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Original Paper

Parental Education Ain't Enough: A Study of Race (Racism), Parental Education, and Children's Thalamus Volume

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Abstract

Introduction. *The thalamus is the hub of the brain and has a significant role in various brain activities.* ***Purpose.*** *This study explored racial differences in the association between parental education and thalamus volume among American children.* ***Methods.*** *Using data from the Adolescent Brain Cognitive Development (ABCD), we analyzed the structural Magnetic Resonance Imaging (sMRI) data of 11141 9-10 years old children. The main outcome was the thalamus volume. The independent variable was parental education. Age, sex, ethnicity, family marital status, and intracranial volume were the covariates. Race was the moderator. To analyze the data, we used mixed-effects regression models.* ***Results.*** *In race-stratified models, high parental education was associated with smaller thalamus volume in White but not Black children. In the pooled sample, significant interactions were found between race and parental education suggesting that the effect of parental education on left thalamus volume is significantly smaller for Blacks and mixed/other race children than White children.* ***Conclusions.*** *The effect of parental education on children's thalamus volume seems to be weaker for Black and other/mixed-race children than their White counterparts. This finding is in support of Minorites' Diminished Returns (MDRs) that suggest due to social stratification and racism, economic resources have weaker than expected effects in minority populations.*

Keywords

socioeconomic position, socioeconomic factors, brain development, thalamus, children, MRI

1. Introduction

Parental education is one of the main socioeconomic status (SES) indicators (Oshri et al., 2019). High SES is associated with lower odds of antisocial behaviors (Palma-Coca et al., 2011), school problems (Sirin, 2005), learning disorders (Fluss et al., 2009), attention deficit and hyperactivity disorder (Assari & Caldwell, 2019a; Collins & Cleary, 2016; Jablonska et al., 2020; Machlin, McLaughlin, & Sheridan, 2019), aggression (Heshmat et al., 2016), early sexual initiation (Feldstein Ewing et al., 2018), and use of tobacco (Barreto, de Figueiredo, & Giatti, 2013; Kaleta, Usidame, Dziankowska-Zaborszczyk, & Makowiec-Dabrowska, 2015), alcohol (Moore & Littlecott, 2015; Silveira et al., 2014), and drugs (Gerra et al., 2020). The SES effects are at least in part due to the effects of SES on brain structures and function (Javanbakht et al., 2015; Masten, Telzer, & Eisenberger, 2011; Wu et al., 2015).

A wide range of brain structures such as the thalamus, hippocampus, amygdala, and cerebral cortex carry the effects of high SES on brain function (Baxendale & Heaney, 2011; D. J. Kim et al., 2019; Lawson et al., 2017; Noble, Houston, Kan, & Sowell, 2012; Staff et al., 2012). The thalamus is shown to be linked to SES (Lisanne M Jenkins et al., 2020). Thalamus size and function correlate with psychosis, depression, anxiety, and attention deficit hyperactivity disorder (ADHD) (Adriano, Spoletini, Caltagirone, & Spalletta, 2010; Huang et al., 2017; Mills et al., 2012; Nugent, Davis, Zarate Jr, & Drevets, 2013; Rosch et al., 2018; Tsatsanis et al., 2003; Young, Bonkale, Holcomb, Hicks, & German, 2008; Young, Holcomb, Yazdani, Hicks, & German, 2004). Some research suggests that altered structure and function of brain regions such as thalamus, hippocampus, amygdala, and cerebral cortex may partially mediate the effect of high family SES on brain development and function (Lisanne M Jenkins et al., 2020; Hair, Hanson, Wolfe, & Pollak, 2015; Hanson et al., 2015; L. M. Jenkins et al., 2020; Johnson, Riis, & Noble, 2016; Machlin et al., 2019; McEwen & Gianaros, 2010; McLean et al., 2012; K. G. Noble et al., 2015; Noble et al., 2012; Staff et al., 2012; Suchy-Dicey et al., 2019).

Although a growing literature has documented a link between high SES and children's brain development, most of the existing knowledge is on a select few brain structures such as the amygdala, hippocampus, cortex, and cerebral cortex (Evans et al., 2016; Javanbakht et al., 2016; Javanbakht et al., 2015; Kimberly G Noble et al., 2015). For example, most research on the effects of trauma, stress, adversities, and SES are on the amygdala structure and function (Evans et al., 2016; Javanbakht et al., 2016; Javanbakht et al., 2015; Kimberly G Noble et al., 2015). While the overall effects of SES on both volume and function of the amygdala are well established (Evans et al., 2016; Javanbakht et al., 2016; Javanbakht et al., 2015), some recent evidence has documented diminished effects of SES on the amygdala for Black than White children (Assari, Boyce, & Bazargan, 2020b). However, less is known on group differences in the effect of SES on thalamus volume (Baxendale & Heaney, 2011; Hair et al., 2015; Hanson, Chandra, Wolfe, & Pollak, 2011; Hanson et al., 2015; Lawson et al., 2017; K. G. Noble et al., 2015; Noble et al., 2012; Wang et al., 2016).

Besides, most previous studies have investigated the effects of SES indicators such as household income and poverty (Gonzalez et al., 2020; Kimberly G Noble et al., 2015; K. G. Noble et al., 2015; Piccolo et al.,

2016; Uban et al., 2020) on children's brain function. However, these SES indicators are mainly related to the presence of financial resources in the family. Parental education may reflect another aspect of SES that is not reflected by household income and poverty status (Assari, 2020; Assari, Boyce, Akhlaghipour, Bazargan, & Caldwell, 2020; Assari, Boyce, Bazargan, & Caldwell, 2020; L. M. Jenkins et al., 2020; Parker et al., 2017; Willis et al., 2014).

There is a need to test racial differences in the effects of parental education on brain development. As race and parental education closely overlap (Kaufman, Cooper, & McGee, 1997), family SES may explain why race impacts brain development. In this view, it is family SES, not race or ethnicity, which is the true driver of inequalities in children's brain development (Assari, 2018). At the same time, high family SES may have different effects on children's brain development across racial groups (Kimberly G Noble et al., 2015). This is supported by a growing body of research on Minorities' Diminished Returns (MDRs) (Assari, 2017; Assari, 2018), a phenomenon of weaker effects of SES on various health outcomes, including brain development of Black than White children in terms of attention (Assari, Boyce, & Bazargan, 2020a), impulse control (Assari, Caldwell, & Mincy, 2018), inhibitory control (Assari, 2020), depression (Assari & Caldwell, 2018), suicidality (Assari, Boyce, Bazargan, et al., 2020), anxiety (Assari, Caldwell, & Zimmerman, 2018), social and behavioral problems (Assari, Boyce, Caldwell, & Bazargan, 2020; Boyce, Bazargan, Caldwell, Zimmerman, & Assari, 2020), and attention deficit hyperactive disorder (ADHD) (Assari & Caldwell, 2019a). However, very little, if any is not on the multiplicative effects of race (as a proxy of racism) and parental education on thalamus volume.

1.1 Aims

This study compared racial groups for the effects of parental education on 9-10 year old children's left thalamus volume. In line with the MDRs literature (Assari, Boyce, Caldwell et al., 2020; Boyce et al., 2020), we expected a weaker effect of parental education on thalams volume for Black and other racial minorty children than White children. That means, we hypothesized a multiplicative effect of race and parental education on children's left thalamus volume.

2. Methods

2.1 The ABCD Study Design and Setting

This secondary data analysis had a cross-sectional methodological design. We used the existing data from the

This investigation used data from the Adolescent Brain Cognitive Development (ABCD) study (Alcohol Research: Current Reviews Editorial, 2018; Casey et al., 2018; Karcher, O'Brien, Kandala, & Barch, 2019; Lisdahl et al., 2018; Luciana et al., 2018). This cross-sectional study used wave 1 data from the ABCD study. ABCD is a national brain imaging study of children's brain structure and function (Alcohol Research: Current Reviews Editorial, 2018; Auchter et al., 2018).

2.2 Ethics

The ethics review board approved the ABCD study of the University of California in San Diego. While

youth signed assent, parents signed consent (Auchter et al., 2018). Given the de-identified nature of the data, our secondary analysis was exempt from the Charles R Drew University of Medicine and Science ethics review board.

2.3 Samples and Sampling

The ABCD study participants were drawn from schools in various cities across various US states. The subject recruitment was mainly conducted through local school systems. Schools were selected based on characteristics such as race, ethnicity, SES, sex, and urbanicity (Garavan et al., 2018). This paper's analytical sample was 11141 children who were between 9 and 10 years old. Inclusion in this analysis was limited to 9-10 years old children who had complete data on race, ethnicity, parental education, and thalamus volume.

2.4 sMRI and Image Acquisition

T1 weighted structural MRI images were taken using General Electric 750, 3 tesla (T) Siemens Prisma, and Phillips multi-channel coiled scanners. All MRI scanners were capable of multiband echo-planar imaging (EPI) acquisitions (Casey et al., 2018). A localizer was implemented at the beginning of the scan, followed by the T1 weighted structural image acquisition. Structural T1 weighted scan sequences were optimized for cortical/subcortical segmentation using a magnetization-prepared rapid acquisition gradient-echo. The outcome was left thalamus size measured in mm3. We operationalized this variable as a continuous measure. Using sMRI, ABCD data has thalamus volume in the data set. We also used intra-cranial volume (mm3) as a control variable.

2.5 Variables

Parental education. The independent variable was parental education, treated as a five-level variable: Less than high school diploma, High school diploma, some college, college graduation, and graduate school.

Age. Parents were asked to report children's age. Age was a dichotomous measure in years (9 vs. 10).

Sex. A dichotomous variable, sex was coded as male = 1 and female = 0.

Parental marital status. Family marital status, a dichotomous variable, was coded as married = 1, non-married = 0 (reference).

Race. The race was a self-identified variable: Black, Asian, Mixed/Other, and White.

Ethnicity. Parents were asked if they were from a Latino background. Ethnicity was coded as Latino = 1 and = 0.

2.6 Data Analysis

Using Data Exploration and Analysis Portal (DEAP), we reported mean (SD) and frequency tables (%) for our variables overall and by race. We calculated Chi-square and Analysis of variance (ANOVA) to explore bivariate associations (racial differences in the variables). To run multivariable analyses, four mixed-effects regression models were run. The first two models were run in the total sample. Model 1 did not include race by parental education interaction terms. Model 2 did include such interaction terms. Model 3 and Model 4 were run in White and Black children. To test our modeling assumptions, we ruled

out collinearity between study variables. We then tested the distribution of our outcome variables and error terms (residuals) of our regression models. In all these models, the predictor variable was parental education. The outcome was thalamus volume. Confounders included ethnicity, sex, age, and parental marital status. Moderator was race. Regression coefficient, standard errors (SEs), and p-values were reported. A p-value of less than 0.05 was significant.

3. Results

3.1 Descriptive Data

This secondary analysis included 11141 9-10 years old children. Children were either White (n = 1721; 15.4%), Black (n = 256; 2.3%), Asian (n = 1910; 17.1%), or other/mixed race (n = 5308; 47.6%). Table 1 shows the summary statistics of the study variables in the overall sample and by race.

Table 1. Descriptive Data by Race

	level	All	White	Black	Asian	Other/Mixed	p
N		11141	7254	1721	256	1910	
			Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Age (Month)		118.98 (7.47)	119.05 (7.49)	118.87 (7.28)	119.55 (7.78)	118.75 (7.50)	0.223
Subcortical Intracranial Volume (mm3)		1512812.35 (148911.63)	1535501.90 (145521.10)	1458117.59 (142193.28)	1458146.17 (137512.78)	1483249.09 (149238.94)	< 0.001
Left Thalamus Volume (mm3)		7696.59 (748.10)	7777.17 (738.29)	7480.88 (707.84)	7519.02 (683.90)	7608.71 (776.18)	< 0.001
Parental Education	< HS Diploma	485 (4.4)	200 (2.8)	142 (8.3)	6 (2.3)	137 (7.2)	< 0.001
	HS Diploma/GED	1016 (9.1)	372 (5.1)	420 (24.4)	4 (1.6)	220 (11.5)	
	Some College	2897 (26.0)	1550 (21.4)	683 (39.7)	18 (7.0)	646 (33.8)	
	Bachelor's	2871 (25.8)	2127 (29.3)	243 (14.1)	69 (27.0)	432 (22.6)	
	Postgraduate Degree	3872 (34.8)	3005 (41.4)	233 (13.5)	159 (62.1)	475 (24.9)	
Sex	Female	5308 (47.6)	3400 (46.9)	857 (49.8)	133 (52.0)	918 (48.1)	0.073
	Male	5833 (52.4)	3854 (53.1)	864 (50.2)	123 (48.0)	992 (51.9)	
Married Family	No	3540 (31.8)	1552 (21.4)	1209 (70.2)	36 (14.1)	743 (38.9)	< 0.001
	Yes	7601 (68.2)	5702 (78.6)	512 (29.8)	220 (85.9)	1167 (61.1)	
Hispanic	No	8941 (80.3)	5949 (82.0)	1639 (95.2)	235 (91.8)	1118 (58.5)	< 0.001
	Yes	2200 (19.7)	1305 (18.0)	82 (4.8)	21 (8.2)	792 (41.5)	

3.2 Models' Fit

Table 2 summarizes the fit of our mixed-effects regression models in the total sample and by race. As shown in this table, including race by parental education helped the model explain a larger proportion of the variance of thalamus volume.

Table 2. Variance Explained by Our Models

	All (Main Effects)	All (Interaction Effects)	Whites	Blacks
N	11141	11141	7254	1721
R-squared	0.60787	0.60874	0.59985	0.60452
ΔR-squared	0.00039 (0.04%)	0.00378 (0.38%)	0.00158 (0.16%)	0.00248 (0.25%)

3.3 Parental Education and Left Thalamus Volume

Table 3 shows the results of our mixed-effects regression models in the total sample and by race. In all models, left thalamus volume as the outcome. In the pooled sample, parental education was not associated with left thalamus volume, net of confounders. Significant interactions were found between race and parental education on left thalamus volume, indicating larger effect for White than Black and other/mixed-race children. For White children, parental education was associated with smaller left thalamus volume. This association could not be found for Black children.

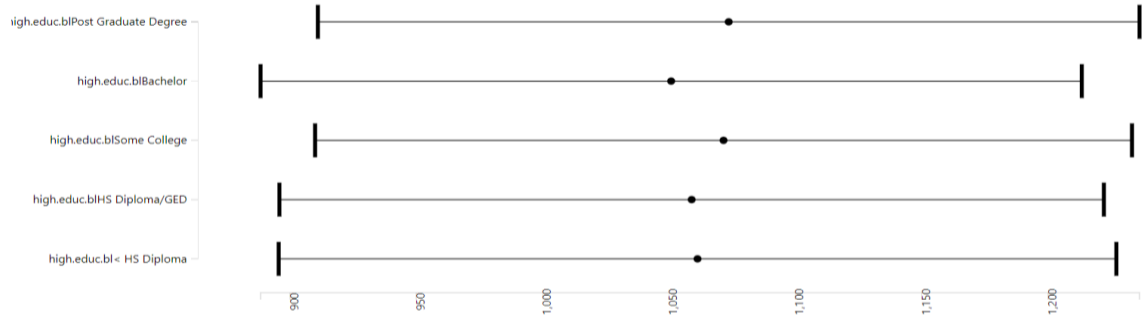
Table 3. Regressions in the Overall Sample and by Race with Left Thalamus Volume as the Outcome

All	**All (Main Effect)**			**All (Interaction Effect)**			**White**			**Black**		
	b	SE	p	b	SE	p	b	SE	p	b	SE	p
Parental Education (HS Diploma/GED)	-2.322	26.716	0.931	-113.895**	42.066	0.007	-117.876**	42.206	0.005	45.881	44.438	0.302
Parental Education (Some College)	10.303	24.085	0.669	-82.936*	36.586	0.023	-88.812*	36.975	0.016	48.007	42.487	0.259
Parental Education (Bachelor's)	-10.433	25.052	0.677	-105.911**	36.671	0.004	-114.613**	37.370	0.002	82.586#	49.592	0.096
Parental Education (Postgraduate Degree)	12.343	25.001	0.622	-84.861*	36.415	0.020	-95.165*	37.225	0.011	92.072#	50.490	0.068
Intracranial Volume (mm3)	0.004***	0.000	< 0.001	0.004***	0.000	< 0.001	0.004***	0.000	< 0.001	0.004***	0.000	< 0.001
Race (Black)	25.010#	14.894	0.093	-106.284*	53.884	0.049	-	-	-	-	-	-
Race (Asian)	35.441	30.319	0.242	-89.085	185.154	0.630	-	-	-	-	-	-
Race (Other/Mixed)	43.008***	12.910	0.001	-143.479**	52.404	0.006	-	-	-	-	-	-
Parental Education (HS Diploma/GED) × Race (Black)	-	-	-	149.919*	62.968	0.017	-	-	-	-	-	-
Parental Education (Some College) × Race (Black)	-	-	-	119.203*	57.665	0.039	-	-	-	-	-	-
Parental Education (Bachelor's) × Race (Black)	-	-	-	165.089**	62.875	0.009	-	-	-	-	-	-
Parental Education (Postgraduate Degree) × Race (Black)	-	-	-	147.442*	62.952	0.019	-	-	-	-	-	-

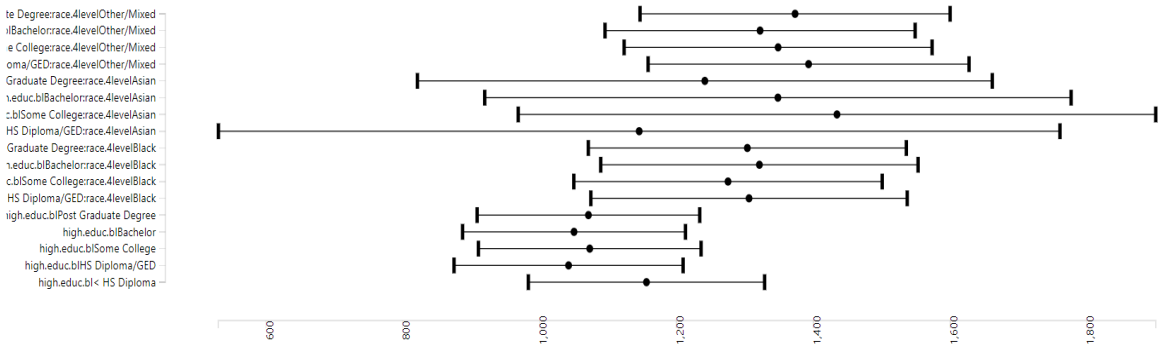
Parental Education (HS Diploma/GED) × Race (Asian)	-	-	-	-10.651	297.506	0.971	-	-	-	-	-	-
Parental Education (Some College) × Race (Asian)	-	-	-	278.506	215.236	0.196	-	-	-	-	-	-
Parental Education (Bachelor's) × Race (Asian)	-	-	-	192.138	193.919	0.322	-	-	-	-	-	-
Parental Education (Postgraduate Degree) × Race (Asian)	-	-	-	85.332	189.115	0.652	-	-	-	-	-	-
Parental Education (HS Diploma/GED) × Race (Other/Mixed)	-	-	-	236.965***	66.290	0.000	-	-	-	-	-	-
Parental Education (Some College) × Race (Other/Mixed)	-	-	-	192.432***	57.044	0.001	-	-	-	-	-	-
Parental Education (Bachelor's) × Race (Other/Mixed)	-	-	-	166.080**	58.366	0.004	-	-	-	-	-	-
Parental Education (Postgraduate Degree) × Race (Other/Mixed)	-	-	-	217.228***	57.579	0.000	-	-	-	-	-	-

3.4 Parental Education and Left Thalamus Volume Overall and by Race

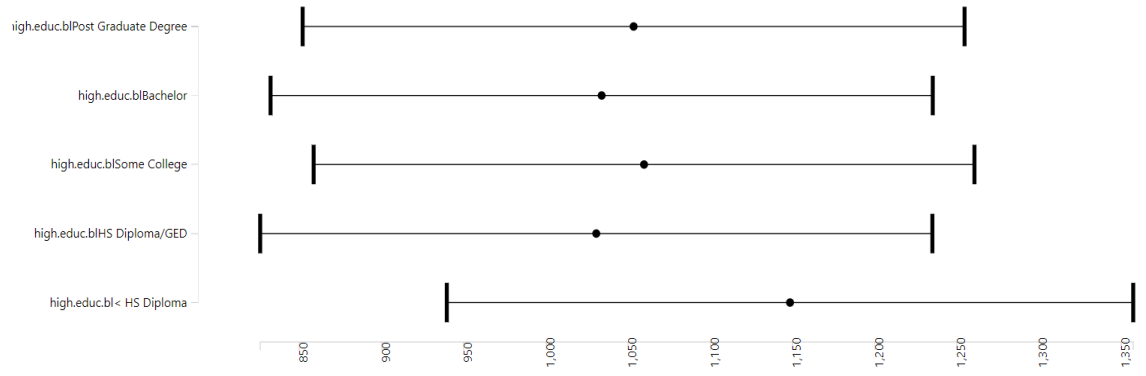
Figure 1 shows the associations between parental education and left thalamus size overall and by race. Figure 1-a shows no association between parental education and left thalamus volume, net of confounders, in the pooled sample. Figure 1-b shows that this effect is significantly larger for White than Black and other/mixed-race children. As Figure 1-c shows, for White children, parental education was associated with smaller left thalamus volume. As Figure 1-d shows, this association could not be found for Black children.



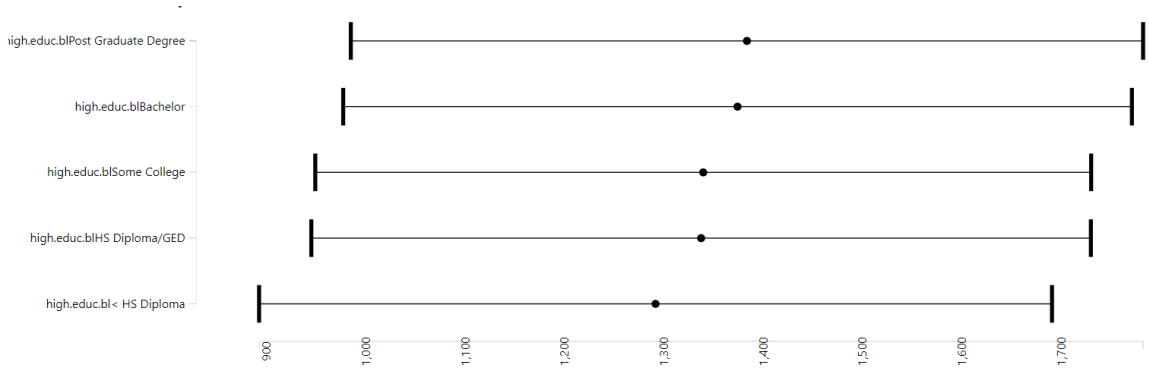
a. All overall



b. All by race



c. White



d. Black

Figure 1. Association between Parental Education and Left Thalamus Volume Overall and by Race

4. Discussion

While higher parental education was associated with smaller left thalamus volume, this effect was larger for White than Black and other/mixed-race families.

Various studies have shown that high SES, commonly measured by parental education or household income, is associated with various functional and structural aspects of brain in children (Assari, Boyce, et al., 2020b; Assari, 2020) and adults (P. Kim et al., 2013; Staff et al., 2012). Studies also show a link between higher family SES on functional brain connectivity between various brain regions including the thalamus (Cassidy L McDermott et al., 2019; C. L. McDermott et al., 2019). The function and structure of brain regions such as the thalamus, hippocampus, amygdala, and cerebral cortex may mediate the effect of childhood SES on children's cognitive function and emotions (Barch et al., 2016). However, less is known about the effect of parental education than household income on children's brain development.

The reason parental education is linked to brain structure is that high parental education is a proxy of high-quality parenting (Anton, Jones, & Youngstrom, 2015; Emmen et al., 2013; Kiang, Andrews, Stein, Supple, & Gonzalez, 2013; Perkins, Finegood, & Swain, 2013; Woods-Jaeger, Cho, Sexton, Slagel, & Goggin, 2018) and lower parental risk behaviors (Danese et al., 2009; Ladebauche, 1997; Spann et al.,

2014; Subic-Wrana et al., 2011). These parenting behaviors have a salient role in childhood brain development (Assari & Bazargan, 2019). As a result of these cumulative economic and parenting advantages, children from high SES backgrounds show protection against psychopathologies (Chassin, Presson, Sherman, & Edwards, 1992; Kocaoglu et al., 2005; Padilla-Moledo, Ruiz, & Castro-Pinero, 2016), problem behaviors (Barbarin et al., 2006; Choi, Wang, & Jackson, 2019; Palma-Coca et al., 2011), and poor cognitive performance (Assari, 2020; Assari & Caldwell, 2019b; Assari, Caldwell, & Bazargan, 2019; Darvishi, Assari, Farhadian, Chavoshi, & Ehsani, 2019). At the same time, low family SES is a proxy of low income, poverty, and scarcity of resources which can interfere with the healthy development of youth's brains.

There is a growing body of literature using ABCD that documents racial differences in the effects of SES on children's brain development (Assari, 2020). Similar to this paper, those papers also show a larger effect of SES for White than non-White children (Assari, 2020). In a recent paper, subjective SES showed diminished returns on hippocampus size of Black than White children (Assari, 2020). In another paper, the effect of subjective SES on Amygdala size was weaker for Black and Latino children than White and non-Latino children (Assari, Boyce et al., 2020b). Similar to the current study, both of these studies have shown that race and SES do not have independent but interdependent effects on children's brain development (Assari, 2020).

We should re-emphasize that we see race as social, not biological determinants of thalamus volume. In our study, the race is proxies of racism, poverty, SES, differential access to resources, and unequal treatment by society. This view is different from biological frameworks that conceptualize race as innate, unchangeable biological markers (Herrnstein & Murray, 2010).

We found that race and parental education have multiplicative rather than additive effects. While for White children, high SES reflects low and low SES indicates high risk, high SES and low SES Black children have similar risk. Small thalamus volume is linked to problems in memory and learning, cognition, and motions, future research should test how societal and structural conditions impact emotional, cognitive, and behavioral outcomes through altered thalamus function (Chozick, 1983; Montagrin, Saiote, & Schiller, 2018; Yavas, Gonzalez, & Fanselow, 2019). The results of such investigations may have useful implications for clinical practice and public health, as well as the social and economic policy on how to reduce racial inequalities in brain development. The results of this investigation may direct policymakers on how they can promote brain health equity in the US. The results advocate for enhancing social justice across diverse racial groups.

Due to racism, high and low- SES Black children show similarly high risk. This is different for White children whose low SES are at risk and high SES are protected against risk. For Black children, under racism, family SES seems not to be enough to compensate for racism and adversities. Although we found MDRs of parental education for thalamus volume, similar patterns are shown for the effects of subjective SES on amygdala (Assari, Boyce et al., 2020b) and hippocampus (Assari, 2020) size.

The smaller protective effects of SES on brain development of Black children is due to various aspects of the society. These may be because of race-related stressors like racism and discrimination, segregation, and blocked opportunities. Racial discrimination, stress, trauma, and adversities have all been shown to impact the thalamus of Blacks across all SES levels (Moadab, Bliss-Moreau, Bauman, & Amaral, 2017; Thames et al., 2018; Tottenham & Sheridan, 2009).

Race, ethnicity, and SES have multiplicative and complex effects as social determinants of thalamus activity. The same may hold for other brain regions (Clark, Miller, & Hegde, 2018) such as amygdala (Assari, Boyce et al., 2020b) and hippocampus (Assari, 2020). Thus, programs and interventions should be in place to alleviate the risk and promote brain development of both low and high SES Black children. This means, middle-class Black children also need our attention. Early childhood programs and after school programs are effective in promoting brain development (Garces, Thomas, & Currie, 2002; Gershoff, Ansari, Purtell, & Sexton, 2016; Neville et al., 2013; Zigler & Valentine, 1979). Other social and economic policies should reduce the environmental and structural adversities in the lives of Black families, across the full SES spectrum.

It would be a mistake to interpret our findings as biological effect of race on brain through genetics. There is a growing number of publications complicating the seeming straightforward division between social science, epigenetics, and biology. This research intends to add complexity to the emerging discussions concerning socio-economic inequity, structural and cultural racism, societal marginalization, and brain development. It is the hope of the authors that our findings inspire more nuanced investigations into the consequences of societal inequity and marginalization and avoid the race pseudo-science asserting racial differences in mental capacity and I.Q. (Herrnstein & Murray, 2010). A full understanding of the multifaceted effects of racism and economic marginalization requires a deeper investigation into the sociological and biological antecedents of these disparities in brain development between intersectional groups. A comparative study of poor white and Black populations may be helpful in this regard.

4.1 Limitations

Our first methodological limitation is the cross-sectional design of the current investigation. Due to a cross-sectional design, no causal link can be made between parental education and thalamus volume. The second limitation is that all our SES indicators were measured at the family level. Other SES indicators such as employment and neighborhood SES were not included. We only described the differential effects of parental education and did not investigate how social adversities, stress, or neighborhood context could explain such MDRs.

5. Conclusions

In summary, parental education is associated with smaller left thalamus volume among White American children. However, these effects are weaker for Black and other/mixed race than White children. These

results are in line with Minorities Diminished Returns (MDRs). Under social stratification, segregation, and racism, Black and other/mixed-race children show weaker SES effects than White children.

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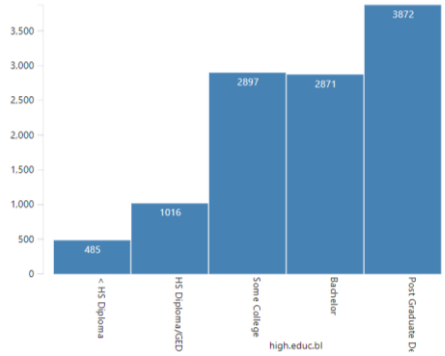

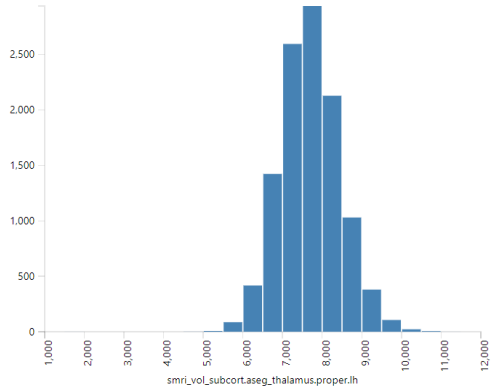

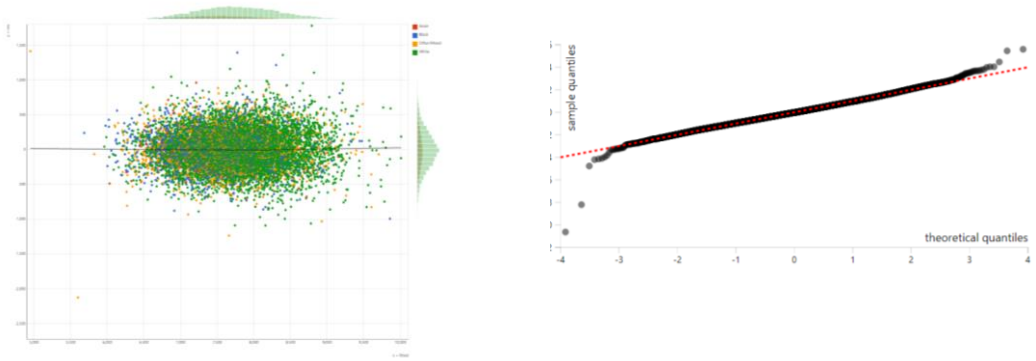

Figure 1. Models Assumptions (Predictor, Outcome, Residuals, Quantiles)

Table 1. Model Formula

Model 1 (All, Overall Effect)

smri_vol_subcort.aseg_thalamus.proper.lh ~ high.educ.bl + smri_vol_subcort.aseg_intracranialvolume + race.4level + sex + married.bl + age + hisp

Random: ~(1|rel_family_id)

Model 2 (All, Interaction Effect)

smri_vol_subcort.aseg_thalamus.proper.lh ~ high.educ.bl + smri_vol_subcort.aseg_intracranialvolume + race.4level + sex + married.bl + age + hisp + high.educ.bl * race.4level

Random: ~(1|rel_family_id)

Model 3 (Whites)

smri_vol_subcort.aseg_thalamus.proper.lh ~ high.educ.bl + smri_vol_subcort.aseg_intracranialvolume + sex + married.bl + age + hisp

Random: ~(1|rel_family_id)

Model 4 (Blacks)

smri_vol_subcort.aseg_thalamus.proper.lh ~ high.educ.bl + smri_vol_subcort.aseg_intracranialvolume + race.4level + sex + married.bl + age + hisp

Random: ~(1|rel_family_id)