



Acculturation and daily cigarette use among Mexican-origin youth: The moderating role of executive functions

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ABSTRACT

Introduction: Acculturation and enculturation have been conceptualized, respectively, as risk and protective factors for cigarette use. Although acculturation/enculturation orientations are often studied as stable characteristics, they represent a dynamic process influenced by individuals' social environments and can fluctuate across time. Therefore, investigating how youth actively navigate their acculturation and enculturation beliefs and behaviors on a day-to-day basis can advance scientific understanding of factors related to cigarette use. Executive functions, including inhibitory control, shifting, and working memory, are robust predictors of smoking (e.g., cigarette use). However, we know little about the protective role of executive functions on the daily level associations between acculturation/enculturation and cigarette use among Mexican-origin youth.

Objectives: In a low-income Mexican-origin youth sample ($M = 16.94$, $SD = 1.01$; 52 % female), this study examined within-person associations between daily acculturation/enculturation and daily cigarette use and the moderating role of individual-level executive functions.

Method: We captured the daily fluctuations of acculturation/enculturation and smoking by utilizing data from a 4-day daily diary. The study assessed inhibitory control, shifting, and working memory using behavioral paradigms.

Results: A multilevel logistic moderation model revealed statistically significant interactions between acculturation (but not enculturation) and all executive function skills predicting cigarette use. Higher daily acculturation levels were related to greater odds of daily cigarette use only for youth with lower levels of executive function skills.

Conclusion: Findings suggest that interventions aimed at improving executive functions may protect Mexican-origin youth from the possible adverse effect of acculturation on cigarette use.

1. Introduction

As the fastest-growing ethnic minority and immigrant population in the United States (Gonzalez-Barrera & Lopez, 2013), Latinx need to manage the acculturation process in their daily life, which involves both *acculturation*, a process of adapting to and incorporating the U.S. culture and norms (Ward & Geeraert, 2016), and *enculturation*, a process of learning and maintaining aspects of their Latinx heritage culture

(Schwartz et al., 2010). High levels of acculturation are shown to be a risk factor for health behaviors, including cigarette use. Latinx youth with high levels of enculturation, on the other hand, may be protected by maintaining or adopting aspects of their heritage culture, and thus be less likely to engage in health-risky behaviors (e.g., Schwartz et al., 2011). Cigarette use can heighten the risk for many health problems (e.g., cardiovascular and respiratory diseases; severe COVID-19 outcomes) (Sanchez-Ramirez & Mackey, 2020) and is the leading preventable cause

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of death in the United States (Prevention, 2010). The prevalence of cigarette use among Latinx youth surges from early to late adolescence (Latinx youth: 8th grade: 5.3 %; 12th grade: 19.3 %. Total prevalence: 8th grade: 7 %; 12th grade: 17.8 %) (Miech et al., 2021). To reduce cigarette use among Latinx adolescents during late adolescence, researchers must conduct a nuanced investigation that considers the changing experiences of acculturation on a daily basis while taking into account individual difference factors (e.g., executive functions) to understand adolescents' day-to-day cigarette use behaviors. Thus, the current study investigates how within-person changes in acculturation/enculturation are related to youth daily cigarette use, and explores how such links may vary for youth with different levels of executive functions.

Previous limited literature on the association between acculturation and cigarette use yields inconclusive findings and is limited in two ways. First, most studies assessed acculturation and enculturation orientations as stable individual difference factors. Yet acculturation and enculturation are dynamic processes influenced by the changing social environment, which may fluctuate on a day-to-day basis (Ward & Geeraert, 2016). The dynamic nature of acculturation/enculturation may be particularly salient during adolescence, when youth are developing and navigating their personal and social identities (Tanti et al., 2011). Second, individual differences in the association between acculturation/enculturation and cigarette use are relatively unknown, especially among the Latinx population. One potential individual difference factor related to cigarette use is executive functions, which are central to impulse control. Executive functions are shown to be associated with a lower probability of youth cigarette use (Gustavson et al., 2017; Pharo et al., 2011). Yet we know little about whether high levels of executive functions may be a protective factor in terms of the influence of acculturation/enculturation on cigarette use.

The current study aims to address these limitations by examining how daily fluctuations of racial/ethnicity-related experiences (e.g., acculturation/enculturation) are related to daily cigarette use among adolescents with different levels of executive functions. The current study focuses specifically on Mexican-origin adolescents, for three reasons. First, Mexican-origin individuals comprise the largest Latinx subgroup in the United States (Gonzalez-Barrera & Lopez, 2013), and second, adolescence is a developmental period that is highly susceptible to environmental influences, such as acculturation/enculturation and reward seeking (e.g., cigarette use) (Gee & Casey, 2015; Somerville, 2013). Third, executive function skills continue developing during adolescence, resulting in great variability in executive functions among youth (Shulman et al., 2016). The current study (1) adopts a four-day daily diary design to explore whether adolescents are more likely to smoke on the day when they reported higher/lower than their own average acculturation/enculturation levels, and (2) investigates whether such associations display different patterns for adolescents with high or low levels of executive functions.

1.1. Acculturation process and cigarette use

Individuals navigating the acculturation process can adopt behavioral practices common in the mainstream host culture (i.e., acculturation) and simultaneously retain or acquire practices from their cultural heritage (i.e., enculturation) (Schwartz et al., 2010). Latinx youth who endorse higher enculturation in their daily life may be protected by their heritage culture and thus be less likely to engage in risky behaviors (Schwartz et al., 2011), such as cigarette use. For example, as Mexican culture values familism (Knight et al., 2010), on the days when youth practice familism with their family members, they may experience higher levels of family support and thus be less likely to use cigarettes. In contrast, according to the erosion theory (Prado et al., 2009), acculturation is a risk factor for substance use because it deteriorates the protective features of the Mexican culture (e.g., familism) over time and across immigrant generations (Gil et al., 2000). Moreover, acculturated

adolescents may experience greater exposure to US social norms that reflect more permissive attitudes about substance use, resulting in a greater risk of substance use, such as smoking cigarettes.

The influence of the acculturation process on smoking behaviors among Latinx youth is understudied, and existing findings are inconclusive. For example, Schwartz and colleagues (Schwartz et al., 2014) found that higher levels of acculturation in cultural values/beliefs were associated with higher odds of cigarette use, whereas higher levels of endorsement of heritage cultural values/beliefs (i.e., enculturation) were associated with lower odds of cigarette use in the previous three months among adolescent girls. Some studies found no detrimental influence of acculturation on past-month cigarette use among Latinx (mostly Mexican-origin) adolescents (e.g., Unger et al., 2014), but enculturation was negatively associated with cigarette use among early adolescents (Zamboanga et al., 2009). Schwartz et al. (2013) found that greater acculturation predicted lower odds of cigarette use indirectly through reduced family functioning, which was counterintuitively associated with a lower likelihood of smoking cigarettes among Latinx adolescents. Those previous studies have mainly focused on how differences in the acculturation process across individuals are associated with adolescent cigarette use over a certain amount of time (e.g., past month). Thus, these previous studies have been unable to disentangle the intra-individual changes of acculturation experiences (e.g., daily changes of acculturation for any given adolescent) from inter-individual differences in the acculturation process, and few of them have considered possible moderators (e.g., executive functions) that may influence the associations observed. These mixed findings in previous studies highlight the importance of a more nuanced investigation of the association between the acculturation process and adolescent cigarette use by considering the intra-individual fluctuations of the acculturation process and possible moderators for the association.

1.2. Understanding acculturation as a dynamic process

Most studies have examined acculturation and enculturation orientations as stable individual difference factors. As proposed by Bornstein's specificity principle in acculturation science (Bornstein, 2017), however, the process of acculturation is "interactive, transactional and bidirectional". That is, acculturation is a dynamic process fluctuating over time for any given individual. In fact, using a daily diary study over 12 consecutive days, a previous study has shown that adolescents' acculturation and enculturation both fluctuate from day-to-day on a scale from 1 to 5, with standard deviation ranges from 0.24 to 0.68 across days (Schwartz et al., 2021). That is, aspects of acculturation, such as having a sense of belonging to the U.S. or heritage ethnic group and feeling comfortable speaking English or Spanish in social interactions, change on a daily basis for Latinx youth. The current study focused on the cultural values/beliefs and practices aspects of acculturation, as daily fluctuations in acculturation may be due to the fact that youth both actively search for and respond to culturally appropriate beliefs and behaviors in different situations. Through daily interactions with their social environment, youth are likely to be exposed to cultural values (e.g., social norms) and practices from both the U.S. (European) and their Mexican heritage cultures, depending on with whom they interact (e.g., European American peers versus Mexican American peers) and what social settings they are in (e.g., school events versus family gatherings). For example, youth may be more likely to use cigarettes when they are with European American peers and observe their peers' smoking behaviors. Hence, adolescents' practices and beliefs towards U. S. American and heritage cultures may fluctuate on a day-to-day basis (Schwartz et al., 2021).

To reflect the dynamic nature of acculturation and enculturation, methods (e.g., daily diary) that can capture this intra-individual variability are important. More importantly, considering that adolescence is a critical period for developing smoking habits or even addiction, it is worthwhile for research to explore how such fluctuations in

acculturation/enculturation may relate to cigarette use on a daily basis.

1.3. Executive function as a moderator

Executive functions are shown to protect against youth cigarette use. According to a tripartite model (Miyake et al., 2000), executive functions include top-down mental processes that can be grouped into three distinct constructs: (1) inhibition of a dominant or prepotent response (i.e., inhibitory control), (2) focusing on and holding goal-related information in mind and mentally working with it (i.e., working memory), and (3) mental set shifting between tasks. These executive function components show more distinctive development patterns during late adolescence (Laureys et al., 2021). Adolescence is characterized by a hyperactive reward processing system, along with an executive function system that has not been fully developed (Shulman et al., 2016). As a result, this “imbalance” (Casey et al., 2008) may facilitate heightened reward-driven behavior (e.g., sensation seeking) based on an inability to exert executive functions over the reward system during adolescence. That is, youth may have limited impulse control abilities (i.e., executive functions) when it comes to sensation-seeking, which may contribute to risky behaviors, such as cigarette use. Although executive functions are robust predictors for lower odds of cigarette use among mostly non-Latinx youth (Pharo et al., 2011), few studies have examined associations between executive functions and cigarette use among Latinx youth.

Although acculturation/enculturation and executive functions are critical factors influencing youth cigarette use, and both are salient developmental processes that develop during adolescence, existing studies on the influence of acculturation/enculturation and executive functions on cigarette use are two separate lines of research, and no study thus far has examined the joint contributions of acculturation orientations and executive functions on adolescents’ daily cigarette use. In theory, during the process of daily acculturation, adolescents are being exposed to U.S. (European) social norms and practices relating to substance use. Those with higher levels of executive functions may be better able to resist the influence of acculturation on cigarette use through impulse control. Specifically, on a day when adolescents experience higher acculturation, those with better executive functions may be better at 1) inhibiting the desire to smoke, 2) focusing on keeping information in their mind to manipulate goal-related tasks (e.g., studying), and/or 3) flexibly shifting their attention away from reward-driven behavior (e.g., cigarette use) and/or negative social influences (e.g., deviant peers) that promote cigarette use. If so, adolescents with well-developed executive functions may be less likely than their peers with less developed executive functions to use cigarettes on days when they feel more acculturated to the U.S. culture.

1.4. The current study

Our first goal was to examine the effect of intra-individual variability in acculturation/enculturation on daily cigarette use behaviors among Mexican-origin youth, using a 4-day daily diary design. We hypothesized that youth would have higher odds of cigarette use on days when they reported higher acculturation (relative to days when they reported lower acculturation), and lower odds of cigarette use on the days they reported higher enculturation, based on previous literature (e.g., Rodriguez et al., 2019; Rogers et al., 2022). Our second goal was to explore the moderating effect of executive function skills on associations between the intra-variability of acculturation/enculturation and cigarette use. We hypothesized that the influence of daily acculturation on cigarette use would be attenuated for individuals with higher executive functions. We also explored whether specific executive function skills (inhibitory control, shifting and working memory) would have different moderating effects, but did not make any specific hypothesis given insufficient evidence on this topic.

2. Method

2.1. Participants

The current data came from a multi-method study on language brokering in Mexican immigrant families (Author, 2018). Mexican-origin adolescents who translated between English and Spanish for at least one of their parents were recruited from a metropolitan area in Central Texas from 2017 to 2020. Participants were involved in a longitudinal yearly assessment ($N = 334$) in which a subsegment of the sample completed daily diaries ($N = 289$) about one month before the yearly assessment. Compared to adolescents who did not participate in the daily diary study, adolescents who participated were younger ($t(332) = 6.38, p < .001$), but the study found no differences in adolescent sex ($\chi^2(1) = 0.23, p = .65$), nativity ($\chi^2(1) = 0.06, p = .86$), family income ($t(296) = 0.97, p = .33$) or maternal education levels ($t(326) = -0.34, p = .73$) between the two groups. Participants were between 14 and 20 years old at the time of daily diary data collection ($M = 16.94, SD = 1.01$; 52 % female). Most participants were born in the United States (76 %). For first-generation immigrants, Mexican-born youth (24 %) had immigrated to the United States at the age of 3.46 ($SD = 2.45$) on average. On average, mothers were 43.45 years old and had lived in the United States for 19.76 years ($SD = 5.43$); fathers were 47.21 years old and had lived in the United States for 21.31 years ($SD = 6.61$). Median annual family income reported by participating families was \$30,000 to \$40,000; this amount supported about five family members. On average, parents reported middle school as the highest level of education obtained.

2.2. Procedures

The initial data collection for this longitudinal study involved research assistants reaching out to potential participants through a roster of students enrolled in public schools, school presentations, and community recruitment (Author, 2018). School presentations and community recruitment occurred in all the schools and communities to which research assistants gained permission and access in the Austin metropolitan area. Research assistants screened student names from all publicly-available school records in the Austin area and identified students with Spanish-sounding last names. Research assistants contacted all potential participants through phone calls. Eligible families were immigrant families with Mexican-origin parents and at least one adolescent child who translated for parents. After eligibility was checked with a phone call, parents and adolescent participants provided informed consent and assent, respectively, during an in-person visit. The current study included a four-day diary section and a yearly assessment. The diary study asked participants to report on their daily acculturation and enculturation levels, cigarette use, physical and emotional well-being, and other daily experiences before going to bed each night over the four days from Monday to Thursday. All measures were presented in both Spanish and English simultaneously. The study compensated adolescents up to \$20 for participating in the daily diary surveys. The Institutional Review Board at the University of Texas at Austin approved the study.

In the yearly assessment, participants reported their demographic information, including age, sex, nativity, and lifetime smoking, and completed the executive function tasks during a home visit. Participants were instructed to finish the Backward Digit Span task (for working memory), followed by the Simon task (for inhibitory control) and Color Shape task (for shifting ability) in E-Prime 2.0 on a laptop (Dell Latitude 3480 14 Inch) brought by the research assistant (Kim et al., 2021). For the Simon task and Color Shape task, we asked participants to complete practice trials before the experimental trials to familiarize them with the tasks. Participants chose either Spanish or English to finish the home visit interview and executive function tasks. The study compensated participants \$90 for participation.

2.2.1. Daily cigarette use

The study measured daily cigarette use with two items, “Did you smoke today?” and “How many cigarettes did you smoke today?” We recoded cigarette use to a binary variable from the two items, given the low proportion of participants engaging in daily cigarette use across survey days. Daily cigarette use was coded as 1 on days when participants reported cigarette use (e.g., “yes” for the first item or/and reported no less than “one” cigarette used). Otherwise, the study coded daily cigarette use as 0.

2.2.2. Self-reported instrument for daily acculturation and enculturation

The study used eight items adapted from The Vancouver Index of Acculturation to assess adolescent participants’ daily acculturation/enculturation using a 5-point scale (Ryder et al., 2000). The Vancouver Index of Acculturation has demonstrated construct and predictive validity with Mexican-origin adolescents (Zhang et al., 2020). Four items tapped acculturation (e.g., “I was comfortable working with U.S. Americans today”; “It was important for me to maintain or develop typical U.S. American cultural practices (way of living or doing things) today”; $\alpha_{\text{day1}} = 0.84$; $\alpha_{\text{day2}} = 0.84$; $\alpha_{\text{day3}} = 0.87$; $\alpha_{\text{day4}} = 0.87$). Another four items tapped enculturation (e.g., “I was comfortable working with Mexicans today”; “It was important for me to maintain or develop typical Mexican cultural practices (way of living or doing things) today”; $\alpha_{\text{day1}} = 0.85$; $\alpha_{\text{day2}} = 0.84$; $\alpha_{\text{day3}} = 0.90$; $\alpha_{\text{day4}} = 0.89$).

2.2.3. Behavioral assessment of executive function

The study assessed the three executive functions (i.e., inhibitory control, shifting/cognitive flexibility and working memory) by the Simon task, Color Shape task, and Digit Span task, respectively.

Inhibitory control. The Simon task, comprising 32 experimental trials (16 for congruent condition, 16 for incongruent condition), measured participants’ inhibitory control (Bialystok et al., 2004). This task has been used in previous studies with Mexican-origin adolescents (López et al., 2021). Given the particularly high accuracy in the congruent condition (mean = 97.5 %), we chose reaction time (RT) as the index for inhibitory control ability (Zelazo et al., 2013). Longer RT differences between the incongruent condition and the congruent condition (i.e., mean incongruent RT minus mean congruent RT) indicated more difficulty in inhibiting the prepotent response, which represented lower levels of inhibitory control.

Shifting/cognitive flexibility. The Color Shape task (24 trials for stay condition, 24 trials for switch condition) measured cognitive switching/shifting ability (Mittal et al., 2015). The study instructed participants to categorize the stimulus according to each trial’s target word by pressing corresponding keys with their index fingers. In the stay condition, the target word was the same as the one in the previous trial (e.g., “SHAPE” to “SHAPE”); in the switch condition, the target word was different from the one in the previous trial (e.g., “SHAPE” to “COLOR”). Given the high accuracy for the stay condition ($M = 94.6$ %), we used reaction time (RT) as the index for shifting ability, consistent with prior literature (Zelazo et al., 2013). Longer RT differences between the switch condition and the stay condition (i.e., mean switch RT minus mean stay RT) indicated increased difficulty in shifting attention between tasks, which represented lower levels of shifting/cognitive flexibility.

Working memory. Working memory was measured by the computer-based Backward Digit Span task, modified from the digit span portion of Della Sala et al. (1995) and Wechsler Memory Scale - 3rd Edition (Wechsler, 1997). The task presented participants with digit lists ranging from three to nine numbers (6 trials for each length). Participants were instructed to remember the digits and type them in the backward order of presentation after the digits disappeared.

The digit span score was the longest digit list for which the participant answered at least four out of the six trials correctly. The study coded digit span score as missing when participants did not pass the three-digit practice trials successfully. Higher scores/accuracy in the backward digit span task indicated a higher level of working memory.

2.3. Covariates

Covariates include individual-level variables measured in the yearly assessment and daily level variables measured in the daily diary. In the yearly assessment, participants reported their age, sex (1 = male, 0 = female), and lifetime cigarette use status (recoded as 0 = no, 1 = yes; 13.1 % yes) as older male adolescents born in the United States and those who had previously smoked were more likely to use cigarettes on any given day (Wilkinson et al., 2005). In the daily diary portion of the study, participants reported their somatic symptoms (headache, cold, tired, allergies, stomachache, other) and negative affect (nervous, on edge, uneasy, discouraged, sad, hopeless) on a 5-point scale. Somatic symptoms and negative affect were included as covariates, as they have been linked to cigarette use (Jones et al., 2007). We included the day of study as a covariate to control the effect of time. The study also included individual-level acculturation and enculturation, calculated by averaging acculturation and enculturation across the four days, as between-person covariates to account for variance in acculturation and enculturation between adolescents.

2.4. Analysis plan

Daily diary responses reflected within-person variation; hence, the study team conducted logistic multilevel analysis in Mplus 8.3 with the maximum likelihood parameter estimator with robust standard errors (MLR) to predict daily cigarette use (Muthén & Muthén, 2018). Level 1 is the within-person level, with time-varying variables; level 2 is the between-person level, with time-invariant variables. Fig. S1 in the supplementary materials shows the conceptual model for the study with level 1 and level 2 variables. Time-varying variables (acculturation, enculturation, day of the study, negative affect, and somatic symptoms) were centered within each participant (Enders & Tofghi, 2007), whereas time-invariant variables (age, individual-level enculturation and acculturation, Simon task reaction time, Color Shape task reaction time, and digit span) were grand-mean centered.

The current study modeled the three executive function components separately because they become more distinct constructs during late adolescence (Miyake et al., 2000). For each of the three EFs, model 1 (i.e., a random intercept with fixed slope model) tested the main effects of within-person changes in acculturation and enculturation, as well as between-person variations in executive functions after controlling all covariates. In model 2, which tested the interaction effects between daily acculturation and EF, the interactions between person-centered acculturation and grand mean-centered inhibitory control, shifting, or working memory were added to model 1, respectively. Thus, the study estimated the association between daily acculturation and daily cigarette use as a random slope predicted by each EF. Model 2 analyses were repeated when testing the interaction effects between enculturation and EF. Therefore, the current study tested nine models in total (three for model 1, with one for each of the three EFs; three for model 2, for the cross-level interactions between acculturation and each of the three EFs; and three for model 2, for the cross-level interactions between enculturation and each of the three executive functions). The study calculated simple slopes to probe the relationship between acculturation/enculturation and cigarette use probability at high and low (1 SD above and below the mean) levels of executive functions (Aiken et al., 1991). We used the Johnson-Neyman technique to further reveal the significant regions at different levels of the moderator (i.e., executive functions; Bauer & Curran, 2005).

3. Results

In the daily diary portion of the study, 84.4 % of adolescents participated on all four days, and adolescents participated on 3.75 days on average. Across the four survey days, 6.9 % of Mexican-origin adolescents reported cigarette use (Table S1), and those adolescents smoked

for 1.6 days on average. Among the participants, 13.1 % of them reported lifetime cigarette use.

Overall, being older and reporting lifetime cigarette use were related to greater odds of daily cigarette use; the day of study was not associated with the odds of daily cigarette use; and the study found no significant relationship between within-person acculturation or enculturation and the odds of daily cigarette use (Table 1). However, significant interactions did occur between acculturation and all executive function components, such that higher daily acculturation was related to greater odds of daily smoking only for adolescents with lower levels of executive function performance (Table 2).

Specifically, after controlling for within-person enculturation, day of study, daily negative emotions and somatic symptoms, lifetime cigarette use, age, sex, and individual-level enculturation and acculturation, the study found a significant cross-level interaction of within-person acculturation and individual-level executive functions, including inhibitory control RT ($b = 31.31$, $SE = 13.05$, $p = .02$), shifting RT ($b = 6.24$, $SE = 2.11$, $p < .01$), and working memory ($b = -2.34$, $SE = 0.75$, $p < .01$), on cigarette use probability (Table 2). Adolescents with lower levels of shifting ability (longer RT) were more likely to use cigarettes on the days when they reported higher acculturation than their own average ($OR = 7.14$, $p < .01$; Fig. 1). In contrast, for adolescents showing higher levels of shifting ability (shorter RT), daily acculturation fluctuation within any given adolescent was not associated with that adolescent's daily cigarette use odds ($OR = 0.74$, $p = .58$; Fig. 1). Johnson-Neyman analysis further showed that higher acculturation was associated with greater odds of cigarette use at the daily level for adolescents who had higher than moderate (i.e., the mean) shifting reaction times (i.e., lower than average shifting ability). In terms of working memory, adolescents with lower levels of working memory (low digit span accuracy) were more likely to use cigarettes when they reported higher acculturation compared to their own average ($OR = 9.56$, $p = .01$; Fig. 2). For adolescents with better working memory (high digit span accuracy), the daily fluctuation of acculturation within any given adolescent was associated with lower odds of the adolescent's cigarette use ($OR = 0.09$, $p = .02$; Fig. 2). Johnson-Neyman analysis further showed that higher acculturation was associated with a greater likelihood of cigarette use at the daily level only for adolescents who had working memory that was lower than 0.53 SD below the average. In terms of inhibitory control, despite the nonsignificant simple effects, the interaction pattern was the same as for shifting ability and working memory. Johnson-Neyman analysis further showed that acculturation

was not significantly associated with the odds of cigarette use at the daily level for any adolescent whose inhibitory control ability was in the range of 1 SD below or above the mean.

The study examined interactions between daily enculturation and EFs in three models (one for each EF). The results revealed no significant cross-level interaction of daily enculturation and adolescents' inhibitory control ($b = 1.03$, $p = .94$), shifting ($b = 1.84$, $p = .60$) or working memory ($b = -0.99$, $p = .20$) on daily cigarette use odds (Table S2).

4. Discussion

The current study is one of the first to investigate the daily level associations of acculturation/enculturation and cigarette use after considering individual differences in executive functions among Mexican-origin adolescents. In sum, the findings show that daily fluctuations of acculturation were associated with greater odds of daily cigarette use only among youth with low levels of executive functions.

4.1. Daily-level associations of acculturation and cigarette use

The findings suggest that acculturation and enculturation were not generally associated with cigarette use at the daily level, even though prior literature has documented a pernicious influence of acculturation on cigarette use among immigrant minority adolescents at the individual (between-person) level (Schwartz et al., 2014). Previous research considered acculturation as a stable trait with a long-lasting influence on cigarette use one year later (Schwartz et al., 2014). In this previous study, acculturation is viewed as a composite of cultural values, practices, and identifications that are internalized differently across adolescents. In contrast, the current study focuses on aspects of daily acculturation that may have a concurrent influence on daily cigarette use decisions for any given adolescent. That is, while the previous study focused on the longitudinal and between-person associations, the current study takes a novel perspective and examines the concurrent and within-person associations at the daily level, which yields different findings. Moreover, as mentioned, empirical findings have been inconsistent on the effect of acculturation on cigarette use (Lorenzo-Blanco et al., 2011; Schwartz et al., 2013; Unger et al., 2014), supporting the current study's exploration of executive functions as the potential moderator.

Table 1

Multi-level logistic model examining main effects of within-person acculturation, enculturation, and between-person executive functions on daily cigarette use probability.

	BP executive function											
	Inhibitory control reaction time				Shifting reaction time				Working memory accuracy			
	OR	b	SE	p	OR	b	SE	p	OR	b	SE	p
Outcome: daily cigarette use												
Thresholds		6.90	0.95	<.01		6.86	0.92	<.01		6.95	0.92	<.01
WP acculturation	1.64	0.50	0.69	.47	1.65	0.50	0.69	.47	1.65	0.50	0.70	.48
WP enculturation	0.39	-0.95	0.88	.28	0.39	-0.95	0.88	.28	0.38	-0.97	0.90	.28
BP executive function	2.60	0.96	7.12	.87	0.39	-0.93	1.35	.49	1.30	0.27	0.33	.42
Covariates												
WP day of study	0.89	-0.12	0.24	.62	0.88	-0.13	0.24	.60	0.89	-0.12	0.24	.62
WP negative mood	1.34	0.29	0.78	.71	1.33	0.29	0.79	.72	1.35	0.30	0.79	.70
WP physical condition	0.95	-0.05	0.33	.88	0.96	-0.05	0.33	.89	0.95	-0.05	0.33	.88
BP acculturation	5.05	1.62	0.83	.05	4.90	1.59	0.80	.05	5.37	1.68	0.84	.04
BP enculturation	0.52	-0.65	0.71	.36	0.53	-0.64	0.70	.36	0.47	-0.75	0.68	.27
BP lifetime smoking	50.05	3.91	0.68	<.01	46.99	3.85	0.67	<.01	57.57	4.05	0.66	<.01
BP age	4.63	1.53	0.43	<.01	4.59	1.52	0.40	<.01	4.79	1.57	0.40	<.01
BP sex	3.11	1.14	0.73	.12	3.09	1.13	0.71	.11	3.27	1.19	0.72	.10
AIC	1665.90				2478.75				3369.50			
Adjusted-BIC	1709.51				2522.37				3413.12			

Note. $N = 278$ adolescents; number of observations = 1013. WP = within-person; BP = between-person. Sex: 1 = male, 0 = female; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion.

Table 2

Multi-level logistic moderation model examining cross-level interaction between acculturation and executive functions on daily cigarette use probability.

	BP executive function											
	Inhibitory control reaction time				Shifting reaction time				Working memory accuracy			
	OR	b	SE	p	OR	b	SE	p	OR	b	SE	p
<i>Outcome: daily cigarette use</i>												
Thresholds		7.45	1.13	<.01		7.46	1.16	<.01		8.18	1.51	<.01
WP acculturation	1.90	0.64	0.59	.28	2.29	0.83	0.42	.05	0.91	−0.09	0.55	.86
WP enculturation	0.34	−1.07	0.93	.25	0.89	−0.12	0.80	.14	0.83	−0.18	0.95	.05
BP executive function	11.40	2.43	6.73	.72	0.60	−0.51	1.46	.73	1.11	0.10	0.40	.80
BP acculturation × BP EF		31.31	13.05	.02		6.24	2.11	<.01		−2.34	0.75	<.01
<i>Covariates</i>												
WP day of study	0.88	−0.12	0.26	.63	0.89	−0.12	0.25	.64	0.92	−0.08	0.26	.75
WP negative mood	1.98	0.69	0.73	.35	1.46	0.38	0.76	.62	2.00	0.70	0.70	.32
WP physical condition	0.87	−0.14	0.35	.69	0.92	−0.09	0.33	.79	0.70	−0.35	0.34	.30
BP lifetime smoking	67.63	4.21	0.75	<.01	65.83	4.19	0.79	<.01	109.84	4.70	0.99	<.01
BP acculturation	6.12	1.81	0.92	.05	5.81	1.76	0.86	.04	7.29	1.99	1.04	.06
BP enculturation	0.45	−0.81	0.77	.29	0.46	−0.78	0.72	.28	0.42	−0.86	0.78	.27
BP age	5.24	1.66	0.48	<.01	5.06	1.62	0.46	<.01	6.35	1.85	0.57	<.01
BP sex	3.33	1.20	0.78	.12	3.38	1.22	0.79	.13	3.93	1.37	0.88	.12
AIC	1665.31				2478.43				3366.68			
Adjusted-BIC	1712.42				2525.53				3413.78			

Note. $N = 278$ adolescents; number of observations = 1013. WP = within-person; BP = between-person. Sex: 1 = male, 0 = female; the effect from acculturation to daily cigarette use is the mean of the random effect; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion.

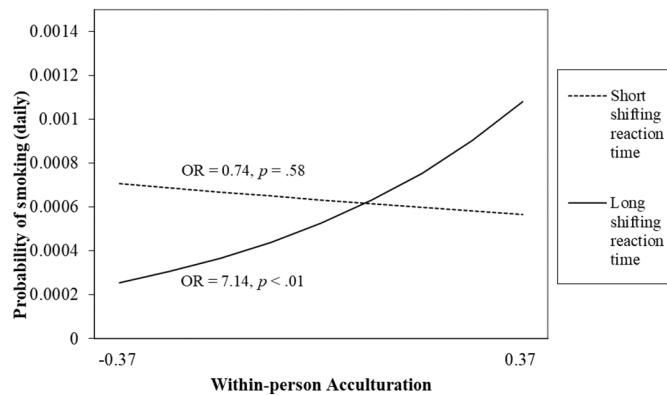


Fig. 1. The interaction between daily acculturation at within-person level and adolescent shifting ability at between-person level on daily probability of cigarette use.

Note. Enculturation, day of study, negative mood, and physical condition were controlled at the within-person level. Individual-level acculturation, enculturation, lifetime cigarette use, sex, and age were controlled at the between-person level.

4.2. Executive functions buffer the influence of acculturation on cigarette use

The findings show that the within-person association of daily acculturation and daily cigarette use varies for adolescents with different levels of executive functions. Specifically, after accounting for individual-level variability in acculturation and enculturation, adolescents with lower performance on all executive function tasks had greater odds of using cigarettes on the days when they reported higher levels of acculturation (i.e., practiced US culture and endorsed more US cultural values/beliefs), whereas adolescents with higher performance on executive function tasks did not show such a tendency. The consistent patterns observed for all executive functions (i.e., inhibitory control, shifting, and working memory) suggest that the moderating effect may not be specialized for any type of executive function, but may be more generally related to impulse control ability. Although executive functions have been identified as a predictor of adolescent substance use (Atherton et al., 2016; Pharo et al., 2011), our study is one of the few empirical studies to consider executive function abilities in the context

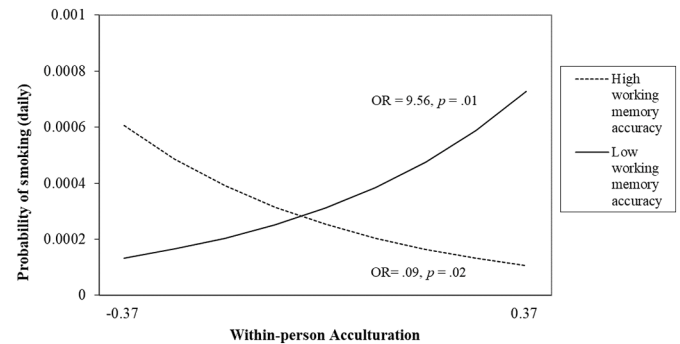


Fig. 2. The interaction between daily acculturation at within-person level and adolescent working memory at between-person level on daily probability of cigarette use.

Note. Enculturation, day of study, negative mood, and physical condition were controlled at the within-person level. Individual-level acculturation, enculturation, lifetime cigarette use, sex, and age were controlled at the between-person level.

of acculturation. The finding that executive functions play a role in reducing the detrimental impact of daily acculturation on cigarette use can be explained by the cultural norm (Bethel & Schenker, 2005) or the acculturative stress perspective (Gonzalez-Guarda et al., 2020).

From the cultural norm perspective, cigarette use is a normative behavior among youth in US mainstream culture (Bethel & Schenker, 2005), and executive function skills may be protective against the influence of such a cultural norm on cigarette use in the acculturation process. For example, on a day when Mexican-origin adolescents encounter cultural values/beliefs and practices that are endorsed in US mainstream society (e.g., when visiting US American friends or watching US movies), they may be exposed to the norm of cigarette use, perhaps by seeing peers smoking or by watching shows that include more smoking behaviors. Adolescents with better executive functioning might be able to control their desire to smoke under such influences through focusing on their goal-related work (e.g., studying) and holding or manipulating the goal-related information in mind while inhibiting their desire to smoke, or through flexibly shifting their attention to different things other than smoking. On the other hand, adolescents with lower levels of executive functions may be more susceptible to daily acculturation-related experiences (e.g., exposure to US culture) and thus

more likely to decide to use cigarettes on a day when they have more acculturation experiences.

Alternatively, from the acculturation-related stress perspective, the acculturation process includes multiple cultural stressors, such as discrimination (Gonzalez-Guarda et al., 2020), and it is plausible that adolescents with higher levels of executive functions may be better able to handle such stressors (Shields et al., 2017). On days when adolescents experience higher acculturation, they may have more interactions with people or institutions from US mainstream culture. Such interactions may come with cultural stress or microaggressions that underline the racial and cultural differences between Mexican-origin adolescents and the mainstream United States. For example, adolescents may experience a sense of being a misfit or being perceived as foreigners on a day when they report higher levels of acculturation compared to their own average. Considering that smoking often serves as a maladaptive coping strategy for dealing with daily stressors and negative emotions (Minami et al., 2011), adolescents may be more likely to use cigarettes on a day when they experience higher acculturation, especially for adolescents with lower levels of executive functions. Adolescents with better executive functions may be able to use adaptive strategies, allowing them to handle stress during acculturation in a healthier way. Although the precise mechanisms are unknown and need further investigation, the current study provides preliminary evidence for the protective role of executive functions on the association between daily acculturation and cigarette use, suggesting a potential avenue for interventions aiming to decrease smoking behaviors among Mexican-origin adolescents. For instance, intervention programs that target improving executive function skills (Diamond, 2013) may be effective at decreasing the likelihood of daily smoking, especially for Mexican-origin adolescents who are developing social identity through daily acculturation experiences (Liebkind, 2006).

As one of the first studies to consider the association between acculturation and cigarette use at the daily level, and the variability in executive functions among Mexican-origin youth, this research informs interventions aiming to reduce cigarette use among Mexican-origin youth. Specifically, the findings emphasize the need for personalized interventions for vulnerable youth who have low levels of executive functions. Momentary interventions on a daily basis would be particularly helpful, considering the changing day-to-day experiences of acculturation among Mexican-origin youth.

4.3. Limitations and future studies

In addition to the strengths of our study, we should note some limitations. First, the generalizability of the findings may be limited, since the current study is not based on a nationally representative sample of all Mexican-origin adolescents in the United States. Second, given the limited sample size and number of days of study, caution should be exercised in making interpretations of the nonsignificant findings related to enculturation and executive functions on daily cigarette use. Since the current study gathered data on only four days, the power for detecting significant results is limited. Future studies with larger sample sizes or more study days should replicate the findings. However, despite the limited power, this study reveals consistent patterns in terms of the interaction between daily acculturation and executive functions on daily cigarette use, demonstrating the robustness of this finding. Third, previous studies suggest that acculturation may have a different effect on cigarette use across gender (Flores et al., 2019; Schwartz et al., 2014). However, the current study only controlled for gender in the analyses, and thus was not able to reveal gender differences in the associations among acculturation, enculturation, executive functions, and cigarette use at the daily level. Future studies should investigate whether the associations show the same pattern for different gender identities. Last, this study is unable to reveal the mechanism underlying the within-person association of acculturation and cigarette use for adolescents with different levels of executive functions. Daily exposure to cigarette

use-related norms or experiences of acculturation-related stress may explain the association between daily acculturation and cigarette use for adolescents with lower levels of executive functions. Future studies should identify the mechanism underlying such associations by considering specific experiences related to acculturation.

5. Conclusion

Within a sample of 289 Mexican-origin adolescents from immigrant families, the current study examined how daily fluctuations of acculturation and enculturation are associated with daily cigarette use decisions for adolescents with different levels of executive functions. This study is one of the first to investigate such associations at the daily and within-person levels, as well as the first to explore the heterogeneity among Mexican-origin adolescents in terms of the moderating role of executive functions. The findings reveal that adolescents with low levels of executive functions were more likely to use cigarettes on days when they encountered more acculturation experiences compared to their own average, while adolescents with better executive functions were not influenced by daily fluctuations of acculturation experiences in terms of their cigarette use. The findings suggest that while acculturation is needed for Mexican-origin adolescents to adapt better to mainstream US culture, daily practice and endorsement of mainstream US culture is a risk factor for daily cigarette use among those with low levels of executive functions. Thus, the field needs interventions to improve Mexican-origin adolescents' executive functions to enable their adaptation to US mainstream culture in their daily lives without encountering risks related to cigarette use.

Declaration of competing interest

The authors declare that they have no competing interests.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Ethical review

Study procedures received institutional review board approval from the University of Texas at Austin. Informed consent was obtained from study participants.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.josat.2022.208948>.

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