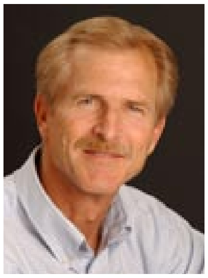
Early Influences on Brain Architecture

An Interview with Neuroscientist Eric Knudsen

Abstract: Early experience has a powerful and lasting influence on how the brain develops. The physical and chemical conditions that encourage the building of a strong, adaptive brain architecture are present early in life. As brains age, a number of changes lock in the ways information is processed, making it more difficult for the brain to change to other ways of dealing with information. Maintaining plasticity—keeping the brain open to change—takes energy, and this energy is finite. The right kinds of early experiences make the best use of this energy for the benefit of both individuals and society.



Council Member **Eric Knudsen, Ph.D.** is the Edward C. and Amy H. Sewall Professor of Neurobiology at Stanford University. His research focuses on mechanisms of learning and strategies of information processing in both the developing and adult brain. He investigates how the capacity for learning changes with development and maturation, and the effects of early experience on brain architecture and function.

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Why is a child's early experience so important to the development of brain architecture?

Early childhood provides a unique window of opportunity that allows complex sets of experiences to shape a child's brain architecture. The brain's neural circuits are enabled by experience to adapt to the full range of challenges an individual will deal with throughout life.

Can stressful early experiences derail the development of the brain's architecture?

Absolutely. The early period of development is one of both opportunity and vulnerability. During this time, the brain is very receptive and very malleable, and has the capacity to shape itself dramatically. This is the time when a child's brain architecture responds to experiences with the environment. When those experiences are healthy, brain architecture develops in a way that anticipates living in a healthy environment, and subsequently the child is able to meet successfully the expected challenges in life.

However, if the early environment is in some way impoverished or adverse, the brain will come to expect that this is the world it will need to deal with in the future. Then it will adapt itself to that impoverished situation, which will make it less adaptive when it encounters a richer or more complex environment later. "Toxic stress" (stress caused by negative experience that is prolonged and uncontrollable) is an example of adverse early experience. Other negative experiences can include poor nutrition, lack of cognitive input, or lack of nurturing and stable social relationships. Such adverse early experiences can cause long-lasting and dysfunctional alterations in brain architecture, resulting in a brain that is not suited for operating in a healthy, complex environment.

Whether an individual's early experiences are good or bad, those experiences will alter the connections being formed in the brain, both in terms of their chemistry and their architecture. This is important because early experience, both positive and adverse, influences the "set points" of the brain.

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Could you define a "set point"?

Set points are the "optimal operating ranges" that become established in the brain.Think of a thermostat. We're each born with a certain genetic range of capability in any given area. Early experience influences how much of that potential genetic capability we'll have access to throughout life. If the set point for a part of the brain related to a particular ability is set correctly, which is what generally happens with normal and healthy early experience, then that brain structure can respond optimally to a wide spectrum of experiences later in life. A correctly set thermostat is capable of maintaining an optimal temperature by activating the heater in the winter and the air conditioner in the summer. On the other hand, a brain function that ends up locked into an atypical set point, due to deprivation or exposure to toxic stress, only responds well to a narrowly defined set of atypical circumstances. The thermostat only engages the heater; it assumes it's always winter. It's possible to adjust the thermostat later, but only with considerable effort and by a limited amount. Here's an example. Children who live in abusive homes have a hard time interpreting facial expressions, except for anger. They become very good at identifying angry expressions, but tend to misidentify ambiguous expressions as "anger." These children go on to have a higher probability of anxiety disorders and/or aggressive behavior. Their early exposure has altered the "set point" for how they operate socially in terms of interpreting social cues. They're very adapted to operating around anger, but that "adaptation" is not helpful when they start operating in a healthier, more complex social environment.

If you want to ensure that the adult brain will operate optimally in healthy environments, one of the best ways is to train the brain in a healthy environment early, when it has the greatest capacity for plasticity. Establishing healthy set points early on stabilizes physical architecture and chemical connections in a way that encourages optimal performance. Once these conditions are established, they tend to persist into adulthood.

What about individuals who haven't had appropriate early experiences? Is there still an opportunity to change the brain architecture later?

The good news is that, even in adults, nearly all brain circuits are capable of plasticity. We know that plasticity persists throughout life, but over time, plasticity dramatically decreases. With intense effort and appropriate conditions, some circuits can show clear progress and improvement, and respond to remediation. However, this requires more effort to get results, and the results may not be optimal. There's still hope, but it takes more effort. One example of this is training an adult, whose first language is Japanese, to distinguish between "r" and "l" sounds. It can be done, to some extent, with a lot of specialized effort. In contrast, a young Japanese child learns to make these, and all other phonetic distinctions, easily and reliably. One principle we've found is that, in older brains, a greater range of plasticity can be achieved if the learning happens in small incremental steps, rather than in single, large steps. Another way to increase learning in older brains is to get the individual more engaged, more attentive to the task at hand, by making the training emotionally engaging. But the main point is that younger brains show more plasticity, so it's best to build a strong brain architecture early.

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What causes the brain to be less adaptable over time?

The physical and chemical conditions in the brain that exist early in life encourage the building of brain architecture. A young brain is not yet committed to processing information in a particular way. As the brain ages, changes take place that lock-in certain ways of processing information. As time goes on, this makes it difficult for the brain to change to other ways of processing information. Maintaining plasticity—keeping the brain open to change—takes energy and this energy isn't endless. In addition, there's a trade-off between plasticity and stability. Brain architecture that remains highly plastic is also less able to preserve what has already been learned. At times, you have to solidify what you've learned by locking in a pattern of connectivity. The brain builds on these established patterns. Brain systems need to be stabilized so that high-level systems can depend on them when learning higher functions. Think of it this way: You can't build a house on shifting sand.

What does your work tell us about enrichment or deprivation, as opposed to appropriate, healthy experience?

We do know a lot about the negative consequences of impoverished environments on the development of brain architecture, and there is much that society can do to reduce neglect and abuse. However, enrichment as it's usually understood—providing artificially complex experiences beyond the range of what a child would normally encounter in a typical environment—is a tricky subject. There's little scientific evidence to support the assertion that "enrichment" (like classical music CDs intended to increase intelligence, or highly structured classes for toddlers) builds better brains. Most "enrichment" studies, which use animal subjects, simply restore the typically complex conditions under which an animal would learn in its natural environment. So most "enrichment" studies involving animals aren't really applicable to children living in typical environments. The one caveat is that attention promotes learning, so those activities that help children be more attentive and emotionally engaged (and those two things are linked) will help them to learn better.

What would you say are the broad policy implications or principles that could be derived from your work?

Early experience lays the foundation for later learning, and makes later learning much easier and much more efficient.

The first very clear implication is that early experience has powerful and lasting influences on how the brain develops. That early malleability is a double-edged sword. It's a window of opportunity to optimize development, but also a period of vulnerability to harmful or stressful experiences. If children have stressful or impoverished early environments, there will be long-term implications for the building of the brain. However, though early experience is very important, later experience is also important. You need to have appropriate experiences throughout life to take advantage of the architecture built in childhood, even when that architecture is sturdy and strong. Since the brain develops in a hierarchical fashion, later learning builds on brain architecture that is the result of early experience. If you have good early experiences, grow up in healthy personal and public environments, and build strong "foundational" brain architecture, that makes it more likely that the higher order brain functions and behaviors will develop optimally. So it's extremely important for policy makers to know that early experience lays the foundation for later learning, and makes later learning much easier and much more efficient. Finally, because later plasticity tends to be more limited, children who may have missed out on positive early experiences—so necessary for sturdy brain architecture development—need to be highly engaged with what they're learning in order to make changes in their brain architecture. That can be achieved by fostering learning through positive relationships or active experiences—by engaging that child's attention and emotions. These observations have numerous implications for the nation's health system and its mental health system, as well as its child care and education systems. At the very least, the scientific research would suggest that these systems need to be examined and restructured to be fully supportive of early childhood development.

The interviewer: 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.A. in Communication Studies from the University of North Carolina at Chapel Hill.