**Examining the Effects of Neighborhood Disadvantage on Neural Responses to Executive Control**

**BY**

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## ABSTRACT

Previous research has shown that neighborhood disadvantage is strongly associated with internalizing behaviors, or negative behaviors directed towards oneself (Leventhal & Brooks-Gunn, 2000). Such behaviors have also been linked to altered neural responses during executive control as well as abnormalities within the anterior cingulate cortex (Karlsgodt et al., 2017; Marusak et al., 2016). However, it remains unclear whether neural responses during executive control mediate the effects of the neighborhood environment on internalizing behaviors. To investigate this issue, we used data from the Adolescent Brain Cognitive Development Study (ABCD Study), which contains longitudinal assessments of brain and behavior from over 10000 adolescents (N = 11876). We hypothesized that neural responses to executive control mediate the effect of the environment on internalizing behaviors, providing insights into the underlying mechanisms of these associations. The primary region of interest was the dorsal anterior cingulate cortex (dACC), a key region for executive control and working memory. We used data from the stop-signal task, which measures inhibitory control and captures dynamic responses within the executive network. Results indicate that there is an association between neighborhood disadvantage and internalizing behaviors even when accounting for any mediation, but the dACC itself does not mediate this relationship. This approach aims to deepen the understanding of how environmental factors and brain activity intersect to influence adolescent mental health.

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# CHAPTER 1

# INTRODUCTION

Internalizing behaviors, or negative emotional responses directed towards oneself, are closely linked to an individual's emotional and psychological well-being. These behaviors can vary, but often include symptoms such as social withdrawal, somatic complaints, anxiety, depression, and difficulty concentrating (Liu et al., 2011). Internalizing behaviors are particularly prevalent in children and adolescents and can be associated with negative outcomes like chronic absenteeism from school, substance use, psychiatric disorders, and even suicide.

Given the significant impact of internalizing behaviors on child and adolescent mental health and welfare, it is important to examine factors that contribute to their development and persistence. Previous research has established a strong association between neighborhood disadvantage and internalizing behaviors (Leventhal & Brooks-Gunn, 2000). Neighborhood disadvantage, which is based on the socioeconomic conditions of specific residential areas, is characterized by factors such as high rates of poverty, violence, and limited access to resources. Such environmental stressors can affect the social and emotional development of children who grow up in disadvantaged neighborhoods, with heightened levels of adversity contributing to the symptoms of internalizing behaviors seen in higher levels in adolescents from disadvantaged neighborhoods (Hackman et al., 2012; Humphrey & Root, 2017).

With these findings, it is crucial to investigate the role that the brain plays in the association between the environment or neighborhood and behavior. Neural responses to executive control, processes involved in higher level cognitive functions like executive control, and abnormalities within the dorsal anterior cingulate cortex (dACC) of the brain have been linked to both internalizing behaviors and neighborhood disadvantage. Specifically, internalizing behaviors have been associated with higher activation in the medial prefrontal cortex and dorsal anterior cingulate cortex (Karlsgodt et al., 2018; Marusak et al., 2016). Additionally, research has shown that neighborhood disadvantage is associated with heightened activity in the anterior cingulate cortex and impaired executive control (Tomlinson et al., 2020; Webb et al., 2023).

Given these established associations, it is important to examine whether activity in the dACC as a region of interest during tasks of executive control serves as a potential mechanism in the link between neighborhood disadvantage and internalizing behaviors. Executive control includes processes such as conflict monitoring, inhibitory control, error detection, and emotional regulation that are functions of the dACC. Impairments in these functions have been associated with the development of internalizing behaviors (Compas et al., 2017; Silveira et al., 2021; Yang et al., 2016). Because adolescents in disadvantaged neighborhoods may experience chronic stressors that diminish the executive control functions described above, this may be a factor contributing to higher rates of internalizing behaviors in disadvantaged youth. Yet, it remains unclear whether executive control of functions like emotional regulation in brain regions like the dACC influence the relationship between neighborhood disadvantage and internalizing behaviors.

The goal of this study is to examine whether neural responses to executive control in the dACC mediate the association between internalizing behaviors and neighborhood disadvantage in adolescents. This approach aims to deepen the understanding of how environmental factors and neural activity intersect to actively influence adolescent mental health.

# CHAPTER 2

# METHOD

## Adolescent Brain Cognitive Development (ABCD) Study

Researching adolescent brain development has historically been limited by various factors, including sample size, the diversity of participants recruited to participate in studies, and the amount and type of data collected. In an attempt to combat some of the limitations of research in adolescence, the Adolescent Brain Cognitive Development℠ (ABCD) study was established to collect data from a population of adolescents in the United States across time that can be used to determine risk factors for future mental and physical health problems. The study began in 2015 and continues to track over 11,000 adolescents for 10 years, beginning at ages 8-10. Data is collected across numerous domains, including neuroimaging, substance use, behavioral assessments, and environmental factors, so research can examine the factors contributing to development and adverse outcomes in adolescence.

## Participants

Participants for the ABCD Study were recruited through random sampling of schools that aimed to accurately reflect the diversity in the population of the United States. Adolescents were ineligible to participate if they (1) were not fluent in English or Spanish or did not have a guardian fluent in English or Spanish, (2) had a major medical condition, (3) had MRI contraindications, (3) were born extremely preterm or with a birth weight lower than 1200 grams, and/or (4) a current diagnosis of schizophrenia, level 2 or level 3 autism spectrum disorder, or intellectual disability (Dick et al., 2021). The ABCD Study collected data from over

11,000 participants, with an exact sample size of 11,876. Participants were excluded based on missing data for variable measures collected at baseline and two-year checkpoints, resulting in an updated sample size of 5,857.

## Mediation Model

We hypothesize that neural responses to executive control, specifically in the dACC during a task of inhibitory control, mediate the effect of neighborhood disadvantage on internalizing behaviors. In this study, neighborhood disadvantage serves as the independent variable, internalizing behaviors as the dependent variable, and dACC activity during the stop-signal task as the mediator.

## Measures

### Internalizing Behaviors

The first measure used was internalizing behaviors, which was based on parental reports of their adolescent's behaviors in the categories of Anxious/depressed, Withdrawn/depressed, and Somatic complaints using the Child Behavior Checklist (Achenbach, 2011). T-score composites were used at each age group for internalizing behaviors.

### Executive Control

The variable used for executive control was dACC activity during responses of accurate stop versus correct go during the stop-signal task, a cognitive task that measures inhibition. Because the dorsal anterior cingulate cortex (dACC) is a key region for executive control and working memory, analyses specifically looked at the beta weight of the dACC, defined by the anatomical region, during accurate stop versus correct go responses during the stop-signal task. The weights were averaged across the two brain hemispheres.

### Neighborhood Disadvantage

Neighborhood disadvantage was based on national percentile values of Area Deprivation Index (ADI) measures taken from residential history. ADI is based on U.S. Census data for scores in the following domains: federal poverty level (FPL) of 150% or 100%, income disparity, less than 8 years of education, 12 or more years of education, white collar occupation, unemployment, single parent, owner occupied, crowding, no motor vehicle, no telephone, no plumbing, median income, median home value, median rent, and median mortgage (Petterson, 2023).

## Statistical Approach

All statistical analyses, including mediation analyses, were conducted in R software version 4.3.2 (R Project for Statistical Computing). It was hypothesized that dACC responses during the stop-signal task would mediate the effects of neighborhood disadvantage on internalizing behaviors. Data were analyzed from February 2025 to April 2025.

# CHAPTER 3

# RESULTS

Table 1: Descriptive Statistics

| Variable | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Internalizing Behaviors | 48.83 | 10.27 | 31 | 96 |
| Neighborhood Disadvantage (Percentile) | 39.19 | 26.28 | 1 | 100 |
| Neighborhood Disadvantage (Weighted Sum) | 94.40 | 20.80 | 1.07 | 125.75 |

Parents reported a wide range of internalizing behaviors assessed by the Child Behavior Checklist, as shown in Table 1. Given representative recruiting, the mean score of 48.83 for internalizing behaviors reflects relatively low levels of symptoms in the sample, with scores above 70 recognized as clinically significant manifestations of these behaviors. 1662 adolescents scored above this threshold.

Percentile scores for neighborhood disadvantage as determined by ADI were negatively skewed, with a mean percentile score of 39.19 lower than the national average of 50. When taken as weighted sum scores, the distribution did not exhibit the same negative skew. This difference may be due in part to the characteristics of the weighting system used, which affects how the data is aggregated and transformed.

The following figures display the distribution of the variables used. Neighborhood disadvantage was taken as the weighted sum of ADI scores based on area zip code in Figure 2 and based solely on the percentile scores in Figure 1.

**Figure 1.** Distribution of ADI Percentile Scores

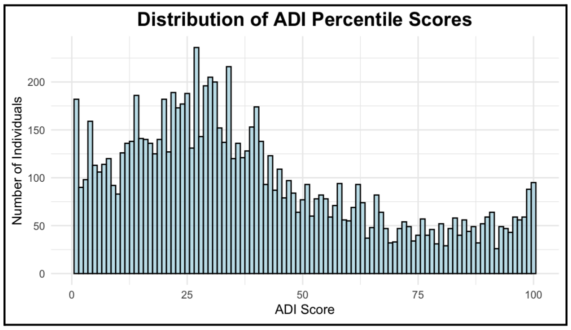



**Figure 2.** Distribution of ADI Weighted Sum Scores

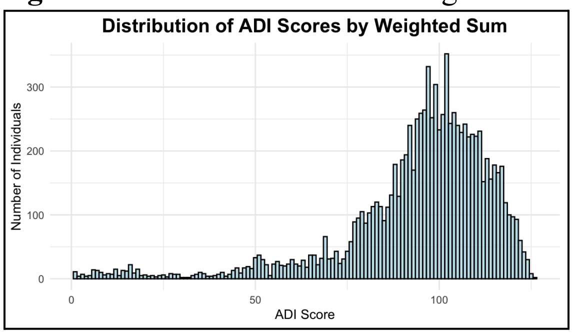



**Figure 3.** Distribution of Internalizing Symptoms

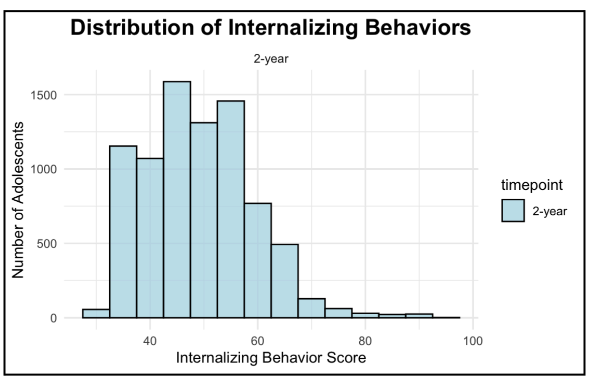


**Figure 4.** Internalizing Behaviors versus ADI at Two-Year Follow-Up

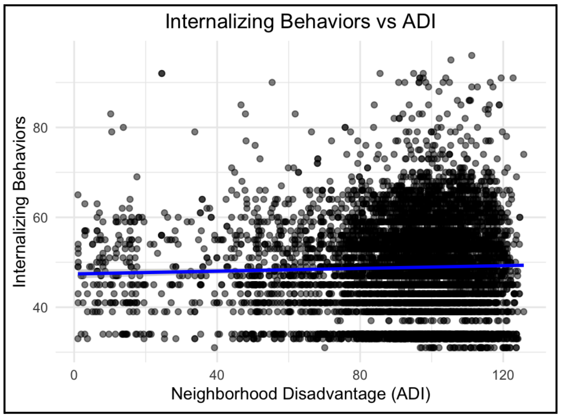
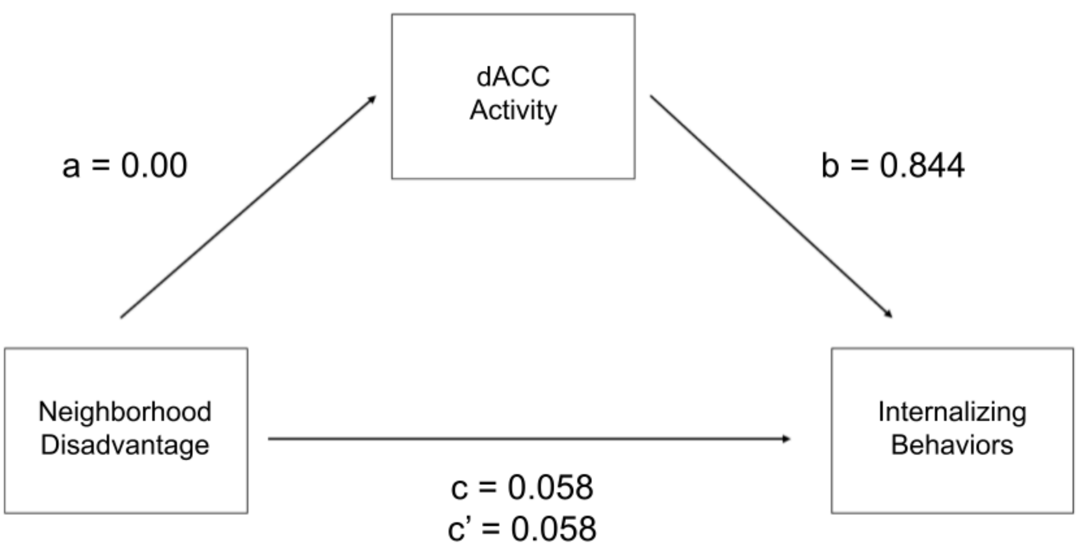



Figure 4 shows the association between neighborhood disadvantage and internalizing behaviors. There is a weak positive correlation between neighborhood disadvantage, as taken by the weighted sum of ADI scores, and internalizing behaviors at the two-year follow up.

**Figure 5.** *Mediation model testing whether dACC activity mediates the association between internalizing behaviors and neighborhood disadvantage (ADI)*



In the mediation analysis, dACC activity during the stop-signal task was used as the mediator. While increased weighted sum scores for ADI were associated with increased internalizing behaviors, dACC activity did not mediate this association ($p$ = 0.758, 95% bootstrap, CI [-0.00016, 0]). In the model used, the direct effect of neighborhood disadvantage on internalizing behaviors was statistically significant ($c'$ = 0.058, $p$ = .022), while the indirect path through dACC was not significant ($a \times b$ = 0.000, $p$ = .701), indicating no evidence of mediation.

# CHAPTER 4

# DISCUSSION

In this study, we investigated the relationship between neighborhood disadvantage and internalizing behaviors in adolescents while considering dACC activation during an executive control task as a potential mediating factor. Results indicated that neighborhood disadvantage, as defined by ADI, is associated with internalizing behaviors at the two-year checkpoint in adolescents enrolled in the ABCD study. Additionally, the mediation analysis showed that dACC activity does not mediate the relationship between neighborhood disadvantage and internalizing behaviors.

Childhood internalizing behaviors remain an important area of research due to the impact of these behaviors on long-term development and outcomes. Internalizing behaviors in adolescence are associated with increased risk of depression, substance use, and suicidal behavior in adulthood (Keyes et al., 2024; Liu et al., 2011; Sands et al., 2022). Furthermore, internalizing behaviors are also linked to unfavorable economic and social outcomes in early adulthood, including lower employment, decreased incidence of intimate relationships, and increased reliance on welfare programs (Alaie et al., 2021; Fletcher, 2012; Vergunst et al., 2023). Given the significance of these effects, it is critical to investigate mechanisms that contribute to the development of internalizing symptoms in adolescents, including environmental adversity.

These data suggest that the association between neighborhood disadvantage and internalizing behaviors is an area for further study. Examining this association is an important area of research because adolescents exposed to chronic environmental stressors may have a particular vulnerability to behavioral deficits, including internalizing symptoms. To date, the literature has primarily focused on cross-sectional associations or limited longitudinal data without accounting for neural mechanisms that may act as potential mediators of environmental influences that affect individual behavioral outcomes. Understanding these associations is essential to identifying accommodating factors that affect the development of negative behavioral outcomes, a goal that guided the design of the present study.

Due to sample characteristics and the restricted specificity of neural measures in this study, the findings should be interpreted within the context of limitations. While the ABCD study itself has a diverse sample size meant to reflect population demographics in the United States, data were excluded if participants did not participate in the longitudinal aspect of the study to ensure the same participants could be tracked over time. Additionally, use of dACC activity during the stop-signal task as a parameter for executive control was a very targeted variable based on a specific region of interest (ROI) in the brain. Because the dACC is one part of a vast executive network, there is a basis for future research involving other regions of interest, such as the dorsolateral prefrontal cortex.

Future directions for this research may focus on following the current mediation model over time or adjusting the mediation model to include alternative regions of interest. With future releases of ABCD study data upcoming, including the 6.0 release planned for 2025, longitudinal analyses could be extended to include data from these timepoints. Other regions of interest within the executive network could also be examined beyond the dACC to provide a more comprehensive understanding of how broader executive control pathways contribute to the association between the environment and behavior.

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