**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.

**Data**

**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; *Mage* = 12.92, *SDage* = 0.92) and 595 mothers (*Mage* = 38.89, *SDage* = 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?”

*Traditional 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.”

*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.”

**Adolescents’ depressive symptoms and anxiety**

Adolescents’ and their mothers’ self-reported depressive symptoms were measured at Wave 1 and Wave 3 using the Center for Epidemiological Studies Depression Scale (CES-D) (Radloff, 1977). Adolescents and their mothers responded 20 items such as “I felt people disliked me” using a scale ranging from 0 = rarely or none of the time to 3 = most of the time. A high score indicates more depressive symptoms.

**Analytical strategy**

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).

**Adolescent Allostatic Load Profiles**

Based on a holistic evaluation of model fit indices for latent profile analyses (Table 1) and evaluation of substantive meaning of allostatic load profiles (Spurk et al., 2020), the 3-profile solution was the optimal solution for mother-adolescent depressive symptoms profiles both in two waves. Figure 1 displays the mean scores of mother and adolescent’s 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)* .

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Figure 1a. Wave 1 Mother-adolescent depressive symptom profiles

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

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Figure 1b. Wave 3 Mother-adolescent depressive symptom profiles

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

**Modeling and validation**

There are 3 profiles in the dataset, which are MAL (profile 1), MH (profile 2), and ML (profile 3). A profile is referred to as a class in the language of machine learning. To tell a story about the three classes of the dataset, we will use out dataset to train three classifiers, decision tree, random forest, and XGBoost. Their performances will be evaluated by calculating the accuracy defined as below:

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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 would be employed to analyze the feature importance by using **SHAP (SHapley Additive exPlanations).**

Regarding the validation, the dataset is split into the training set and testing set with the ratio of 0.67:0.33. We use the training set to train the models and use the testing set to calculate the accuracy.

**Results**

* Wave1 Cultural stress to Wave 1 profiles:

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自動產生的描述We calculate the accuracy and compare the performance of the three models. The comparison result is shown in the figure below.

Fig 2. Performances of the decision tree, random forest, and XGBoost

From this result, one can clearly see that the performances of the random forest and XGBoost are much better than the performance of the decision tree. The optimal model among them is the random forest with the maximum depth equal to 3, so we use this model to extract the five most important features as shown in the bar chart, Fig 3.

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Fig 3. Feature importance for Wave 1 profiles

The five most important features are 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 include the combined information from all the three profiles in the Wave 1 data. What if one needs to access the feature importance in each individual profile? More ambitiously, how can we investigate the impact of each feature on the prediction outcome in every profile? There are several possible ways to answer this question of interpretation. In our study, we opt to use a power tool “SHAP” to analyze the features’ impacts on the prediction outcomes.

Fig 4. shows the SHAP analysis of the feature importance for the Profile 1 (MAL) in Wave 1 data. The most important feature is “smits”, whose full name is Teen reported Language Brokering Stress for Mother. In this feature, as the feature value increases (data points get redder), the SHAP value decreases. A decreased SHAP value indicates a less likelihood that an instance is classified into the MAL profile. Thus, when the Teen reported Language Brokering Stress for Mother increases, mother and adolescents both have 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 Fig 5. and Fig 6., respectively.

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Fig 4. SHAP analysis for Profile 1 (MAL) in Wave 1

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Fig 5. SHAP analysis for Profile 2 (MH) in Wave 1. The most important feature is “meds”, whose full name is Mom Reported Discrimination Because of Being Mexican. When the feature value increases, mother has higher likelihood than adolescent to have depressive symptoms.

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Fig 6. SHAP analysis for Profile 3 (ML) in Wave 1. The most important feature is “disc”, whose full name is Teen Reported Daily Discrimination.When the feature value increases, mother has less likelihood than adolescent to have depressive symptoms.

* Wave1 Cultural stress to Wave 3 profiles:

We calculate the accuracy and compare the performance of the three models. The comparison result is shown in the figure below.

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Fig 7. Performances of the decision tree, random forest, and XGBoost

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自動產生的描述From this result, one can clearly see that the performances of the random forest and XGBoost are much better than the performance of the decision tree. The optimal model among them is the XGBoost with the maximum depth equal to 5, so we use this model to extract the five most important features as shown in the bar chart below (Fig 8).

Fig 8. Feature importance for Wave 1 profiles

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自動產生的描述The five most important features are 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 use SHAP to do the feature importance analysis. Fig 9. shows the SHAP analysis of the feature importance for the Profile 1 (MAL) in Wave 3 data. The most important feature is “disc”, whose full name is Teen Reported Daily Discrimination. The more adolescent reported daily discrimination, the less likelihood of adolescent in the profile that mother-adolescent both have low depressive symptom (daily discrimination can be harmful to mother-adolescent dyad in terms of their depressive symptom profiles). The second most important feature is “accl”, whose full name is adolescent enculturation. When there is higher level of adolescent enculturation (maintaining Mexican cultural tradition/norms), there is higher likelihood of adolescent in the profile that mother-adolescent both have low depressive symptom (traditional cultural orientation can benefit mother and adolescent). The same principle can be applied to interpret the SHAP results for Profile 2 (MH) and Profile 3 (ML), as shown in Fig 10. and Fig 11., respectively.

Fig 9. SHAP analysis for Profile 1 (MAL) in Wave 3

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Fig 10. SHAP analysis for Profile 2 (MH) in Wave 3. The most important feature is “tnemo”, whose full name is Mom Reported Own Negative Emotions When Child Translates. When the feature value increases, mother has lower likelihood than adolescent to have depressive symptoms.

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Fig 11. SHAP analysis for Profile 3 (ML) in Wave 3. The most important feature is also “tnemo”, whose full name is Mom Reported Own Negative Emotions When Child Translates. When the feature value increases, mother has higher likelihood than adolescent to have depressive symptoms.

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