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Original Paper

Nucleus Accumbens Functional Connectivity with the Default Mode Network: Black Children's Diminished Returns of Household Income

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Abstract

Introduction: *Although research has established a link between socioeconomic status (SES) and neuroimaging measures, weaker SES effects are shown for Blacks than Whites. This is, in part, due to processes such as stratification, racism, mineralization, and othering of Black people in the US.* **Purpose:** *This study had two aims: First, to test the association between household income and the nucleus accumbens (NAcc) resting-state functional connectivity with the Default Mode Network (DMN) in children; and second, to investigate racial heterogeneity in this association.* **Methods:** *This cross-sectional study used data from the Adolescent Brain Cognitive Development (ABCD) study. We analyzed the resting-state functional connectivity data using Magnetic Resonance Imaging (rsfMRI) of 7903 US pre-adolescents who were between 9 and 10 years old. The main outcome was the NAcc resting-state functional connectivity with DMN. The independent variable was household income. Age, sex, and family structure were the study covariates. Race was the moderator. Mixed-effects regression models were used for data analysis with and without interaction terms between household income and race.* **Results:** *Higher household income was associated with higher NAcc resting-state functional connectivity with DMN. Race showed a statistically significant interaction with household income, suggesting that the NAcc resting-state functional connectivity with DMN was significantly weaker for Black compared to White pre-adolescents.* **Conclusions:** *In line with Minorities' Diminished Returns (MDRs), the association between household income and pre-adolescents' NAcc resting-state functional connectivity with DMN is weaker in Black than in White children. This result is of interest because*

DMN's functional connectivity with NAcc may have a role in cognitive flexibility and reward processing. The weaker links between SES indicators and neuroimaging findings for Blacks than for Whites may reflect the racialization of Black people in the US. Social stratification, racism, and discrimination may minimize the returns of SES for Black families, who have been oppressed for centuries.

Keywords

socioeconomic status, household income, brain development, youth, pre-adolescents, MRI, functional MRI, functional connectivity

1. Introduction

Nucleus accumbens (NAcc), a component of the ventral striatum and basal ganglia, is the main element of brain reward processing (Cho et al., 2019; Morales et al., 2019; Oginsky & Ferrario, 2019; Tronnier et al., 2018; Wei et al., 2019). This structure is involved in reward systems as well as cognitive function. A wide range of NAcc connections with other brain structures and networks have implications for cognitive function and reward processing (Alonso-Caraballo et al., 2020; S. Assari, S. Boyce, & M. Bazargan, 2020; Costall, Naylor, Cannon, & Lee, 1977; Rapuano et al., 2020; Waeiss, Knight, Engleman, Hauser, & Rodd, 2020).

Resting-state functional connectivity between NAcc and default mode network (DMN) is believed to have a role in cognitive flexibility and reward processing (Vatansever, Manktelow, Sahakian, Menon, & Stamatakis, 2016). Cognitive flexibility is defined as the brain's ability to shift attention to select behaviorally relevant stimuli in a given context (Vatansever et al., 2016). Impairment in cognitive flexibility is linked to schizophrenia and Parkinson's disease, which are recognized by significantly altered neurotransmitter systems of the brain (Vatansever et al., 2016). Altered cognitive flexibility can be measured through various tasks, including but not limited to intra/extra-dimensional (IED) set-shifting task. It is suggested that the connections between NAcc and DMN may contribute to this function. More specifically, parts of the DMN, namely the medial prefrontal and posterior cingulate/precuneus cortices, connectivity with the NAcc and striatum at rest correlate with fewer total adjusted errors during the attention shift. As such, the DMN – NAcc resting-state connectivity is believed to be essential for the adaptive nature of human cognition (Vatansever et al., 2016).

Advancement of neuroimaging modalities, such as resting-state functional magnetic resonance imaging (rsfMRI), has led to the advancement of our understanding regarding children's brain development (Ehrler, Latal, Kretschmar, von Rhein, & Tuura, 2020; Lei et al., 2015; Mueller, Lim, Hemmy, & Camchong, 2015), and how socioeconomic status (SES) indicators influence children's brain development (Agorastos, Pervanidou, Chrousos, & Kolaitis, 2018; Basmacı Kandemir et al., 2016; Butler, Yang, Laube, Kühn, & Immordino-Yang, 2018; Di Segni, Andolina, & Ventura, 2018). Several rsfMRI indicators, such as those between NAcc and DMN, may correlate with various higher-level cognitive functions of children, including but not limited to memory, learning, and executive function (Sowell et al., 2003). Altered rsfMRI measures reflect a wide range of cognitive disorders, such as schizophrenia (Zhou et al., 2008), ADHD (Tian et al., 2006), PTSD (Rabinak et al., 2011), depression (Mulders, van Eijndhoven, Schene, Beckmann, & Tendolkar, 2015), and learning disorder (Banker et al., 2021).

Socioeconomic status (SES) indicators such as household income are linked to functional connectivity of brain structures and networks such as NAcc and DMN (Rakesh, Zalesky, & Whittle, 2021), which correlate with various aspects of emotional and cognitive development in domains, such as language, learning, reward process, and cognitive function (Ystad, Eichele, Lundervold, & Lundervold, 2010). High SES is a proxy of high-quality parenting and lower exposure to stress and poverty, which interfere with healthy brain development (Yaple & Yu, 2020). High household income is commonly linked to high parenting quality (Lugo-Gil & Tamis-LeMonda, 2008) and cognitively stimulating environments (Golinkoff, Hoff, Rowe, Tamis-LeMonda, & Hirsh-Pasek, 2019). High household income is also linked to the child's availability of material and financial resources (Shervin Assari & Shanika Boyce, 2021).

Recent research, however, has suggested that SES indicators such as family income may have weaker effects on the brain development of Black than White children, in part due to racism and discrimination against Black people. Black and other racial and ethnic minority groups may earn access to fewer services for the very same income (Shervin Assari, Caldwell, & Bazargan, 2019). Marmot has mentioned that, while having money is important, how much services this money can buy for each population is also critical (Marmot, 2015). As a result, the health effects of the same money may vary for different populations and contexts (Shervin Assari, 2020a; Shervin Assari, Boyce, Caldwell, Bazargan, & Mincy, 2020; S. Assari & S. Islam, 2020). Black families with high income are more likely to be discriminated against (S. Assari, 2018). Similarly, Black families with the same income have less wealth than White families with a similar income (Shervin Assari, 2020b). Additionally, household income and other SES indicators may generate fewer cognitive and emotional outcomes for Blacks than Whites (Shervin Assari, 2020c; Shervin Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H Caldwell, 2020; Shervin Assari et al., 2019). However, some studies suggest that, while parental education generates unequal outcomes across racial groups, income is the SES indicator that generates the most equal outcomes compared to other SES indicators, such as parental education (Shervin Assari & Shanika Boyce, 2021).

According to the Marginalization-related Diminished Returns (MDRs) framework (Shervin Assari, 2018, 2020c), SES effects, including the effects of household income, on developmental, behavioral, and health outcomes are weaker for racial minority families, particularly Blacks, compared to Whites. These MDRs are believed to be due to discrimination, racism, racialization, stratification, othering, and marginalization of populations of color (Shervin Assari & Shanika Boyce, 2021). Weaker effects of SES indicators are shown for depression (Shervin Assari & Caldwell, 2018), attention (Shervin Assari, Shanika Boyce, & Mohsen Bazargan, 2020), impulse control (S. Assari, C. H. Caldwell, & M. A. Zimmerman, 2018), social and behavioral problems (Shervin Assari, Boyce, Caldwell, & Bazargan, 2020; Boyce, Bazargan, Caldwell, Zimmerman, & Assari, 2020), inhibitory control (Shervin Assari &

Sondos Islam, 2020), suicidality (Shervin Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H. Caldwell, 2020), anxiety (S. Assari & Jeremiah, 2018), and attention deficit hyperactivity disorder (ADHD) (Shervin Assari & Cleopatra Howard Caldwell, 2019) for Black than White children. As a consequence of these MDRs, we observe sustained developmental disparities in Black children across SES levels (Noble et al., 2015). To our knowledge, however, very few studies have examined the relationship between household income and pre-adolescents' resting-state functional connectivity between brain networks across racial groups (S. Assari & S. Boyce, 2021; S. Assari et al., 2020).

Among various functional connectivity measures evaluated by rsfMRI that are linked to SES, is connectivity between NAcc and DMN (Rakesh et al., 2021). Analysis of connectivity between DMN and brain regions such as NAcc is important, because they reflect cross-system-level measures and are involved in higher-order brain function. As such, NAcc-DMN functional connectivity may reflect some of the coordinated multi-system cognitive, emotional, and behavioral tasks across multiple regions and networks. NAcc resting-state functional connectivity with DMN may correlate with altered cognition, emotions, and psychiatric disorders (Karcher, O'Brien, Kandala, & Barch, 2019; Smallwood et al., 2021).

1.1 Aims

Built on the MDRs, this study used data of a national sample of 9-to-10-year-old pre-adolescents from the Adolescent Brain Cognitive Development research (ABCD) data (B. Casey et al., 2018; Karcher et al., 2019; Lisdahl et al., 2018; Luciana et al., 2018; Research & Staff, 2018) for two aims: First, to test the association between household income and NAcc resting-state functional connectivity with DMN; and second, to explore racial heterogeneity in this association. We expected a positive association between household income and NAcc resting-state functional connectivity with DMN. Additionally, in line with the MDRs theory (Shervin Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H Caldwell, 2020; Boyce et al., 2020), we expected weaker effects of household income on NAcc resting-state functional connectivity with DMN for Black pre-adolescents compared to White pre-adolescents.

2. Methods

2.1 Design and Settings

This secondary cross-sectional analysis was based on the Adolescent Brain Cognitive Development (ABCD) study (B. Casey et al., 2018; Karcher et al., 2019; Lisdahl et al., 2020; Luciana et al., 2018; Research & Staff, 2018), the largest child brain development study ever, with a diverse sample in terms of SES, sex, race and ethnicity (Auchter et al., 2018; Research & Staff, 2018). Detailed information regarding ABCD methods is available here (Auchter et al., 2018).

2.2 Participants and Sampling

The ABCD study participants were 9 to 10 years old and were selected from 21 sites across 15 states, encompassing over 20 % of the total United States population of 9/10-year-old children (Auchter et al., 2018; Garavan et al., 2018). For sampling and selection, school selection was informed by sex, race, ethnicity, SES, and urbanicity. These recruitment processes were precisely designed, implemented, and evaluated across the 21 study sites (Ewing, Bjork, & Luciana, 2018). Although the ABCD sample is not representative, the sample is a near approximation of U.S. children (Garavan et al., 2018). Participants, 7903 children aged 9-to-10-year-olds, could be included regardless of race and ethnicity (Garavan et al., 2018). They needed to have complete data on our variables and meet satisfactory criteria for rsfMRI (according to the DEAP baseline data).

2.3 Process

Brain Imaging:

Functional MRI (rsfMRI) was used to estimate pre-adolescents' NAcc resting-state (task-negative) functional connectivity with DMN. Brain imaging in the ABCD study was based on three 3 tesla (T) scanner platforms: Philips Healthcare, GE Healthcare, and Siemens Healthcare (Hagler Jr et al., 2019). T1-weighted and T2-weighted brain images, carefully harmonized, were drawn from the MRI devices (B. Casey et al., 2018). In order to reduce bias due to variation in imaging sites, images were corrected for gradient non-linearity distortions (Jovicich et al., 2006). Pre-processed structural data are available from the ABCD study, and are calculated based on T1- and T2-weighted images that maximize mutual information's relative position and orientation across images (Wells III, Viola, Atsumi, Nakajima, & Kikinis, 1996). By using tissue segmentation and sparse spatial smoothing, the ABCD study performed intensity non-uniformity correction. Moreover, the images have been resampled with 1-mm isotropic voxels into rigid alignment within the brain atlas. Furthermore, using FreeSurfer software, version 5.3.0 (Harvard University), these volumetric measures were constructed. The images have also undergone surface optimization (Fischl & Dale, 2000; Fischl, Sereno, & Dale, 1999), and nonlinear registration to a spherical surface-based atlas (Fischl et al., 1999).

2.4 Study Variables

The study variables included household income (independent variable), race (moderator), age, sex, and family structure (confounders), and NAcc resting-state functional connectivity with DMN (dependent variable).

Independent Variable:

Household income: Household income was a three-level nominal variable: less than 50k, 50-100k, and 100k+ per year. Household income less than 50k was the reference group.

Dependent Variable:

NAcc resting-state functional connectivity with DMN: This variable was a continuous measure and reflected the Pearson correlation test between the BOLD measures of the two networks over time. DMN was defined according to the Gordon parcellation scheme that divides brain networks into 12 predefined resting state networks (RSN) (Gordon et al., 2016). In this study, we only used data of DMN, not the other 11 brain networks. To calculate this information, the ABCD completed 4–5 five-minute resting state scans (eyes open). This was used to ensure at least eight minutes of relatively low-motion data. More details are explained here (Hagler et al., 2019). Preprocessing was carried out by the ABCD Data Analysis and Informatics Core using the standardized ABCD pipeline (Hagler et al., 2019). Next, fMRI time courses were projected onto FreeSurfer's cortical surface. Using these time courses, within- and between-network connectivity (Pearson correlation) were calculated on the basis of standard protocols based on the Gordon scheme (Gordon et al., 2016). For more information regarding these processes, please see here (B. J. Casey et al., 2018; Hagler et al., 2019). Family SES is shown to be correlated with rsfMRI of the DMN (Karcher et al., 2019). Our outcome was associated with a wide range of cognitive measures as an indicator of validity of our measure (**Supplementary Figure**).

Moderator:

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

Confounders:

Age. Age was a continuous variable. Parents reported the child's age as months.

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

Family Structure. Family Structure was also a dichotomous variable, self-reported by the parent interviewed, and coded 1 vs. 0 for married and unmarried (any other condition).

2.5 Data Analysis

We used the Data Exploration and Analysis Portal (DEAP), which is a user-friendly online platform for multivariable analysis of the ABCD data, for data analysis. For multivariable analyses, two mixed-effects regression models were estimated (**Supplementary Table**). *Model 1* tested the additive effects of household income, race, and covariates. *Model 2* also included interaction terms between household income and race. In all models, the NAcc resting-state functional connectivity with DMN was the outcome. Regression coefficient (b), standard error (SE), and p-value were reported from our regression models.

2.6 Ethical Aspect

While the original ABCD research protocol went through an Institutional Review Board (IRB) in several institutions, including the University of California, San Diego (UCSD), our analysis was found to be exempt from further IRB review by the Charles R Drew University of Medicine and Science (CDU). Moreover, several institutional IRBs approved the study protocol. All children provided assent. Parents provided consent (Auchter et al., 2018).

3. Results

This study was performed on 7903 children aged between 9 to 10 years old. From this number, almost half were male, and almost half were female. From all participants, 5416 (68.5%) were White, 1034 (13.1%) were Black, 160 (2.0%) were Asian American, and 1293 (16.4%) were other/mixed race. Racial groups did not differ in age. However, they did differ in sex. Black and mixed/other race participants showed the lowest household income compared to White children. Racial groups also varied in family structure. Additionally, NAcc resting-state functional connectivity with DMN was significantly different across racial groups (**Table 1**).

Table 1. Descriptive Characteristics Overall and by Race (n = 7903)

Level	Overall	White	Black	Asian	Other/Mixed	p
N	7903	5416	1034	160	1293	
	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	
Age (month)	119.40 (7.54)	119.46 (7.55)	119.33 (7.26)	119.93 (8.13)	119.15 (7.62)	0.446
Functional Connectivity between NAcc and DMN	0.07 (0.19)	0.08 (0.18)	0.03 (0.24)	0.08 (0.18)	0.07 (0.19)	< 0.001
	n(%)	n(%)	n(%)	n(%)	n(%)	p
Household income						
< 50K	2107 (26.7)	934 (17.2)	670 (64.8)	22 (13.8)	481 (37.2)	< 0.001
> =50K& < 100K	2302 (29.1)	1665 (30.7)	232 (22.4)	38 (23.8)	367 (28.4)	
> =100K	3494 (44.2)	2817 (52.0)	132 (12.8)	100 (62.5)	445 (34.4)	
Sex						
Female	3986 (50.4)	2678 (49.4)	547 (52.9)	95 (59.4)	666 (51.5)	0.016
Male	3917 (49.6)	2738 (50.6)	487 (47.1)	65 (40.6)	627 (48.5)	
Married Family						
No	2236 (28.3)	1031 (19.0)	713 (69.0)	26 (16.2)	466 (36.0)	< 0.001
Yes	5667 (71.7)	4385 (81.0)	321 (31.0)	134 (83.8)	827 (64.0)	

Notes. Source: Adolescent Brain Cognitive Development (ABCD) Study; * Chi-square test; ** Analysis of Variance (ANOVA)

Table 2 summarizes mixed-effects regression models' fit statistics performed in the total sample. *Model 2* showed a better fit when compared to *Model 1*, suggesting that interaction between household income and race help explain the outcome.

Table 2. Effect Sizes and % Variance Explained by Each Model

	Model 1	*Model 2*
	Main Effects	Interactions
N	7903	7903
R-squared	0.00549	0.00688
ΔR-squared	0.00063	0.00551
ΔR-squared %	0.06%	0.55%

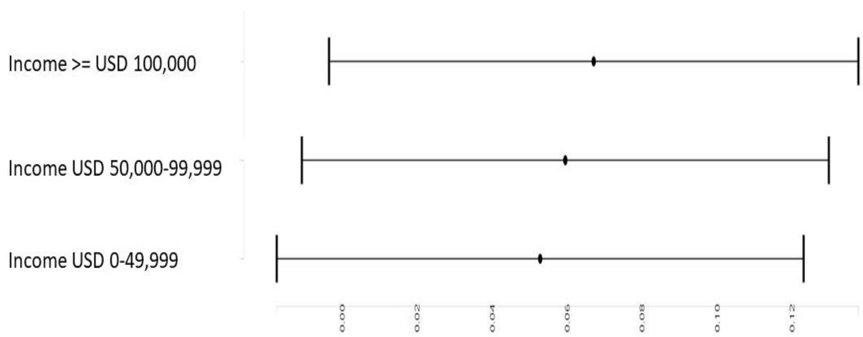
As shown by **Table 3** and **Figure 1**, when all confounders were controlled, household income showed a positive association with the NAcc resting-state functional connectivity with DMN. *Model 2* showed that household income had interactions with race on the outcome. This interaction was indicative of a weaker positive association between household income and the DMN's resting-state functional connectivity in Black than White children.

Table 3. Mixed-effects Regressions in the Overall Sample and by Race with NAcc Resting-state Functional Connectivity with DMN as the Outcome

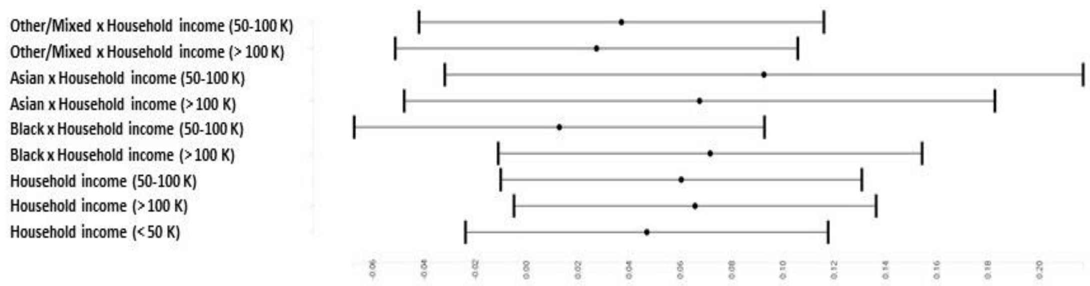
	Model 1				*Model 2*			
	b	SE	p	Sig	b	SE	p	Sig
Household income								
Household income (50-100 k)	0.007	0.006	0.293		0.013	0.008	0.099	#
Household income (> 100 K)	0.014	0.007	0.030	*	0.019	0.008	0.018	*
Race								
Black	-	-	-	-	-0.028	0.010	0.006	* *
Asian	-	-	-	-	-0.021	0.041	0.603	
Other/Mixed	-	-	-	-	0.004	0.011	0.680	
Race × Income								
Black × Household income (50-100 K)	-	-	-	-	-0.034	0.017	0.040	*
Black × Household income (> 100 K)	-	-	-	-	0.025	0.020	0.210	
Asian × Household income (50-100 k)	-	-	-	-	0.046	0.052	0.378	
Asian × Household income (> 100 K)	-	-	-	-	0.021	0.046	0.652	
Other/Mixed × Household income (50-100 K)	-	-	-	-	-0.010	0.015	0.522	
Other/Mixed × Household income (> 100 K)	-	-	-	-	-0.020	0.015	0.179	

Note. Race, age, sex, and family structure were controlled in both models.

# p < 0.1, *p < 0.05, **p < 0.01



Overall



by race

Figure 1. Effects of Household Income on Pre-adolescents' NAcc Resting-state Functional Connectivity with DMN Overall and by Race

4. Discussion

First, we found a positive association between household income and the NAcc resting-state functional connectivity with DMN. Second, there were racial differences in the associations between household income and the resting-state DMN's functional connectivity with the striatum. In line with the MDRs phenomenon, the correlation between household income and the NAcc resting-state functional connectivity with DMN was larger for White than Black children.

Our first finding aligns with the well-described effects of SES indicators such as household income on brain structure and function in adolescents and young people. However, most of this work has been conducted on individual brain structures (Hanson, Chandra, Wolfe, & Pollak, 2011; Jednoróg et al., 2012; Lawson, Duda, Avants, Wu, & Farah, 2013; Noble, Houston, Kan, & Sowell, 2012). High SES, for example, is linked to the activity and size of brain structures such as the NAcc, amygdala, hippocampus, and cerebral cortex (Hanson et al., 2011; Muscatell et al., 2012; Noble et al., 2012; Noble et al., 2015). One study using the ABCD study showed that SES is linked to the DMN functional connectivity at rest (Rakesh et al., 2021). These neurodevelopmental correlates of SES may mediate why SES influences language, reading, social cognition, executive functions, and spatial skills (Noble et al., 2015). However, very few studies to date have explored the relationship between household income and the NAcc resting-state functional connectivity with DMN.

The association between household income and NAcc resting-state functional connectivity with DMN may be because household income is a proxy of low-risk (Spann et al., 2014), high-support (Anton, Jones, & Youngstrom, 2015; Woods-Jaeger, Cho, Sexton, Slagel, & Goggin, 2018), low-stress (Parkes, Sweeting, & Wight, 2015), and positive social environment, which predicts healthy brain development of children (Shervin Assari & Bazargan, 2019). Indeed, parenting and home environment are all under the influence of SES indicators such as household income (Golinkoff et al., 2019). As such, SES indicators such as household income protect children against problem behaviors (Choi, Wang, & Jackson, 2019), psychopathologies (Padilla-Moledo, Ruiz, & Castro-Piñero, 2016), and cognitive problems (Shervin Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H Caldwell, 2020; Shervin

Assari & Cleopatra H Caldwell, 2019).

Our 2nd finding was in line with the MDRs. Similar MDRs are reported for social and behavioral problems (Shervin Assari & Boyce, 2020), attention (Shervin Assari, Shanika Boyce, & Mohsen Bazargan, 2020), impulsivity and inhibitory control (Shervin Assari, Caldwell, & Mincy, 2018), ADHD (Shervin Assari & Cleopatra Howard Caldwell, 2019), anxiety (Shervin Assari, Cleopatra Howard Caldwell, & Marc A Zimmerman, 2018), depression (Shervin Assari, Gibbons, & Simons, 2018), and suicidality (Shervin Assari, Shanika Boyce, Mohsen Bazargan, & Cleopatra H. Caldwell, 2020) in Black adolescents. However, this is the first study on MDRs of income for NAcc functional connectivity.

Household income and race have multiplicative rather than additive effects on NAcc resting-state functional connectivity with DMN. Under racism, Black pre-adolescents remain at high risk, regardless of their SES. This is in contrast to White pre-adolescents for whom high SES considerably reduces the risk. These unequal associations may be due to racism.

In this study, race was a social rather than biological determinant. Race is a social factor in all the MDRs literature, including studies on adolescents' brain development. Subsequently, the racial differences reported here have resulted from the differential treatment by society, which is preventable, not differences due to genes that are innate. Race is a proxy of racism, including labor market discrimination, low school quality, segregation, and differential policing, leading to reduced household income, even for high SES and successful people who have secured economic and human resources. This view contrasts with a biologic deterministic approach that attributes racial differences to genetics (Herrnstein & Murray, 2010).

5. Conclusions

While high household income is associated with higher NAcc resting-state functional connectivity with DMN, this link may be weaker for Black than White American pre-adolescents. This racial variation might be in part due to racism, social stratification, and segregation, all reducing the effects of SES indicators such as household income for Black communities. This finding is in line with the Marginalization-related Diminished Returns (MDRs), and may be due to differences in the living experiences of middle-class Black and White families. For centuries, Black Americans have been secondary citizens.

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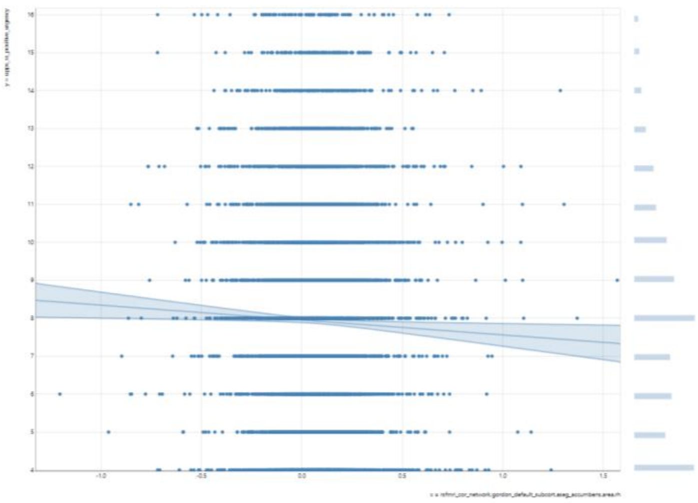
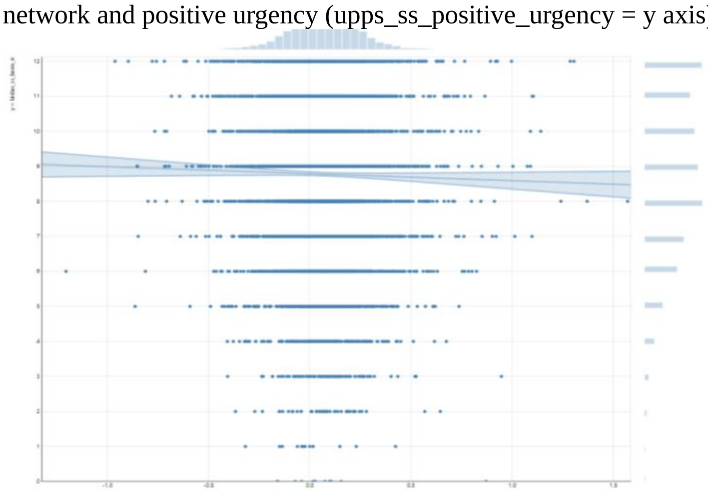
Supplementary Table 1. Model formula in DEAP

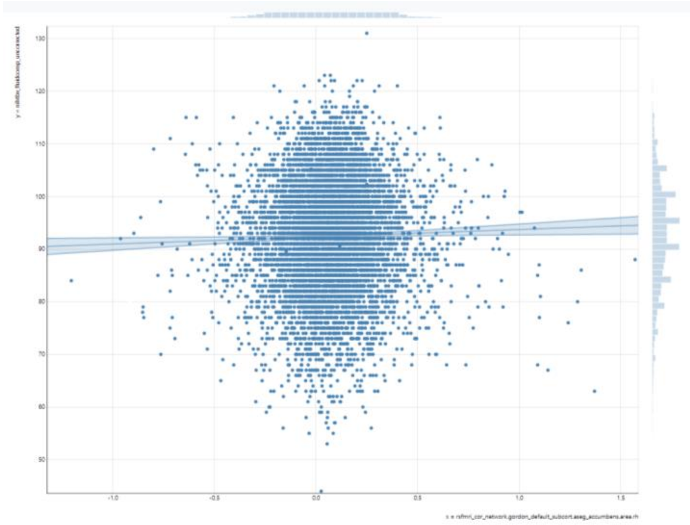
Model 1
rsfmri_cor_network.gordon_default_subcort.aseg_accumbens.area.rh ~ household.income.bl + race.4level + sex + married.bl + age
Random: ~(1|abcd_site/rel_family_id)
Model 2
rsfmri_cor_network.gordon_default_subcort.aseg_accumbens.area.rh ~ household.income.bl + race.4level + sex + married.bl + age + household.income.bl * race.4level
Random: ~(1|abcd_site/rel_family_id)



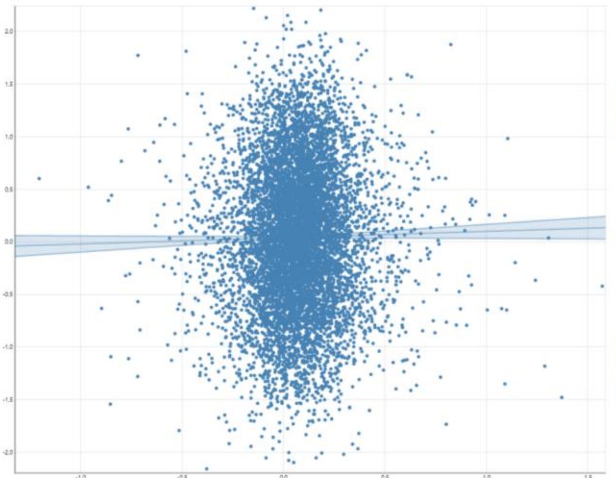
a) Correlation between the resting-state functional connectivity between NAcc and default mode network and positive urgency (upps_ss_positive_urgency = y axis)



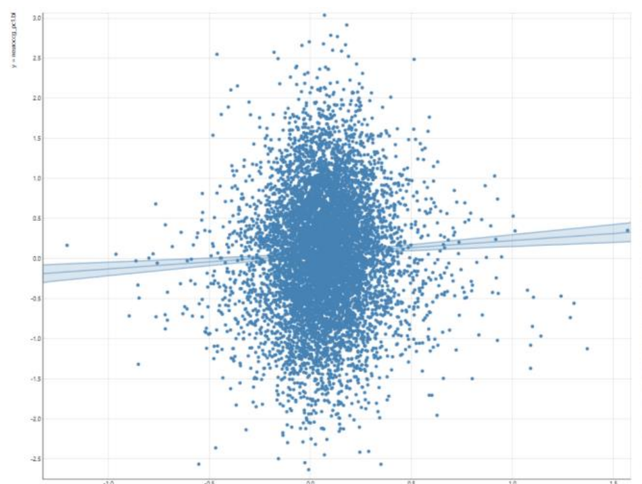
b) Correlation between the resting-state functional connectivity between NAcc and default mode network and reward responsiveness (bisbas_ss_basm_rr= y axis)



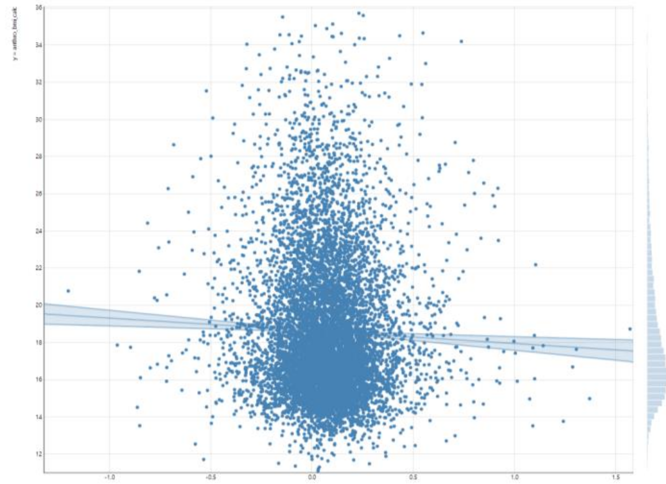
c) Correlation between the resting-state functional connectivity between NAcc and default mode network and fluid executive function (nihtbx_fluidcomp_uncorrected) (y axis)



d) Correlation between the resting-state functional connectivity between NAcc and default mode network and learning and memory (neurocog_pc3.bl) (y axis)



e) Correlation between the resting-state functional connectivity between NAcc and default mode network and general cognitive ability (neurocog_pc1.bl) (y axis)



f) Correlation between the resting-state functional connectivity between NAcc and default mode network and body mass index (anthro_bmi_calc) (y axis)

Supplementary Figure: Validation of the outcome (resting-state functional connectivity between NAcc and default mode network)