

Original Paper

Are Teachers Biased against Black Children? A Study of Race, Amygdala Volume, and Problem Behaviors

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Abstract

Introduction: While the amygdala has a core role in behaviors, less is known about racial variation in the association between amygdala volume and teachers' behavioral rating of children. According to the Minorities' Diminished Returns (MDRs) phenomenon, the effects of individual-level risk and protective factors tend to be weaker for Black than White children due to structural factors such as social stratification and racism. **Purpose:** Built on the MDRs framework and conceptualizing race as a social rather than a biological factor, this study explored racial variation in the magnitude of the effects of amygdala volume on teachers' behavioral ratings of children. **Methods:** For this cross-sectional study, we used baseline socioeconomic data and structural magnetic resonance imaging (sMRI) data of 4305 American children ages 9-10 who had participated in the Adolescent Brain Cognitive Development (ABCD) study. The primary outcome was the teachers' behavioral rating of the child. The independent variable was amygdala volume. Age, sex, parental education, parental marital status, and ethnicity were the covariates. Race was the moderator. We used mixed-effect models for data analysis to adjust for the participants' nested nature within families and study sites. **Results:** Teachers rated children with larger amygdala volumes as having lower behavioral problems. The concordance between size of amygdala volume and teachers' behavioral rating of the child was modified by race. For white children, teachers reported the children to have lower behavioral problems when they had a large amygdala. For Black children, teachers reported high behavioral problems across all amygdala sizes. **Conclusions:** The results can be explained in two ways. The first explanation is minorities' diminished returns hypothesis (MDRs). In line with MDRs, due to structural inequalities and school segregation, a large amygdala

would result in a more favorable behavioral rating of the White children than Black children, as we expect an unequal effect of equal resources across racial groups in the presence of racism. The second explanation is systemic bias of teachers against Black children: meaning that due to their anti-Black bias, teachers report high behavioral problems in Black children, across all amygdala sizes (behavioral profiles). That means, race may trigger some cues and biases in the teachers, so they do not pay attention to the details of the behavioral profile of the Black child. For White children, however, in the absence of such racial bias, teachers behavioral rating of a child reflects the child's amygdala size.

Keywords

amygdala, Limbic, Children, MRI, population groups

1. Introduction

The amygdala, an almond-like structure (Brierley, Shaw, & David, 2002), located deep in the brain's medial temporal lobe of each hemisphere, is a core element of the limbic system (Gallagher & Holland, 1994). Both for humans and animals, the amygdala modulates all reactions to events and input, a function that is essential for survival (Gallagher & Holland, 1994). The amygdala is primarily responsible for human emotions and behaviors (Sarter & Markowitsch, 1985). This subcortical brain structure is linked to processing fearful and rewarding environmental stimuli (Tottenham & Sheridan, 2010) and perceiving certain emotions in other people (Brierley et al., 2002). Although it is best known for its role in processing fear, it also has a role in motivated behaviors and association of emotions to situations and contexts (Baas, Aleman, & Kahn, 2004). The amygdala is commonly linked to anxiety disorders such as general anxiety disorder (GAD), post-traumatic stress disorder (PTSD), phobias, and panic disorder (PD) (Shin, Rauch, & Pitman, 2006). The amygdala's abnormal functioning, resulting from damage, developmental problems, or neurotransmitter imbalance, is also linked to autism, depression, and schizophrenia (Machado & Bachevalier, 2003; Marsh et al., 2008).

In children and adolescents, altered amygdala size and function are associated with depression (Mervaala et al., 2000) and aggression (Coccaro, McCloskey, Fitzgerald, & Phan, 2007; Pardini, Raine, Erickson, & Loeber, 2014). Youth and adults with smaller amygdala sizes are at an increased risk of mood disorders (Siegle, Thompson, Carter, Steinhauer, & Thase, 2007) such as bipolar disorder (Garrett & Chang, 2008) and depression (Mervaala et al., 2000; Sheline, Gado, & Price, 1998). For most of these psychiatric disorders, the amygdala is small in size but hyperactive (Siegle et al., 2007). Most of the literature on the link between amygdala size and psychopathologies, however, is on adults (Monk et al., 2008). It is, however, unknown if behavioral correlates of amygdala size differ across various sub-groups of children. Race and socioeconomic status (SES), both serving as proxies of exposure to environmental factors, influence many brain structures including the amygdala (Brito, Fifer, Myers, Elliott, & Noble, 2016; Gianaros & Hackman, 2013; Hao & Farah, 2020; Jenkins et al., 2020). Race and SES jointly impact the amygdala structure because they reflect chronicity of exposure to economic disadvantage and hardship (Noble et al., 2015). Noble, Sowell, and others have documented SES effects on brain morphometry

(Noble et al., 2015); however, these SES effects are complicated as they may vary across demographic groups. For example, some studies have suggested that the effect of income on brain structures may be more robust for children from lower-income families (Noble et al., 2015). Another factor that may change the correlates of the amygdala structure/function is race. Due to racism and segregation, racial groups differ in behavioral and mental health correlates of the amygdala (Assari, Boyce, & Bazargan, 2020b).

Research has documented an extensive degree of Black-White differences in the effects of SES on trauma (Assari, 2020a), ADHD (Assari & Caldwell, 2019), suicide (Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H. Caldwell, 2020a), depression (Assari & Caldwell, 2018a), anxiety (Assari, Caldwell, & Zimmerman, 2018), aggression (Assari, Caldwell, & Bazargan, 2019), tobacco use (Assari et al., 2019; Assari, Mistry, & Bazargan, 2020; Assari, Mistry, Caldwell, & Bazargan, 2020), impulsivity (Assari, C. H. Caldwell, & R. Mincy, 2018a), school bonding (Assari, 2019b), school performance (Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H Caldwell, 2020b), and inhibitory control (Assari, 2020c). All these SES effects are stronger in White than Black youth, a pattern called Minorities' Diminished Returns (MDRs) (Assari, 2018a; Assari & Lankarani, 2016a; Assari, Preiser, & Kelly, 2018; Healthy People 2020,). These MDRs are because high SES Black families have lower household income and wealth, and experience high levels of stress and discrimination (Assari, 2018b; Assari, 2020a, 2020f; Assari & Mohsen Bazargan, 2019b; Assari, Preiser et al., 2018). As a result of residential segregation, high SES Black children remain with high-risk peers (Assari, Caldwell, & Bazargan, 2020) and in high-risk schools (Boyce, Bazargan, Caldwell, Zimmerman, & Assari, 2020) and neighborhoods (Assari, Boyce, Caldwell, Bazargan, & Mincy, 2020). Similarly, high SES Black children still experience high stress (Assari, 2020a; Assari, Boyce, Caldwell, et al., 2020; Shervin, 2020), which hinders their healthy brain development (Javanbakht et al., 2015; Kim et al., 2013; Oshri et al., 2019; Yu et al., 2019).

These Black-White differences in the SES effects (MDRs) are commonly replicated (Assari, 2018a; Assari & Lankarani, 2016a; Assari, Preiser, et al., 2018; Healthy People 2020,), suggesting that weakened effects of SES are a robust phenomenon in Black than White children (Assari & Lankarani, 2016a). In this view, family-level SES have smaller than expected effects on shaping Black children's brain development (Assari, 2018a, 2020g; Assari, Akhlaghipour, Boyce, Bazargan, & Caldwell, 2020; Assari, Boyce, Akhlaghipour, Bazargan, & Caldwell, 2020; Assari, Boyce, & Bazargan, 2020a; Assari, Boyce, Caldwell, & Bazargan, 2020; Assari & Caldwell, 2019). That means it is the system-level and structural barriers such as segregation, SES resources lose some of their effects for Blacks, when compared to Whites (Assari & Lankarani, 2016a). For example, due to labor market discrimination, segregation, and racism, high SES and low SES Black families are more similar (Assari & Lankarani, 2016a) than high SES and low-SES White families (Assari, 2018b). This is partly because SES can do more for a population who do not face racism (Whites) (Assari, 2020f; Shervin Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H. Caldwell, 2020c).

In a recent work using data from Adolescent Brain Cognitive Development (ABCD) study (Auchter et al.,

2018; Feldstein Ewing, Bjork, & Luciana, 2018; Garavan et al., 2018; Karcher & Barch, 2020), Assari showed that family SES increases the amygdala size for White children but not Black children (Assari, Boyce, & Bazargan, 2020b). Analysis of 9,380 children who were 9–10 years-old showed the effect of subjective family SES and parental education on total amygdala volume. High subjective SES and parental education were independently associated with a larger total amygdala size. The effect of high subjective SES on larger total amygdala volume was weaker for black children than white children. The paper suggested that for American children, family SES has unequal effects on amygdala size and function, a pattern that is consistent with MDRs. That means, high and low SES blacks have similar amygdala size, while high SES and low SES Whites differ drastically in their amygdala size (Assari, Boyce, & Bazargan, 2020b). In a study among older adults, SES showed stronger effects on brain structure and function in White people than Black people (Waldstein et al., 2017).

Similar to SES, non-economic resources and assets lose some of their effects in Blacks (Assari, 2018a, 2020d; Maharlouei, Cobb, Bazargan, & Assari, 2020). For example, emotion regulation, age, self-efficacy and coping show larger health consequences for Whites than Blacks (Assari, 2017a, 2017b, 2017e, 2018b; Assari & Burgard, 2015; Assari & Lankarani, 2016b; Assari, Lankarani, & Burgard, 2016; Chalian, Khoshpouri, & Assari, 2019). In the same manner that SES indicators generate less outcomes for Blacks than Whites due to racism, resources such as brain mechanisms and structures may also generate fewer outcomes for Black than White communities, who are fighting an uphill battle (Assari, 2020f; D. Hudson, Sacks, Irani, & Asher, 2020).

1.1 Aims

Borrowing data from ABCD data and built on past work on MDRs on behaviors (Assari et al., 2019) and brain imaging findings (Assari, Boyce, & Bazargan, 2020b), this study investigates the differential effect of amygdala size on teachers' report of internalizing and externalizing behavioral problems of 9-10 years old American children. Our first hypothesis was an inverse association between amygdala size and internalizing and externalizing behavioral problems of the children, reported by teachers. Our second hypothesis was a weaker association between amygdala size and teachers' report of internalizing and externalizing behavioral problems for Black than White children. In other words, we expect teachers to report high levels of internalizing and externalizing behavioral problems for Black children, regardless of the child's amygdala size. For White children, however, we expect child amygdala size to correlate with teachers' report of internalizing and externalizing behavioral problems.

2. Methods

2.1 Design and Settings

This is a secondary analysis of existing data. Data were borrowed from the Adolescent Brain Cognitive Development (ABCD) study (Auchter et al., 2018; Feldstein Ewing et al., 2018; Garavan et al., 2018; Karcher & Barch, 2020). The ABCD is a landmark brain development study in the United States. Although detailed information regarding ABCD study methods, sampling, sample, measures, and

imaging techniques are available (Auchter et al., 2018; Bjork, Straub, Provost, & Neale, 2017; Casey et al., 2018; Feldstein Ewing et al., 2018; Garavan et al., 2018; Karcher & Barch, 2020), we briefly review some key aspects of the study.

2.2 Participants and Sampling

Participants of the ABCD study were children who were between ages 9 and 11 years. Children in the ABCD study were recruited from multiple cities across multiple states. Overall, participants were enrolled from 21 sites. The primary source of recruitment for the ABCD sample was US school systems. The sampling protocol of the ABCD study is described in detail here (Garavan et al., 2018). A total number of 4305 participants entered this analysis. Our analysis's eligibility included valid data on race, ethnicity, demographics, parental education, parental marital status, and children's amygdala volume. Participants were included in this analysis regardless of their race or ethnicity.

2.3 Study Variables

Amygdala volume. The independent variable was the child's left amygdala volume (mm^3), measured by structural MRI at rest. More information on sMRI in the ABCD is available here (Hagler et al., 2019). Our outcome had a normal distribution, as shown in Appendix 1. Appendix 2 shows the name of variables in the DEAP.

2.3.1 Moderator

Race. Race was self-identified by the parents. Race was a categorical variable: Black/African American, Asian, Mixed/Other, and White/Caucasian (reference category).

Outcomes. Outcomes were internalizing, externalizing, and total behavioral problems. The Brief Problem Monitor-Teacher (BPM-Teacher) scale (Achenbach, McConaughy, Ivanova, & Rescorla, 2011; Daniels, Volpe, Fabiano, & Briesch, 2017; Penelo, De la Osa, Navarro, Domènech, & Ezpeleta, 2017; Piper, Gray, Raber, & Birkett, 2014) was used to measure the internalizing behavioral problems of the pre-adolescents. The BPM can be implemented by the child, parent, or teacher, and is an abbreviated form of the Child Behavior Checklist (CBCL) (Bilenberg, 1999; Bordin et al., 2013; Diler et al., 2009; Dominguez-Lara, 2017; Kaat et al., 2019; Kristensen, Henriksen, & Bilenberg, 2010; Papachristou et al., 2013), developed by the Achenbach System of Empirically Based Assessment (ASEBA). In the current study, teachers reported child behavioral problems. This short measure takes 1-2 minutes and provides a continuous score that reflects internalizing problems. The BPM scale is a useful screening tool for screening of pre-adolescents internalizing behavioral problems across settings. Items were 1) Feels worthless or inferior, 2) Too fearful or anxious, 3) Feels too guilty, 4) Self-conscious or easily embarrassed, 5) Unhappy, sad, or depressed, and 6) Worries. Responses were 0 = Not True (as far as you know); 1 = Somewhat True; 2 = Very True. The overall score ranged between 0 and 12, with a higher score indicating more internalizing behavioral problems (Achenbach et al., 2011; Daniels et al., 2017; Penelo et al., 2017; Piper et al., 2014).

Age, sex, ethnicity, and parental marital status were the confounding variables. Parents reported the child's age and were calculated as months between the date of birth and the study's date. Sex of the child

was a dichotomous variable that was coded 0 for males and 1 for females. Child ethnicity was measured by the self-identification of the parents. Ethnicity was a dichotomous variable and coded 1 for Latino and 0 for non-Latino (reference category) families. Parental educational attainment was an ordinal variable: less than high school (reference category), high school, college, graduate+ school. Parental marital status was also a dichotomous variable, self-reported by the parent interviewed, and coded 1 vs. 0 for married and unmarried.

2.4 Data Analysis

We used the Data Exploration and Analysis Portal (DEAP) for data analysis. Provided by the Data Analysis and Informatics Core of ABCD, DEAP uses the R statistical package and provides a user-friendly online platform for multivariable analysis of the ABCD data. The DEAP platform was available here <https://deap.nimhda.org>, and ABCD data was downloaded from <https://nda.nih.gov/abcd>. For our univariate analysis, we reported Mean [standard deviation (SD)] and frequency (%) depending on the variable type. We also performed Analysis of Variance (ANOVA) for all our variables. R square and p-value were reported for each model. For each model's parameter, unstandardized regression coefficients (b), SE, and p-value were reported for each model. A p-value equal to or less than 0.05 was considered as statistically significant.

Linear regression in DEAP is based on mixed-effect models, given participants are nested to families, and families are nested to sites. The primary outcomes were internalizing, externalizing, and overall behavioral problems ($n=3$). The independent variable was amygdala volume. Covariates were age, sex, parental marital status, parental education, and ethnicity. As such, in all our models, we controlled for the effects of families as sites. Our multilevel modeling approach is shown in Appendix 3. These models are run in a nested fashion, and small variations distinct them at each step. *Model 1* tested the additive effects of amygdala size and race, with the same covariates, without interaction terms. *Model 2* tested the interaction between amygdala size and race. We checked a wide range of assumptions, including normal distribution of our outcome, lack of collinearity between predictors, and the distribution of errors for our model and the association between observed and theoretical quantiles of our model (Appendix 4).

2.5 Ethical Aspect

Our secondary analysis was found by the Charles R Drew University of Medicine and Science (CDU) Institutional Review Board (IRB) to be exempt from a full IRB review. However, the original ABCD study underwent an Institutional Review Board (IRB) in several institutions, including but not limited to the University of California, San Diego (UCSD). The IRB in multiple institutions approved the study protocol, and all children provided assent and parents signed consent.

3. Results

3.1 Sample Descriptive Data

Table 1 shows descriptive data overall. This study included 4305 children who were either 9 or 10 years old. From this number, most (68.4%) were White, 12.6% were Black, 2% were Asian American, and

17% were other/mixed race. Most participants (84.4%) were non-Latino, and 15.6% were Latino. The mean left amygdala volume was 1567 mm³ (SD = 233 mm³).

Table 1 also compared study variables by race. Racial groups did not differ in age or sex, but they differed in Hispanic ethnicity. Left amygdala size, internalizing behavioral problems, externalizing behavioral problems, and total behavioral problems varied across racial groups. All these problems were highest in Blacks and lowest in Whites and Asians. Left amygdala size was smallest in Black and largest in White children.

Table 1. Descriptive Statistics in the Pooled Sample by Race

level		All	White	Black	Asian	Other/Mixed	p
		n = 4305	n = 2944	n = 544	n = 87	n = 730	
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Age (Months)		118.98 (7.49)	119.03 (7.50)	118.72 (7.36)	119.20 (7.80)	118.91 (7.51)	0.817
Internalizing Behavioral Problems (BPMT)		0.28 (0.38)	0.27 (0.36)	0.35 (0.45)	0.15 (0.23)	0.28 (0.40)	< 0.001
Externalizing Behavioral Problems (BPMT)		0.20 (0.38)	0.16 (0.33)	0.42 (0.54)	0.09 (0.17)	0.21 (0.38)	< 0.001
Total Behavioral Problem (BPMT)		0.31 (0.34)	0.28 (0.32)	0.47 (0.44)	0.16 (0.19)	0.32 (0.36)	< 0.001
Left Amygdala Volume (mm3)		1567.92 (232.95)	1597.45 (233.00)	1473.81 (209.11)	1540.71 (225.93)	1522.19 (224.30)	< 0.001
		n(%)	n(%)	n(%)	n(%)	n(%)	
Hispanic	No	3634 (84.4)	2585 (87.8)	515 (94.7)	82 (94.3)	452 (61.9)	< 0.001
	Yes	671 (15.6)	359 (12.2)	29 (5.3)	5 (5.7)	278 (38.1)	
Sex	Female	2078 (48.3)	1420 (48.2)	273 (50.2)	47 (54.0)	338 (46.3)	0.379
	Male	2227 (51.7)	1524 (51.8)	271 (49.8)	40 (46.0)	392 (53.7)	
Parental Education	< HS Diploma	115 (2.7)	42 (1.4)	37 (6.8)	1 (1.1)	35 (4.8)	< 0.001
	HS Diploma/GED	325 (7.5)	117 (4.0)	124 (22.8)	1 (1.1)	83 (11.4)	
	Some College	1046 (24.3)	580 (19.7)	225 (41.4)	5 (5.7)	236 (32.3)	
	Bachelor	1177 (27.3)	890 (30.2)	84 (15.4)	22 (25.3)	181 (24.8)	
	Post Graduate Degree	1642 (38.1)	1315 (44.7)	74 (13.6)	58 (66.7)	195 (26.7)	
Married Family	No	1188 (27.6)	546 (18.5)	368 (67.6)	9 (10.3)	265 (36.3)	< 0.001
	Yes	3117 (72.4)	2398 (81.5)	176 (32.4)	78 (89.7)	465 (63.7)	

behavioral problems monitoring behavioral: BPMT

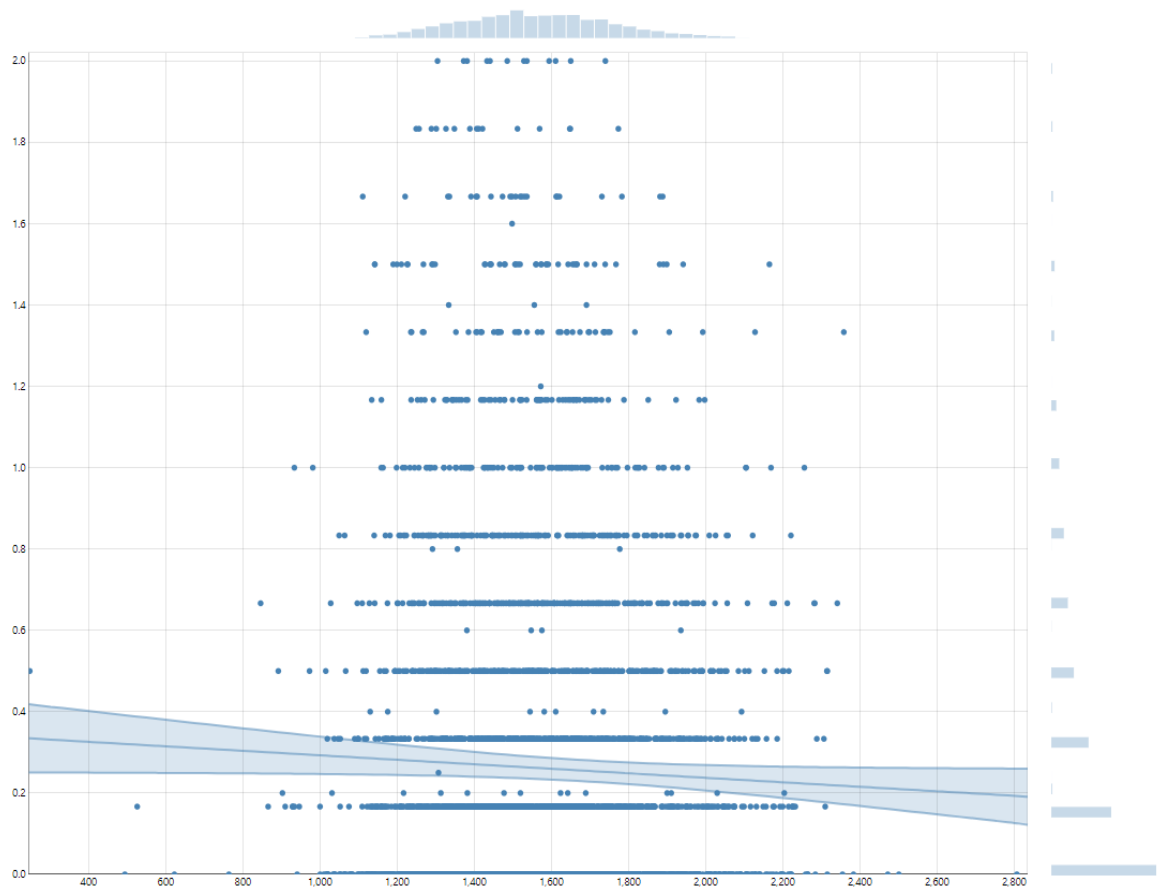
3.2 Externalizing Problems

As shown by Table 2, the amygdala size did not affect externalizing problem behaviors, when all confounders were controlled. As shown by Table 2, the effects of amygdala size on externalizing problem behaviors were smaller in Black than White children. These are also shown in Figures 1 and 2.

Table 2. Association between Amygdala Volume and Internalizing Behaviors Problem

	Internalizing behavioral problems			Externalizing behavioral problems			Total behavioral problems		
	B	SE	P	B	SE	P	B	SE	P
Model 1									
Left amygdala volume (mm3)	0.00*	0.00	0.050	0.00	0.00	0.529	-0.00005*	-0.00002	0.026
Model 2									
Left amygdala volume (mm3)	0.00*	0.00	0.045	0.00	0.00	0.196	-0.00007**	0.00003	0.008
Race (Black)	-0.26*	0.12	0.034	-0.19	0.12	0.110	-0.24175*	0.10732	0.024
Race (Asian American)	-0.31	0.28	0.271	0.09	0.27	0.739	-0.12274	0.24240	0.612
Race (Other/Mixed)	0.11	0.11	0.301	0.02	0.10	0.809	0.05762	0.09237	0.532
Left amygdala volume (mm3) × Black	0.00*	0.00	0.026	0.00**	0.00	0.002	0.00022**	0.00007	0.001
Left amygdala volume (mm3) × Asian American	0.00	0.00	0.440	0.00	0.00	0.612	0.00003	0.00016	0.866
Left amygdala volume (mm3) × Other/Mixed	0.00	0.00	0.211	0.00	0.00	0.881	-0.00004	0.00006	0.527

*p<0.05 **p<0.01 ***p<0.001

**(a) internalizing problems**

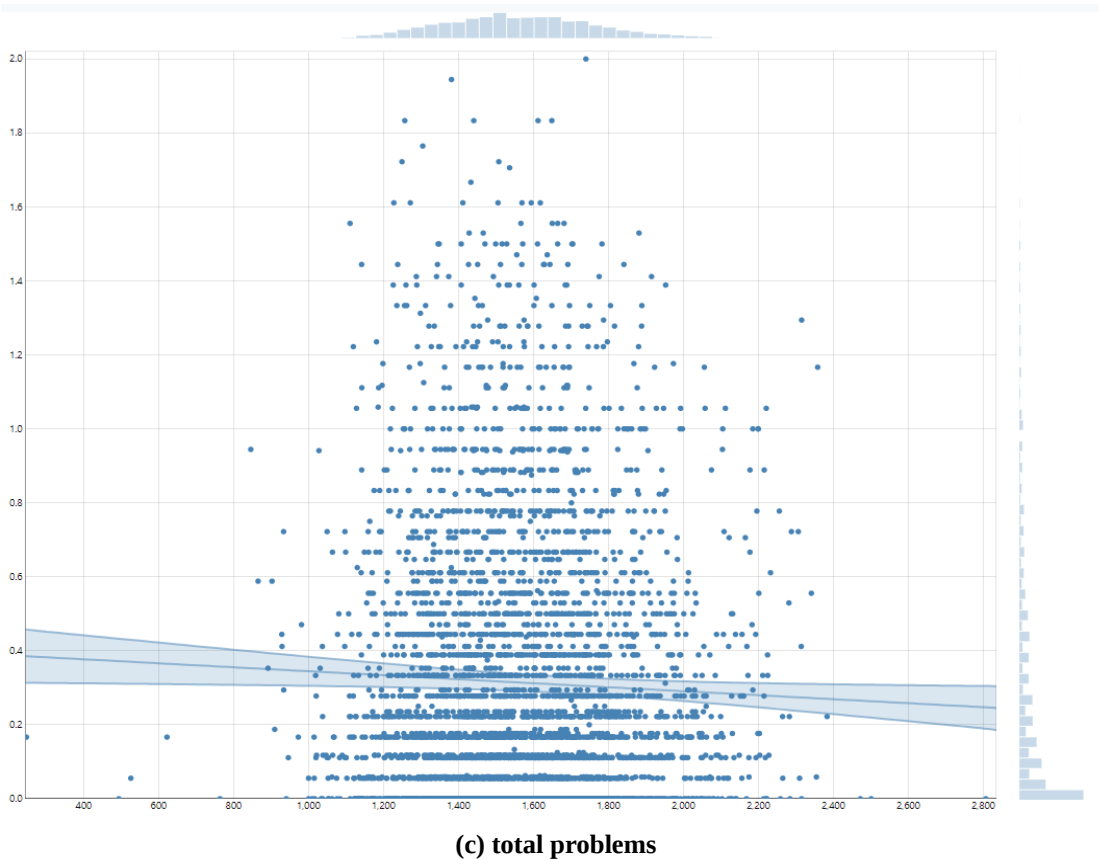
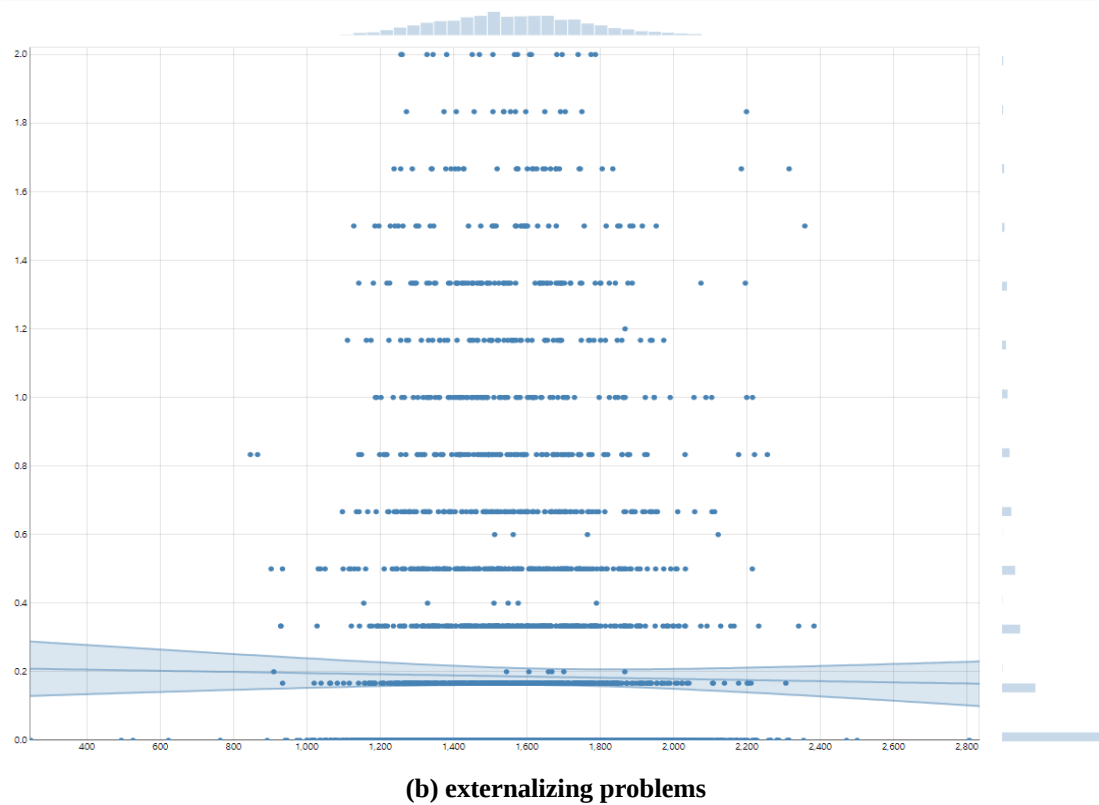
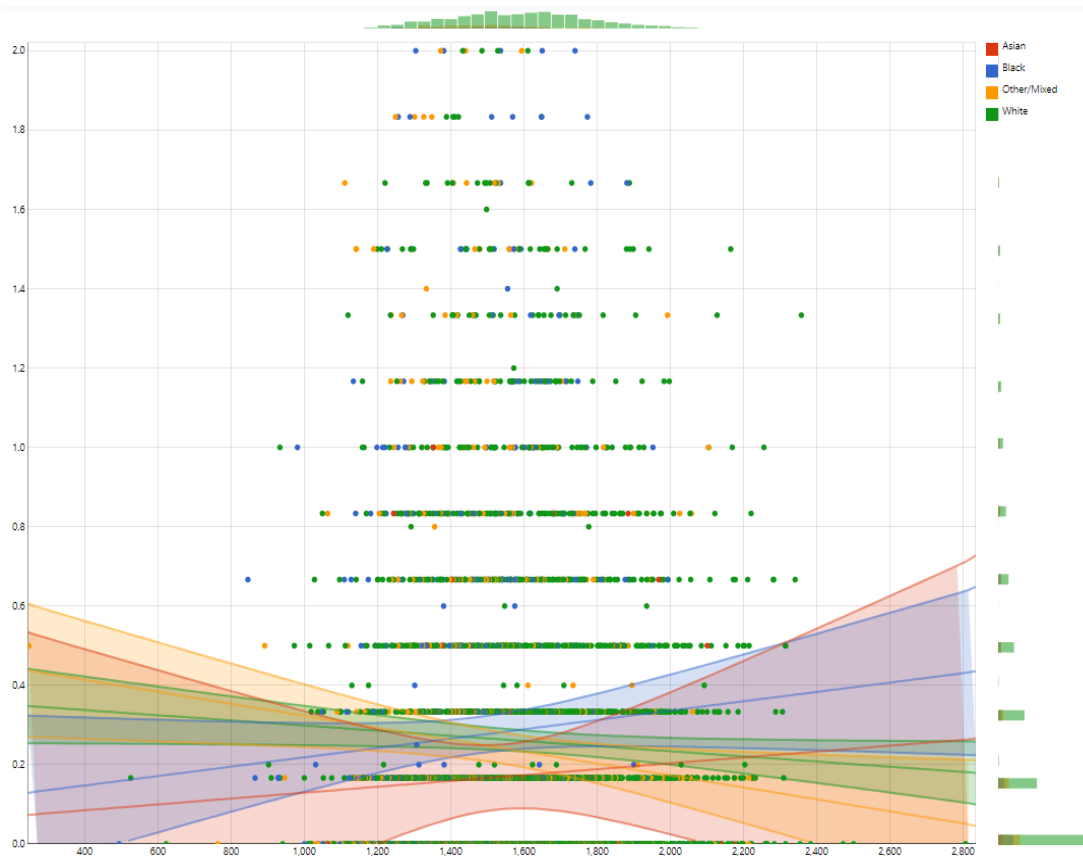
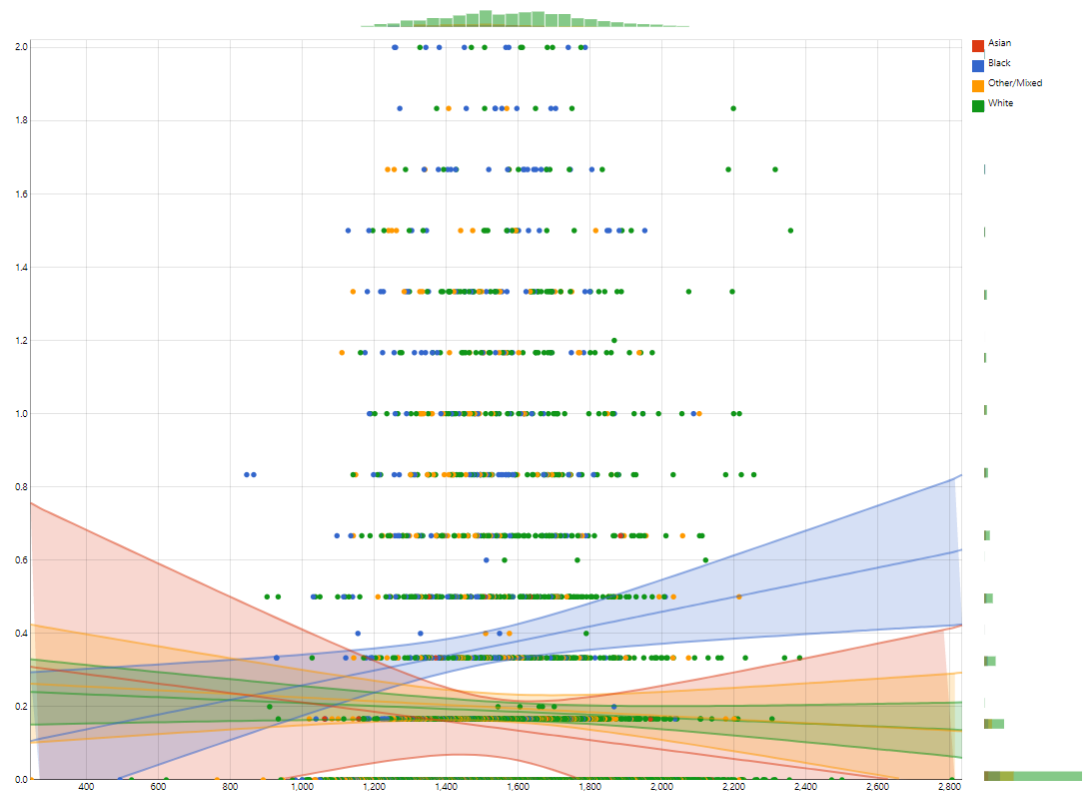


Figure 1. Effects of Amygdala Size on Internalizing (a), Externalizing (b), and Total (c) Problems in the Whole Sample



(b) internalizing problems



(b) externalizing problems

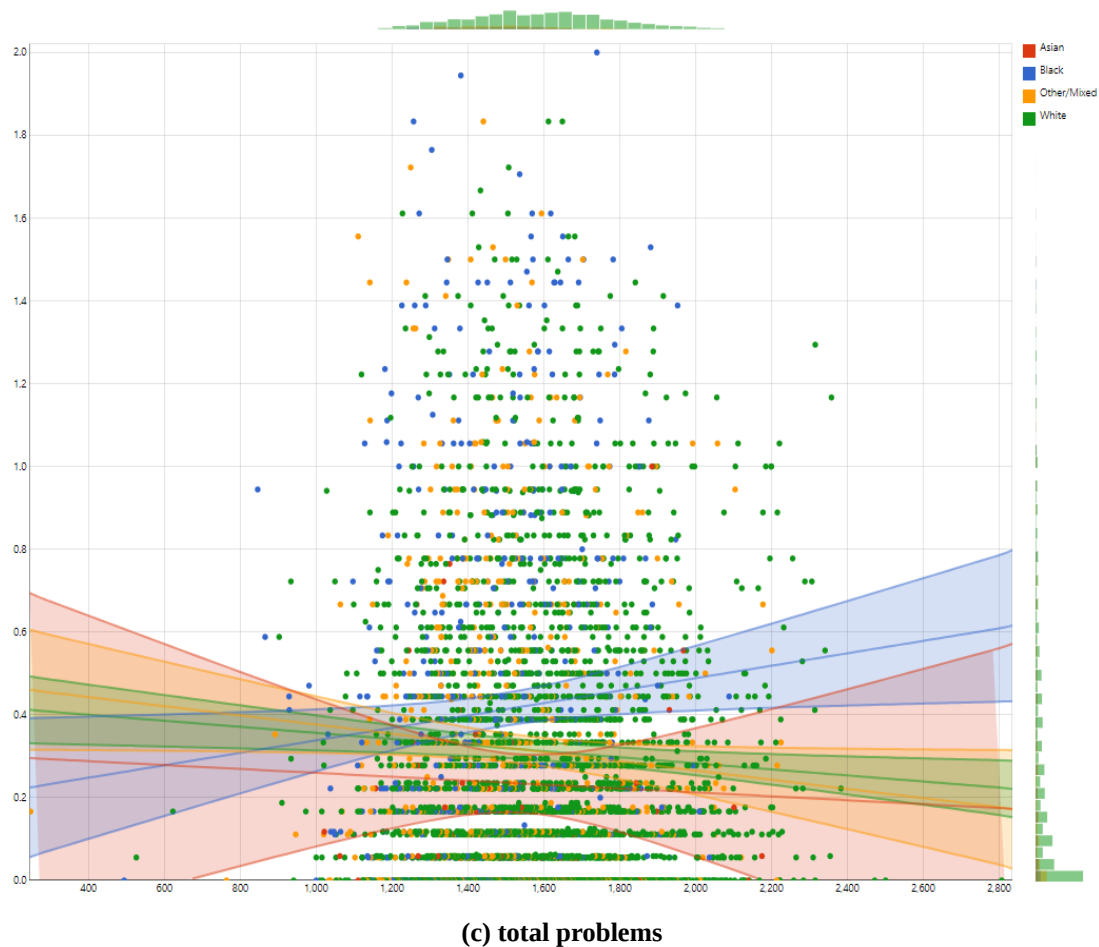


Figure 2. Effects of Amygdala Size on Internalizing (a), Externalizing (b), and Total (c) Problems by Race

4. Discussion

Overall, we found inverse associations between amygdala size and internalizing and overall problem behaviors. However, the amygdala volume's effect was weaker for Black than White children. We found statistical interactions between amygdala size and race on internalizing, externalizing, and overall problems, reflecting Black children's disadvantage relative to White children in gaining behavioral outcomes from their amygdala size.

Our result (interaction) can be explained in two ways. First, we can explain it through the minorities' diminished returns (MDRs) lens. In line with MDRs, due to structural inequalities and school segregation, a large amygdala would result in more favorable behavioral profile of White than Black children. This is because of unequal effects of equal resources across racial groups in the presence of racism (Assari, 2017d; Assari, 2018a). The second explanation is systemic bias of (predominantly non-Black) teachers against Black children: meaning that due to their anti-Black bias, teachers report high behavioral problems in Black children, across all amygdala sizes (behavioral profiles). That means, race may trigger some cues and biases in the teachers, so they do not pay attention to the details of

behavioral profile of the Black child (Assari & Caldwell, 2018c; Chavous, Rivas-Drake, Smalls, Griffin, & Cogburn, 2008). For White children, however, in the absence of such racial bias, teachers behavioral rating of a child reflects child's amygdala size.

We showed that while family SES is controlled, a larger amygdala size was associated with fewer problem behaviors. The effect of SES on brain development is well established (Farah, 2017). Many investigators such as Farah (2017), Noble, Norman and Farah (2005), and Lawson, Duda, Avants, Wu and Farah (2013) have shown an association between SES and various aspects of brain development. For example, Lawson used structural MRI and SES data from a sample of 283 healthy children from the Study of Normal Brain Development and established a positive link between family SES and prefrontal cortical thickness in children. After confounders were controlled and multiple comparisons were adjusted in their study, parental education significantly predicted cortical thickness in the left superior frontal gyrus and right anterior cingulate gyrus. They argue that some cortical changes may mediate (explain) the effects of SES and cognitive function of healthy, typically developing children (Lawson et al., 2013). Sowell has also conducted multiple studies on the developmental change of cortex (Sowell, Thompson, & Toga, 2004; Sowell, Trauner, Gamst, & Jernigan, 2002). Her team has also studied cortical differences that correlate with demographic factors (Sowell et al., 2007), psychopathologies (Sowell et al., 2003) as well as environmental factors (Sowell et al., 2008). Most recently, Sowell used the ABCD data and among 9712 9 and 10-year-old children, showed a stronger negative association of living in high-lead-risk census tracts in children from lower SES families compared to higher SES families. Increased lead exposure was associated with smaller cortical surface area, smaller cortical volume, and lower cognitive test scores, but these associations were larger for needy families. Based on her findings, a change in the lead at the neighborhood level may generate a larger gain in low-SES brain development than high-SES children (Marshall et al., 2020).

Our second finding is that an increase in amygdala size may be associated with a smaller improvement in problem behaviors for Blacks than Whites is an extension of the MDRs literature. Past research using the ABCD data (Assari, 2020c; Assari, Boyce, Akhlaghipour, et al., 2020; Assari, Boyce, Bazargan, & Caldwell, 2020a; Assari, S. Boyce, M. Bazargan, & C. H. Caldwell, 2020), Add Health (Assari, Boyce, Bazargan, Caldwell, & Zimmerman, 2020), FFCWS (Assari, 2019b, 2020b; Assari & Caldwell, 2019; Assari, Caldwell, & Mincy, 2018a; S. Assari, C. H. Caldwell, & R. B. Mincy, 2018b; Assari, Mardani, Maleki, & Bazargan, 2019; Assari, Thomas, Caldwell, & Mincy, 2018), MTF (Assari, Boyce, Bazargan, & Caldwell, 2020b), NSAL (Assari & Caldwell, 2018a), FAS (Assari, Caldwell, & Zimmerman, 2018), and FACHS (Assari, F. X. Gibbons, & R. Simons, 2018a; Assari, F. X. Gibbons, & R. L. Simons, 2018b) have shown a significantly weaker effect of SES indicators such as parental education on various health outcomes for Black than White children. Parental education and household income were both associated with a larger protective effect for depression (Assari & Caldwell, 2018a), and anxiety (Assari, Caldwell, & Zimmerman, 2018), aggression (Assari et al., 2019), tobacco use (Assari, Mistry, et al., 2020), school attachment (Assari, 2019b), school performance (Assari, Boyce, Bazargan, &

Caldwell, 2020b), ADHD (Assari & Caldwell, 2019), impulsivity (Assari, Caldwell, & Mincy, 2018a), inhibitory control (Assari, 2020c), stress (Assari, 2020a; Assari, 2020b), obesity (Assari, Thomas, et al., 2018), physical health (Assari et al., 2019), for White than Black children.

The pattern observed in this paper and the summary provided describe Blacks' Diminished Returns (Assari, 2018a) of SES indicators, defined as systematically smaller protective effects of SES indicators for Black children than White children. However, as the same pattern is shown for Latino (S. Assari et al., 2019), Asian American (Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H. Caldwell, 2020d), and Native American (Assari & Mohsen Bazargan, 2019a) families, it was renamed to Minorities' Diminished Returns. Then as it was also found for LGBT (Assari, 2019a; Assari & M. Bazargan, 2019), immigrant (Assari, 2020b; Assari, 2020e), and even marginalized White families who were living in poor neighborhoods (Assari, Boyce, Bazargan, Caldwell et al., 2020), this pattern is called Marginalization-related Diminished Returns (MDRs) (Assari, Boyce, Bazargan, Caldwell et al., 2020). Based on this model, any social identity, either visible (e.g., race) or invisible (LGBT status), would be associated with diminished SES returns for the participants.

To give examples of MDRs, we have found a higher prevalence of depression in high SES Black children and adults (Assari, 2017c; Assari & Caldwell, 2018a, 2018b; Assari, Gibbons et al., 2018a; Assari, Gibbons et al., 2018b; Assari, Lankarani, & Caldwell, 2018). In Flint Michigan, White children from married families have protected future symptoms of anxiety; however, this was not the case for Black children whose parental marital status does not protect against anxiety symptoms (Assari, Caldwell, & Zimmerman, 2018). In the Fragile Families and Child Wellbeing Study (FFCWS), which followed a sample of Black and White children from birth to age 15, we found that parental education and household income at birth better changed the mental and physical health outcomes of White than Black children when they were 15 years old. For example, while White children with high SES families were protected against ADHD, this protection was statistically smaller for Black families (Assari & Caldwell, 2019). Alternatively, in the Population Assessment of Tobacco and Health (PATH) data, we have found that high SES Black children remain at risk of tobacco use. However, White children with high SES are protected against tobacco use (Assari, Mistry et al., 2020). In the Monitoring the Future (MTF) data, we found the highest GPA in high SES White children. For Black children, however, GPA was staying low even when SES was high (Assari, Boyce, Bazargan, & Caldwell, 2020b). Finally, in the PATH data, we found that high SES White children are protected against aggression, obesity, tobacco use, and chronic disease. For Black children in the PATH data, family SES was not very protective (Assari et al., 2019).

The observed MDRs can be attributed to societal and structural factors such as racism. The MDRs framework argues that structural racism, social stratification, and contextual inequalities are the main reasons individual- and family-level resources and assets show diminishing returns for Black families compared to White families (Assari, 2017d). As long as higher-level barriers hinder Black families, discrimination is rampant (D. L. Hudson, Bullard, et al., 2012; D. L. Hudson, Neighbors, Geronimus, & Jackson, 2012, 2016), and Black families pay extra costs for their upward social mobility (D. Hudson et

al., 2020), individual-level resources and assets (either SES or brain structure) will continue to show smaller protective effects for Black children than White children. In this case, amygdala size shows weaker association with behavioral profile of Black children because Black children experience high levels of stress and discrimination (Assari, 2020a; Assari, 2020b), live in high risk neighborhoods (Assari, Boyce, Caldwell et al., 2020), attend high risk schools (Boyce et al., 2020), and spend time with high risk peers (Boyce et al., 2020) and relatives (Assari, Caldwell et al., 2020). In such context, an individual level factor may operate as a weaker determinant (Assari, 2018a; Assari, 2017d), because every person is at risk, regardless of their resilience or risk factor status.

4.1 Limitations

A few limitations can be listed. This study only investigated correlates of amygdala volume, not other aspects of the amygdala. Amygdala diffusivity (dMRI), function (fMRI), and connectivity (fMRI) with other brain networks also have a role in the behavioral profile of youth. We also investigated the left amygdala without studying the asymmetry between the right and left amygdala.

Any study that investigates race and brain development has the potential to be mis-interpreted. As such, we distant ourselves from any racist interpretation of these results. We do not believe that racial groups are biologically different. We do not study brain structure of racial groups to suggest that one race is superior than the other race. We studied brain structure but we still believe that the observed differences are shaped by social forces that hinder Black communities. Studying mechanisms of social inequalities at the brain/biological level provides more convincing and stronger evidence regarding the deeply interwoven inequalities that are embedded in the US society.

4.2 Future Research

This study only described the existing MDRs without seeking the societal causes of such MDRs. There is a need to conduct more research to test how contextual factors such as racism and segregation result in the observed MDRs, and which social policies can undo their existence. There is a particular need to study to test how these MDRs emerge and their type of neighborhoods. Residential and school segregation, neighborhood SES, crime, peer risk, and other environmental factors may explain MDRs for Black families. Future research may also investigate if multilevel discrimination reduces the benefits of assets for Black children. We also need to replicate these findings across other domains, brain structures, and marginalizing identities. We have shown that these MDRs are not specific to Black but can be seen for other groups based on race (Assari, Boyce, Akhlaghipour, et al., 2020; Assari, Boyce, Bazargan, & Caldwell, 2020a), ethnicity (Assari et al., 2019), nativity (Assari, 2020b), sexuality (Assari, 2019a), and even place (Assari, Boyce, Bazargan, Caldwell, et al., 2020).

4.3 Implications

Under racism, the effect of brain structures such as the amygdala are weaker in Black children than White children, in addition to SES effects. While amygdala volume generates behavioral health outcomes, this effect is weakened in Black children compared to White children. These unequal effects of equal resources in Black people reflect deep structural inequalities in which resources are not enough to

generate outcomes for the historically oppressed group. As such, at the same level of resources, Black children do worse than White children. As a result, to promote brain health equity, eliminating the racial gap in resources may not be enough. It is unknown how residential segregation, labor market discrimination, risk in peers, and quality of schooling and neighborhoods explain why Black children remain at risk of low behavioral and emotional problems regardless of their amygdala. There is also a need to study structural and social factors that cause these MDRs, in addition to public and social policies to reduce such risk for children in middle-class Black families.

5. Conclusion

While larger amygdala size is associated with lower internalizing and overall behavioral problems for children reported by teachers, these effects are weaker for Black children than White children. We not only see MDRs for the effects of SES on the amygdala (Assari, Boyce, & Bazargan, 2020b); we also see MDRs for the effects of the amygdala on behaviors. Thus, MDRs can be seen for the effects of environmental inputs on brain, and also for the effects of brain on behaviors. Our approach to eliminating health and behavioral inequalities requires efforts beyond equalizing resources. As far as racism and segregation exist, resources and assets, including brain structures, show a weaker predictive role for Black families than White families. A true solution to health inequalities includes strategies to reduce racism in the US.

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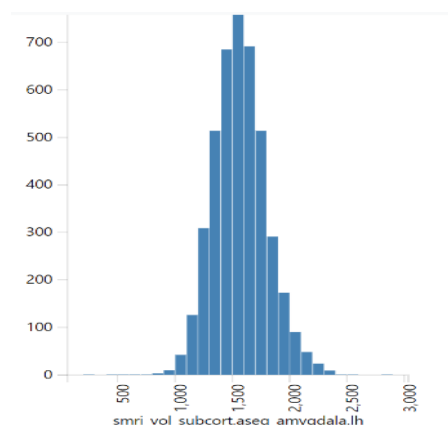
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Appendices

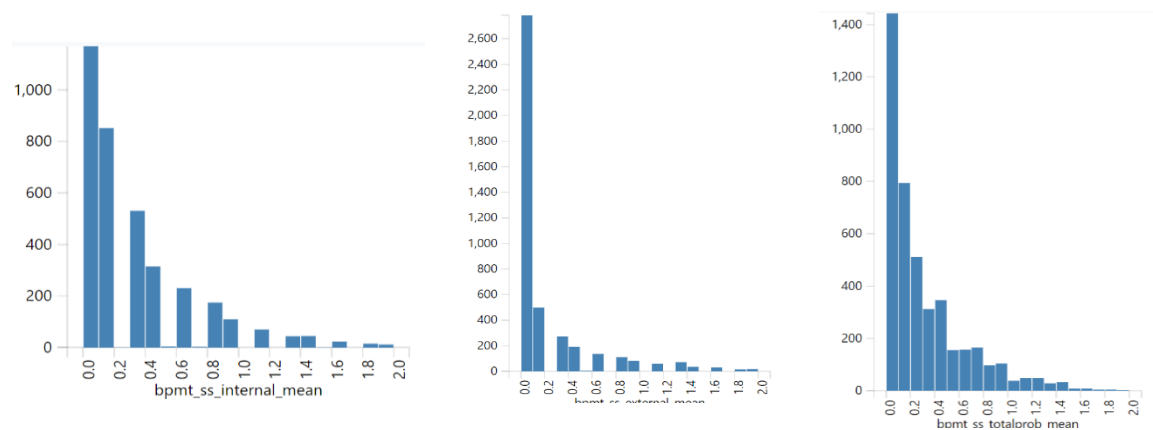


Appendix 1. Distribution of our Predictor (Amygdala Volume)

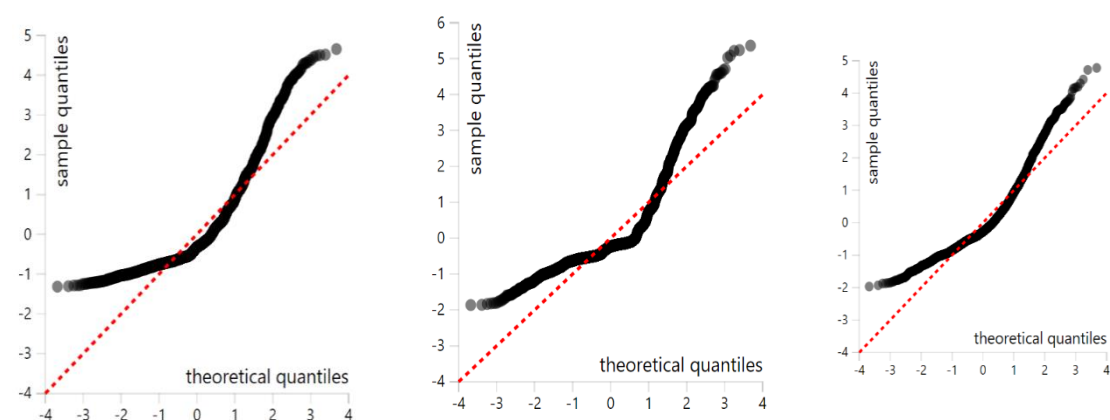
Appendix 2. Variable in this Study

	Role	Type	
Brief Problem Monitoring (BPM) – Internalizing	Outcome	Continuous	bpmt_ss_internal_mean
Brief Problem Monitoring (BPM) – Externalizing	Outcome	Continuous	bpmt_ss_external_mean
Brief Problem Monitoring (BPM) – Total	Outcome	Continuous	bpmt_ss_totalprob_mean
Left Amygdala Volume (sMRI)	Predictor	Continuous	smri_vol_subcort.aseg_amygdala.lh
Race	Moderator	Categorical	race.4level
Parental Education	Covariate	Categorical	high.educ.bl
Age	Covariate	Continuous	Age
Sex	Covariate	Categorical	Sex
Ethnicity (Hispanic)	Covariate	Categorical	hisp

a



b



Appendix 3. Testing Assumptions of our Models. a) Histogram Showing Normal Distribution of our Outcomes, b) and b) Association between Observed and Theoretical Quantiles of our Model

Appendix 4. Mixed-effect Model Formulas in DEAP

Model 1 - Internal

Internalization = Amygdala volume + Race + Sex + Parental Education + Married Family + Age + Hispanic

$\text{bpmt_ss_internal_mean} \sim \text{smri_vol_subcort.aseg_amygdala.lh} + \text{race.4level} + \text{sex} + \text{high.educ.bl} + \text{married.bl} + \text{age} + \text{smri_vol_subcort.aseg_amygdala.lh}$

Model 2 – Internal

Internalizing = Amygdala volume + Race + Sex + Parental Education + Married Family + Age + Hispanic + Amygdala volume x Race

$\text{bpmt_ss_internal_mean} \sim \text{smri_vol_subcort.aseg_amygdala.lh} + \text{race.4level} + \text{sex} + \text{high.educ.bl} + \text{married.bl} + \text{age} + \text{smri_vol_subcort.aseg_amygdala.lh} * \text{race.4level}$

Model 1 - External

Externalization = Amygdala volume + Race + Sex + Parental Education + Married Family + Age + Hispanic

$\text{bpmt_ss_external_mean} \sim \text{smri_vol_subcort.aseg_amygdala.lh} + \text{race.4level} + \text{sex} + \text{high.educ.bl} + \text{married.bl} + \text{age} + \text{smri_vol_subcort.aseg_amygdala.lh}$

Model 2 - External

Externalizing = Amygdala volume + Race + Sex + Parental Education + Married Family + Age + Hispanic + Amygdala volume x Race

$\text{bpmt_ss_external_mean} \sim \text{smri_vol_subcort.aseg_amygdala.lh} + \text{race.4level} + \text{sex} + \text{high.educ.bl} + \text{married.bl} + \text{age} + \text{smri_vol_subcort.aseg_amygdala.lh} * \text{race.4level}$

Model 1 - Total

Total problems = Amygdala volume + Race + Sex + Parental Education + Married Family + Age + Hispanic

$\text{bpmt_ss_totalprob_mean} \sim \text{smri_vol_subcort.aseg_amygdala.lh} + \text{race.4level} + \text{sex} + \text{high.educ.bl} + \text{married.bl} + \text{age} + \text{smri_vol_subcort.aseg_amygdala.lh}$

Model 2 – Total

Total problems = Amygdala volume + Race + Sex + Parental Education + Married Family + Age + Hispanic + Amygdala volume x Race

$\text{bpmt_ss_totalprob_mean} \sim \text{smri_vol_subcort.aseg_amygdala.lh} + \text{race.4level} + \text{sex} + \text{high.educ.bl} + \text{married.bl} + \text{age} + \text{smri_vol_subcort.aseg_amygdala.lh} * \text{race.4level}$

All Models: Random: ~(Site / Family)

Random: $\sim(1|\text{abcd_site}/\text{rel_family_id})$