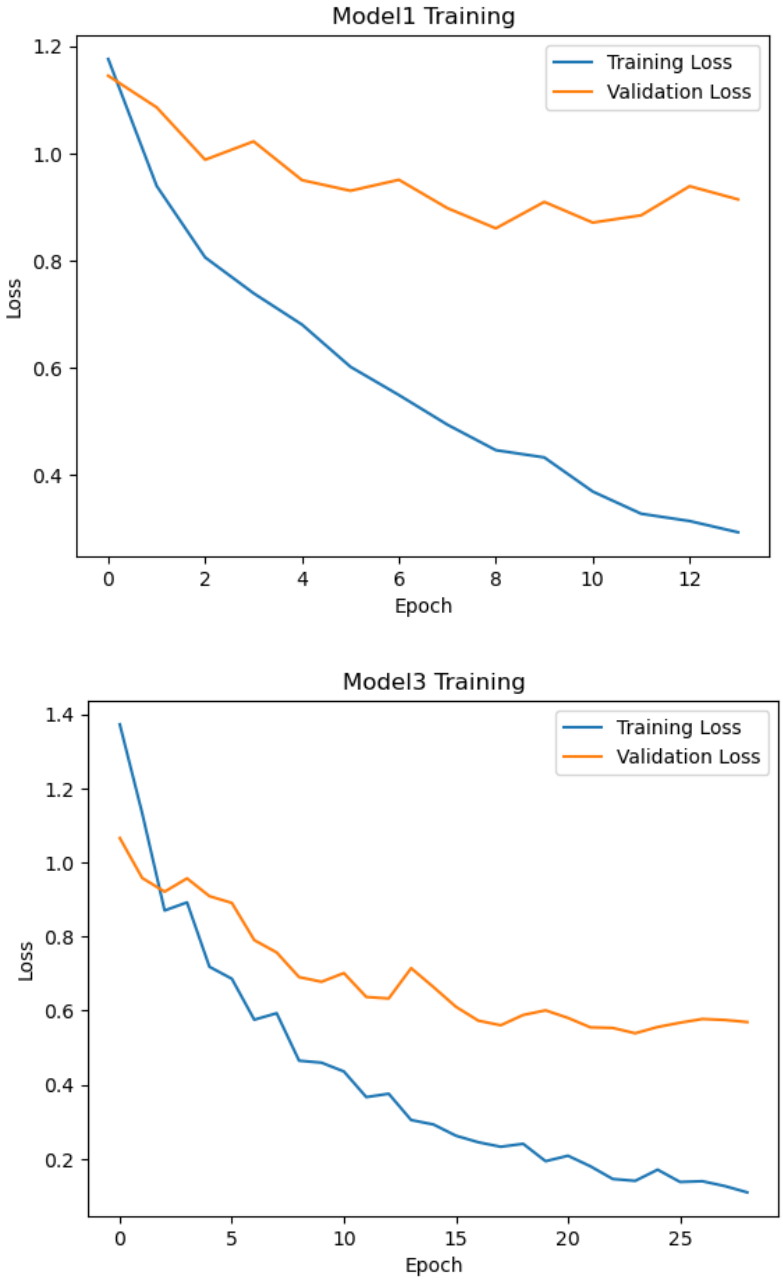
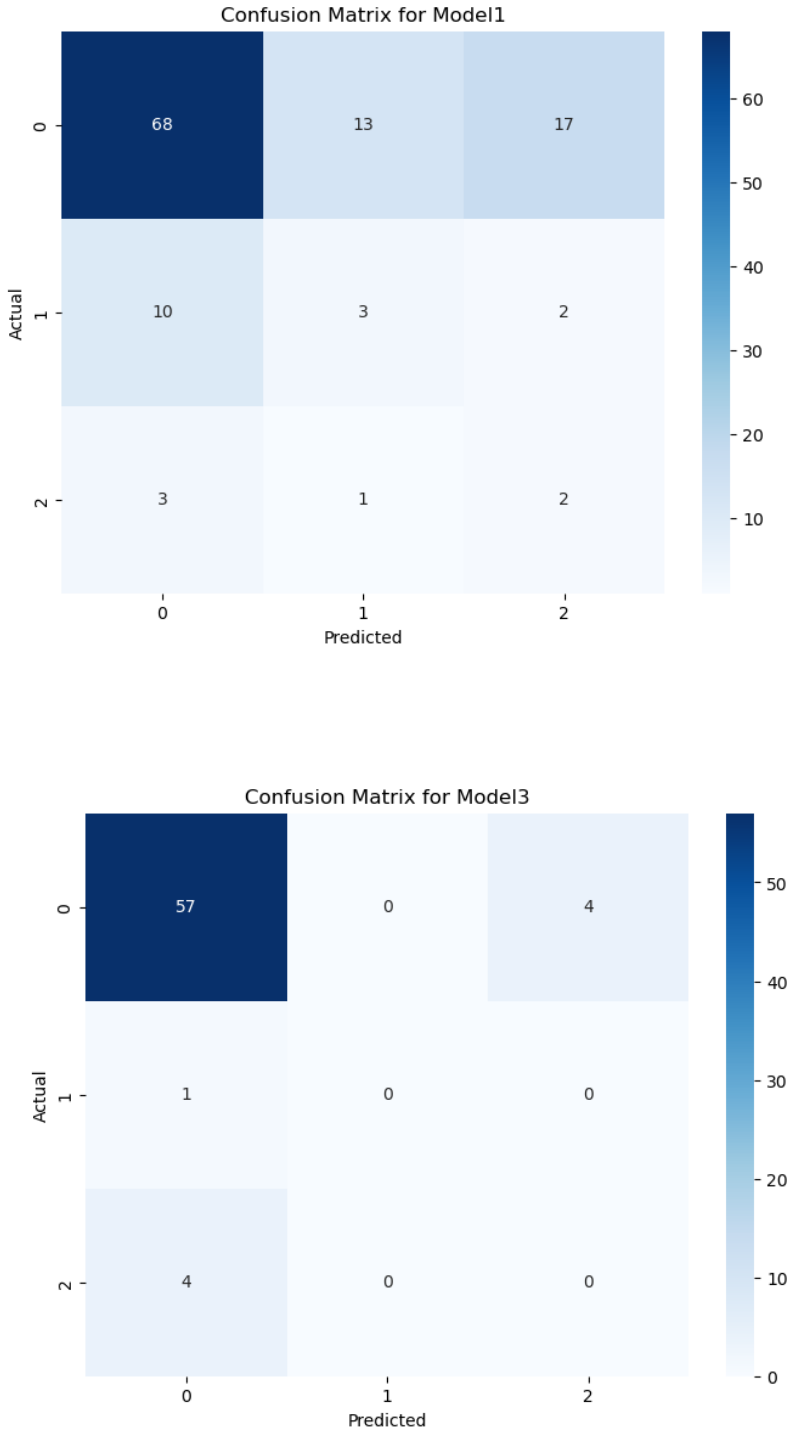


Figure 13

Confusion matrices for wave 1 data (Model1) and wave 3 data (Model3), with classification labels 0,1, and 2 corresponding to MAL, MH, and ML profiles respectively



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