Childhood and adolescence are characterized by heightened neural plasticity—the brain's ability to change in response to experience. This plasticity brings both opportunity and risk to the developing brain. On the one hand, plasticity facilitates learning and allows children to be highly adaptable to their environment. On the other hand, this heightened plasticity can also have costs for children who encounter adversity—including consequences for academic achievement, socioemotional development, and mental health. As a developmental cognitive neuroscientist, my research program focuses on how the brain develops to support complex cognitive functions like attention and memory, and how early life adversity alters neurocognitive development in ways that contribute to difficulties in school and mental health problems. My graduate work as a cognitive neuroscientist and vision scientist[1–3] has prepared me to apply rigorous neuroimaging methods to study development. With support from an F32 National Research Service Award at the University of Washington and a K99/R00 Pathway to Independence Award at Harvard University, I leverage the tools of cognitive neuroscience and developmental psychology to uncover how aspects of a child's environment—especially those associated with socioeconomic status, such as cognitive stimulation and exposure to violence—influence cognitive, socioemotional, and neural development from preschool to adolescence.

My lab will utilize both lab-based assessment of children's environments and neurocognitive development as well as large-scale publicly available data to produce replicable and generalizable findings. Three specific branches of my research examine: 1) how the developing brain supports higher-order cognitive functions, such as attention, memory, and executive function; 2) the environmental, cognitive, and neural mechanisms that explain socioeconomic disparities in academic achievement; and 3) and factors that promote resilience and adaptive functioning among children who have experienced adversity. My record reflects my deep passion for **engaging undergraduates in research** at all levels of study: from conducting behavioral and functional magnetic resonance imaging (fMRI) studies to processing and analyzing neuroimaging data, all of which I plan to continue in my lab.

Neurodevelopmental Mechanisms Scaffolding Higher-Order Cognition

Characterizing typical patterns of neurocognitive development is a critical first step to understanding the mechanisms underlying atypical development. My work focuses on neural mechanisms of higher-order cognitive abilities—including attention, memory, and executive function—that play a meaningful role in supporting academic performance in children and adolescents. Specifically, I have demonstrated the important role that sensory processing regions play in scaffolding multiple higher-order cognitive abilities. Prior work has focused largely on how areas of the brain like the hippocampus and prefrontal cortex (PFC) support the development of these capacities. However, my work has demonstrated that visual processing regions in the ventral visual stream (VVS)—a set of brain regions that respond preferentially to different categories of visual stimuli—also play an important role in supporting the development of complex cognitive processes including attention, working memory, and long-term memory. I have shown that recruitment of category-preferential regions of the VVS increases linearly with age from childhood to adolescence during attention and memory tasks[4,5]. Critically, greater recruitment of these regions predicts better attention and memory performance, suggesting that these sensory processing regions meaningfully contribute to higher-order cognitive processes. Furthermore, greater recruitment of these visual processing regions mediates age-related improvements in memory over and above the contribution of areas known to support these abilities, like the hippocampus[5]. Given that the VVS develops earlier in life than regions thought to support development of attention and working memory, these findings have meaningful implications for understanding how early life adversity influences these cognitive abilities via pathways involving early-developing sensory processing regions. Understanding how the brain develops to support emerging complex cognitive abilities is a critical step in uncovering how experiences of adversity may impact this development.

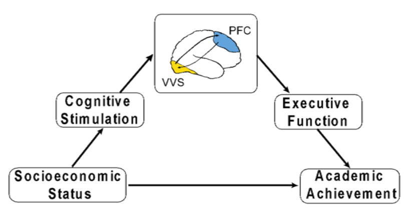
Mechanisms in the Income-Achievement Gap

Children raised in families with low socioeconomic status (SES) tend to exhibit lower academic performance than their higher-SES peers and this income-achievement gap has not diminished over the last half century. Understanding the mechanisms through which differences in childhood SES lead to differences in achievement is critical to addressing this gap. My second line of research examines these mechanisms. My research focuses on identifying the environmental, cognitive, and neural mechanisms that explain the income-achievement gap, with the aim of informing interventions to reduce SES-related differences in children's achievement.

Cognitive stimulation. One of the primary environmental pathways I have examined is cognitive stimulation, which refers to access to learning materials, caregiver involvement in learning, and exposure to complex language. To examine whether differences in cognitive stimulation contribute to the income-achievement gap, I conducted home visits with families of five-to-six-year-olds to quantify cognitive stimulation through gold-standard observational methods. In addition to finding that the cognitive stimulation available to children increased dramatically with family SES, cognitive stimulation was also strongly associated with executive function—including working memory, inhibition, and cognitive flexibility—and mediated SES-related differences in executive function[6]. These differences in executive function predicted academic achievement 18 months later and served as a mechanism explaining SES-related differences in academic performance. These findings highlight the importance of cognitive stimulation in scaffolding the development of executive function and identifies a key target in addressing the income-achievement gap. Along with two undergraduate mentees, I recently extended these findings to further highlight the importance of cognitive stimulation in explaining SES-related differences in children's language abilities[7].

Neurodevelopmental Mechanisms. How might differences in cognitive stimulation shape neural development? My research has also examined how SES and cognitive stimulation are associated with the structure and function of the frontoparietal network, a network of regions known to support cognitive functions critical for academic achievement. I have demonstrated that SES is positively associated with cortical thickness and white matter microstructure, as well as activation in the frontoparietal network during a working memory[5]. Critically, I showed that SES-related differences in the structure of the frontoparietal network were explained by the degree of cognitive stimulation in the home environment. Again, cognitive stimulation, along with working memory performance and frontoparietal structure and function, mediated the association between SES and children's academic achievement. These findings provide a mechanistic explanation of central environmental, cognitive, and neural mechanisms that link SES with academic achievement.

I have extended this work by highlighting the important role that visual processing regions play as an additional neurodevelopmental mechanism in the achievement gap. My work in typical neurocognitive development shows that category-preferential visual processing regions in the VVS support cognitive development. I have consistently found that lower SES is associated with reductions in the recruitment of these regions during complex cognitive tasks, including attention and working memory[5,8]. These patterns dovetail with frequently reported reductions in cortical thickness in these regions in large-scale studies of SES and neurodevelopment, though they have rarely been interpreted or linked to behavioral outcomes.



Conceptual model of neurodevelopmental mechanisms of the income-achievement gap

The VVS develops earlier in life than the PFC, has feed-forward projections to the PFC, and receives input through feedback connections from the PFC. I have proposed that cognitive stimulation in the context of caregiver interactions early in life supports VVS development, which in turn scaffolds development of the PFC and executive function[9]. My K99/R00 award will directly test these hypotheses. Supporting this theoretical argument, I recently found that lower SES was associated with lower VVS recruitment during an attention task, which in turn, was associated with lower executive function and predicted lower academic achievement in children[8]. These findings i) replicate my prior work demonstrating the important role that the VVS plays in supporting higher-order cognitive abilities[4], ii) demonstrate that SES is associated with VVS function, and (iii) highlight that individual differences in VVS function may be an additional neural mechanism in the income-achievement gap.

Fostering Adaptive Development following Experiences of Adversity

Why is it that some children who experience adversity go on to develop academic, socioemotional, and mental health difficulties while others do not? My third line of research explores factors that promote adaptive development and confer resilience among children and adolescents who have experienced adverse environments.

My work has shed light on how typical patterns of neurodevelopment help support adaptive behaviors not only in relation to higher-order cognitive abilities, but also socio-emotional development. For example, I have shown that patterns of neurodevelopment previously associated with risk for problem behaviors may actually confer benefits for adaptive social behavior during adolescence. Adolescents exhibit heightened neural sensitivity to social and emotional information (e.g., social evaluation) compared to adults and children. This sensitivity is thought to increase vulnerability to peer pressure and risky behavior, although some have suggested that increased sensitivity to social feedback during this period helps adolescents flexibly update behavior and enhance social belonging. Indeed, my work has shown that adolescents exhibit heightened neural sensitivity in the salience network in response to changes in the emotional facial expressions of others.[10] Critically, greater sensitivity in the salience network was associated with lower levels of social anxiety and social problems. These findings suggest that adolescent-specific patterns of neurodevelopment confer advantages that produce adaptive social behavior during this key developmental window. Understanding these typical developmental patterns is a critical first step towards understanding how experiences of adversity might alter these patterns of neurodevelopment.

My research also investigates factors that can promote resilience and buffer children against negative developmental consequences following stressful life events and experiences of adversity. In collaboration with a student mentee, we have found that having a growth mindset—the belief that one's abilities are malleable and can be cultivated through effort—promotes academic achievement and even protects children who have experienced violence from risk for psychopathology[11]. In research with collaborators in clinical psychology, I have shown that while exposure to violence increases risk for depression, children who are more sensitive to rewards at both behavioral and neural levels are protected against developing depression following such trauma[12,13], suggesting that reward sensitivity may serve as a protective factor for children exposed to violence. These findings may have utility in identifying early intervention targets for children who have encountered trauma and adversity, and suggest that they may benefit most from existing evidence-based interventions that target growth mindset and reward sensitivity (e.g., behavioral activation).

Most recently, with a team of undergraduates, I have investigated factors that promote resilience in the wake of the stressful life events that have accompanied the COVID-19 global pandemic. Using two longitudinal cohorts, I found that greater physical exercise and time in nature, less screen time and news consumption, and higher sleep quality and quantity all play important roles in buffering against the emergence of mental health problems following COVID-19-related stressors, especially among younger children[14]. Expanding on my work on SES-related disparities in executive function, I also found that children with lower executive function prior to the pandemic are particularly at risk for negative mental health outcomes following exposure to COVID-related stressors during the pandemic.

Identifying malleable factors that confer resilience among children and adolescents exposed to early life adversity is key to designing effective interventions to promote positive outcomes in children.

Future Directions

My work explores the links between the environment, brain, and behavior to understand typical development and factors that put children at risk for negative outcomes and provide resilience in the face of adversity. My lab will combine neuroimaging and behavioral techniques to assess how different dimensions of the early environment influence neural and cognitive development with have lasting downstream consequences for children's well-being. I will continue to utilize lab-based behavioral and neuroimaging studies that carefully quantify children's environmental experiences. Moreover, large publicly available data sets such as the ABCD, the Human Connectome Project-Development (HCP-D), and HEALthy Brain and Child Development Study (HBCD) are the next frontier of developmental cognitive neuroscience and feasibly allow undergraduates to engage in neuroimaging research. Critically, I will take advantage of the fact that all of these studies include measures of socioeconomic status, early adversity, and cognitive development to expand my research program. Below I elaborate on the future directions of the three arms of research outlined above.

Neurodevelopmental Mechanisms Scaffolding Higher-Order Cognition. I have shown that lower-order sensory processing regions are important in the development of complex cognitive ability. However, recruitment of visual processing regions to support memory and attention across development could reflect either (1) greater *depth* of perceptual processing, or (2) enhanced *top-down attention* to visual stimuli across development. To determine whether age-related changes in cognitive development are predicted by patterns of basic visual processing or by patterns of top-down modulation during cognitively demanding tasks, I will conduct longitudinal fMRI studies using tasks with higher-order cognitive demands (e.g., working memory) as well as basic sensory processing tasks (e.g., passive viewing) and multivariate neuroimaging analyses. Additionally, I have shown that function in visual processing regions predict higher-order cognitive abilities, but it remains unknown whether this extends into regions that process other sensory modalities. To that end, I also plan to use tasks with auditory and tactile stimuli to determine whether development of other sensory processing regions similarly predicts development of higher-order cognitive function.

Mechanisms of the Income-Achievement Gap. I have demonstrated the importance of cognitive stimulation and development of the frontoparietal network and VVS in explaining SES-related differences in academic achievement. With support from my R00 award, my future work in this area will examine the home environment in more powerful and rich ways (e.g. Language Environment Analysis or LENA to quantify linguistic experience in children's natural environments, careful quantification of the perceptual and physical environment, and home observation methods) and leverage multimodal neuroimaging techniques (fNIRS, MRI, fMRI) to assess neural structure and function. My future work will incorporate cutting-edge multivariate techniques (e.g., representational similarity analysis) to characterize how well different categories of stimuli (e.g., faces and both familiar and novel objects) are differentiated in the VVS before children enter school. I will then use these measures of VVS structure and function—in addition to environmental and cognitive measures—to predict later executive function, structure and function of the PFC, and academic achievement. Moreover, I will leverage publicly available data from the ABCD study to further examine these associations in a large sample. Together, these efforts will allow for deeper understanding of the mechanisms that explain the income-achievement gap.

Fostering Adaptive Development following Experiences of Adversity. My future work in this area will explore additional factors that protect children exposed to adversity from negative outcomes related to poor school performance and socioemotional problems. For example, parental involvement in children's learning not only confers benefits for cognitive development but could also play a role in buffering against mental health and adjustment problems. As part of my R00 study, I will employ measurements of parent-child interactions during problem-solving, book reading, and free play. I will use these interactions to assess how certain aspects of parenting (e.g., warmth, sensitivity, and responsiveness) contribute to resilience in the face of stress in academic and social domains.

Another important avenue of my future research is focusing on the *strengths* of children that are raised in adverse environments. Work on this topic has traditionally taken a deficit-based approach, but increasing work suggests that developmental changes following adversity help children adapt to challenging environments and experiencing adversity can create unrecognized strengths. This orientation focuses on how adaptations in response to adverse environments confer behavioral advantages, such as increased creativity, cognitive flexibility, more diffuse attention, and heightened perception of socioemotional information. I plan to characterize these adaptations with the hope that understanding these strengths can be leveraged, for example, to better align curricula and school environments with these strengths.

Together, my lab will work to uncover the environmental, cognitive, and neurobiological mechanisms that underlie risk and resilience among children who have experienced adversity. I look forward to a career focused on the neuroscience of adversity with a lab that centers undergraduate research education.

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