Brain Basics: A Brain in Sync

By: Dr. Robert Melillo

The idea of a functional relationship between the left and right sides of the brain is hardly new. In 1949, Canadian neuropsychologist Donald O. Hebb, PhD, famously concluded that “cells that fire together wire together” after he conducted research to figure out how the brain thinks and processes information. The adage means that brains cells that are activated, fired, and come to threshold at the same time will literally build physical connections to one another. In order for this to happen, timing is crucial, especially during early brain development. If neurons don’t fire at precisely the right time, the connection doesn’t happen and it is lost forever. This glitch can happen at any time, especially in the womb when early right brain development is taking place. This is why pregnancy is such a vulnerable time for autism to begin.

Even though brain cells develop very rapidly in the womb, a baby does not have much of a brain at birth, just enough to perform the basic functions of life, such as breathing. The basic structure and cells of the brain are built during early pregnancy, but the growth that builds these basic survival skills takes place toward the end of pregnancy. At birth, a baby has only about 25 percent of its brain, which essentially consists of the brain stem. The reason for this is obvious, as a baby’s head barely fits through the birth canal. Once born, the brain grows rapidly and by age three, 90 percent of the adult brain will be formed.

By building the brain, I do not mean adding brain cells. More brain cells than a person will ever need are formed while in the womb, and about half of them will be lost during the first crucial years of brain development. Once a baby is born, neurons are directed by and interact with the genes that will control neural development, an introduction that is made by the various forms of environmental stimulation they will also interact with for the rest of life. Taste, temperature, touch, movement, light, sound, vibration, and gravity are crucial types of stimulation that a young brain requires. This is why a mother's touch and tenderness are so important. Parents are key players in stimulating brain growth.

There are two basic types of brain cells involved in brain growth. The majority of the work involves neurons, which comprise what is known as gray matter. The job of a neuron is to receive and transmit information. It does this by activating genes that stimulate the chain of events that make growth happen. The tip of each neuron contains a bunch of tentacles that act like an antenna to collect information from the surrounding environment through electrical and chemical signals. If the signal is strong enough, it goes to a neuron's central processing center called the nucleus. If the signal is very strong, it will filter to a cable-like structure called an axon, which releases chemicals that float across a very small gap, called a synapse, and make contact with receptors which rest on the surface of antennae like structures called dendrites on a neighboring cell. These chemicals do one of two things: They excite the neighboring cell to send the signal farther down the line, or they inhibit the cell and turn off the signal. The complexity of the brain results from millions of these signals happening at the same time to integrate information that forms a new memory, experience, or understanding.

Brain growth also depends on the involvement of another type of cells called glial cells. These cells are fatty and have the important job of wrapping themselves around a neuron's axon. They act as a kind of insulation that allows impulses to travel faster down the length of the neuron.

The interaction of these cells is what gives the brain its power to grow. It is a process that enables neurons to increase in size and thickness. Like a muscle, each neuron grows thicker with use. However, key brain growth comes from actually increasing the number of functional connections formed from cell to cell, which spread like the roots of a tree. These connections are already starting to form by the end of pregnancy, but at birth they are still sparse, like a young plant that has newly taken root. By the time a child reaches age three, a vast jungle of trillions of connections has taken hold. Each brain cell ends up with about ten thousand connections to other brain cells. With one hundred billion brain cells in the average brain, this means connections will number in the trillions. It is a process that never stops.

This whole process of receiving and transmitting information is started by receptors that send information to the brain from outside stimulators, much like a Morse code relays information. There are receptors for all kinds of stimulators—light, sound, vibration, touch, temperature, taste, smell, movement, pressure, pain, etc. These receptors convert the stimulation into a signal, which activates a neuron. The neuron takes the signal and sends it along at a certain frequency of electrical activity to site-specific areas of the brain for decoding. If the signal is familiar, the brain's memory center will respond. If the signal is unfamiliar, the brain will then learn and store it in memory for future use. The chain of cells involved in making these connections is called a network. Initially, as brain cells start making more connections, they reach out and connect with their close neighbors and coordinate a firing pattern for quick and efficient communication. They will "fire together" at the same time and then they will "wire together" by creating networks.

Immature connections are seen as short-range, or local, connections. This is what you see in babies; their ability to communicate is very limited. As the brain starts to grow in infancy and builds more and more connections and coordinates with larger groups of cells, longer-range connections start to develop in distant parts of the brain, eventually crossing over to the other side. Long-distance communication is taking place from one side of the brain to the other. Walking, for example, is a skill that requires left and right brain communication. As these cells mature and generate faster and faster impulses, they coordinate more and more cells to fire simultaneously and over longer and longer distances. As more and more cells are able to fire together at the same time, they start to break up and segregate into networks that all do a similar job. Each network can connect to millions or even billions of other cells and networks in the brain. This is what we see as maturity. As a toddler starts walking, she is slow, clumsy, and uncoordinated. This is because the brains cells that are driving the action as also slow, clumsy, and uncoordinated. As the brain cells strengthen through their connections with other brain cells and synchronize with networks on the opposite side of the brain, walking becomes more balanced and fluid. Maturing brain cells mature the child. This principle is at the core of neuroplasticity, which says that the brain has the ability to chemically and physically change throughout life, based on the stimulation and training it receives. Like protein and muscle fibers that build a bicep into a stronger arm through frequent exercise, brain cells will produce more connections and build a stronger brain through the type and frequency of stimulation it gets from the environment. It is how we continue to learn and remember new information throughout life. And it can happen rather quickly. Studies show that *within two hours* of learning something new, there are measurable differences in the size of the neurons in the brain.

It’s a Matter of Timing

The brain is the most complex and important organ in the body, yet it’s also the one we know the least about. One of the many mysteries of brain mechanics is how all these trillions of connections coordinate to form the big picture of our world. We do know that they are not all working together at the same time, as that would be impossible. The key appears to be the right connections happening at the right time, like a drawbridge that opens at a precise moment to allow a large-masted sailboat to pass through without holding up highway traffic.

Time is the glue. Time is what coordinates all of the cells to work together as one unit and gives the human brain all of its tremendous powers and ability. A memory or thought is made when cells from different areas of the brain all fire at the exact same moment. When this happens, a pattern of electrical activity or cells is frozen in time, making a memory or thought. To activate the memory means calling up the exact pattern of cells. If you can only recall part of a memory, it means you are only recalling a piece of the pattern. As you try harder to remember, more and more memory cells start to wake up. When they all come on line and synchronize, the pattern is whole and the "lightbulb" goes off in our brain.

Timing is one of the primary features that make the human brain unique in its intellect. It's what gives our brains tremendous processing power. An analogy I like to use to demonstrate this involves lining up ten people in front of a three-hundred-pound barbell. If I'd ask them to close their eyes, put one hand on the weight and randomly try to lift the weight, they wouldn't be able to do it. However, if I said, *Count one, two, three, lift,* they'd pick it up together, with no difficulty at all. The reason is timing. Time is the glue that makes lifting the barbell possible, and it is the glue that makes brain cells function as a whole brain. It is the difference between many cells firing independently or many cells firing together at the same time, essentially forming one big cell. The processing power is exponentially greater even though the number of cells is exactly the same. The human brain's ability to marshal cells and get networks to work together is what makes the human brain so superior.

The second thing that makes the human brain unique is lateralization—the phenomenon of left brain and right brain. Each side of the brain is designed to perform specific tasks that frequently must work in unison. For example, the left brain processes information, and the right brain interprets it. It means the left brain reads the words, but the right brain understands the story. We have dozens of specialized centers on either side of the brain that process particular types of information and control specific functions. The fact that we can then mix and match or combine these different areas of the brain within each side and between each side gives us an almost limitless repertoire of skills that we can tap into and develop. However, both sides of the brain must act simultaneously. The timing and speed of coordination gives the human brain its unique ability, but it also makes the brain vulnerable.

A Brain Out of Sync

Brain development is very sensitive to timing. It is as precise as the atomic clock. Everything is scheduled to happen in a precise order in a set window of time. For example, the terrible twos are the hallmark that brain development primarily has switched to the left side—from the negative right brain to the positive but independent and aggressive left. It's why hearing a toddler yell *no, no, no* is actually good, good, good. A child learns to crawl before he can walk. It's the path of normal brain development. If a child walks but never crawled, it is not a good sign. It means he literally missed a step in brain development.

The growing brain goes through many, many developmental windows of time before a child reaches each new milestone. Each window involves the expression of a cascade of genes that must come together at a precise moment in time. If some of these genes are turned off when they should be on, the window of time is missed and the learning doesn’t takes place. It can happen in a millisecond or even a nanosecond. We can’t see timing problems, and we can barely measure them. However, we know they occur. As Dr. Hebb said, cells that fire together wire together. And if they don’t fire together, they don’t wire together. This breakdown in coordination and timing in an otherwise healthy brain is the core principle of functional disconnection syndrome.

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