**Your Child's Brain**

*A baby's brain is a work in progress, trillions of neurons waiting to be wired into a mind. The experiences of childhood, pioneering research shows, help the brain's circuits--for music and math, language and emotion.*

by [Sharon Begley](http://www.thedailybeast.com/contributors/sharon-begley.html) | February 18, 1996

**Early influences on neural development**

When a baby comes into the world her brain is a jumble of neurons, all waiting to be woven into the intricate tapestry of the mind. Some of the neurons have already been hard-wired, by the genes in the fertilized egg, into circuits that command breathing or control heartbeat, regulate body temperature or produce reflexes. But trillions upon trillions more are like the Pentium chips in a computer before the factory preloads the software. They are pure and of almost infinite potential, unprogrammed circuits that might one day compose rap songs and do calculus, erupt in fury and melt in ecstasy. If the neurons are used, they become integrated into the circuitry of the brain by connecting to other neurons; if they are not used, they may die. It is the experiences of childhood, determining which neurons are used, that wire the circuits of the brain as surely as a programmer at a keyboard reconfigures the circuits in a computer. Which keys are typed -- which experiences a child has -- determines whether the child grows up to be intelligent or dull, fearful or self-assured, articulate or tongue-tied. Early experiences are so powerful, says pediatric neurobiologist Harry Chugani of Wayne State University, that "they can completely change the way a person turns out.''

By adulthood the brain is crisscrossed with more than 100 billion neurons, each reaching out to thousands of others so that, all told, the brain has more than 100 trillion connections. It is those connections -- more than the number of galaxies in the known universe -- that give the brain its unrivaled powers. The traditional view was that the wiring diagram is predetermined, like one for a new house, by the genes in the fertilized egg…Another possibility: genes might determine only the brain's main circuits, with something else shaping the trillions of finer connections. That something else is the environment, the myriad messages that the brain receives from the outside world.

**“Critical periods”**

Yet, once wired, there are limits to the brain's ability to create itself. Time limits. Called "critical periods,'' they are windows of opportunity that nature flings open, starting before birth, and then slams shut, one by one, with every additional candle on the child's birthday cake. In the experiments that gave birth to this paradigm in the 1970s, Torsten Wiesel and David Hubel found that sewing shut one eye of a newborn kitten rewired its brain: so few neurons connected from the shut eye to the visual cortex that the animal was blind even after its eye was reopened. Such rewiring did not occur in adult cats whose eyes were shut. Conclusion: there is a short, early period when circuits connect the retina to the visual cortex. When brain regions mature dictates how long they stay malleable. Sensory areas mature in early childhood; the emotional limbic system is wired by puberty; the frontal lobes -- seat of understanding -- develop at least through the age of 16.

The implications of this new understanding are at once promising and disturbing. They suggest that, with the right input at the right time, almost anything is possible. But they imply, too, that if you miss the window you're playing with a handicap...[T]hey make clear the mistake of postponing instruction in a second language. As Chugani asks, ""What idiot decreed that foreign-language instruction not begin until high school?''

Neurobiologists are still at the dawn of understanding exactly which kinds of experiences, or sensory input, wire the brain in which ways. They know a great deal about the circuit for vision. It has a neuron-growth spurt at the age of 2 to 4 months, which corresponds to when babies start to really notice the world, and peaks at 8 months, when each neuron is connected to an astonishing 15,000 other neurons. A baby whose eyes are clouded by cataracts from birth will, despite cataract-removal surgery at the age of 2, be forever blind. Researchers believe that cognitive abilities work much like sensory ones…"Connections are not forming willy-nilly,'' says Dale Purves of Duke University, "but are promoted by activity.''

**The Importance of Early Language Development**

Before there are words, in the world of a newborn, there are sounds. In English they are phonemes such as sharp ba's and da's, drawn-out ee's and ll's and sibilant sss's. In Japanese they are different -- barked hi's, merged rr/ll's. When a child hears a phoneme over and over, neurons from his ear stimulate the formation of dedicated connections in his brain's auditory cortex. This "perceptual map,'' explains Patricia Kuhl of the University of Washington, reflects the apparent distance -- and thus the similarity -- between sounds. So in English-speakers, neurons in the auditory cortex that respond to "ra'' lie far from those that respond to ""la.'' But for Japanese, where the sounds are nearly identical, neurons that respond to "ra'' are practically intertwined, like L.A. freeway spaghetti, with those for "la.'' As a result, a Japanese-speaker will have trouble distinguishing the two sounds.

Researchers find evidence of these tendencies across many languages. By 6 months of age, Kuhl reports, infants in English-speaking homes already have different auditory maps (as shown by electrical measurements that identify which neurons respond to different sounds) from those in Swedish-speaking homes. Children are functionally deaf to sounds absent from their native tongue. The map is completed by the first birthday. "By 12 months,'' says Kuhl, "infants have lost the ability to discriminate sounds that are not significant in their language, and their babbling has acquired the sound of their language.''

With this basic circuitry established, a baby is primed to turn sounds into words. The more words a child hears, the faster she learns language, according to psychiatrist Janellen Huttenlocher of the University of Chicago. Infants whose mothers spoke to them a lot knew 131 more words at 20 months than did babies of more taciturn, or less involved, mothers; at 24 months, the gap had widened to 295 words…The sound of words, it seems, builds up neural circuitry that can then absorb more words. "There is a huge vocabulary to be acquired,'' says Huttenlocher, "and it can only be acquired through repeated exposure to words.''

**Music’s Influence on Neural Development**

Last October researchers at the University of Konstanz in Germany reported that exposure to music rewires neural circuits...How long the players practiced each day did not affect the cortical map. But the age at which they had been introduced to their muse did: the younger the child when she took up an instrument, the more cortex she devoted to playing it.

Like other circuits formed early in life, the ones for music endure. Wayne State's Chugani played the guitar as a child, then gave it up. A few years ago he started taking piano lessons with his young daughter. She learned easily, but he couldn't get his fingers to follow his wishes. Yet when Chugani recently picked up a guitar, he found to his delight that "the songs are still there,'' much like the muscle memory for riding a bicycle.

**The Relationship Between Math and Early Exposure to Classical Music**

At UC Irvine, Gordon Shaw suspected that all higher-order thinking is characterized by similar patterns of neuron firing. "If you're working with little kids,'' says Shaw, "you're not going to teach them higher mathematics or chess. But they are interested in and can process music.'' So Shaw and Frances Rauscher gave 19 preschoolers piano or singing lessons. After eight months, the researchers found, the children "dramatically improved in spatial reasoning,'' compared with children given no music lessons, as shown in their ability to work mazes, draw geometric figures and copy patterns of two-color blocks. The mechanism behind the "Mozart effect'' remains murky, but Shaw suspects that when children exercise cortical neurons by listening to classical music, they are also strengthening circuits used for mathematics. Music, says the UC team, "excites the inherent brain patterns and enhances their use in complex reasoning tasks.''

**Early Experiences and Their Impact on Emotional Development**

The trunk lines for the circuits controlling emotion are laid down before birth. Then parents take over. Perhaps the strongest influence is what psychiatrist Daniel Stern calls attunement -- whether caregivers "play back a child's inner feelings.'' If a baby's squeal of delight at a puppy is met with a smile and hug, if her excitement at seeing a plane overhead is mirrored, circuits for these emotions are reinforced. Apparently, the brain uses the same pathways to generate an emotion as to respond to one. So if an emotion is reciprocated, the electrical and chemical signals that produced it are reinforced. But if emotions are repeatedly met with indifference or a clashing response -- Baby is proud of building a skyscraper out of Mom's best pots, and Mom is terminally annoyed -- those circuits become confused and fail to strengthen. The key here is "repeatedly'': one dismissive harrumph will not scar a child for life. It's the pattern that counts, and it can be very powerful: in one of Stern's studies, a baby whose mother never matched her level of excitement became extremely passive, unable to feel excitement or joy.

Experience can also wire the brain's "calm down'' circuit, as Daniel Goleman describes in his best-selling ""Emotional Intelligence.'' One father gently soothes his crying infant, another drops him into his crib; one mother hugs the toddler who just skinned her knee, another screams "It's your own stupid fault!'' The first responses are attuned to the child's distress; the others are wildly out of emotional sync. Between 10 and 18 months, a cluster of cells in the rational prefrontal cortex is busy hooking up to the emotion regions. The circuit seems to grow into a control switch, able to calm agitation by infusing reason into emotion. Perhaps parental soothing trains this circuit, strengthening the neural connections that form it, so that the child learns how to calm herself down. This all happens so early that the effects of nurture can be misperceived as innate nature.

**Effectiveness of Interventions**

All of which raises a troubling question. If the windows of the mind close, for the most part, before we're out of elementary school, is all hope lost for children whose parents did not have them count beads to stimulate their math circuits, or babble to them to build their language loops? At one level, no: the brain retains the ability to learn throughout life. But on a deeper level the news is sobering. Children whose neural circuits are not stimulated before kindergarten are never going to be what they could have been. "You want to say that it is never too late,'' says Joseph Sparling," But there seems to be something very special about the early years.''

And yet . . . there is new evidence that certain kinds of intervention can reach even the older brain and, like a microscopic screwdriver, rewire broken circuits.

We are born with a world of potential -- potential that will be realized only if it is tapped.

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