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NEUROSCIENCE AND PSYCHOLOGY
Published: 31 August 2023
doi: 10.3389/frym.2023.701470

SHAPING THE GROWING BRAIN: NEIGHBORHOOD, HOME, AND SCHOOL ALL MATTER

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YOUNG REVIEWERS:

JORDAN
AGE: 8

THE SCHOOL FOR SCIENCE AND MATH AT VANDERBILT
AGES: 14–15

The neighborhoods children grow up in can influence how their brains develop—but we do not yet know exactly how this happens. In a sample of 7,500 children aged 9–10 years, we found that the quality of neighborhoods, which can be measured in various ways including access to parks and libraries, was associated with differences in the communication between brain regions involved in planning, goal setting, and self-reflection. Some of the patterns of brain connectivity that were associated with neighborhood quality were also associated with brain function and mental health. We also found that, for children with more positive and supportive home and school environments, neighborhood quality was less important for brain connectivity. Our findings suggest that the environments we grow up in may shape the way our brains develop in complex ways.

WHY NEIGHBORHOODS MATTER

WELLBEING

A state of being comfortable, healthy, or happy.

The neighborhoods we grow up in might play a role in shaping our futures, our financial success, and our **wellbeing**. Neighborhoods differ in the average income and education level of the people who live in them, in the availability of resources like parks and libraries, and in the level of crime and pollution. Adults who grow up just streets away from each other can lead quite different lives. To give an example, children who grew up in neighborhoods right across the street from each other in Pittsburgh, Pennsylvania (USA) had different incomes, levels of employment, and imprisonment rates as adults. Differences are evident even during childhood and adolescence. For example, some children from lower-quality neighborhoods have slightly lower academic performance than their peers from neighborhoods with more advantages. Children from lower-quality neighborhoods, on the other hand, can be better at regulating their emotions, coping with difficult situations, and bouncing back after challenging life events like stresses due to the COVID-19 pandemic, which is called a skill called **resilience** [1].

RESILIENCE

The capacity to withstand or to recover quickly from difficulties.

The differences in life outcomes we have described may occur because of neighborhood factors like access to good healthcare or other resources or due to feelings of stress. Although the influence of neighborhood-level factors on life outcomes have been known for a while [2], scientists still do not understand exactly *how* the neighborhoods we grow up in shape us. In our research [3], we tried to understand how the neighborhoods we grow up in shape our brains, and the roles that other environments such as home and school might play.

NEIGHBORHOODS AND BRAIN DEVELOPMENT

Scientists have long believed that the neighborhoods we grow up in can shape our brain structure and the way our brain regions communicate with each other—which, in turn, can affect our behavior and wellbeing. The brain changes substantially during childhood and adolescence, and scientists think that these changes make the brain particularly "plastic" (or adaptable) during this period. The physical and social environments during this time (for example, the way parents interact with children, and children's relationships with their peers) can also shape how the brain develops.

COGNITIVE FUNCTIONS

All forms of knowing and awareness, such as perceiving, conceiving, remembering, reasoning, judging, imagining, and problem solving (from the APA Dictionary of Psychology).

Preliminary research has shown that neighborhood quality is associated with the structure of brain regions that are involved in the development of language and other **cognitive functions** such as attention, planning, goal setting, and self-reflection. Differences in brain structure may be responsible for links between neighborhood quality and academic achievements or language skills, among other outcomes.

WHAT ABOUT RESILIENCE?

Many people who grow up in lower-quality neighborhoods do *not* have negative outcomes. This may be because children in those neighborhoods are exposed to stress, which can be helpful for development. Interestingly, low and moderate levels of stress can foster resilience [4]. It may also be because our neighborhoods are not the only thing that shapes us. Genetic makeup, personalities, and other environmental factors at home and school all play a role. In particular, the way parents interact with their children is very important. Scientists have shown that children whose parents are supportive typically do better at school, regardless of whether they grow up in low- or high-quality neighborhoods. By supporting their children, parents can promote positive development and mental health, and can lessen the negative effects of challenging experiences. What's more, research has found that this positive effect of good parenting might occur through changes in brain development. For example, one study found that parental warmth and support were related to changes in brain structure that were in turn associated with a greater chance of graduating from high school. Importantly, these effects were seen even for children living in lower-quality neighborhoods [5]. Given that the communication between brain regions plays an important role in cognitive function and mental health, we wanted to test whether supportive parenting and favorable school environments, in addition to neighborhood quality, made a difference for brain communication and children's mental health and cognitive functions.

EXAMINING CONNECTIONS IN THE BRAIN

Brain activity can be measured using a brain-imaging technique called **functional magnetic resonance imaging** (fMRI). Basically, this technique looks at blood flow in the brain to determine which brain areas are active. We used data from a large fMRI study of more than 7,500 children aged 9–10 years, from across 21 sites in the United States. Normally, brain regions that work together to perform tasks show synchronized (coordinated) activity, even when people are resting. We wanted to investigate whether neighborhood quality was associated with resting functional connectivity, which refers to the synchronized activity of separate brain regions when someone is resting and thinking of nothing in particular (Figure 1). For our study, we rated neighborhood quality using a special rating system that looks at factors including income, levels of employment, and education for individuals in that neighborhood.

FUNCTIONAL MAGNETIC RESONANCE IMAGING

A type of non-invasive method of imaging brain function. It measures the small changes in blood flow that occur when one is thinking, planning, or simply resting and can be used to make inferences about which parts of the brain are active.

After we identified the patterns of brain connectivity that were linked with neighborhood quality, we investigated whether those patterns of connectivity were associated with cognitive functions and wellbeing. We also investigated whether the patterns of brain connectivity

Figure 1

Brain regions and A and B (orange) show similar patterns of activity, so they can be said to have high positive functional connectivity. Regions B (orange) and C (blue) have low functional connectivity, which means low synchronization between the activity of the two regions. The more synchronized the activity of specific brain areas, the more functionally connected they are.

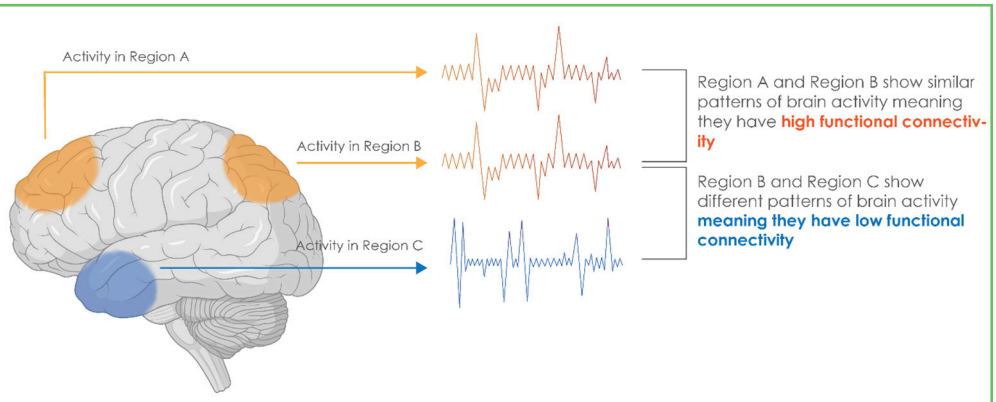

Figure 1

differed when we took other factors, like supportive parenting and favorable school environments, into account.

NEIGHBORHOODS MATTER! BUT THERE IS MORE...

We found that neighborhood quality was associated with widespread patterns of connectivity that spanned across several brain networks—which are groups of functionally similar brain regions. These networks perform many important functions, such as attention, planning, general cognitive ability, goal setting, language, movement, and emotion regulation (to name a few). While we saw general trends in the data, the effect was very small, which means that neighborhood quality is only part of the explanation for the activity patterns we saw. We also saw a lot of individual variability, which means that not all individuals from neighborhoods of the same quality showed the same patterns of brain connectivity (Figure 2).

Figure 2

Each hexagon represents a person's combined score of brain connectivity and neighborhood quality. The darker the hexagon, the more people had that specific combination of scores. See how the yellow line has only a very slight upward slope? This reflects a very small association between neighborhood quality and brain connectivity. Note that there are many hexagons both above and below the yellow line. The green oval highlights individuals with high brain connectivity and the orange oval highlights individuals with low brain connectivity, at the same level of neighborhood quality. This shows that not all individuals who have the same experiences have the same brain connectivity!

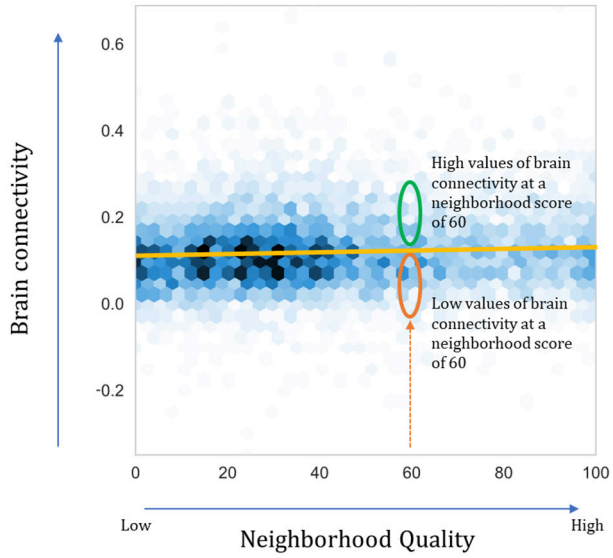

Figure 2

We then studied the relationship between brain connectivity patterns and cognitive functions and mental health. Cognitive functions were subdivided into three components: general cognitive ability (which refers to performance across several different tasks that measure cognitive function including learning and memory, verbal ability, and self-control), learning and memory, and **executive function** (a set of skills including short-term memory, flexible thinking, and self-control). Three aspects of mental health were also examined: feelings of sadness, low self-esteem, or anxiety; traits like aggression or impulsivity; and total mental health issues.

EXECUTIVE FUNCTION

Skills and mental processes that enable us to plan, focus attention, remember, juggle multiple tasks, as well as ability to engage in self-control.

We found that 54% of the connectivity patterns associated with poor neighborhood quality were also associated with lower cognitive function scores (general ability and executive function) and all three aspects of mental health. However, because our research simply looked at *associations* at the same point in time, our data do not tell us about cause and effect. For example, we do not know if neighborhood quality causes changes in brain connectivity, or if brain changes cause differences in cognition and mental health. The relationship between neighborhood quality and brain connectivity may also depend on other things we did not test or measure, such as how long a child was living a neighborhood, or the parents' level of education.

Importantly, we found that positive environmental influences, such as supportive parenting and favorable school environments, influenced the association between neighborhood quality and certain brain connections (Figure 3). Supportive parenting, which was measured using a questionnaire, involved parenting qualities including warmth, love and affection, and being easy to talk to. A favorable school environment, also measured using a questionnaire, includes things like relationships with teachers, feeling safe at school, and the opportunity to participate in extra-curricular activities.

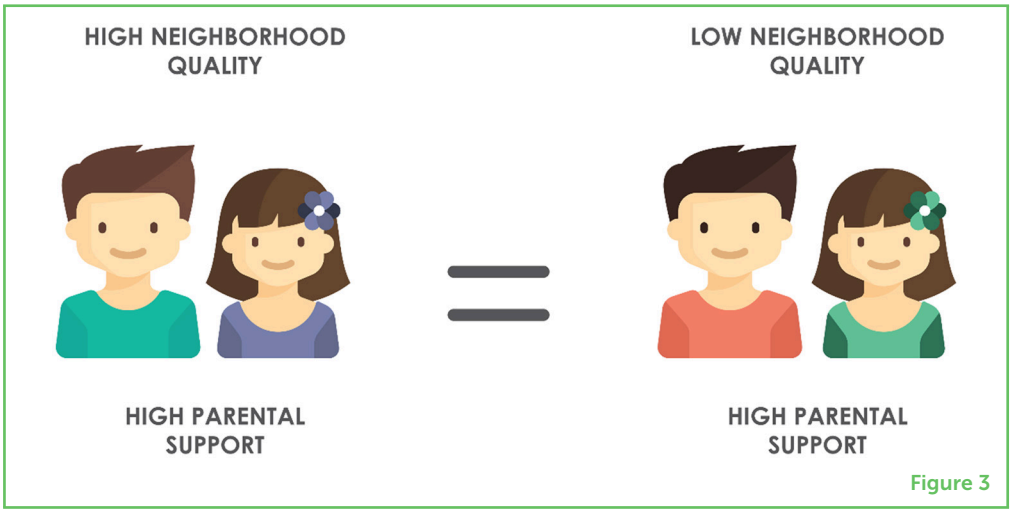

Figure 3

We found that children who received high levels of parental support tended to have similar patterns of functional connectivity, regardless of neighborhood quality. This means that if a child has warm, supportive parents, low neighborhood quality does not matter as much in terms of brain connectivity.

WHAT IS NEXT?

Our findings suggest that, while neighborhood quality might shape children's brains, providing children with better home and school environments—where they feel supported, receive positive feedback, and can engage in a range of activities—might also impact functional connectivity. However, there are several other factors that could contribute to resilience that were not measured in our study. For example, relationships with friends or other family members, feeling connected at school, and owning a pet could all promote children's wellbeing. More work is needed to understand the role that specific brain connections play, and how neighborhood quality and positive environments might alter brain connectivity. We also need to understand what happens to kids' brains over time because we do not know if our findings are specific to the age group we studied—maybe we would see different relationships in younger or older children. In sum, more work is needed to understand why and how specific brain connections are associated with neighborhood quality, whether brain connections are impacted by neighborhoods, and what role these connections play in a child's development.

As we mentioned earlier, some brain changes associated with difficult circumstances might have positive outcomes, and children from neighborhoods of lower quality might outperform their peers at tasks we did not measure in our study. It will be interesting to study how low neighborhood quality contributes to positive outcomes and resilience.

Neighborhood quality—and what makes a high-quality neighborhood—varies considerably depending on the country; so it is hard to know whether our findings from the US will hold true for other countries and cultures. Finally, this study looked at only one point in time, so we have no information on the mental health, achievement, and career outcomes for these children later in life. This would be an interesting question for future work!

I findings from our study could help doctors and scientists to design programs or strategies to improve children's wellbeing or to determine which children might benefit most from such programs. Since the brain is "plastic" during childhood and adolescence, it might be possible to help the brains of young people develop in healthy ways—programs or strategies that promote positive parenting and improve school environments could help to change the brains of young people for the better!

ORIGINAL SOURCE ARTICLE

Rakesh, D., Seguin, C., Zalesky, A., Cropley, V., and Whittle, S. 2021. Associations between neighborhood disadvantage, resting-state

functional connectivity, and behavior in the Adolescent Brain Cognitive Development (ABCD) Study®: moderating role of positive family and school environments. *Biol. Psychiatry: Cogn. Neurosci. Neuroimaging*. 6:877–86. doi: 10.1016/j.bpsc.2021.03.008

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SUBMITTED: 04 August 2021; **ACCEPTED:** 11 August 2023;
PUBLISHED ONLINE: 31 August 2023.

EDITOR: Casey Lew-Williams, Princeton University, United States

SCIENCE MENTORS: Christine Kurlawalla-Martinez and Menton M. Deweese

CITATION: Rakesh D, Seguin C, Cropley V and Whittle S (2023) Shaping the Growing Brain: Neighborhood, Home, and School All Matter. Front. Young Minds 11:701470. doi: 10.3389/frym.2023.701470

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

JORDAN, AGE: 8

I am in third grade. I enjoy different kinds of science. I like to explore things like different rocks, snails, worms and I really like to look at different birds. I like to learn about animal habitats. Space is my favorite subject because there is a huge galaxy that no one has discovered. When I am older, I want to be a scientist that explores space. My favorite animal is a hamster because it is small and cute.

THE SCHOOL FOR SCIENCE AND MATH AT VANDERBILT, AGES: 14–15

We are a class of students from all over Nashville, who come together once per week at Vanderbilt to learn more about science, technology, engineering, and mathematics. We conduct experiments in our classroom and in labs on campus!

AUTHORS

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I am a postdoctoral research scholar at Harvard University, where I study the association between the social environment (e.g., socioeconomic status and the school environment), adolescent brain development, and mental health. I completed my Ph.D. work at the University of Melbourne, and earned a master's degree in neuroscience from the University of Bordeaux, in France. *divyangana.rakesh@gmail.com

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I am a computer scientist working on neuroscience at Indiana University and the University of Melbourne. I use tools from mathematics, statistics, and computer science to study the brain from a network model perspective. I am interested in how we can use networks to understand the elements of the natural world, working at the interface between life and computational sciences.

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I am a Professor at the Melbourne Neuropsychiatry Center, Department of Psychiatry, at the University of Melbourne. I have a background in psychology and my research aims to improve our understanding of the neural basis of mental health problems in young people. I am also interested in how the social environment shapes brain development and the role of risk and resilience for mental health problems in youth.