Chapter

Parental Education, Ethnicity, and Functional Connectivity between Nucleus Accumbens and Frontoparietal Network

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Abstract

While studies have indicated an association between socioeconomic status (SES) and neuroimaging measures, weaker SES effects are shown for Blacks than Whites. This is, in part, due to processes such as stratification, racism, minoritization, and othering of Black people in the United States. However, less is known about Latino youth. This study had two aims: First, to test the association between parental education and the right and left nucleus accumbens (NAcc) resting-state functional connectivity with the frontoparietal network (FPN) in children; and second, to investigate ethnic heterogeneity in this association. This cross-sectional study used data from the Adolescent Brain Cognitive Development (ABCD) study. We analyzed the resting-state functional connectivity data (rsFC) of 10,840 US preadolescents who were between 9 and 10 years old. The main outcomes were the NAcc resting-state functional connectivity with FPN separately calculated for right and left hemispheres. Parental education was our independent variable. Family structure, sex, and age were covariates. Furthermore, ethnicity (Latino vs. non-Latino) was regarded as the moderator. We used mixed-effects regression for data analysis with and without interaction terms between parental education and ethnicity. Most participants (n = 8690; 80.2%) were non-Latino and 2150 (19.8%) were Latino. Parental education was associated with higher right and left NAcc resting-state functional connectivity with FPN. Ethnicity showed statistically significant interactions with parental education, suggesting that the positive associations between parental education and right and left NAcc resting-state functional connectivity with FPN were different in non-Latino and Latino children. For right hemisphere, we found significantly stronger and for left hemisphere, we found significantly weaker association for Latino compared with non-Latino preadolescents. Preadolescents' NAcc resting-state functional connectivity with FPN depends on the intersections of ethnicity, parental education, and laterality.

Keywords: ethnic groups, nucleus accumbens (NAcc), reward system, socioeconomic status, parental education, brain development, preadolescents, MRI, functional MRI, functional connectivity

1. Introduction

The right and left nucleus accumbens (NAcc) are subcortical brain structures, located within the ventral striatum, that serve as a key limbic-motor interface, and have an important role in Pavlovian learning [1, 2]. This means that the right and left NAcc contribute to the regulation of emotional and motivation processing [3], incentive salience [4], pleasure, reward, and reinforcement [5]. In addition, neural reactivity to food- and/or drug-related reward cues evokes robust dopamine responses in the right and left NAcc [1]. This suggests that as parts of the brain reward system, the right and left NAcc function reflects how individuals respond to cues that signal a potential reward [1]. The right and left NAcc have also been implicated in obesity [2, 6], food addiction [7], tobacco, alcohol, and drug-seeking behaviors [8–10], obsessive-compulsive disorder [11, 12], depression [13], and anxiety [12].

To fulfill their functions, the right and left NAcc communicate with a number of large-scale brain networks such as the frontoparietal network (FPN) [14–16]. Neuroimaging studies have revealed some alterations of the connectivity between the NAcc and FPN as an indicator of altered NAcc function [15]. The FPN, also known as the central executive network (CEN), is a large-scale brain network that works with the NAcc, striatum, and basal ganglia [17]. FPN is implicated in the cognitive control [18], attention [19], problem-solving [19], and working memory [19]. Altered FPN function is linked to attention-deficit/hyperactivity disorder (ADHD) [18, 20], cocaine addiction [21], and several mental disorders [22] in children and adolescents. Disruption in the FPN during cognitive control tasks is a common element of schizophrenia, bipolar disorder, unipolar depression, anxiety, and substance use disorders [23].

Functional magnetic resonance imaging (fMRI) techniques have expanded what we know about functional connectivity across brain regions and networks. Resting-state functional connectivity (rsFC) investigates the temporal correlation of the spatially distributed brain regions' activity at the resting state (i.e., when the participant has not engaged in an explicit task yet) [24]. rsFC allows us to identify spontaneous brain activity patterns, which can provide insight into neural activity patterns [25]. One advantage of rsFC is that it can explore networks not easily assessed during tasks and activities. Finally, rsFC tends to be free from bias in task selection and allows relatively easy data collection [25].

The frontoparietal-accumbal connectivity has a role in motivated behavior, food seeking, emotion regulation, food preference, obesity, eating disorders, and dopaminergic and reward systems of the brain [14, 15, 26, 27]. Decreased functional connectivity between the NAcc and the FPN is seen in depression [28]. An increase in the functional connectivity between the FPN and the NAcc is seen following mindfulness training [29]. Connectivity between the right NAcc and the FPN is also associated with substance use and cognitive control [30].

In comparison to peers with high parental education, children from low parental education have worse brain development [31]. The effects of parental education are well described on brain reward system, inhibitory control, cognitive development [32], language [33], executive function [33], and school achievement [32]. Low parental education is a risk factor for several mental, physical, and behavioral problems [32] including anxiety [34], depression [34], substance use problems [35–37], early initiation of sexual behavior [38], delinquency [39], obesity [40], and high blood pressure [41]. Parental education reduces children's antisocial behaviors [42], externalizing problems [43], anxiety and depression [34], behavioral problems [44], psychiatric disorders [44], mental health problems [45], tobacco dependence and aggression [46], and school problems [47] in children and adolescents. High parental education is linked to the size and function of the NAcc [48], thalamus [49], hippocampus [50], amygdala [34], and cerebral cortex.

According to the Minorities' Diminished Returns (MDRs) framework, parental education produces unequal outcomes for subpopulations [51, 52]. Additionally, based on the MDRs, ethnic minority children are less likely to have equal opportunities to gain from their parents' education to ensure health outcomes [53, 54]. Stratification, racism, segregation, and marginalization are shown to decrease parental education's effects on developmental outcomes for ethnic minorities [55, 56]. However, most of the MDRs' literature is on Black, rather than Latino, children [49, 57, 58]. While we know about the poor attention [59], low school performance [60], high reward dependence [61], impulsivity [62], suicide [63], aggression [64], depression [65], and problem behaviors [66] of Black children with highly educated parents, very limited knowledge exists on Latino children.

According to Harrist and Criss, influences of parental conditions such as parental education are not additive to the effects of other social and behavioral determinants. There are complex moderated mediational influences of parental conditions that are beyond additive effects and may be sub-additive, synergistic, or multiplicative. These effects also vary across diverse groups of families with different socioeconomic and demographic backgrounds [67]. For example, parental education may have diminished influences on children brain development of Black than White families, in part because structural racism may reduce what parental education can do for a Black child [68]. Thus, there is an interest to test heterogeneity of the effects of parental conditions and to investigate the multiplicative and non-additive effects of parental resources and other factors that impact child development [67]. While these differential effects of parental education are shown for structure and function of some brain regions such as amygdala [69], thalamus [70], hippocampus [71], and cerebral cortex [68, 72, 73], less is known about heterogeneity of the effects of parental education on NAcc.

Previous neuroimaging studies have shown the association between parental education and children's brain function and structure [56, 65]. Different from other socioeconomic status (SES) indicators such as income and poverty, parental education tends to represent an aspect of SES that is not represented by the presence of financial or material resources in the family [74]. Still, there continues to be a lack of studies on the effects of parental education on brain functional connectivity of the NAcc and FPN in group differences at the resting state. Likewise, it is necessary to examine the connectivity between the right and left NAcc and FPN that may reflect reward salience, reward process, cognitive control [75–77], and various cognition, emotions, and psychological problems [75, 76].

1.1 Aims

Using a sample of 9/10-year-old preadolescents from the Adolescent Brain Cognitive Development research (ABCD) study [75, 78], the present study had two aims: first, to investigate the correlation between parental education and rsFC between the right and left Nacc and FPN; and second, to examine ethnic heterogeneity in this correlation. We hypothesized that parental education would be positively associated with the functional connectivity of the right and left NAcc and FPN, and that there would be a weaker effect of parental education on the right and left NAcc functional connectivity with FPN for Latino than non-Latino preadolescents.

2. Methods

2.1 Design and settings

Data for this secondary analysis came from baseline (wave 1) of the Adolescent Brain Cognitive Development (ABCD) study. The ABCD is an unprecedented study in the examination of children's brain development [75, 79]. The ABCD study is a longitudinal study of a diverse sample of children from age 9 to 10 to their early adulthood [80]. For more information regarding the ABCD sample, methods, measures, and imaging techniques, please see here [80].

2.2 Participants and sampling

The ABCD study is a multi-site longitudinal study that has recruited 11,875 children aged 9–10, from 21 cities across different states, to characterize their psychological and neurobiological development from early adolescence to early adulthood [78]. Most of the participants were recruited through schools across the 21 study sites [81]. Because of well-designed and performed sampling process, the ABCD study sample has generated a sample that although is not nationally representative, it is a balanced sample that has a strong proxy of US adolescents [81]. Thus, the ABCD sample is a close approximation of US children in terms of distribution of age, SES, ethnicity, sex, and urbanicity [81].

2.3 Analytical sample

For this analysis, we only used the ABCD baseline sample. We included the ABCD study regardless of their race, ethnicity, and psychopathologies [81]. However, we limited the sample to those who had complete data on our variables and met satisfactory imaging quality. Our analytical n for the analyses *presented here is 7959.

2.4 Process

2.4.1 Study variables

The study variables included parental education (independent variable), children's ethnicity (moderator), ethnicity, age, race, sex, parental marital status (confounders), and NAcc functional connectivity with the FPN, separately calculated for the right and left (dependent variables).

2.4.1.1 Independent variables

Parental education. Parental education was considered as a five-level nominal variable: less than high school (HS) diploma, high school (HS) diploma, some college, bachelors' degree, and postgraduate degree.

2.4.1.2 Dependent variables

Right and left NAcc resting-state functional connectivity with FPN. Using resting-state fMRI, the NAcc was defined as the average correlation between the FPN and ASEG ROI right-accumbens area. This is the functional connectivity between the FPN and the NAcc. The resting-state fMRI was measured at baseline at the same time that parental education was measured. These results were separately calculated for the right and left NAcc. Our outcomes had normal distributions (Appendix Figure).

2.4.1.3 Moderators

Ethnicity. It was seen as a dichotomous variable and coded as Latino = 1 and non-Latino = 0.

2.4.1.4 Confounders

Age. It was seen as a continuous variable and was reported by the parents as months.

Sex. It was considered as a categorical variable with 0 for girls and 1 for boys.

Race. Race was reported by the parent. It was considered as a moderator and was treated as a nominal variable: Black, Asian, Other/Mixed, and White (reference group).

Family structure. It was a dichotomous variable self-reported by the parent interviewed and coded 1 vs. 0 for married and unmarried or other condition, respectively.

2.5 Data analysis

We used the Data Exploration and Analysis Portal (DEAP), a user-friendly online platform for multivariable analysis of the ABCD data. For multivariable analyses, two mixed-effects regression models were estimated (Supplementary Table). *Model 1* tested the additive effects of parental education, ethnicity, and covariates, without interaction terms. *Model 2* also included interaction between parental education and ethnicity on functional connectivity (FC) between the NAcc and FPN. Moreover, we checked the normal distribution of our outcome (Appendix). In all models, the NAcc resting-state functional connectivity with FPN was the outcome. Similar models were performed for the right and left NAcc as well. In total, we ran four models. Also, regression coefficient (b), standard error (SE), and p-value were reported.

2.6 Ethical aspect

The original ABCD research protocol received Institutional Review Board (IRB) approval in several institutions, including the University of California, San Diego (UCSD). Additionally, we received the ABCD data through an agreement between Charles R. Drew University and NIH/NDA. As the ABCD data were fully de-identified, our study was considered to be a nonhuman subject research. This exempted our study from a full review. Besides, all children in the ABCD study provided verbal assent to the protocol approved by the IRB, and all parents/caregivers signed the written informed consent form [80].

3. Result

3.1 Sample descriptive data

The present study used data from a large sample of 10,840 preadolescents between 9 and 10 years old (M_{Age} = 119 months, SD = 7.5, 5194 females). Most participants (n = 8690; 80.2%) were non-Latino and 2150 (19.8%) were Latino. In terms of race, the study included 7071 White, 1654 Black, 256 Asian American, and 1859 other/mixed race. Latino children showed lower parental education in comparison to non-Latino children (**Table 1**).

The fit of the mixed-effects regression model is summarized in **Table 2**. Models with the interaction effects between parental education and ethnicity showed a better fit when compared with main effect models that only included ethnicity and parental education. This shows that interaction between parental education and ethnicity contributes more to explaining the variance of the outcome for both the right and left NAcc with FPN connectivity.

3.2 Right

3.2.1 Main effect model

As shown by **Table 3** and **Figure 1**, parental education showed a positive association with the functional connectivity between the right and left NAcc with FPN.

	N	**n**	**n**	**n**
N	**10,840**	**8690**	**2150**	
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Age (month)	119.06 (7.51)	119.18 (7.48)	118.61 (7.58)	0.002
Right NAcc functional connectivity with the FPN	−0.01 (0.15)	−0.01 (0.15)	−0.02 (0.15)	0.043
Left NAcc functional connectivity with the FPN	−0.06 (0.17)	−0.06 (0.17)	−0.06 (0.17)	0.421
Parental education				
<HS diploma	470 (4.3)	184 (2.1)	286 (13.3)	<0.001
HS diploma/GED	970 (8.9)	634 (7.3)	336 (15.6)	
Some college	2815 (26.0)	2071 (23.8)	744 (34.6)	
Bachelor	2791 (25.7)	2393 (27.5)	398 (18.5)	
Postgraduate degree	3794 (35.0)	3408 (39.2)	386 (18.0)	
Race				
White	7071 (65.2)	5798 (66.7)	1273 (59.2)	<0.001
Black	1654 (15.3)	1573 (18.1)	81 (3.8)	
Asian	256 (2.4)	235 (2.7)	21 (1.0)	
Other/mixed	1859 (17.1)	1084 (12.5)	775 (36.0)	
Sex				
Female	5194 (47.9)	4162 (47.9)	1032 (48.0)	0.949
Male	5646 (52.1)	4528 (52.1)	1118 (52.0)	
Marital status				
No	3413 (31.5)	2532 (29.1)	881 (41.0)	<0.001
Yes	7427 (68.5)	6158 (70.9)	1269 (59.0)	

Notes: Source: Adolescent Brain Cognitive Development (ABCD) Study.

Table 1.
Descriptive characteristics overall and by ethnicity (n = 10,840).

	Right		Left	
	Main effect	**Interaction effect**	**Main effect**	**Interaction effect**
N	10,840	10,840	10,856	10,856
R-squared	0.00451	0.00559	0.00347	0.00421
ΔR-squared	0.00104	0.00241	0.00109	0.00189
ΔR-squared (%)	0.1%	0.24%	0.11%	0.19%

Table 2.
Effect sizes and % variance explained by models.

	Right				Left			
	B	**SE**	***p***	**Sig**	**b**	**SE**	***p***	**Sig**
Parental education								
HS diploma/GED	0.01328	0.00859	0.1223612		0.00119	0.01272	0.925758	
Some college	0.01023	0.00772	0.1855986		−0.00853	0.01186	0.4721566	
Bachelor	0.02173	0.00802	0.0067889	**	0.00371	0.01208	0.7589529	
Graduate degree	0.01789	0.00800	0.0253812	*	0.00292	0.01203	0.8083342	
Hispanic	−0.00353	0.00404	0.3819443		−0.02965	0.01469	0.0436103	*
Race								
Black	−0.01198	0.00471	0.0109603	*	−0.01335	0.00483	0.0056677	**
Asian	−0.01446	0.00967	0.1350259		−0.01465	0.00967	0.1298128	
Other/mixed	−0.00560	0.00411	0.1724601		−0.00572	0.00411	0.1634748	
Age	0.00021	0.00019	0.2671881		0.00022	0.00019	0.2638408	
Sex	0.00111	0.00292	0.7044723		0.00114	0.00292	0.6950323	
Married family	0.00662	0.00362	0.0670059	#	0.00688	0.00362	0.057242	#
Parental education (HS Diploma/ GED) × hispanic					0.01551	0.01763	0.379094	
Parental education (some college) × hispanic					0.03629	0.01586	0.0221188	*
Parental education (bachelor) × hispanic					0.03788	0.01680	0.0241787	*
Parental education (postgraduate degree) × hispanic					0.01227	0.01677	0.4644527	

Notes: Source: ABCD Study; Mixed-effects regression model is used; all covariates such as race, ethnicity, age, sex, family, and site were controlled.
#p < 0.1.
*p < 0.05.
**p < 0.01.

Table 3.
Mixed-effects regressions on the effects of parental education and ethnicity on the functional connectivity between the frontoparietal network and nucleus accumbens (right).

This positive correlation suggests that children with higher parental education have a stronger rsFC between the right NAcc and FPN.

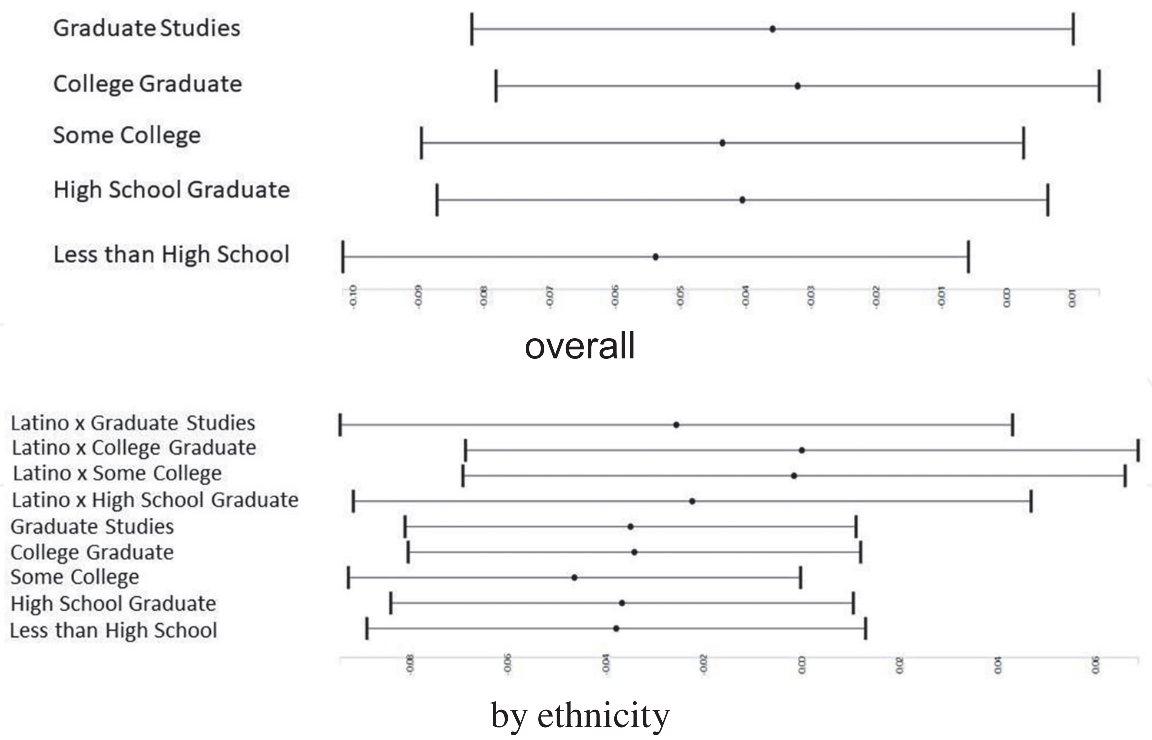

Figure 1.
Association between parental education and functional connectivity between the right NAcc and FPN overall and by ethnicity.

3.2.2 Interactive effects model

Table 4 and **Figure 1** show that parental education had a stronger positive association between parental education and the right FPN resting-state functional connectivity in Hispanic children than non-Hispanic children.

3.3 Left

3.3.1 Main effects model

As shown by **Table 4** and **Figure 2**, parental education showed a positive association with the functional connectivity between the right and left NAcc with FPN. This positive correlation suggests that children with higher parental education have stronger rsFC between left NAcc and FPN.

3.3.2 Interactive effects model

Table 4 and **Figure 2** show that parental education had a negative interaction with ethnicity on the functional connectivity between the FPN and the left NAcc. This interaction was indicative of a weaker positive association between parental education and the left FPN-NAcc resting-state functional connectivity in Hispanic children than non-Hispanic children.

4. Discussion

Our first aim showed a positive correlation between parental education and the NAcc resting-state functional connectivity with the FPN. Our second aim showed ethnic variation in the association between parental education and the right and left NAcc resting-state functional connectivity with the FPN. That is laterality,

		Right					Left		
	B	**SE**	***p***	**b**	**SE**			***p***	
Parental education									
HS diploma/GED		0.01432	0.00971	0.140307		0.04212	0.01439	0.0034347	**
Some college		0.02458	0.00873	0.0048772	**	0.05058	0.01341	0.0001636	***
Bachelor		0.01292	0.00907	0.154451		0.03647	0.01367	0.0076431	**
Graduate degree		0.01748	0.00905	0.053342	#	0.04149	0.01361	0.0023007	**
Hispanic		−0.00232	0.00457	0.612231		0.03703	0.01661	0.0257893	*
Race									
Black		0.01807	0.00533	0.0007057	***	0.01868	0.00546	0.0006308	***
Asian		−0.00606	0.01091	0.578768		−0.00603	0.01091	0.5804568	
Other/mixed		0.01120	0.00465	0.0159763	*	0.01138	0.00465	0.0143508	*
Age		0.00013	0.00022	0.541902		0.00014	0.00022	0.5346076	
Sex		0.00767	0.00329	0.0195458	*	0.00759	0.00329	0.020868	*
Married family		0.00036	0.00409	0.9291253		0.00030	0.00410	0.9418007	
Parental education (HS diploma/GED) × Hispanic						−0.05046	0.01993	0.0113542	*
Parental education (some college) × Hispanic						−0.04662	0.01793	0.0093157	**
Parental education (bachelor) × Hispanic						−0.03491	0.01899	0.066009	#
Parental education (postgraduate degree) × Hispanic						−0.03745	0.01895	0.0482004	*

Notes: Source: ABCD Study; mixed-effects regression model is used; all covariates such as race, ethnicity, age, sex, family, and site were controlled.
#$p < 0.1$.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

Table 4.
Mixed-effects regressions on the effects of parental education and ethnicity on the functional connectivity between the frontoparietal network and nucleus accumbens (left).

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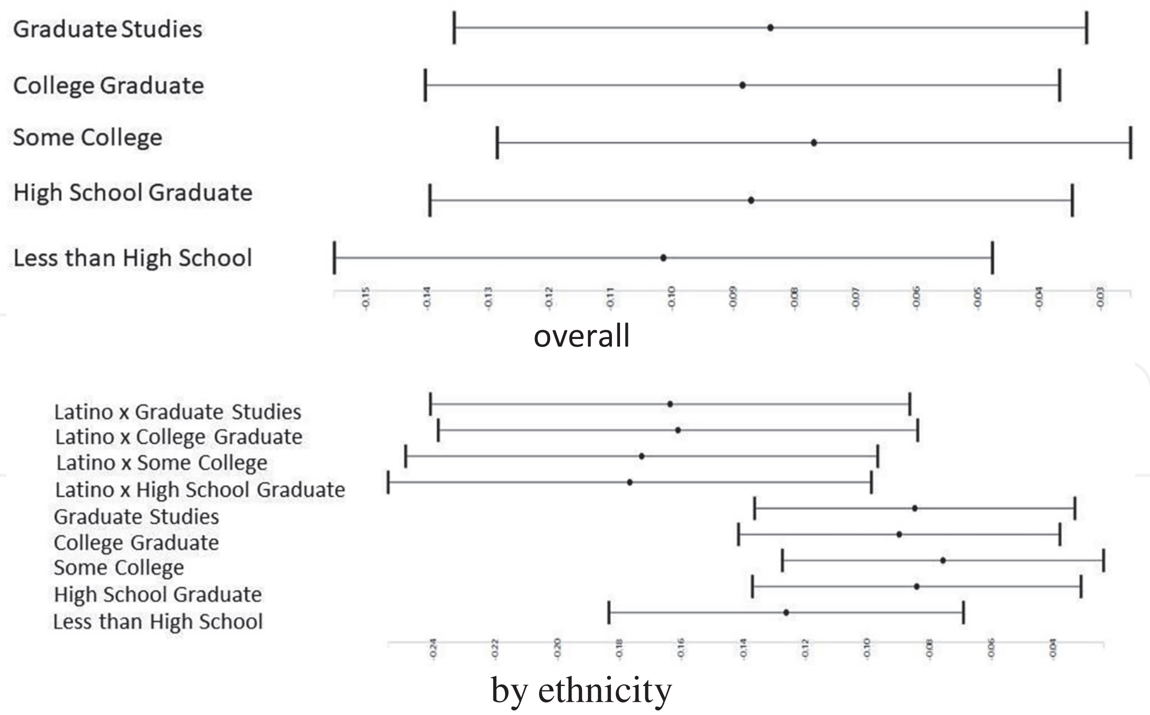


Figure 2.
Association between parental education and functional connectivity between the left NAcc and FPN overall and by ethnicity.

ethnicity, and parental education all show multiplicative effects on NAcc resting-state functional connectivity with the FPN. While we found a stronger correlation between parental education and the resting-state FPN's functional connectivity with the right NAcc in Latino than non-Latino children, parental education showed a weaker association with the same connectivity for the left NAcc. The finding on the right NAcc contrasts with the MDRs, but the finding on the left NAcc supports the MDRs' theory, which shows a weaker association between SES and brain development for marginalized and minority children than White children.

Our first finding is in agreement with other work showing the effects of parental education on brain structure [33], performance in several cognitive domains [82], and mental health problems, such as anxiety and depression [34]. However, most of what we know about SES effects are limited to specific brain regions [74, 83, 84], rather than rsFC. Past research has established a link between parental education and the size and activity of brain structures, such as the NAcc [48], amygdala [34], hippocampus [50], and thalamus [49]. In a study of examining a sample of 283 children and adolescents aged 4–18, higher parental education significantly predicted greater cortical thickness in the right anterior cingulate and left superior frontal gyrus [85]. Among 9475 children from the ABCD study, parental education was associated with reduced within and between sensorimotor network connectivity and increased sensorimotor network connectivity to frontal functional networks [76]. Furthermore, in line with our finding, higher parental education is shown to be linked to the development of frontoparietal connectivity in children [76]. Neurodevelopmental correlates of parental education may mediate why parental education is linked to behaviors [86], executive functions [33], reading ability [87], spatial skills, and inhibitory control [55]. Importantly, however, no studies to our knowledge have examined the associations between parental education and rsFC within the NAcc and FPN.

The effect of parental education on brain function can be explained by underlying mechanisms [88], such as cognitive stimulation available at home, parent–child interactions, and home learning environment, which all predict brain development [33, 88]. For example, more educated parents dedicate more time for their children in ways that seem to improve their children's development [89, 90]. Likewise, more educated parents appear to have higher expectations for their children, provide more stimulating learning materials, use more complex language and speech patterns, and engage more with their children's learning [89, 91]. These can help promote children's cognitive development [90]. Furthermore, the skills obtained from formal education appear to enable parents to arrange their activities in ways that allow them to effectively accomplish their parenting goals [88].

The results of the right NAcc-FPN connectivity were not in line with what is shown from the comparison of Black and White children. According to the MDRs' theory, parental education is more protective for White children than Black children. This finding was observed for the left NAcc-FPN connectivity. Similar to our finding on the left side, the effects of SES on attention [59], reward dependence [61], school performance [60], aggression [64], impulsivity [62], suicide [63], anxiety [92], and problem behaviors [66] are shown to be weaker in Black than White adolescents. This is the first study on the MDRs of parental education for NAcc functional connectivity with the FPN in Latino children. Even when MDRs exist, the right and left NAcc findings may vary largely.

Parental education has different and group-specific effects on children and youth brain development. This means that SES resources and ethnicity may have multiplicative, rather than additive, effects on the right NAcc resting-state functional connectivity with FPN. In this study and all the MDRs' literature, ethnic variation in the SES effects is shaped by social rather than biological mechanisms. Thus, in our study, ethnicity is a social rather than biological factor. Consequently, the differential treatment of society, which is preventable, has resulted in the ethnic differences. Importantly, we consider race as a proxy of racism, such as labor market discrimination, low school quality, segregation, and differential policing, that results in reduced effects of parental education, even for more educated people [93].

5. Limitations

The present study had some limitations. Firstly, a cross-sectional design limits any inference of causal links between parental education, ethnicity, and NAcc functional connectivity with the FPN. Secondly, we only studied parental education; other SES indicators were not included. Moreover, we did not examine how other factors, such as neighborhood context, stress, and social adversities, mitigate these effects across groups. Thirdly, Latino people are highly diverse. Cuban, Mexican, and Puerto Rican families differ in their history, culture, neighborhoods, SES, and other factors that may alter SES effects.

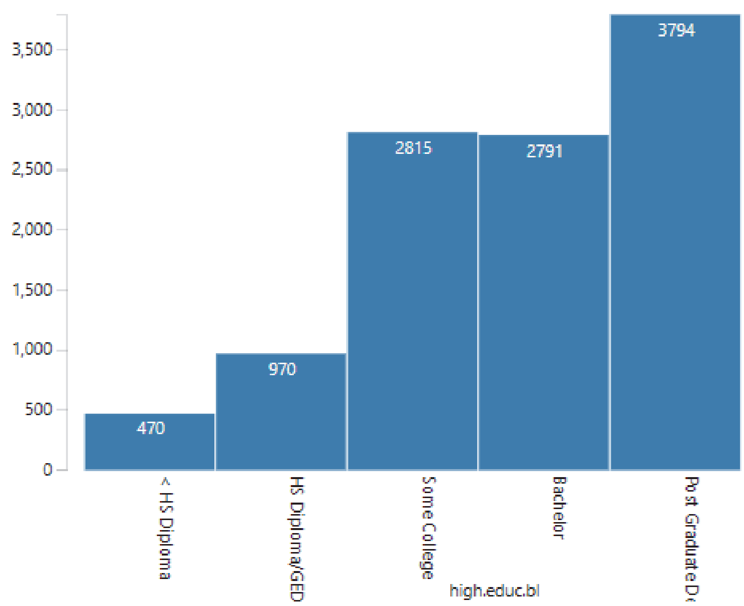
6. Conclusions

Although high NAcc resting-state functional connectivity with FPN is under the influence of parental education, ethnicity, and laterality, these effects are multiplicative rather than additive. This means that, while the parental education gradient was stronger for the right NAcc in Latino than non-Latino American preadolescents, the opposite finding was observed for the left NAcc. Due to qualitative differences in the lived conditions of ethnic groups in the United States, various subgroups may show different SES effects on brain development.

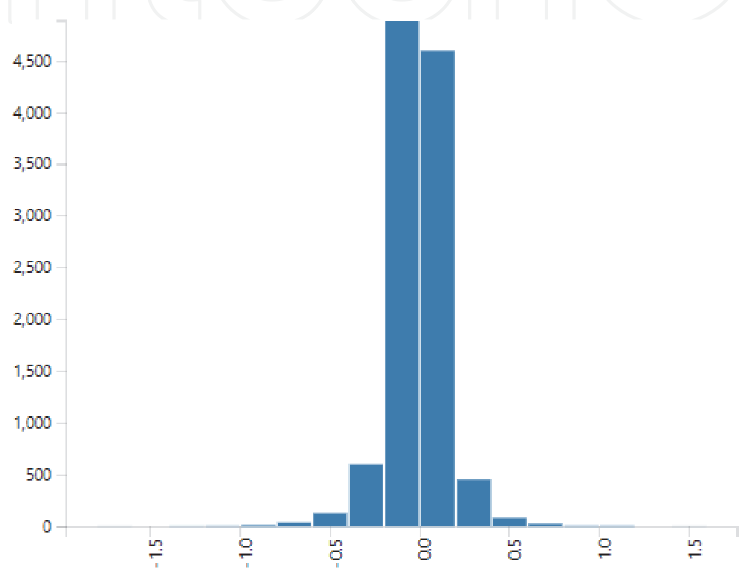
A. Modeling programs used for data analysis

	Right	Left
Model 1	rsfmri_cor_network. gordon_frontoparietal_subcort. aseg_accumbens.area.rh ~ high.educ. bl + hisp + race.4level + age + sex + married.bl Random: ~(1|rel_family_id)	rsfmri_cor_network. gordon_frontoparietal_subcort. aseg_accumbens.area.lh ~ high.educ. bl + hisp + race.4level + age + sex + married.bl Random: ~(1|rel_family_id)
Model 2	rsfmri_cor_network. gordon_frontoparietal_subcort. aseg_accumbens.area.rh ~ high.educ. bl + hisp + race.4level + age + sex + married.bl + high.educ.bl * hisp Random: ~(1|rel_family_id)	rsfmri_cor_network. gordon_frontoparietal_subcort. aseg_accumbens.area.lh ~ high.educ. bl + hisp + race.4level + age + sex + married. bl + high.educ.bl * hispRandom: ~(1|rel_family_id)

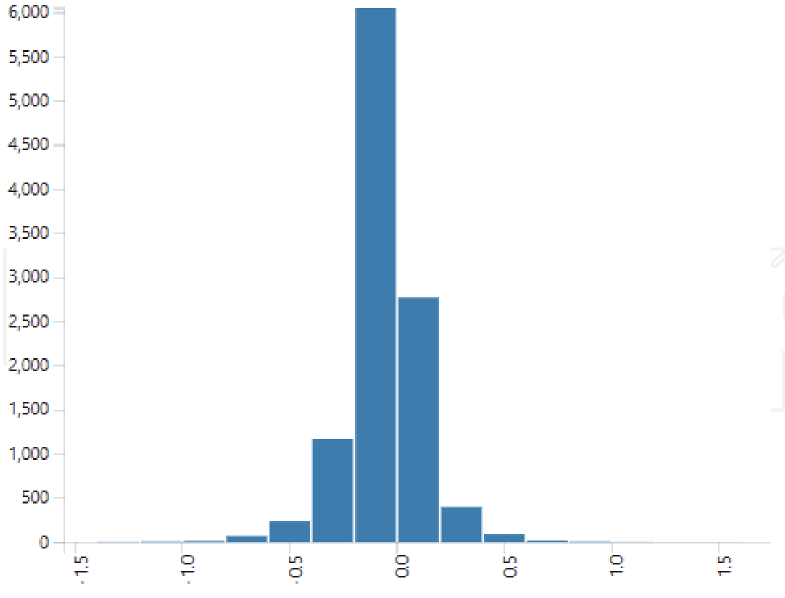
B. Distribution of parental education



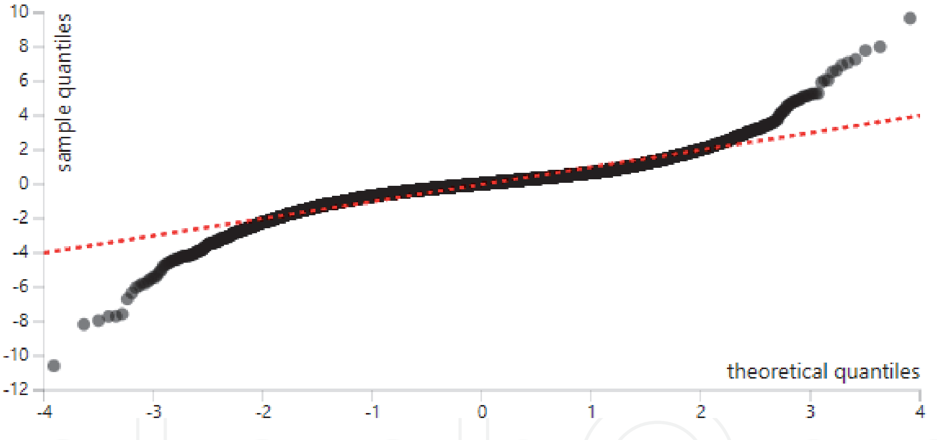
C. Distribution for the functional connectivity between the right NAcc and frontoparietal network



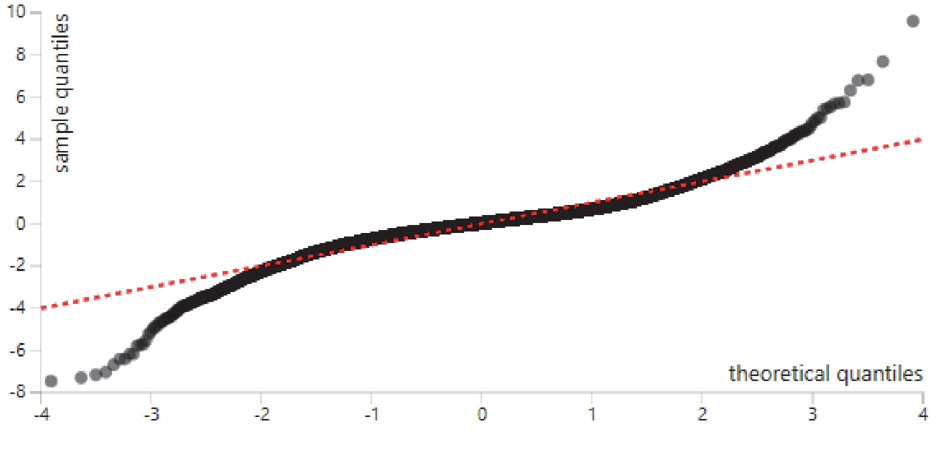
D. Distribution for the functional connectivity between the left NAcc and frontoparietal network



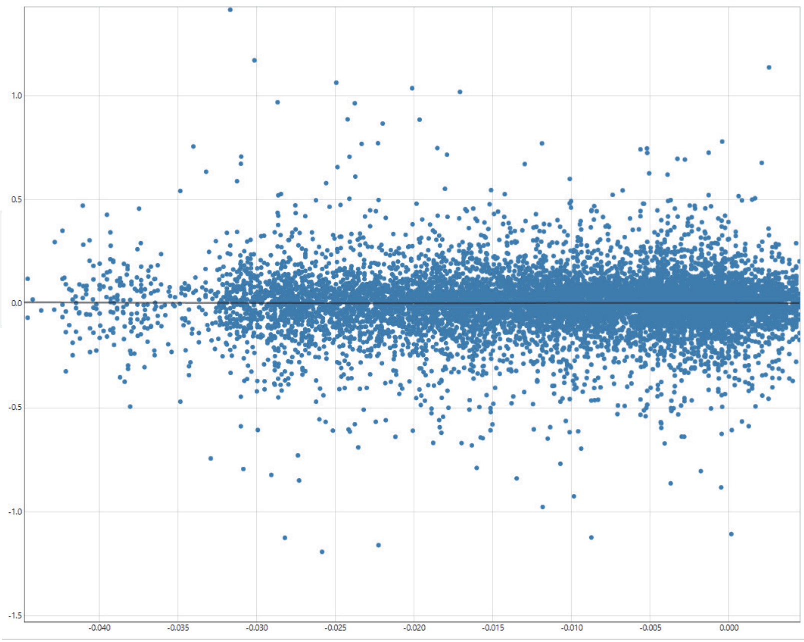
E. Quantiles distribution for the association between parental education and functional connectivity between the right NAcc and frontoparietal network



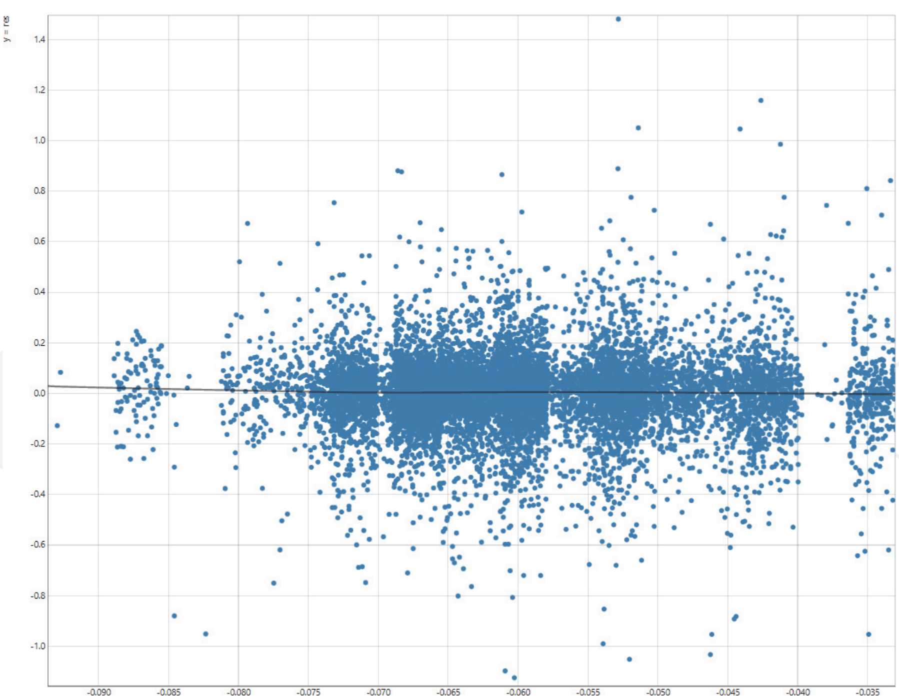
F. Quantiles distribution for the association between parental education and functional connectivity between the left NAcc and frontoparietal network



G. Error terms for the association between parental education and functional connectivity between the right NAcc and frontoparietal network



H. Error terms for the association between parental education and functional connectivity between the left NAcc and frontoparietal network



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