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Original Paper

Race, Ethnicity, Family Socioeconomic Status, and Children's Hippocampus Volume

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Abstract

Introduction: *The hippocampus has a significant role in memory, learning, and cognition. Although hippocampal size is highly susceptible to family socioeconomic status (SES) and associated stress, very little is known on racial and ethnic group differences in the effects of SES indicators on hippocampus volume among American children.*

Purpose: *This study explored the multiplicative effects of race, ethnicity, and family SES on hippocampus volume among American children.*

Methods: *Using data from the Adolescent Brain Cognitive Development (ABCD), we analyzed the functional Magnetic Resonance Imaging (fMRI) data of 9390 9-10 years old children. The main outcome was hippocampus volume. The predictor was parental education. Subjective family SES was the independent variable. Age, sex, and marital status were the covariates. Racial and ethnic group membership were the moderators. To analyze the data, we used regression models.*

Results: *High subjective family SES was associated with larger hippocampus volume. This effect was significantly larger for Whites than Black families.*

Conclusions: *The effect of subjective family SES on children's hippocampus volume is weaker in Black than White families.*

Keywords

socioeconomic position, socioeconomic factors, brain development, hippocampus, children, fMRI

1. Introduction

High socioeconomic status (SES) (Oshri et al., 2019) protects children against 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 effects are partially attributed to the effects of SES on brain development (Javanbakht et al., 2015; Masten, Telzer, & Eisenberger, 2011; Wu et al., 2015).

The hippocampus is one of the main brain structures that 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 hippocampus, a medial temporal lobe structure, is involved in forming memories (Gerges, Alzoubi, Park, Diamond, & Alkadhi, 2004; Hanson, Chandra, Wolfe, & Pollak, 2011; Narayanan & Chattarji, 2010; Nelson et al., 2003; Zahodne, Schupf, & Brickman, 2018), learning (Chozick, 1983; Fischer, Nyberg, & Backman, 2010; Hair, Hanson, Wolfe, & Pollak, 2015; Hu et al., 2016; Magarinos, Verdugo, & McEwen, 1997), emotions(Chang, Hsiao, Chen, Yu, & Gean, 2015; Pavlova, Savenko, Dyuzhikova, Shiryaeva, & Vaido, 2012; Poeggel et al., 2003), and social relations (Rubin, Watson, Duff, & Cohen, 2014). Altered size and function of the hippocampus is shown in post-traumatic stress disorder (PTSD) (Ahmed-Leitao et al., 2019; Filipovic et al., 2011; Jin et al., 2014; E. J. Kim, Pellman, & Kim, 2015; Lindauer, Olff, van Meijel, Carlier, & Gersons, 2006; Lindauer et al., 2004; Morey, Haswell, Hooper, & De Bellis, 2016), depression (Andrus et al., 2012; Dore et al., 2018; Lu, Ho, McIntyre, Wang, & Ho, 2018), and drug use (G. I. Gomez et al., 2018; R. Gomez et al., 2015; Hablitz, 1986; Summa et al., 2015; L. Wang et al., 2015). Some research suggests that altered hippocampus structure and function may partially mediate the effect of high family SES on brain development and function, such as learning and memory (Hair et al., 2015; Hanson et al., 2015; 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 (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 amygdala structure and function (Evans et al., 2016; Javanbakht et al., 2016; Javanbakht et al., 2015; Kimberly G Noble et al., 2015). While 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 amygdala for Black than White children (Assari, Boyce, & Bazargan, 2020b). However, less is known on group differences in the effect of SES on hippocampus volume (Baxendale & Heaney, 2011; Hair et al., 2015; Hanson et al., 2011; Hanson et al., 2015; Lawson et al., 2017; K. G. Noble et al., 2015; Noble et al., 2012; Y. Wang et al., 2016).

Most previous studies have investigated the effects of SES markers such as household income (Kimberly G Noble et al., 2015), poverty (Kimberly G Noble et al., 2015), parental educational attainment (Assari, 2020; Assari, Boyce, Akhlaghipour, Bazargan, & Caldwell, 2020; Assari, Boyce, Bazargan, & Caldwell, 2020), and neighborhood income (Jenkins et al., 2020; Parker et al., 2017; Willis et al., 2014)on children’s brain function. However, all these SES indicators are objective measures and do not reflect the perception of the relative social standing of the family. Subjective family SES may reflect aspects of SES that are not reflected by education, employment, income, and poverty status. According to one study, subjective family SES increased individuals’ vulnerability to stress for racial and ethnic minority families (Assari, Preiser, Lankarani, & Caldwell, 2018).

There is a need to test the additive and multiplicative effects of race, ethnicity, and family SES on brain development. As race, ethnicity, and family SES have close overlap (Kaufman, Cooper, & McGee, 1997), family SES may explain why race and ethnicity impact 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 and ethnic 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 and Latino than non-Latino 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, not much research is done on the additive effects of race, ethnicity, and family SES on hippocampus volume.

1.1 Aims

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) to compare racial and ethnic groups for the effects of subjective family SES on hippocampus volume. We tested additive and multiplicative effects of race, ethnicity, and subjective family SES on hippocampus 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 ABCD study (Alcohol Research: Current Reviews Editorial, 2018; Casey et al., 2018; Karcher et al., 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 determined to be non-human subject research by 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 9390 non-Latino or Latino White or Black 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, subjective family SES, and hippocampus volume.

2.4 fMRI 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.

2.5 Variables

The outcomes were right and left hippocampus size. We operationalized this variable as a continuous measure. We selected hippocampus volume as the outcome because adversities, poverty, economic hardship, stress, trauma, and SS all influence hippocampus function and size (Barch et al., 2016; Calem, Bromis, McGuire, Morgan, & Kempton, 2017; Hanson et al., 2011; Jenkins et al., 2020; Johnson et al., 2016; Luby et al., 2013; McLean et al., 2012; K. G. Noble et al., 2015; Y. Wang et al., 2016).

Subjective Family SES. The independent variable was subjective family SE*S*, measured by the following seven items: "In the past 12 months, has there been a time when you and your immediate family experienced any of the following": 1) "Needed food but could not afford to buy it or could not afford to go out to get it?", 2) "Were without telephone service because you could not afford it?" 3) "Did not pay the full amount of the rent or mortgage because you could not afford it?", 4) "Were evicted from your home for not paying the rent or mortgage?", 5) "Had services turned off by the gas or electric company, or the oil company would not deliver oil because payments were not made?", 6) "Had someone who needed to see a doctor or go to the hospital but did not go because you could not afford it?" and 7) "Had someone who needed a dentist but could not go because you could not afford it?" Responses were either 0 or 1. We calculated an average score with a potential range between 0 and 1—a score of 1 indicating highest possible subjective family SE*S*. Our variable was a continuous variable (Assari, Preiser, et al., 2018; Assari, Smith, Mistry, Farokhnia, & Bazargan, 2019; Boe, Petrie, Sivertsen, & Hysing, 2019; Chen & Paterson, 2006; Moon, 1987; Wright & Steptoe, 2005; Ye, Wen, Wang, & Lin, 2020).

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

Sex. A dichotomous variable, *s*ex was coded as male = 1 and female = 0.

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

Race. Race was a self-identified variable: Blacks = 1, Whites = 0.

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

2.6 Data Analysis

We started our data analysis by describing our study variables, using mean (SD) and frequency tables (%). Then we calculated Pearson correlation to explore bivariate associations between our study variables. To perform multivariable analyses, two regression models were run. The first model did not include race/ethnicity by SES interactions. Model 2 did include such interactions. In the first step, we ruled out collinearity between study variables. We also tested the distribution of our outcome variables and error terms (residuals). The predictor variable was *s*ubjective family SE*S*. The outcome was hippocampus volume. Confounders included race, ethnicity, sex, age, and parental marital status. Moderators were race and ethnicity. Regression coefficient, standard errors (SEs), confidence intervals (CIs), t-values, and p-values were reported. A p-value of less than 0.05 was significant. To perform our data analysis, we used SPSS.

3. Results

3.1 Descriptives

This secondary analysis included 9390 9-10 years old children. From all of the participants, 23.5% were Black and 17.1% were Latino. Table 1 shows the summary statistics of the study variables in the overall sample.

Table 1. Descriptive Statistics of the Sample (*n* = 9390)

	n	**%**
Race		
White	7185	76.5
Black	2205	23.5
Ethnicity		
Non-Latino	7787	82.9
Latino	1603	17.1
Sex		
Male	4446	47.3
Female	4944	52.7
Marital status		
Not- Married	2475	26.4
Married	6854	73.0
	Mean	**SD**
Age (yars)	9.46	0.50
Subjective family SES (0-1)	0.93	0.16
Right hippocampus volume(mm3)	4089.82	432.45
Left hippocampus volume(mm3)	4045.69	438.70

3.2 Bivariate Correlations

Table 2 provides bivariate correlations between all study variables. This study shows a positive and significant bivariate correlation between subjective family SES and right and left hippocampus volumes.

Table 2. Bivariate Correlations (*n* = 9390)

	1	2	3	4	5	6	7	8
1 Race (Black)	1.00	-0.12**	-0.02	0.00	-0.38**	-0.27**	-0.22**	-0.19**
2 Ethnicity (Latino)		1.00	-0.01	-0.02	-0.04**	-0.07**	-0.04**	-0.07**
3 Sex (Male)			1.00	0.02	0.01	-0.01	0.30**	0.29**
4 Age				1.00	0.00	0.02	0.06**	0.06**
5 Family Marital Status (Maried / Partnered)					1.00	0.27**	0.14**	0.12**
6 Subjective Family SES						1.00	0.13**	0.12**
7 Right Hippocampus Volume (mm3)							1.00	0.83**
8 Left Hippocampus Volume (mm3)								1.00

*p<0.05, **p<0.01

3.3 Right hippocampus Volume

Table 3 shows the results of regression models in the total sample with right hippocampus volume as the outcome. Subjective family SES was positively associated with right hippocampus volume, net of confounders. This effect was significantly larger for Whites than Black families, documented by a significant interaction between race and subjective family SES on right hippocampus volume. Although the interaction between ethnicity and subjective SES was also in the same direction, it only approached significance but was not statistically significant.

Table 3. Regressions in the Overall Sample with Right Hippocampus Volume as the Outcome (*n* = 9390)

	Model 1						Model 2					
	b	SE	95% CI		t	P	b	SE	95% CI		t	p
Race (Black)	-194.64	10.95	-216.10	-173.18	-17.78	<.001	-28.49	51.63	-129.69	72.71	-0.55	.581
Ethnicity (Hispanic)	-57.84	11.18	-79.76	-35.92	-5.17	<.001	59.74	64.03	-65.76	185.25	0.93	.351
Sex (Male)	251.48	8.30	235.21	267.76	30.29	<.001	251.56	8.30	235.29	267.82	30.31	<.001
Age	44.77	8.25	28.61	60.93	5.43	<.001	44.57	8.24	28.41	60.72	5.41	<.001
Married / Partnered	41.73	10.32	21.49	61.96	4.04	<.001	40.02	10.33	19.76	60.28	3.87	<.001
Subjective family SES	151.41	26.90	98.67	204.15	5.63	<.001	259.12	41.79	177.20	341.04	6.20	<.001
Subjective family SES × Race (Black)	-	-	-	-	-		-182.89	55.80	-292.27	-73.51	-3.28	.001
Subjective family SES × Ethnicity (Hispanic)	-	-	-	-	-		-124.51	68.31	-258.41	9.38	-1.82	.068

Outcome: Right Hippocampus Volume (mm3); SES: Socioeconomic Status

3.4 Left Hippocampus Volume

Table 4 shows the results of regression models in the total sample with left hippocampus volume as the outcome. Subjective family SES was positively associated with left hippocampus volume, net of confounders. This effect was significantly larger for White than Black families, documented by a significant interaction between race and subjective family SES on left hippocampus volume. Although the interaction between ethnicity and subjective SES was also in the same direction, it only approached significance but was not statistically significant.

Table 4. Regressions in the Overall Sample with Left Hippocampus Volume as the Outcome (*n* = 9390)

	Model 1						Model 2					
	b	SE	95% CI		t	P	b	SE	95% CI		t	p
Race (Black)	-167.48	11.20	-189.42	-145.53	-14.96	<.001	-61.64	52.82	-165.17	41.90	-1.17	.243
Ethnicity (Hispanic)	-86.25	11.44	-108.67	-63.83	-7.54	<.001	36.33	65.51	-92.07	164.74	0.55	.579
Sex (Male)	249.40	8.49	232.76	266.05	29.37	<.001	249.45	8.49	232.81	266.09	29.38	<.001
Age	46.65	8.43	30.12	63.18	5.53	<.001	46.52	8.43	30.00	63.05	5.52	<.001
Married / Partnered	44.59	10.56	23.90	65.29	4.22	<.001	43.17	10.57	22.44	63.90	4.08	<.001
Subjective family SES	140.83	27.52	86.89	194.78	5.12	<.001	219.75	42.76	135.94	303.56	5.14	<.001
Subjective family SES x Race (Black)	-	-	-	-	-	-	-115.75	57.09	-227.66	-3.84	-2.03	.043
Subjective family SES x Ethnicity (Hispanic)	-	-	-	-	-	-	-131.22	69.89	-268.22	5.77	-1.88	.060

Outcome: Left Hippocampus Volume (mm3); SES: Socioeconomic Status

4. Discussion

While higher subjective family SES was associated with larger hippocampus volume, this effect was larger for White than Black families.

Barch et al. (2016) conducted a study and showed a link between family SES (i.e., childhood poverty) and reduced hippocampus connectivity with many brain regions and structures. The study also showed a link between family SES (poverty) and reduced functional brain connectivity between several brain regions and the hippocampus. The study also showed that the brain connectivity between the hippocampus and other brain regions might mediate the effect of childhood SES (poverty) on children’s depression.

High family SES is also a proxy of higher quantity and quality of 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.

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

We found that race, ethnicity, and subjective family SES have additive and multiplicative effects. As a result, low SES Black children are at the highest risk. As small hippocampus 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 hippocampus 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 social and economic policy on how to reduce racial and ethnic inequalities in brain development. The results of such investigations may direct us to how we can promote brain health equity through enhancing social justice across diverse social, economic, racial, and ethnic groups.

Our study findings suggested a major risk for both high and low- SES Black and Latino children. For White and non-Latino children, low SES is a risk factor, and high SES is a protective factor. For Black and Latino children, however, both those from low SES or high SES backgrounds remain at a similarly high risk in terms of small hippocampus volume. The smaller protective effects of SES for Blacks and Latinos may be due to the aspects of race and ethnicity that are not due to SES. These maybe because of race-and ethnicity related stressors like racism and discrimination, segregation, and blocked opportunities. Racial discrimination, stress, trauma, and adversities have all been shown to impact the hippocampus of Blacks and Latinos across all SES levels (Moadab, Bliss-Moreau, Bauman, & Amaral, 2017; Thames et al., 2018; Tottenham & Sheridan, 2009). The same may hold for other brain regions as well (Clark, Miller, & Hegde, 2018). Race, ethnicity, and SES have multiplicative and complex effects as social determinants of hippocampus activity. Thus, programs and interventions should be in place to alleviate the risk and promote brain development of low SES Black children. Early childhood programs and after school programs schools have received attention as programs effective at 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.

4.1 Limitations

To list the main methodological limitations, first, we should refer to the cross-sectional design of this investigation. As a result of this study's cross-sectional design, no causal associations can be made between subjective family SES and hippocampus volume. Second, we only studied one SES indicator, and several other indicators, such as income, employment, and social class were not included. We also described differential effects of SES and did not investigate how adversities, stress, neighborhood factors, and social context could explain such differential returns. Future research should investigate how contextual and environmental factors such as racial and ethnic density, similarity index, toxin exposure, and density of poverty and crime cause the observed MDRs.

4.2 Conclusions

In summary, high subjective family SES correlates with larger right and left hippocampus volume in a national sample of American children. However, these effects are weaker for Black than White families. These results are in line with Minorities Diminished Returns (MDRs), suggesting that under racism, SES is less protective for racial minority groups, particularly Blacks.

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