Rich Experiences, Physical Activity Create Healthy Brains

An Interview with Developmental Psychologist William Greenough

Abstract: Rich, complex experiences are necessary for the development of sound brain architecture, particularly during early childhood, but also throughout the life span. Physical activity is particularly beneficial for brain development and cognitive development, especially when combined with new experiences. These findings underscore the need to create environments for children that support the developing brain architecture.

Council Member **William Greenough, Ph.D.** is a professor in the University of Illinois Urbana-Champaign departments of Psychology, Psychiatry, and Cell and Structural Biology, and a full-time faculty member in the Beckman Institute NeuroTech Group. His research interests include mechanisms of brain-behavioral development, neural mechanisms of learning and memory, and plasticity of non-neuronal cells and systems of the brain.

Your research indicates that connections in the brain change dramatically when a young subject learns something new. Please tell us more.

One thing we've found is that animals that grow up in a challenging, experience-filled environment learn better than animals that grow up in sterile, uninteresting cages. Animals raised in richer environments exhibit more complex behaviors and perform better at solving problems (such as finding their way through a maze more rapidly). Their brains also have more connections between neurons, more cells called glia that support the functioning of neurons and their connections, and a denser network of capillaries supplying blood to the brain. It's clear that a stimulating environment produces a richer brain.

If you take animals that have been raised in bare cages until they were adolescents and put them in a richer environment, you still get some effects, but the effects are smaller. As the animals become older and older, the effects diminish more and more. In truly elderly rats, you see very small effects. They still benefit from being placed in a rich environment, but not nearly as much. The take-home message for humans is that there is still plasticity at later ages but the early environment is critically important to the optimal development of brain architecture.

NATIONAL SCIENTIFIC COUNCIL ON THE DEVELOPING CHILD

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For more information on the Council and the science of early childhood, go to www.developingchild.net.

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Given that the effects are greater earlier in life, how important are the right experiences, at the right time, to the development of brain architecture in the young brain?
Experiences that are well-tuned to the child's behavior and developmental stage and that provide information about the world the child is experiencing are much more valuable than non-interactive information such as images on a television screen that don't relate at all to the child's behavior. Quality and quantity of interaction are both important. Children who don't receive meaningful interaction are likely to suffer developmentally. A particularly sad example is the situation in orphanages in Romania [see Perspectives: "Deprivation and Disruption"], for instance, where the ratio of caregivers to children doesn't allow for meaningful interaction. Children who grow up in this kind of extremely deprived environment have developmental deficiencies that are difficult to reverse later on, even with very intensive efforts at intervention.

You get a bigger impact [on the developing brain] by combining rich experience and physical exercise.

Is rich experience important after childhood, into adulthood, for sturdy brain architecture?
Some things, such as the extra capillaries and glial cells in animals that engage in physical exercise or explore enriched environments, seem to disappear fairly quickly if you take an animal out of the environment. Others, like connections between neurons, diminish very slowly. Results like these emphasize the importance of both a highly supportive earlier environment and continuing environmental stimulation to truly optimize brain development.

So optimal learning situations should continue through the course of childhood, as the human brain is developing?
Exactly. There is no question that the brain continues to benefit from rich, appropriate experiences. We need more research to understand completely the timeline of how the brain develops, but there are some developmental processes in the brain that can continue well into adulthood.

One particular type of experience you study is physical exercise. We know that fresh air and exercise are good for growing bodies. But you have found that physical exercise can also increase blood supply to the brain by causing new capillaries to grow. How does this affect the developing architecture of the brain?
Exercise alone produces cognitive benefits. We found that the rate of learning was enhanced in animals that exercised on a regular basis. With exercise alone, we saw less effect than we saw in animals who lived in a rich environment, and these animals also tended to exercise more. So we think that the combination of rich experience and exercise affect brain development in ways that have been hard to pull apart. If we give an animal nothing but exercise and look at their brain development, we see more new capillaries but not necessarily more connections. And if we look at the brains of animals who learn new information that doesn't involve exercise, we see

more connections, but not more new capillaries. So ongoing research shows that you get a bigger impact by combining rich experience and physical exercise.

One area where research on physical activity and its impact on brain development has been used is in treatment of children with disorders resulting from fetal alcohol exposure. We know that the effects of alcohol on the developing fetal brain can be extremely damaging. Even with increased public awareness of the problem, this remains the leading cause of mental retardation and developmental delay in this country. In your research on a mild form of fetal alcohol syndrome in young rats, you found that appropriate rehabilitative therapy could help with this disorder. What type of intervention was studied, and how did it help repair the brain architecture?

We started with animals that had been exposed to alcohol during the human equivalent of the last three months of pregnancy. The interventions we used were ones that taught active physical skills. Animals who had to put these physical skills to use in different ways on novel problems had vastly enhanced performance compared to animals who just had regular physical activity that wasn't new or applied in a novel way. We were interested in the brain architectural changes underlying these behavioral changes, and we found that the brain was adding many new connections between existing neurons. So this kind of rehabilitation takes the existing, damaged brain architecture and puts it together in the most efficient way to optimize function.

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How might parents or caregivers take what you've learned in your research and use it in daily life?

One important message is that caregivers should interact with kids in ways that emphasize their interaction with new things. You also have to be sensitive to how children pay attention to those new experiences. If a child's attention wavers, which it can for varying reasons, a parent or caregiver has to figure out what things will maintain that child's attention, or maybe just realize that it's time to stop and do something less intense.

It's also important to remember that, for the vast majority of kids in normal homes, all they will need in order to develop strong brain architecture is the kind of rich experience they will get from everyday interactions. But if the parents don't provide this experience, the children can't make up for it on their own.

The interviewer: Dean Stahl is a researcher and writer, and co-author of *Abbreviations Dictionary* (CRC Press), author of *Dolphins* (Child's World Inc., 1991), and a longtime contributor to *Pacific Northwest* magazine. He worked for several years as an editor at *The Seattle Times*.

The editor: Marcy Ray has worked with a number of interdisciplinary research networks. She served as Administrator and Director of Communications for the Research Network on Early Experience and Brain Development, and holds an M.in Communication Studies from the University of North Carolina at Chapel Hill.