Racial inequities and neuroimaging findings in ABCD

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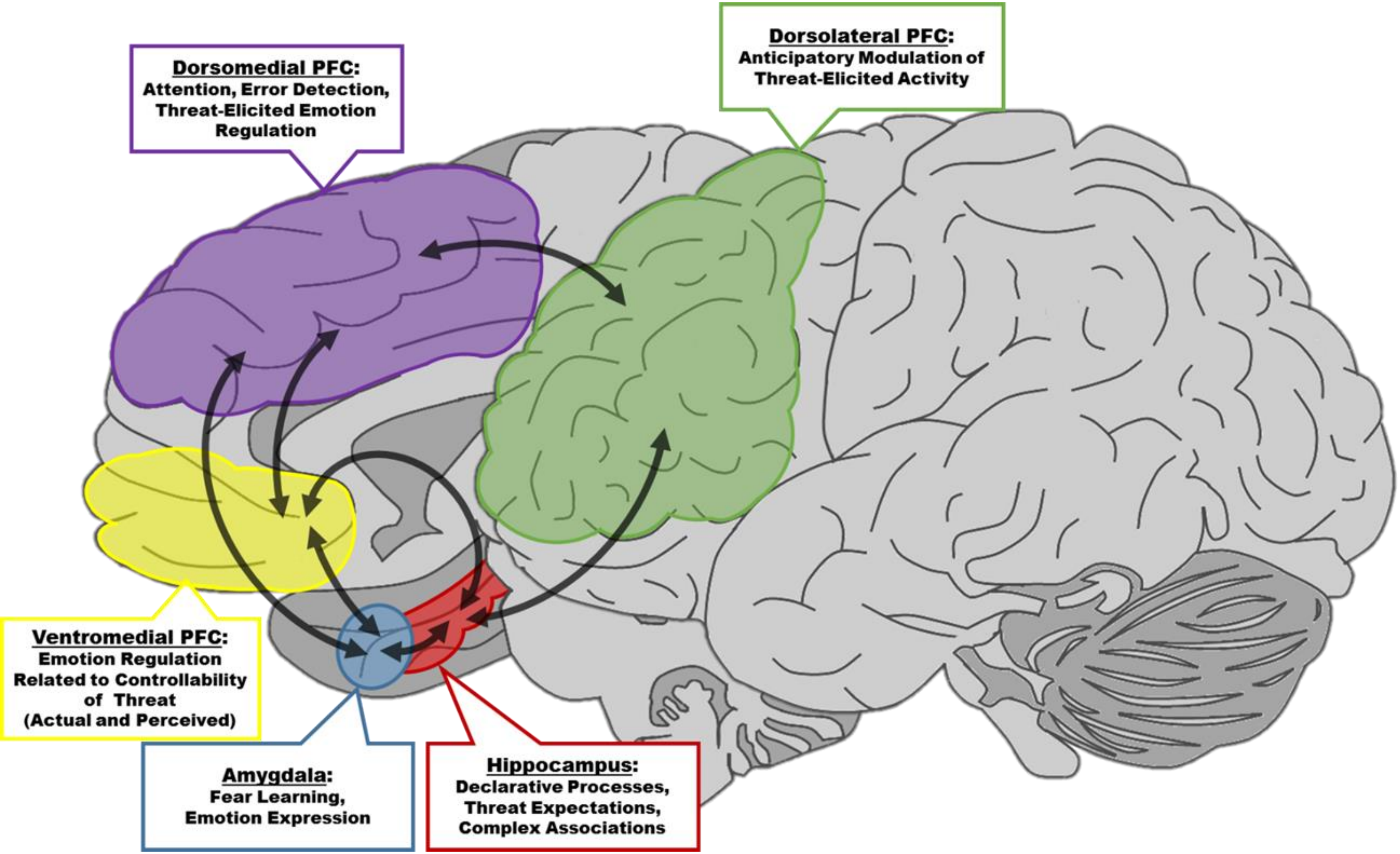
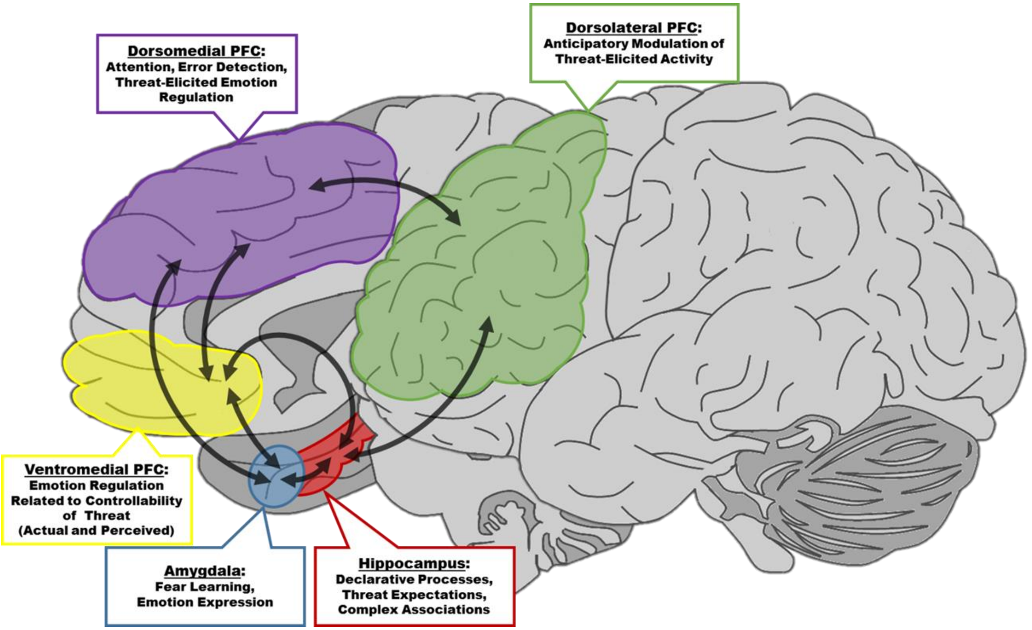
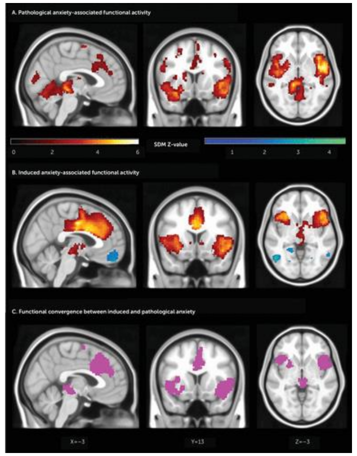
Assistant Professor of Psychiatry | Harvard Medical School


Dorsomedial PFC:
Attention, Error Detection, Threat-Elicited Emotion Regulation
Dorsolateral PFC:
Anticipatory Modulation of Threat-Elicited Activity
Ventromedial PFC:
Emotion Regulation Related to Controllability of Threat (Actual and Perceived)
Amygdala:
Fear Learning, Emotion Expression
Hippocampus:
Declarative Processes, Threat Expectations, Complex Associations

Neural circuitry of threat learning

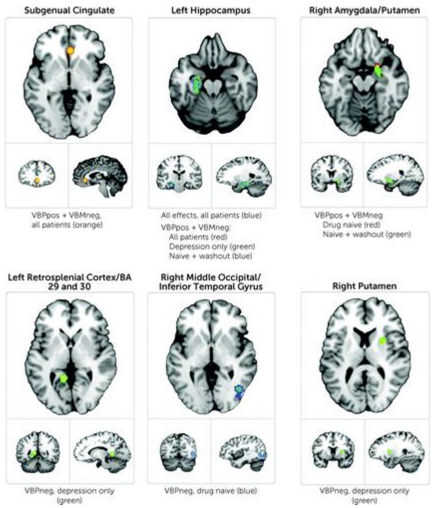


Anxiety



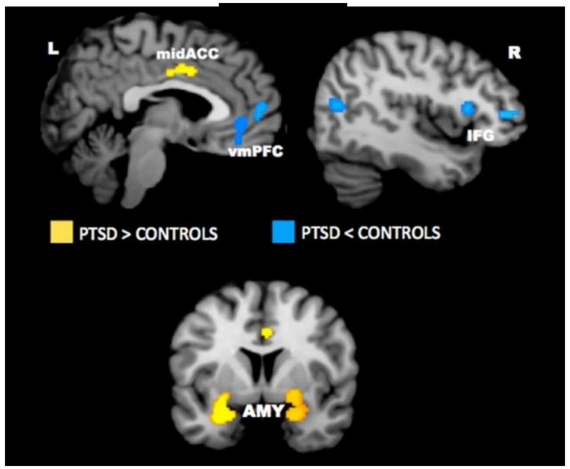
Chavanne & Robinson, 2020

Major Depression

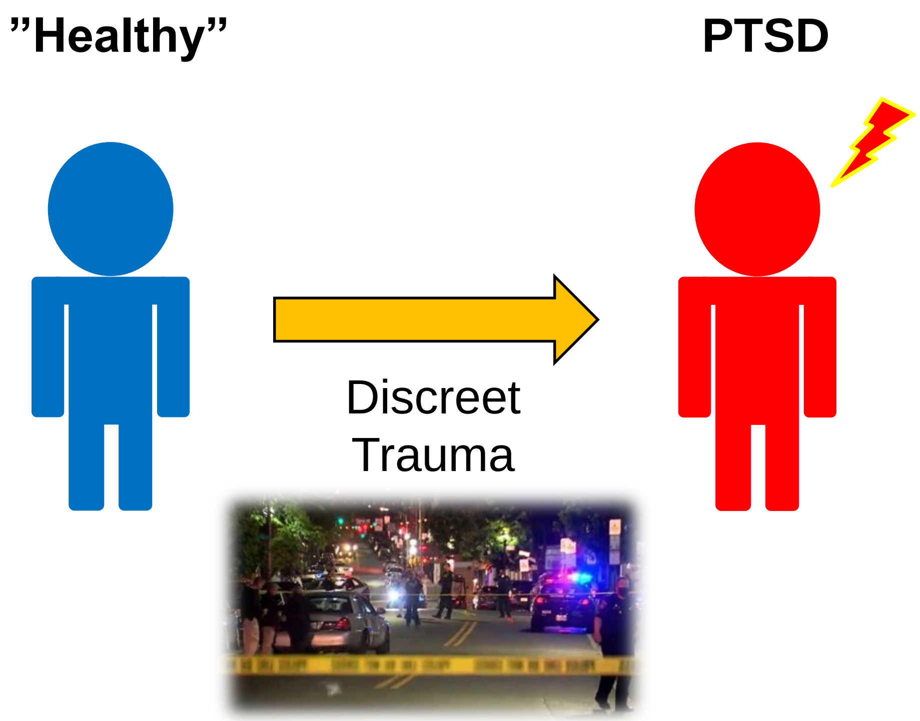


Gray et al., 2020

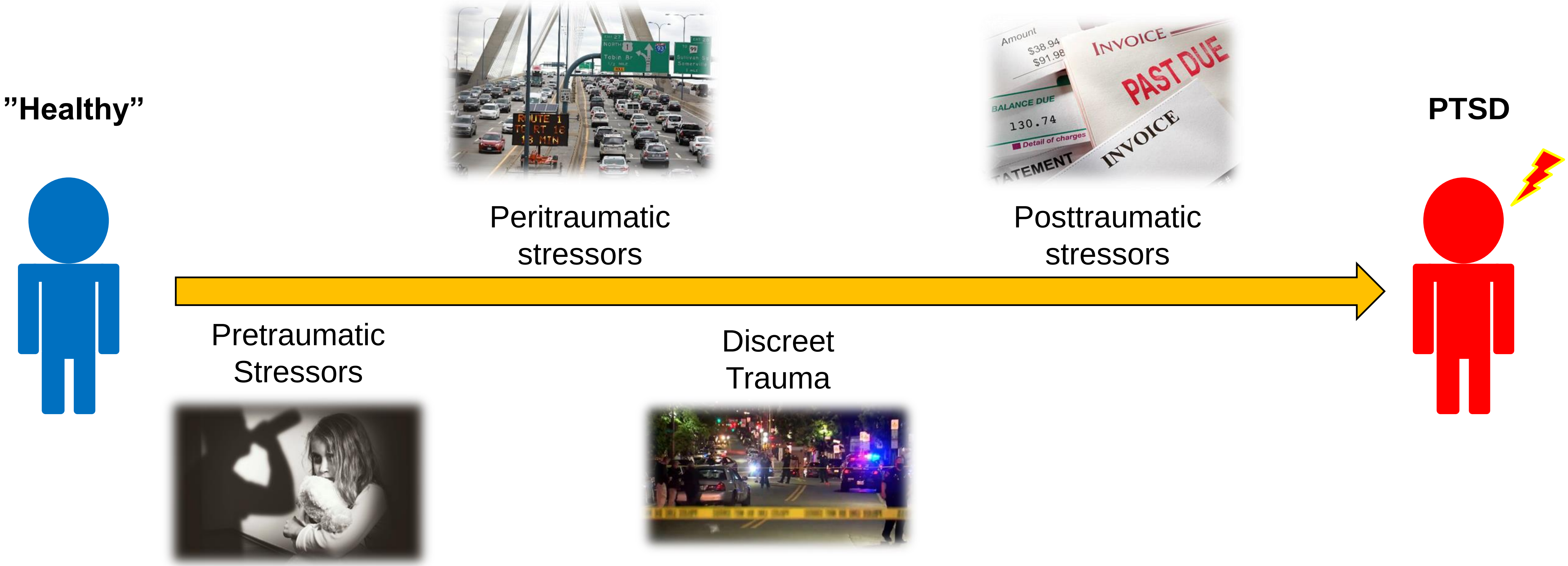
PTSD



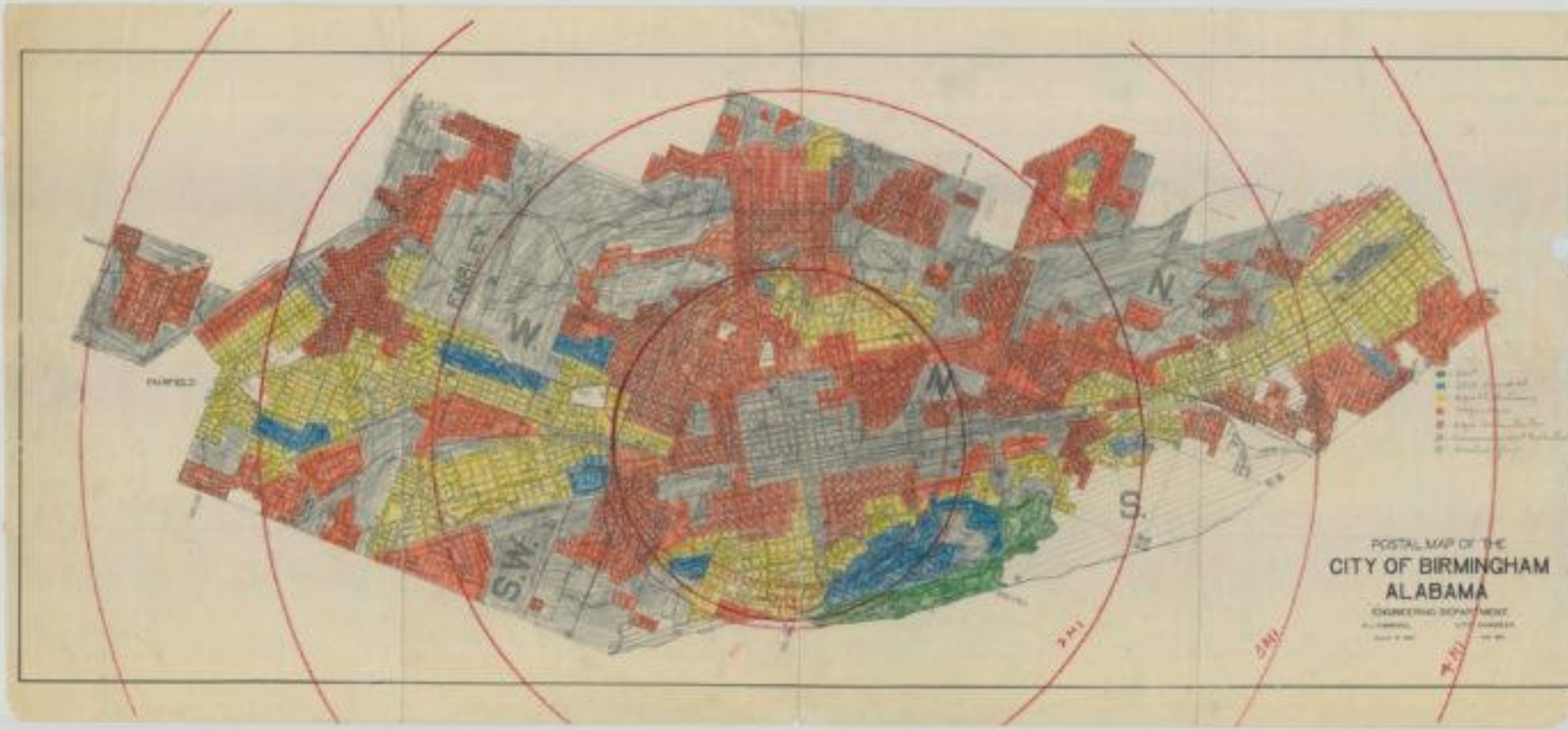
Hayes et al., 2012

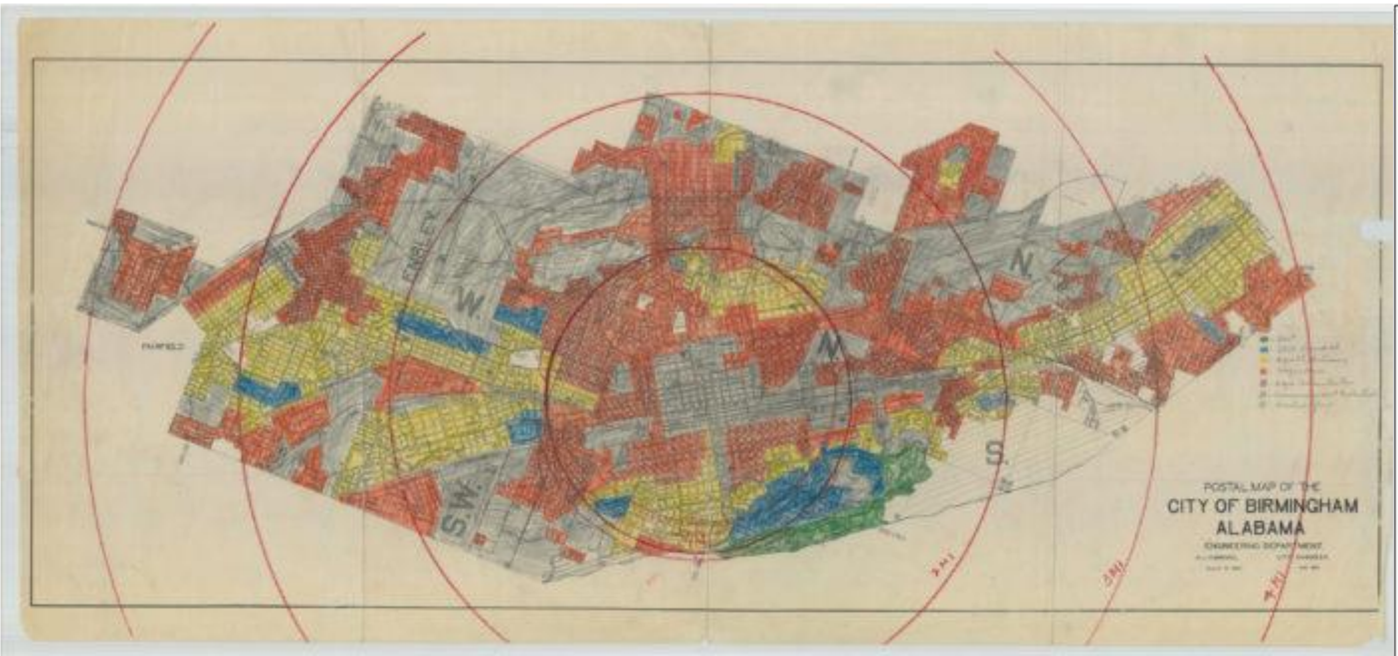


”Healthy”
PTSD
Discreet
Trauma


"Healthy"
PTSD
Peritraumatic
stressors
Posttraumatic
stressors
Pretraumatic
Stressors
Discreet
Trauma
Amount
$38.94
$91.98
BALANCE DUE
130.74
Detail of charges
INVOICE
PAST DUE
INVOICE

Environmental/chronic/lifetime stress


POSTAL MAP OF THE
CITY OF BIRMINGHAM
ALABAMA
ENGINEERING DEPARTMENT
ENSLEY
W.
N.
M.
S.
S.W.
FAIRFIELD


POSTAL MAP OF THE
CITY OF BIRMINGHAM
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FAIRFIELD
W.
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S.
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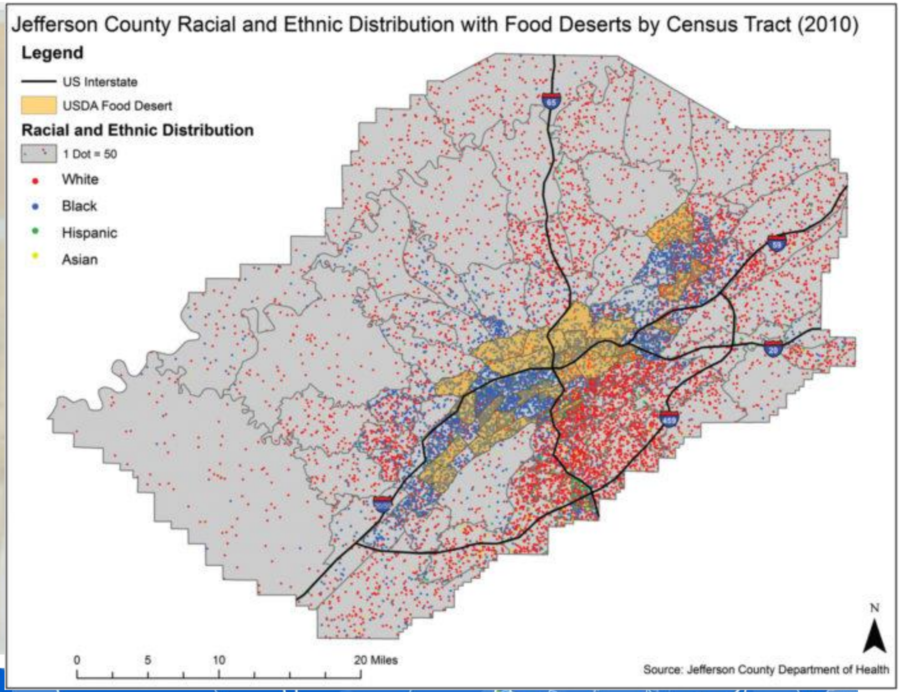
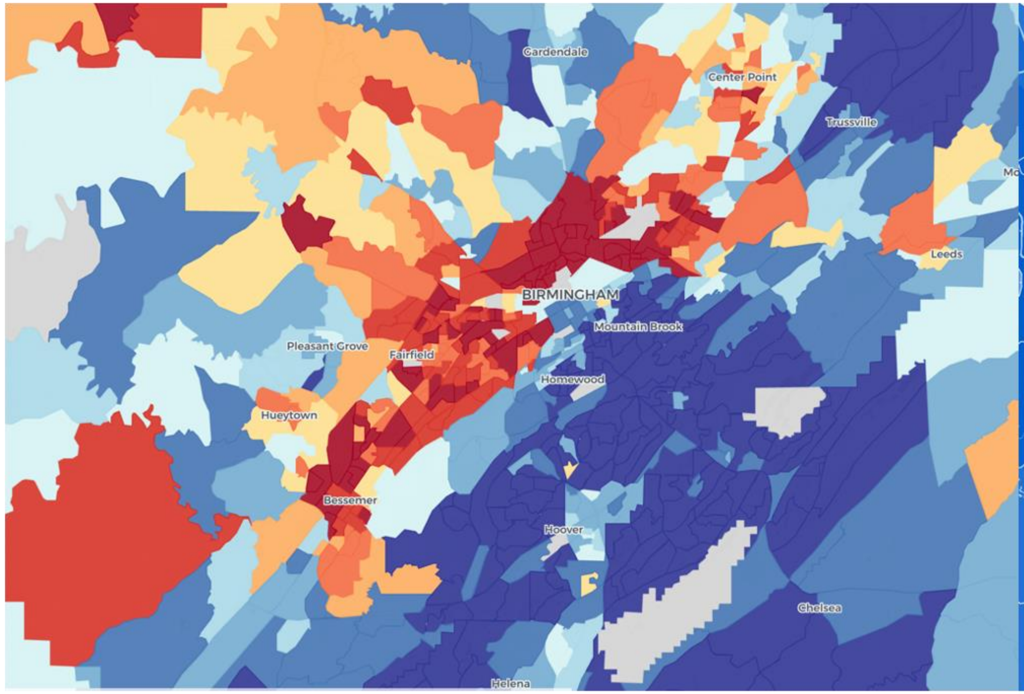
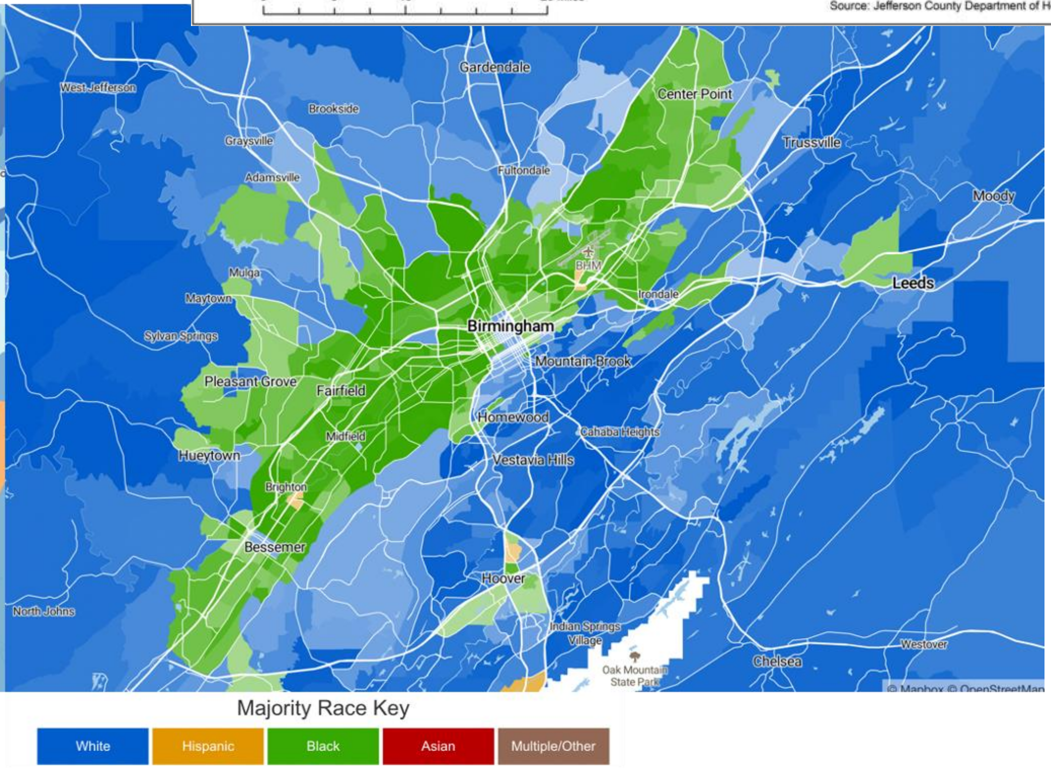

Jefferson County Racial and Ethnic Distribution with Food Deserts by Census Tract (2010)
Legend
US Interstate
USDA Food Desert
Racial and Ethnic Distribution
1 Dot = 50
White
Black
Hispanic
Asian
0
5
10
20 Miles
N
Source: Jefferson County Department of Health

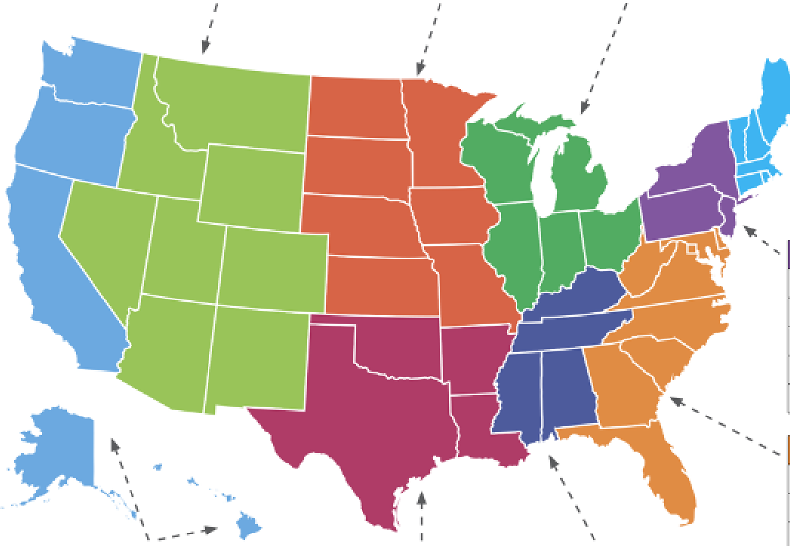

Gardendale
Center Point
Trussville
Leeds
BIRMINGHAM
Mountain Brook
Pleasant Grove
Fairfield
Homewood
Hueytown
Bessemer
Hoover
Chelsea
Helena


West Jefferson
Gardendale
Brookside
Graysville
Center Point
Trussville
Fultondale
Adamsville
Moody
BHM
Mulga
Maytown
Irondale
Leeds
Sylvan Springs
Birmingham
Mountain Brook
Pleasant Grove
Fairfield
Homewood
Midfield
Cahaba Heights
Hueytown
Vestavia Hills
Brighton
Bessemer
Hoover
North Johns
Indian Springs Village
Oak Mountain State Park
Chelsea
Westover
© Mapbox © OpenStreetMap
Majority Race Key
White
Hispanic
Black
Asian
Multiple/Other

Pretraumatic and environmental factors are racialized

Percentage of children with 1 ACE

	United States	Mountain	West North Central	East North Central	New England	Mid-Atlantic	South Atlantic	Pacific	West South Central	East South Central
White NH	22%	22%	20%	21%	22%	24%	22%	21%	20%	23%
Black NH	28%	19%	32%	24%	44%	35%	29%	23%	24%	28%
Asian NH	18%	18%	16%	12%	11%	21%	16%	21%	13%	16%
Other NH	23%	21%	27%	24%	17%	26%	23%	19%	27%	15%
Hispanic	30%	26%	26%	26%	28%	33%	27%	30%	33%	23%

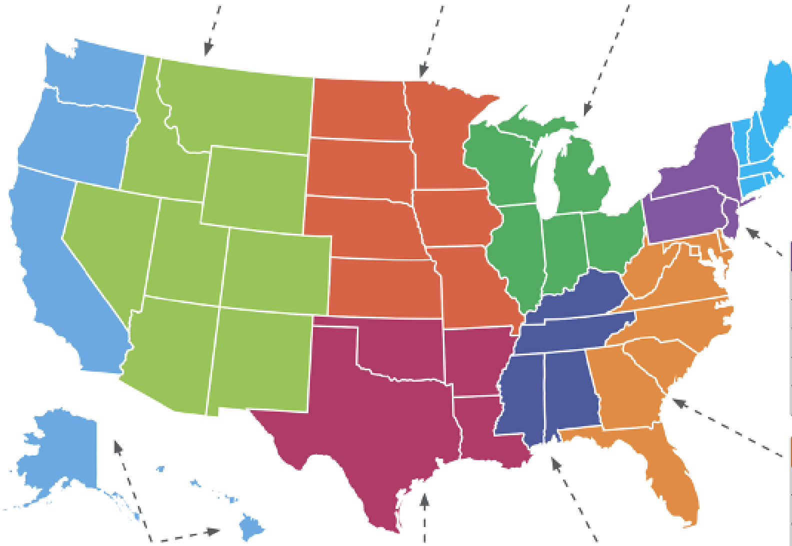


NH=Non-Hispanic

Yellow shading = Percentage is higher than white non-Hispanic children at a statistically significant level.
Blue shading = Percentage is lower than white non-Hispanic children at a statistically significant level.
Red shading = Estimate should be interpreted with caution, because the relative confidence interval is greater than 120 percent. See the "About the data used in this report" section for more information.

Percentage of children with 2 or more ACEs

	United States	Mountain	West North Central	East North Central	New England	Mid-Atlantic	South Atlantic	Pacific	West South Central	East South Central
White NH	19%	19%	19%	19%	16%	15%	20%	16%	22%	24%
Black NH	33%	46%	21%	38%	13%	27%	30%	26%	48%	31%
Asian NH	5%	7%	7%	9%	10%	3%	4%	4%	6%	3%
Other NH	26%	37%	39%	29%	20%	22%	25%	22%	24%	33%
Hispanic	21%	28%	27%	22%	30%	20%	24%	17%	20%	20%



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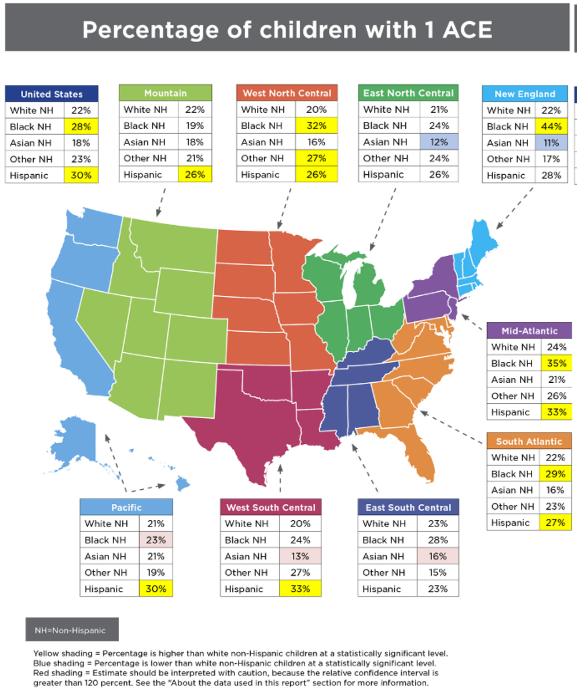
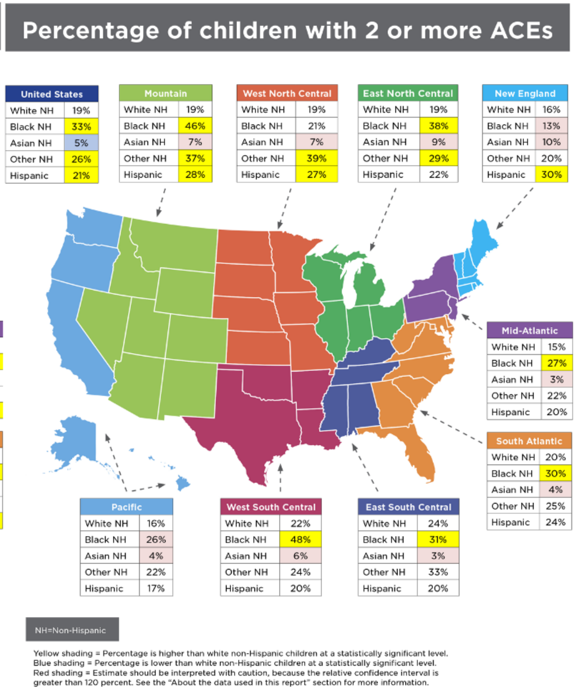
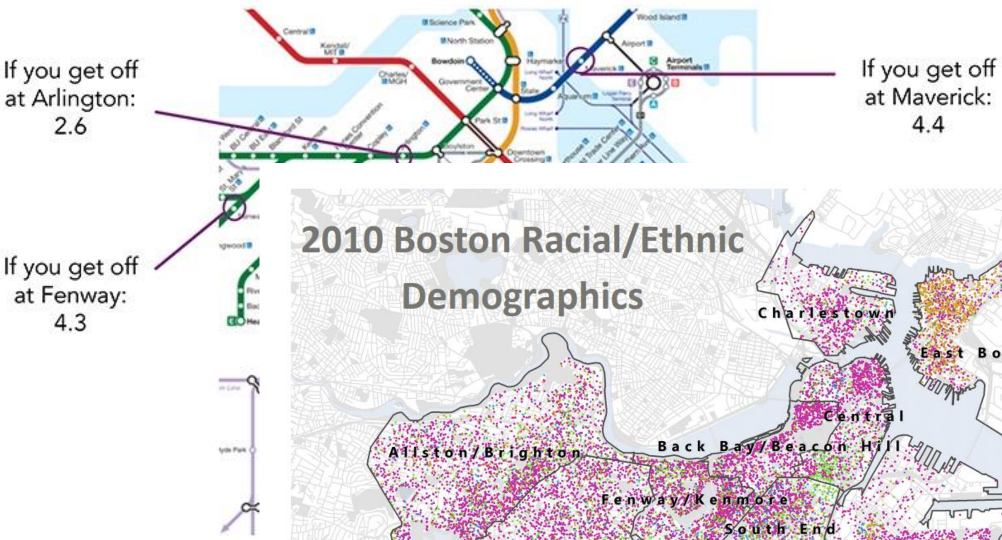
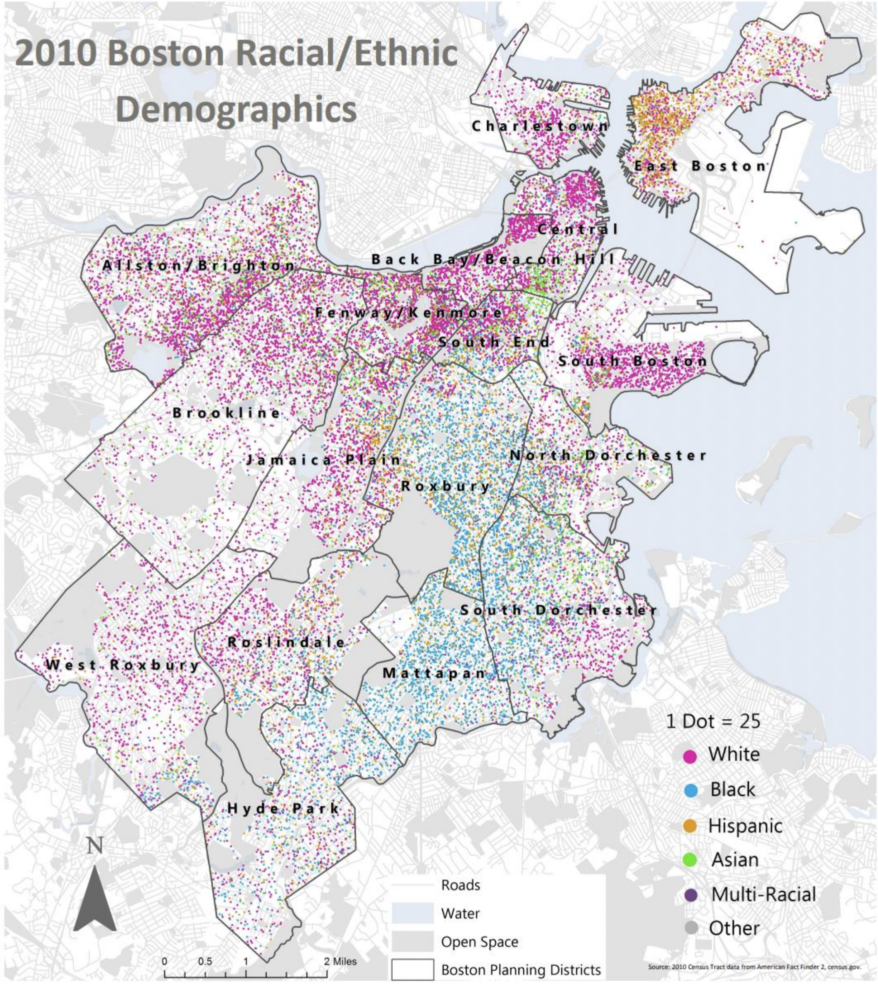
Pretraumatic and environmental factors are racialized



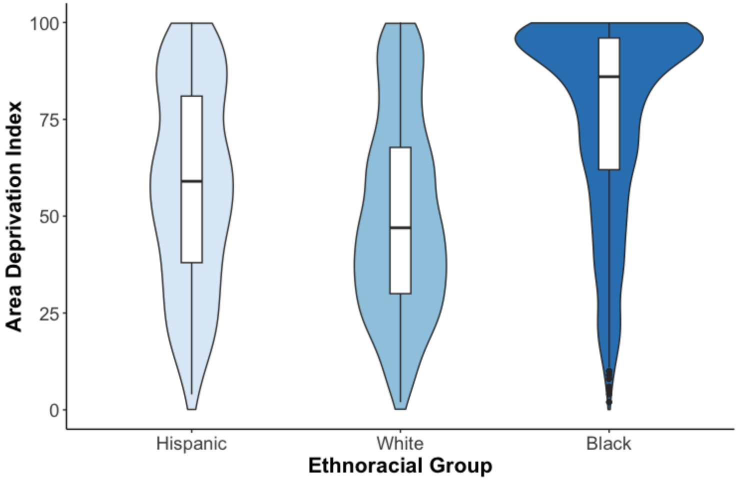


Premature death rates per 1,000 by T stop, 1999-2001

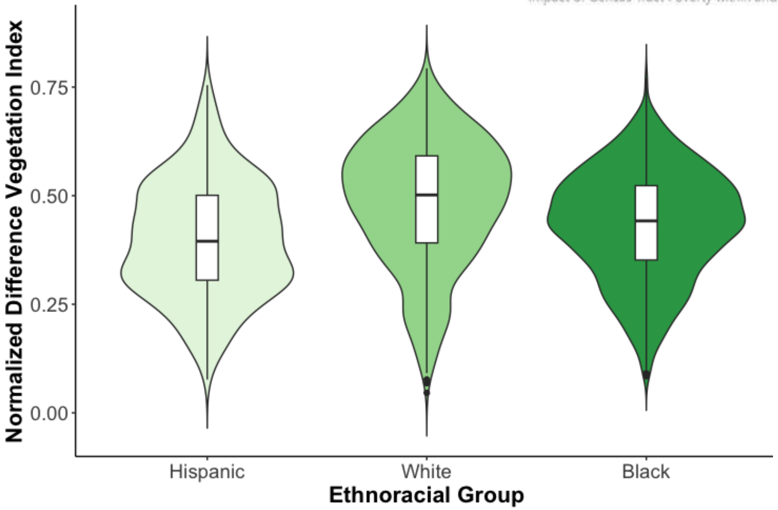




Neighborhood Disadvantage by Ethnoracial Group



Greenspace by Ethnoracial Group



Chen JT, Rehkopf DH, Waterman PD, Subram...
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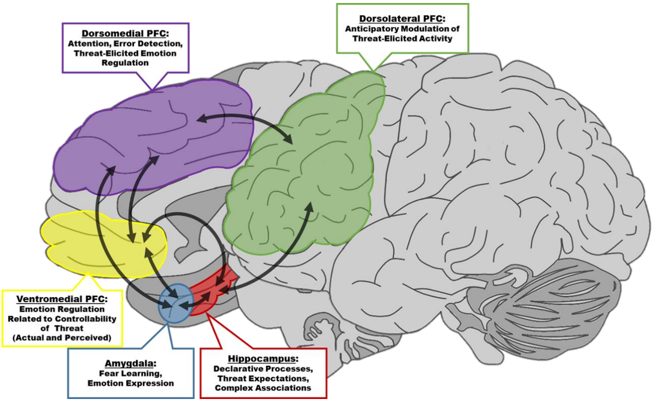
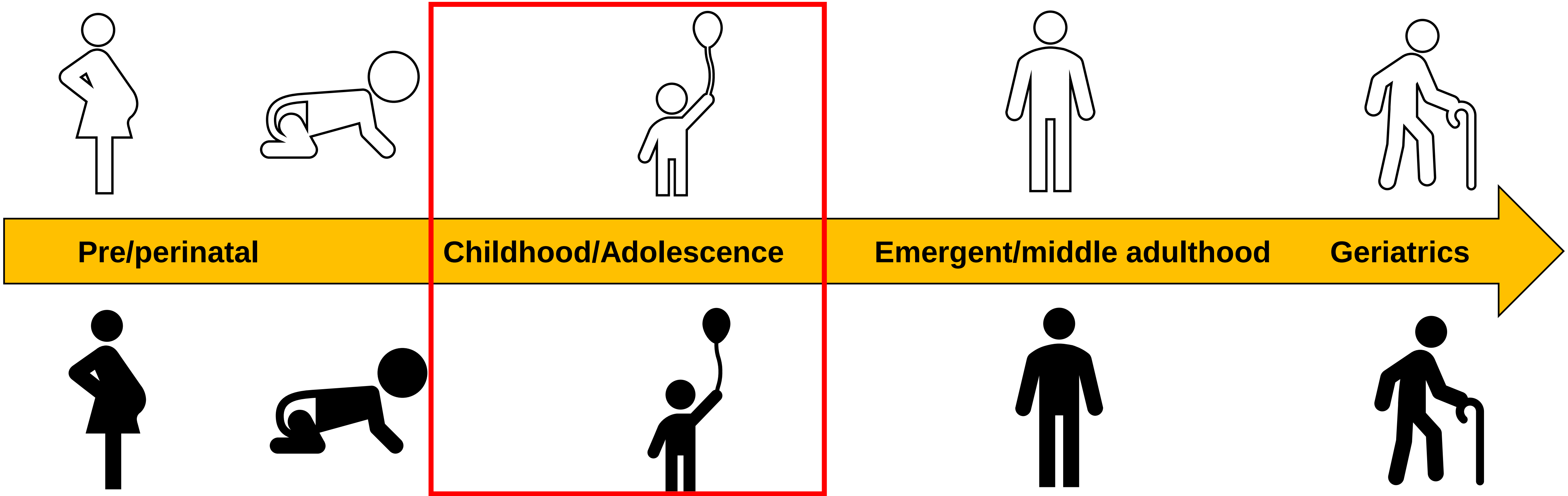
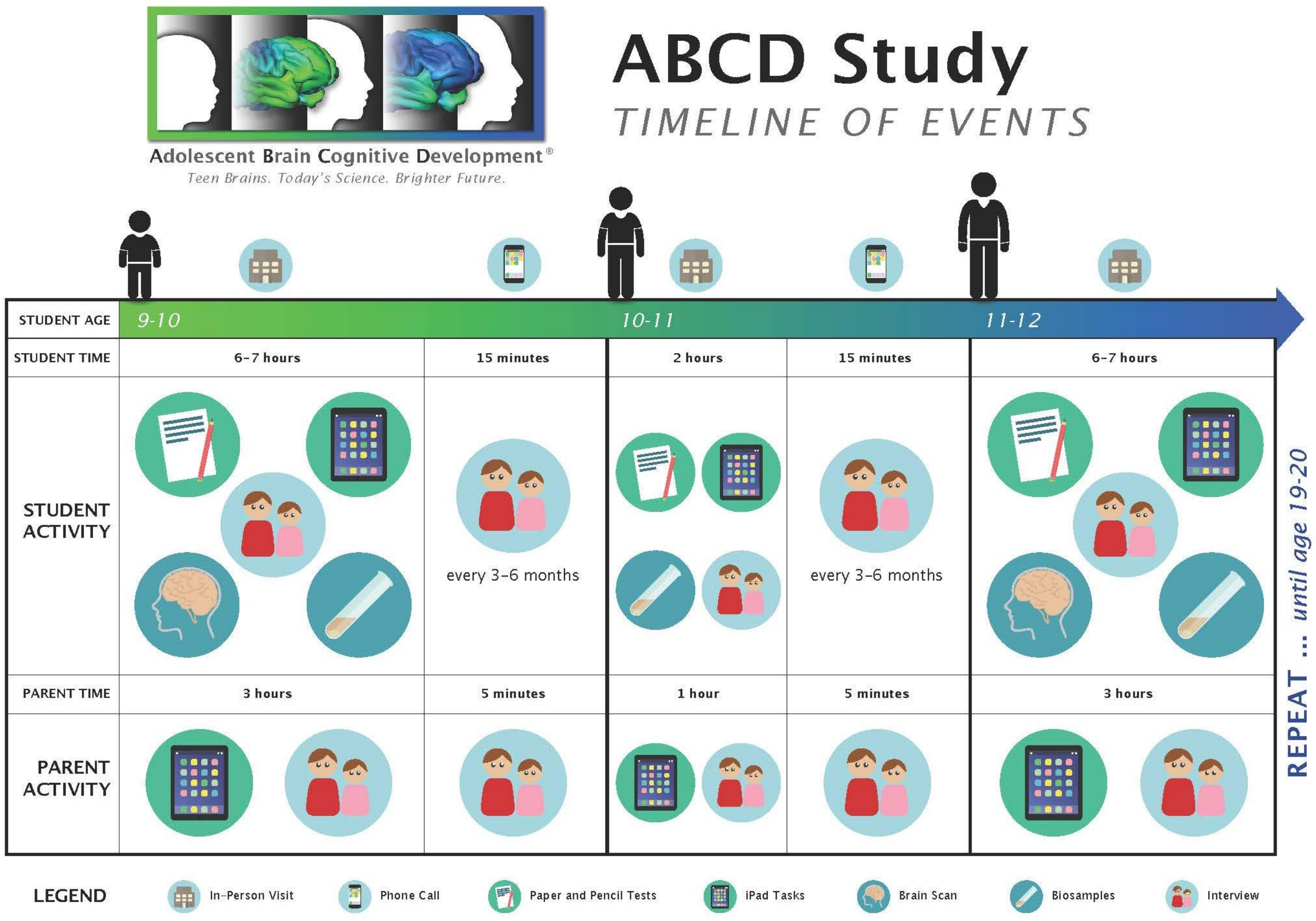
How do disparities in stressor exposure impact PTSD-related neurocircuitry?





Dumornay et al., 2023, *American Journal of Psychiatry*

Inequity and brain structure in children



Demographics:

- Parent reported race and SAAB
  - Black/White, Male/Female

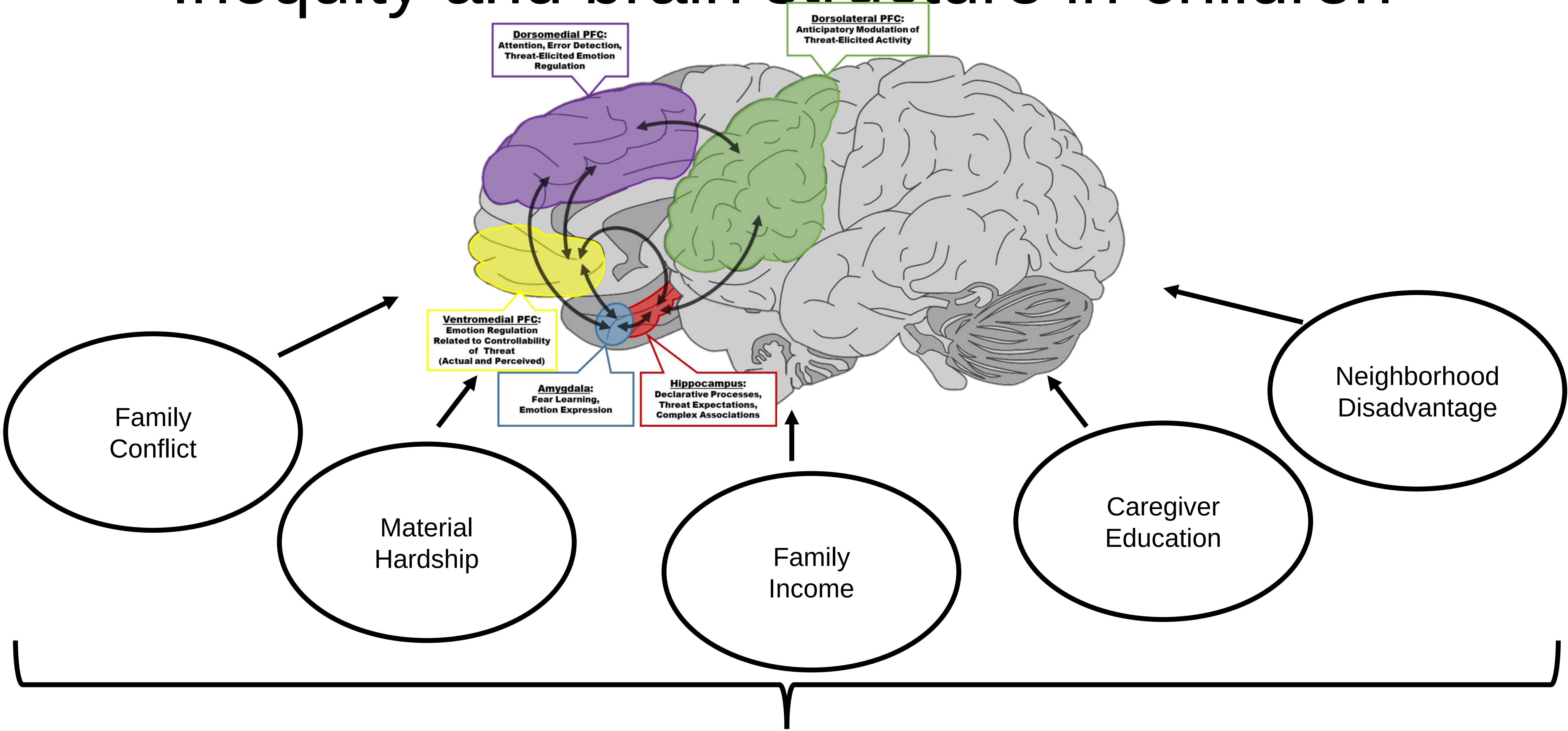
Experiences and context:

- Family conflict
- Family hardship
- Trauma load
- Family income
- Parent education
- Parent employment
- Neighborhood disadvantage

Neuroimaging:

- Gray matter volume

Inequity and brain structure in children



<u>Indices of structural racism</u>

TABLE 1. Demographic characteristics of participants in a study of childhood adversity and brain structure

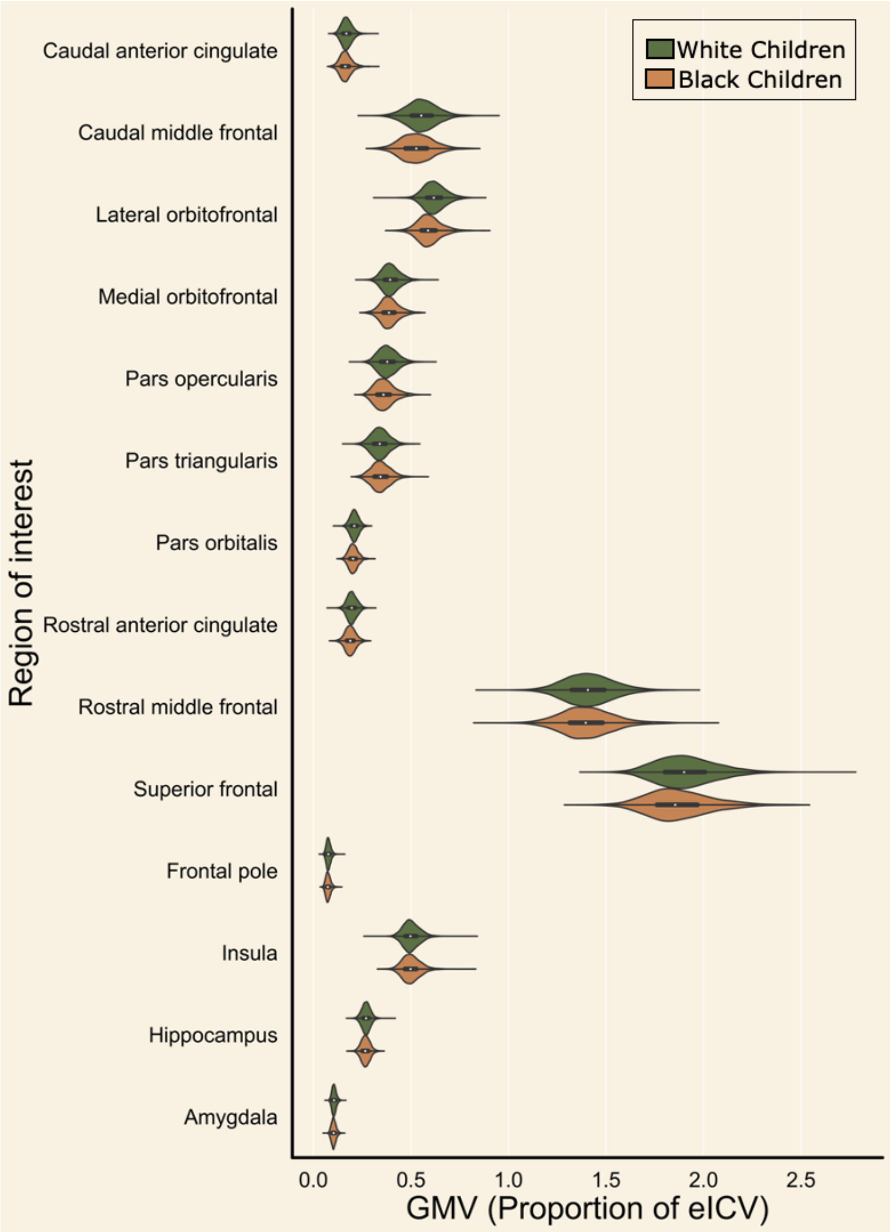
Characteristic	Total N	White American		Black American		Analysis		
						Statistic	df	p
		Mean	SD	Mean	SD			
Age (months)	9,382	119.03	7.50	118.82	7.26	t=1.09	9380	0.28
		N	%	N	%			
Gender	9,382					χ^2=5.86		0.02
Male		3,989	53.1	934	50.1			
Female		3,527	46.9	932	49.9			
Parental education	9,373					t=33.15[a]	2802	<0.001
Grade school		288	3.8	221	11.9			
High school diploma or equivalent		520	6.9	449	24.1			
Some college		1,054	14.0	436	23.4			
Associate's degree		907	12.1	314	16.9			
Bachelor's degree		2,490	33.1	237	12.7			
Master's degree		1,719	22.9	179	9.6			
Doctoral or professional degree		534	7.1	25	1.3			
Parental employment	9,121					χ^2=344.90		<0.001
Not currently employed		409	5.6	342	19.0			
Currently employed		6,914	94.4	1456	81.0			
Annual family income	8,654					t=40.30[a]	1985	<0.001
<$5,000		88	1.2	225	14.2			
$5,000–$11,999		128	1.8	178	11.2			
$12,000–$15,999		97	1.4	93	5.9			
$16,000–$24,999		226	3.2	155	9.8			
$25,000–$34,999		301	4.3	194	12.2			
$35,000–$49,999		463	6.5	211	13.3			
$50,000–$74,999		987	14.0	221	13.9			
$75,000–$99,999		1,164	16.5	122	7.7			
$100,000–$199,999		2,611	36.9	153	9.7			
>$200,000		1,004	14.2	33	2.1			
		Mean	SD	Mean	SD			
Neighborhood disadvantage[b]	8,840	90.30	23.91	105.94	22.25	t=−25.66[a]	2706	<0.001
Family conflict[b]	9,363	1.96	1.94	2.43	2.01	t=−9.17[a]	2786	<0.001
Material hardship[b]	9,296	0.30	0.89	1.01	1.49	t=−19.63[a]	2166	<0.001
Trauma history[b]	9,043	0.48	1.10	0.67	1.02	t=−7.26[a]	2965	<0.001

[a] The test was corrected for unequal variances because of violation of Levene's test for homogeneity of variance.
[b] Neighborhood disadvantage, family conflict, material hardship, and trauma history are four of the seven indices of adversity included in the statistical models. Neighborhood disadvantage was quantified using the weighted Area Deprivation Index sum score. Family conflict was quantified using the Youth Family Conflict Scale. Material hardship was quantified using the questions in the participant demographic screener. Trauma history was assessed using the Schedule for Affective Disorders and Schizophrenia for School-Age Children for DSM-5. See the Methods section for further detail.

Compared to White children, Black children in the ABCD study:

- Have caregivers with less education
- Have more unemployed parents
- Have lower family income
- Come from more disadvantaged neighborhoods
- Experience more family conflict
- Experience more financial hardship
- Have greater endorsement of traumatic events

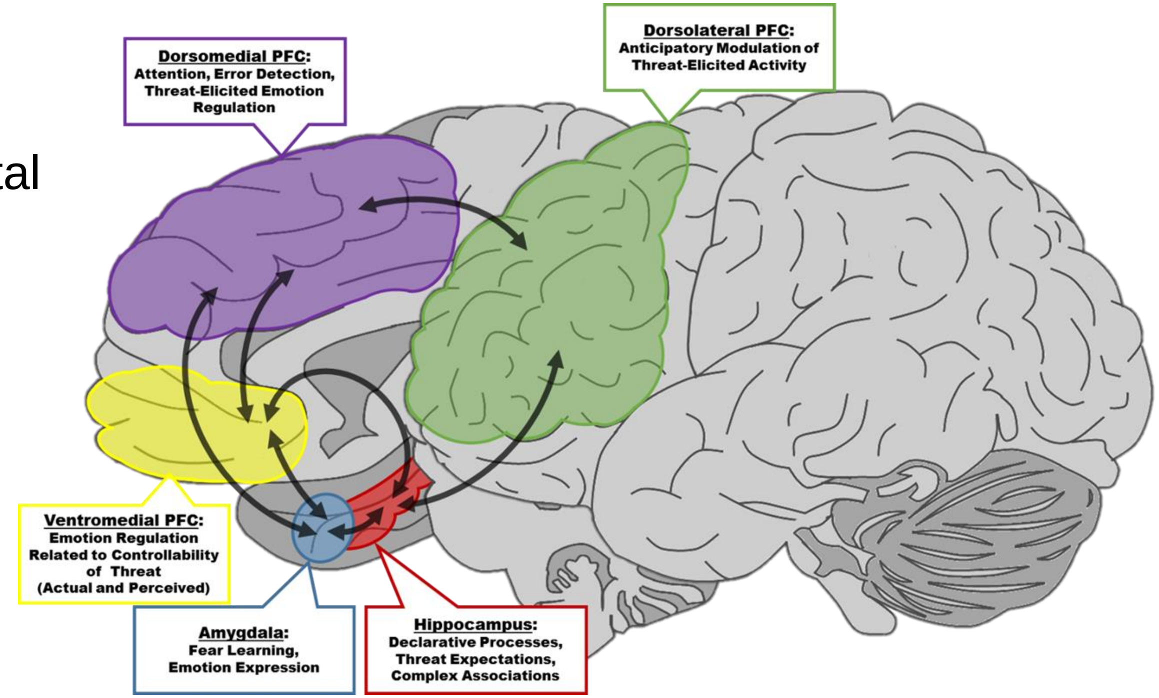
Inequity and brain structure in children



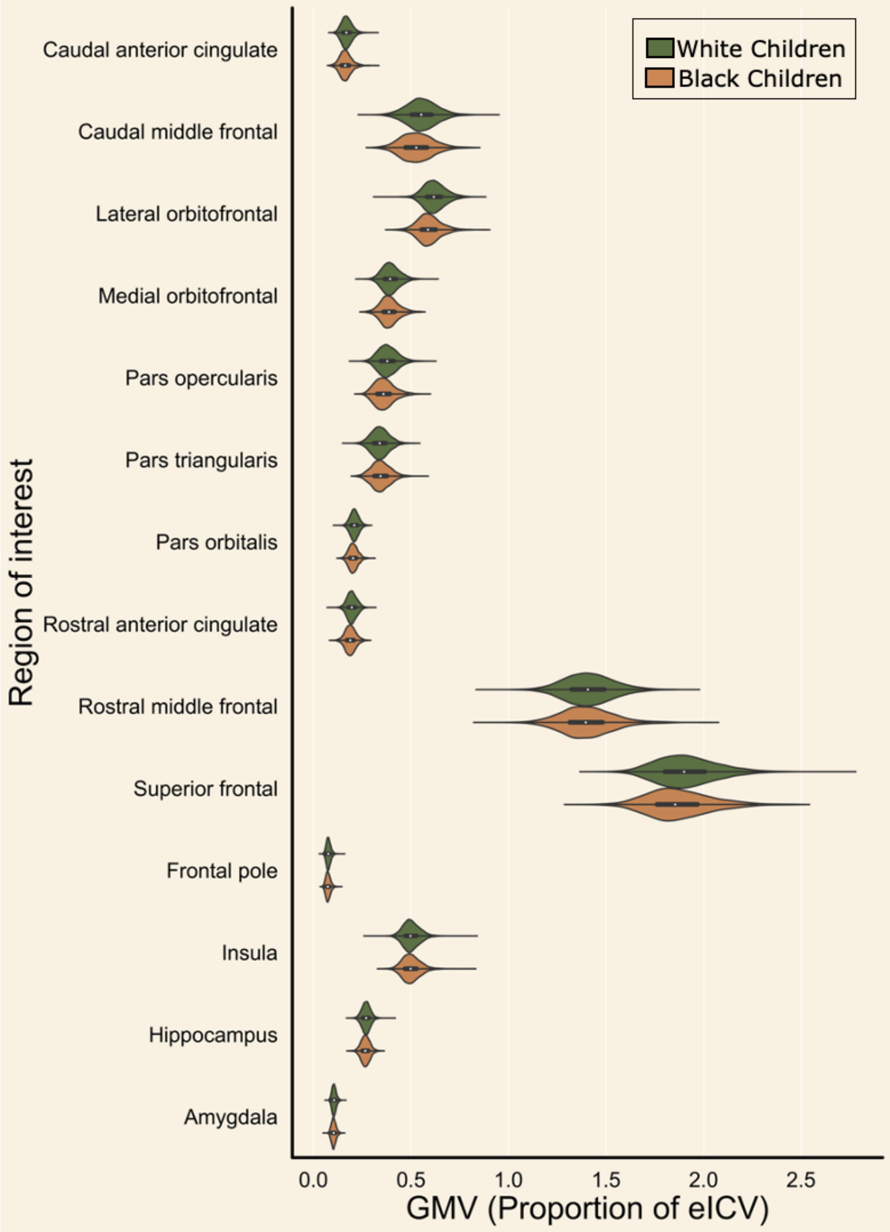
Prefrontal Cortex

Hippocampus

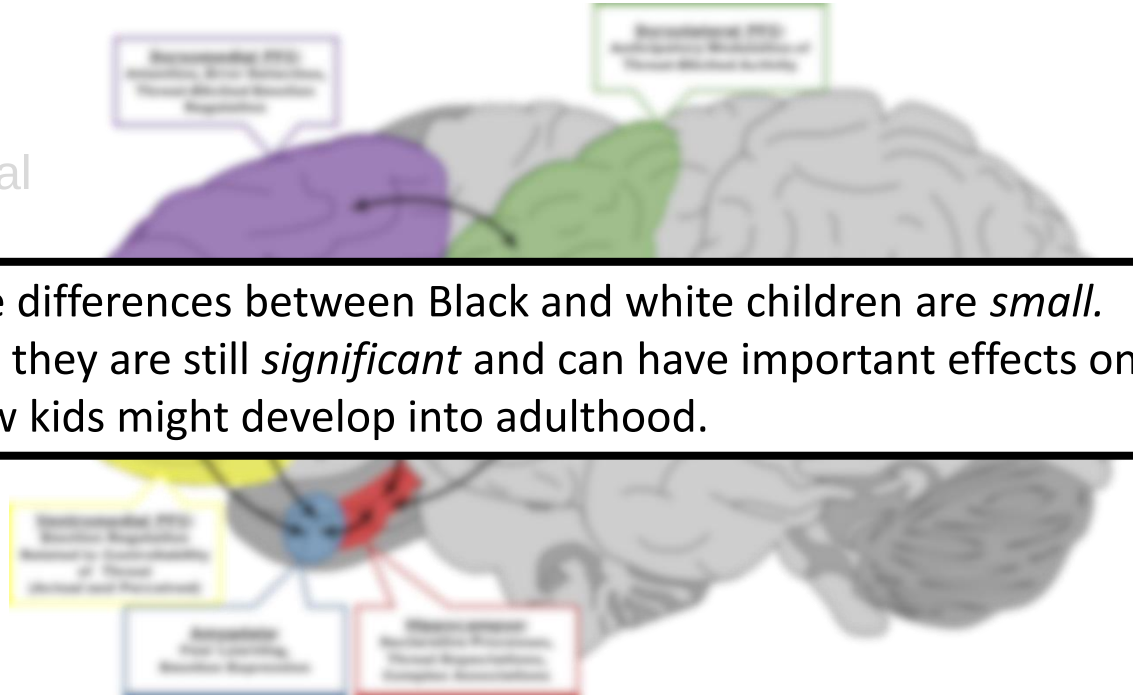
Amygdala



Inequity and brain structure in children



Prefrontal Cortex



The differences between Black and white children are *small.* But they are still *significant* and can have important effects on how kids might develop into adulthood.

Hippocampus

Amygdala

Inequity and brain structure in children

Table S2. Summary of linear regression analysis predicting PTSD symptom severity

Predictor	β	*t-statistic*	*p*
Parental employment	-0.03	-2.63	0.01
Parental education	0.01	0.52	0.60
Family income	-0.06	-4.13	< 0.001
Material hardship	0.10	8.46	< 0.001
Family conflict	0.04	3.58	< 0.001
Neighborhood disadvantage	-0.00	-0.09	0.93
Trauma history	0.26	23.61	< 0.001

Notes. $N = 7{,}623$. Participant's adversity exposure was significantly associated with their PTSD symptom severity, $F(7, 7623) = 132.06$, $p < 0.001$, $R^2 = 0.11$. PTSD symptom severity is an index created by summing twenty-five items assessing present PTSD symptoms from the full parent-reported K-SADS-5 diagnostic interview (NDA: abcd_ksad01).

Table S3. Correlations between PTSD symptom severity and GMV

	PTSD Symptom Severity			
	Before		After	
Region	*r-value*	*p-value*	*r-value*	*p-value*
Caudal anterior cingulate cortex	**-0.03**	**0.004**	-0.02	0.169
Caudal middle frontal gyrus	-0.01	0.203	0.01	0.546
Lateral orbitofrontal cortex	-0.02	0.142	-0.01	0.571
Medial orbitofrontal cortex	0.01	0.678	-0.00	0.751
Pars opercularis	-0.00	0.996	0.01	0.370
Pars triangularis	0.01	0.233	-0.00	0.803
Pars orbitalis	-0.00	0.893	-0.00	0.805
Rostral anterior cingulate cortex	-0.02	0.108	-0.01	0.376
Rostral middle frontal gyrus	-0.02	0.126	-0.02	0.151
Superior frontal gyrus	**-0.02**	**0.033**	**-0.03**	**0.030**
Frontal pole	-0.01	0.291	-0.01	0.607
Insula	-0.00	0.748	-0.01	0.318
Hippocampus	-0.01	0.476	-0.00	0.758
Amygdala	-0.00	0.930	0.01	0.566

Note: Bold values indicate $p<0.05$. "Before" indicates gray matter volume (GMV) estimated from residuals of linear mixed effects models that included age, gender, scanner, and family relatedness. "After" indicates GMV estimated from residuals of linear mixed effects models that included additional terms for adversity metrics noted in the main text.

Inequity and brain structure in children

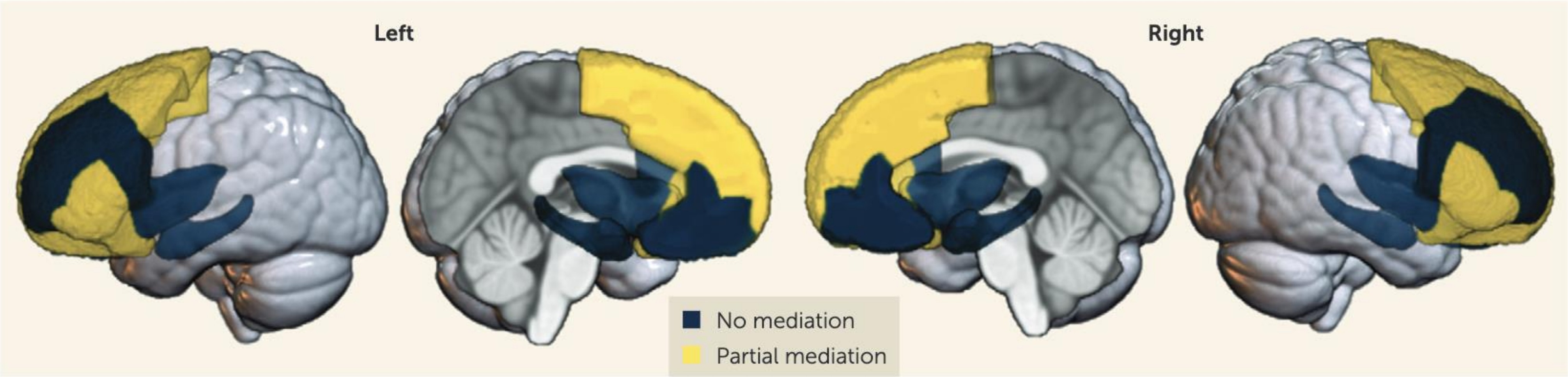
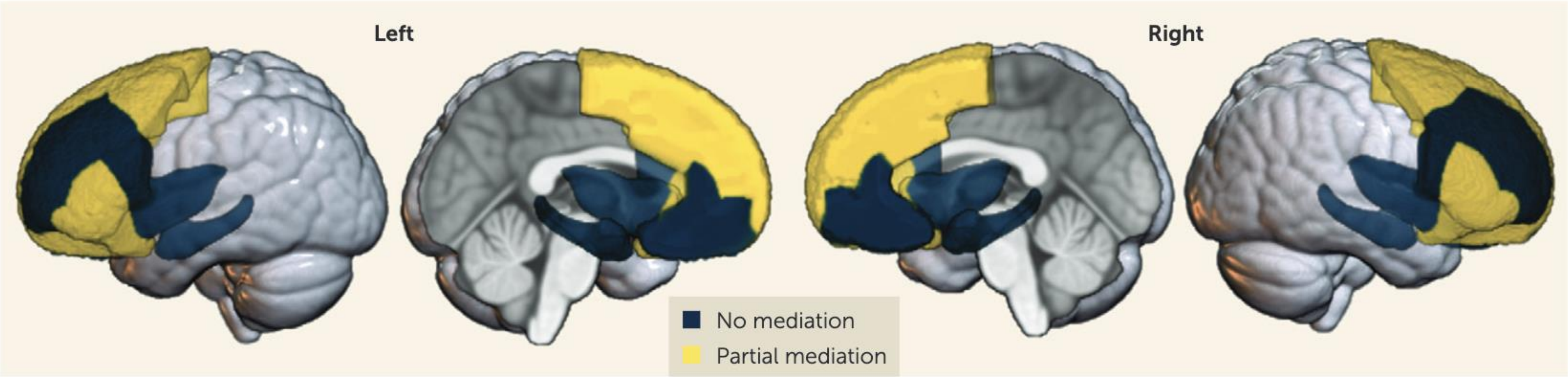


TABLE 4. Summary of parallel mediation analyses of race-related effects on gray matter volume accounting for adversity[a]

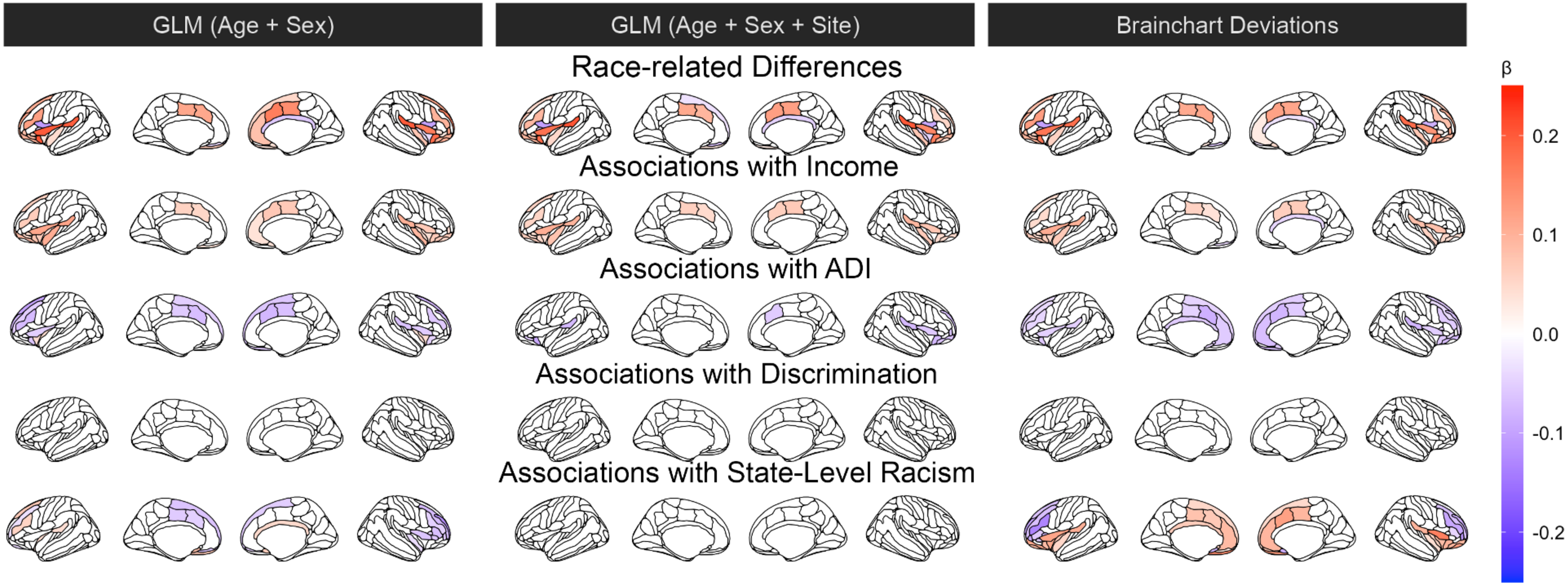
Region	Total Effect (c)	p	Total Indirect Effect (ab)	p	Direct Effect (c′)	p	Percentage Mediated[b] (%)
Caudal anterior cingulate cortex[c]	−0.17	<0.001	−0.04	0.006	−0.13	<0.001	26.04
Caudal middle frontal gyrus[c]	−0.29	<0.001	−0.09	<0.001	−0.20	<0.001	30.58
Lateral orbitofrontal cortex[c]	−0.45	< 0.001	−0.03	0.034	−0.41	<0.001	7.40
Medial orbitofrontal cortex	−0.03	0.333	−0.02	0.287	−0.01	0.748	—
Pars opercularis	−0.31	<0.001	0.01	0.613	−0.32	<0.001	2.57
Pars triangularis[c]	0.13	<0.001	0.06	<0.001	0.08	0.02	42.42
Pars orbitalis[c]	−0.19	<0.001	−0.04	0.008	−0.15	<0.001	21.88
Rostral anterior cingulate cortex	−0.29	<0.001	−0.03	0.098	−0.27	<0.001	8.93
Rostral middle frontal gyrus	0.02	0.597	−0.09	<0.001	0.10	0.001	—
Superior frontal gyrus[c]	−0.20	<0.001	−0.10	<0.001	−0.10	0.003	50.76
Frontal pole[c]	−0.19	<0.001	−0.04	0.006	−0.15	<0.001	23.28
Insula	0.05	0.116	0.02	0.155	0.02	0.501	—
Hippocampus	−0.12	<0.001	−0.01	0.765	−0.11	<0.001	4.27
Amygdala	−0.14	<0.001	−0.01	0.582	−0.13	<0.001	6.67

Inequity and brain structure in children



Structural racism changes the structure of brain regions important for responding to threat in children.

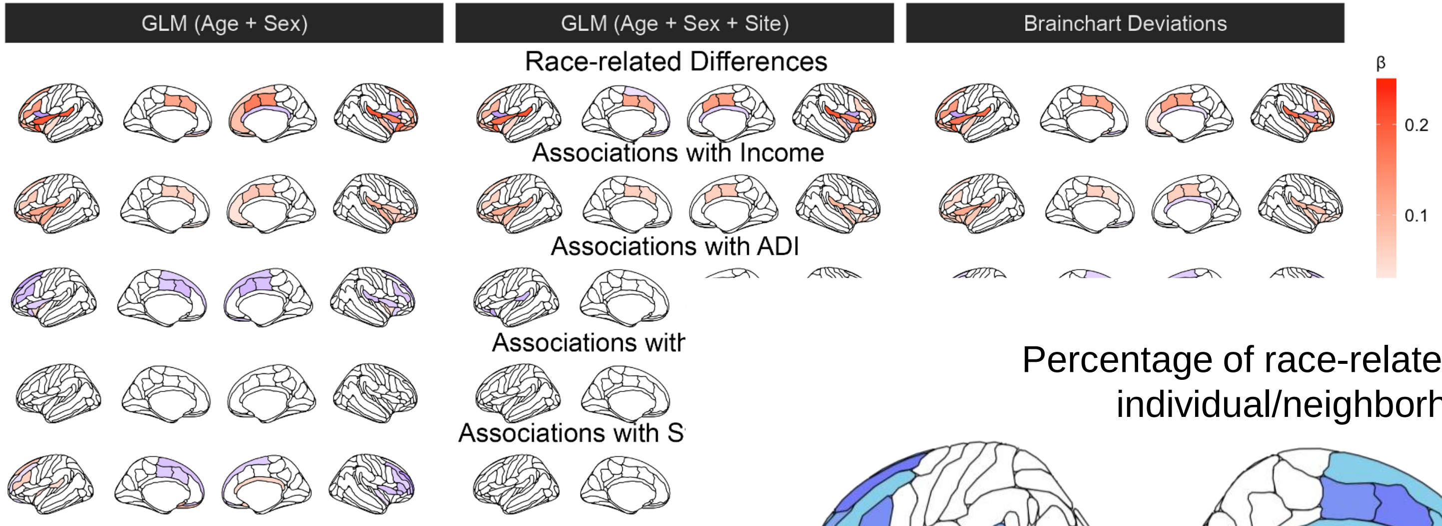
Inequity and brain structure in adolescence

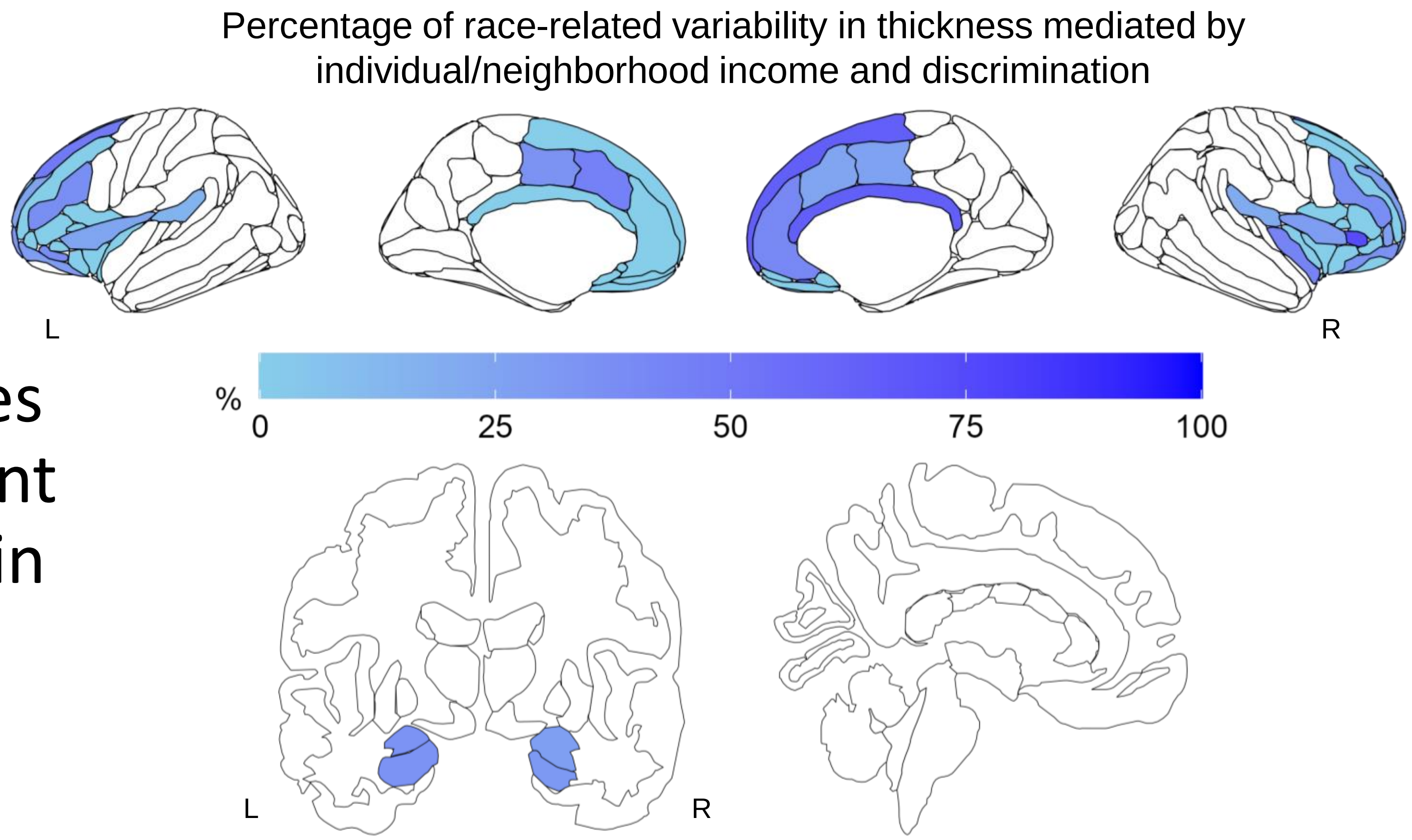


Cortical thickness in a subset of the same adolescents (11-12yo) show similar effects. Modeling choice impacts the extent of effects. Further associations with "deviations" from "normative" development

Harnett et al., Under review

Inequity and brain structure in adolescence

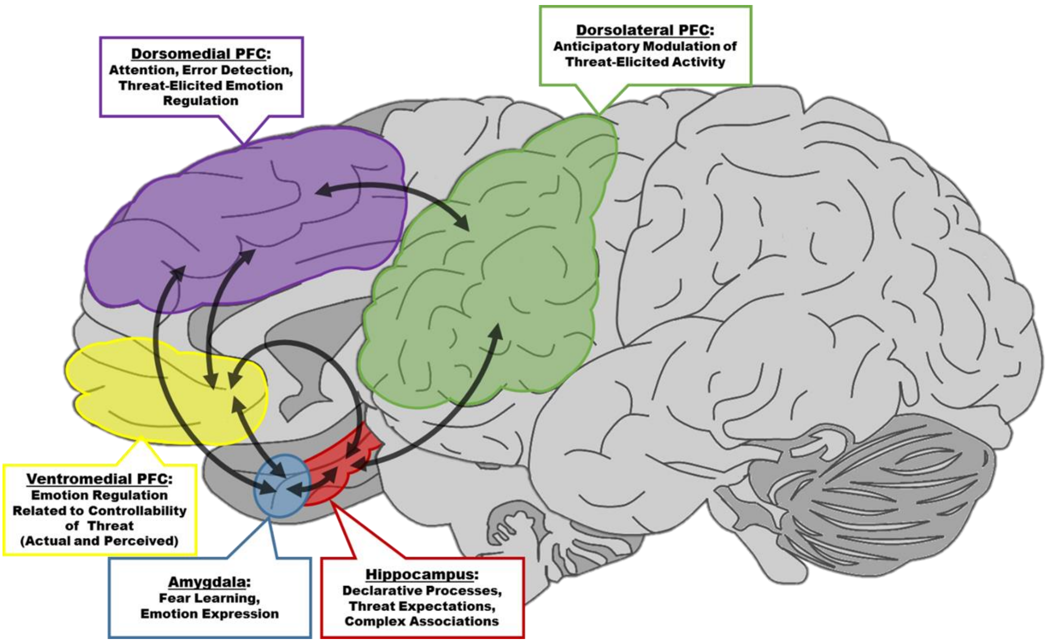


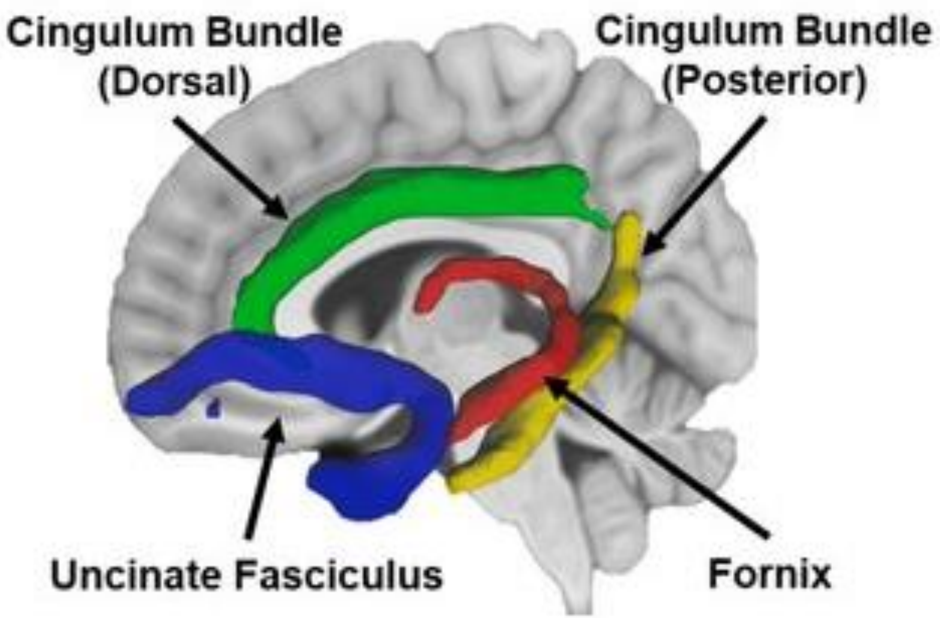


Considerations of disparities continues to explain different amounts of variance in brain morphology

Harnett et al., Under review

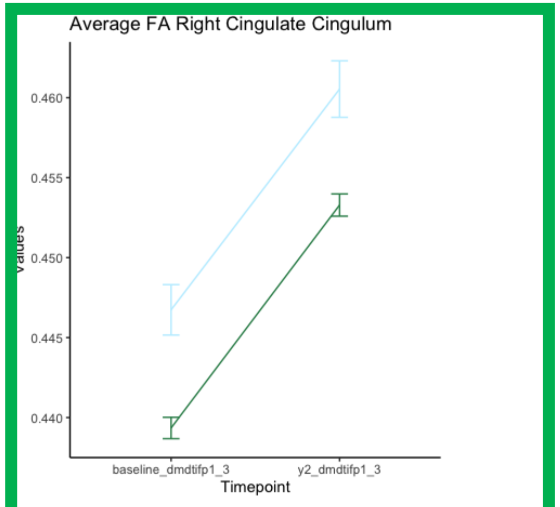
But structural differences may be modality specific

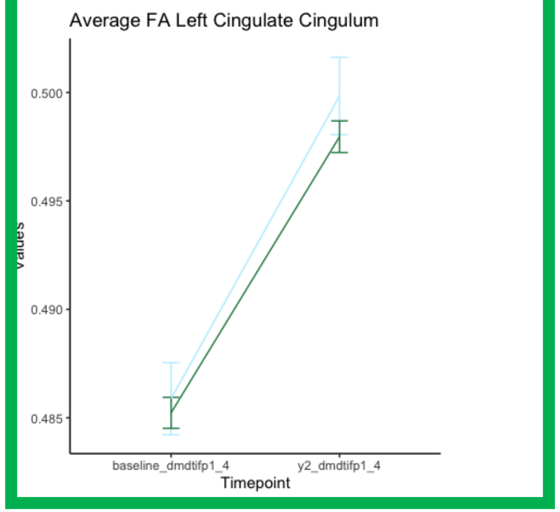


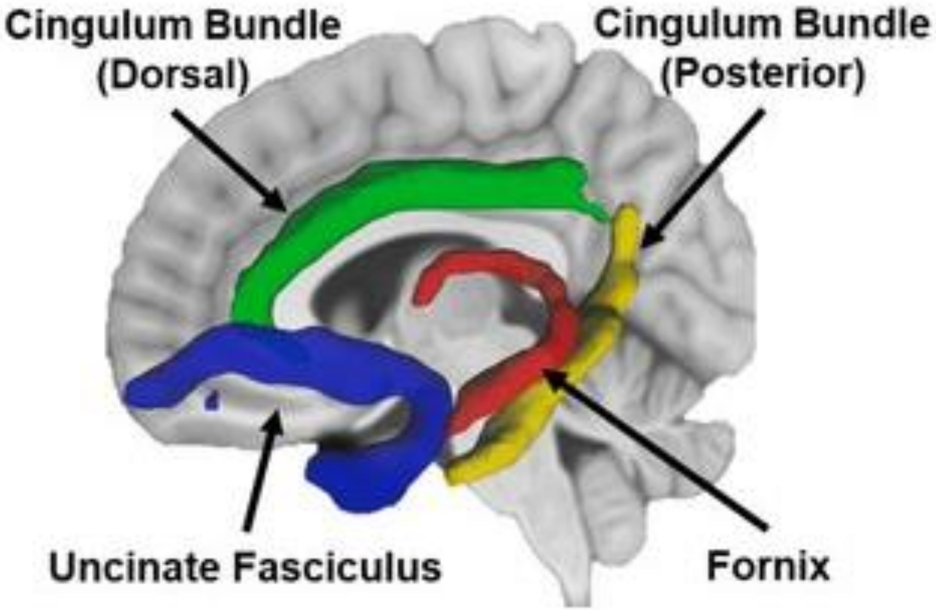


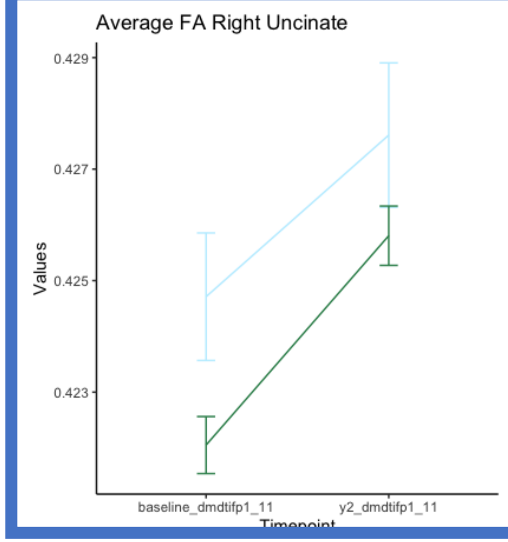
NATE Lab, Unpublished; White matter image is not from ABCD

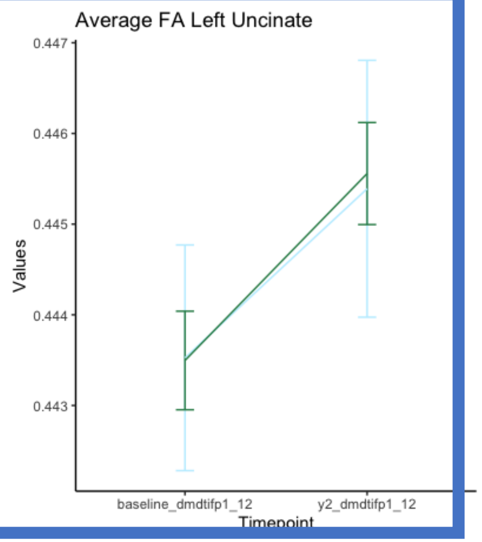
But structural differences may be modality specific

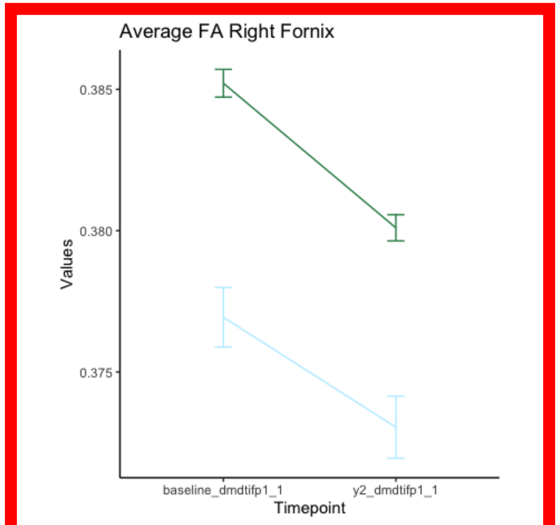


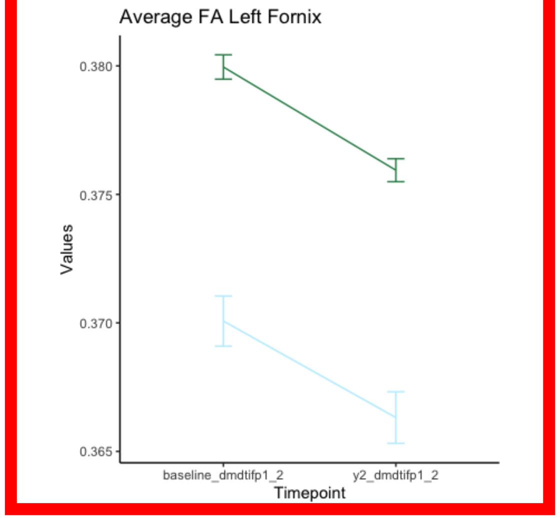






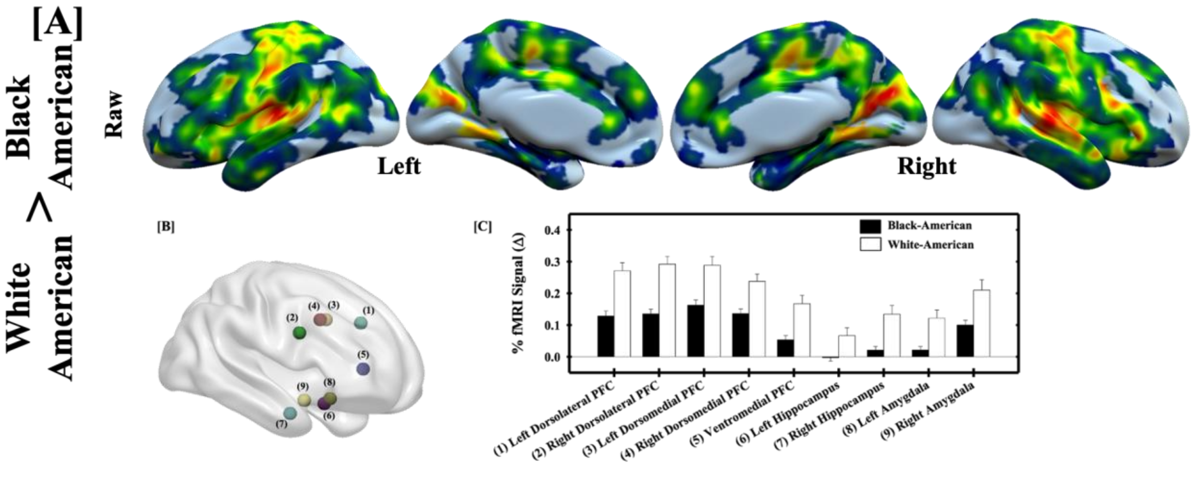




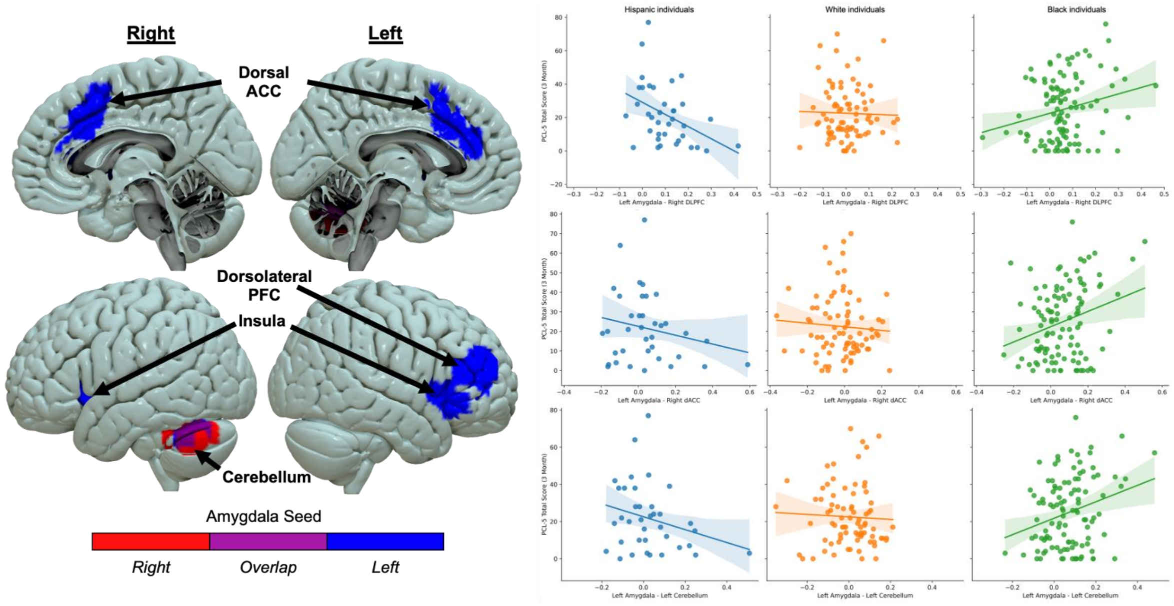


NATE Lab, Unpublished; White matter image is ***not*** from ABCD

Potential long-term impacts



Blunted neurophysiological reactivity to threat in Black compared to white young adults (18-23) (Harnett et al., 2019, *NeuroImage*)



Differential predictive utility of resting-state fMRI of threat network for future PTSD symptoms (18-75) (Harnett et al., 2023, *Molecular Psychiatry)*

Compounding effects of structural inequities

1. Racial inequities contribute to altered structural morphology of threat neurocircuitry in children and adolescents.
2. Racial inequities during development contribute to blunted neural reactivity to threat in young adulthood.
3. Racial inequities contribute to differences in tonic arousal that are tied to PTSD susceptibility.

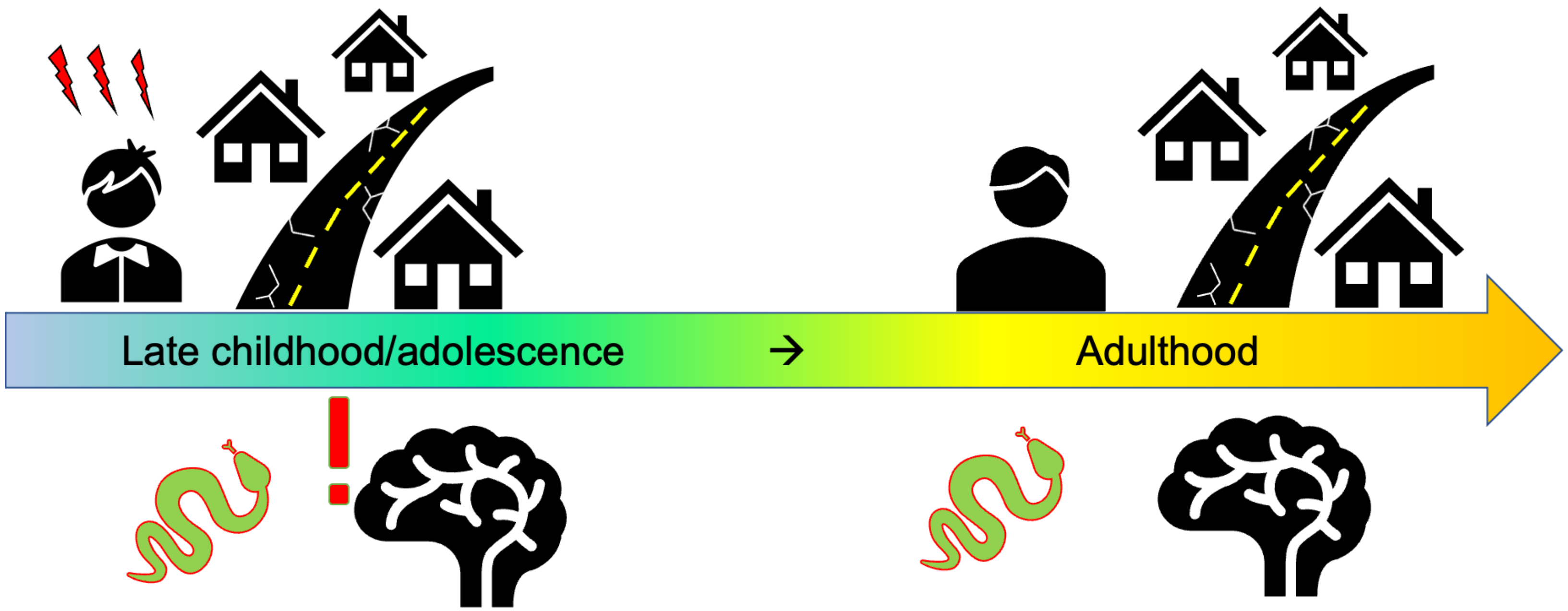
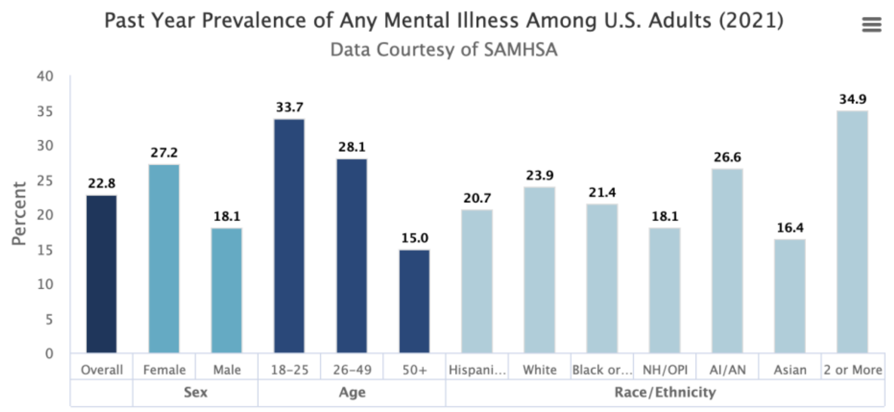


Figure 1



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