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Montessori, the Brain, and the Young Adult

by Paula Polk Lillard

In this enthusiastic dinner presentation to the Fourth Adolescent Colloquium, Paula Polk Lillard surveyed the work of neuroscientists of our time, which concurs in every way with the developmental perspective of Montessori education. "We can now have hard evidence that human beings construct their own brains in collaboration with their environment, just as Montessori proposed one hundred years ago." Furthermore, as Montessori education continues to expand into the frontier of the Third Plane, it is crucial to keep in mind that the forebrain, seat of judgment and self-control, is still being developed during adolescence.

What a wonderful time to be alive and working for Montessori education!

We are poised for the greatest revolution in worldwide education in history, and as pioneers in Montessori for the young adult, we are its leaders.

What makes me certain of this statement? I am going to center my remarks on three themes:

- the startling new discoveries about the brain and its plasticity, its ability to change itself;
- what these discoveries mean for Montessori education; and
- what their profound implications are for you and me as educators, parents, and grandparents.

One hundred years ago Maria Montessori proposed that the child constructs its own self, its own brain. The child is not a seed developing into a tree; it has no pre-set plan to follow, not even instincts as the animals do. What is more, although arduous and risky, this task is the great gift of evolution to the human species, for it allows adaptation to any time, any place, and any culture.

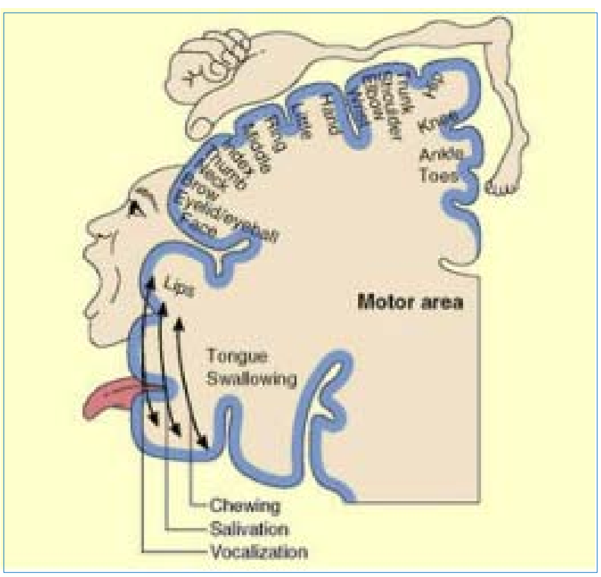

Figure 1. The "localization" view of the brain.

Montessori's proposal was a radical idea in the first half of the twentieth century. The prevailing view of the brain was one of "localization." Areas of the brain were seen as pre-set, hardwired for specific input from sensory modalities: the visual, auditory, tactile, and so forth (see Figure 1). The type of education that fits this model is the one that most of us experienced. The brain is viewed as an empty vessel that the teacher fills with information. Children are seated in rows as in a factory assembly line, being produced by the teacher's input. Such a system

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was not natural to us, so rewards and punishments were instituted to control our behavior. It was a very Newtonian approach, based as it was on rigid laws of cause and effect. The analogy we might use today is the brain as storage space or disk drive.

> *Neural speed is plastic. We can learn to think faster and more clearly, but these changes occur for the long term only when close attention is paid. This conclusion gives strong support for Montessori's emphasis on concentration and interest in the learning process.*

I was in graduate school in the late 1960s when I first learned of compelling contrary evidence to this view of the brain's formation. Maria Montessori had proposed that the child constructs the self in collaboration with the environment. What is more, the child has specific abilities in each of four planes of formation (birth to six, six to twelve, twelve to eighteen, and eighteen to twenty-four years). The special gifts of the first plane are the sensitive periods and the absorbent mind. Two researchers, David Hubel and Torsten Wiesel, in work for which they received the 1981 Nobel Prize, demonstrated that kittens prevented from receiving visual input in one eye during the third and eighth weeks of life were blinded in that eye forever. The scientific community was startled. Hubel and Torsten had shown that in the first weeks of life the environment could permanently alter neuronal structures. Because this evidence of the brain's plasticity had been achieved in infancy, however, it was equated with the process of development. It was not considered a challenge to the prevailing view that the brain is hardwired in certain locations for certain functions. Still, Hubel and Torsten's research did represent a crack in the door for Montessori. Perhaps it even helps to explain the readiness initially to accept Montessori education for preschool children only, even though Montessori already had developed her ideas for education from childhood to adulthood.

As I worked with children through the 1970s and 1980s, I kept looking for further scientific support of Montessori's discovery of self-construction. I felt intuitively that the validation of her approach lay in the field of brain science. I followed studies as they were reported in *Scientific American,* and there was much promising research on neural structures and synaptic formation in the brain. In June, 1984, I had an opportunity to make a more direct connection. I was chair of the Association Montessori Internationale (AMI) conference at Lake Forest College. Ada Montessori, Renilde Montessori, Gool Minwalla (Montessori's colleague and trainer from Pakistan), and many other important delegates were coming from around the world and the United States. I had the opportunity to choose the keynote speaker, and I invited a leading neuroscientist from Harvard University. I sent him a copy of *The Absorbent Mind* by Maria Montessori, hoping that he would see some justification of her ideas in his work or the work of his colleagues. Sadly, he did not. We had many interesting conversations, and he did give a well-received talk at the conference. However, this disappointing reaction by a noted neuroscientist was a reminder to me of just how far ahead of her time Montessori really was.

This incident is also a good example of the dark side of the brain's plasticity. Bruce Wexler, a medical doctor and researcher at Yale University, in his excellent book, *Brain and Culture,* published in 2006, outlines studies showing that our neuronal structures are largely formed by adulthood. As we go forward, we tend to reject or distort—in other words pre-select—information to fit our now established brains. Not to do so makes us feel very uncomfortable, perhaps even disoriented.

It is this reality that we are up against as we try to describe Montessori education to others. Many people, even when they see Montessori's results with their own eyes, are startled and often express disbelief. Visitors to our school come into the hallway after seeing the children at work in the young children's communities or primary classrooms and invariably ask, "Are they always so quiet?" Their tone is incredulous. Clearly, the children's concentration and independence is a brand new experience for them. Subsequently, after visiting the elementary classrooms, their first comments are, "Where is the teacher? How do they know what to do? They are all busy, but they are talking together and working together in small groups all over the place, each group doing something different." They catch the children's enthusiasm, but they clearly miss the order and structure of those desks and workbooks with the teacher obviously "at the helm," so familiar to their own childhoods. In other words, they appear "uncomfortable," much as Montessori herself seemed early in her work. Remember how she said, "Next time I'll believe it" as the tiny children exhibited their extraordinarily deep concentration to her over and over again in the first days?

To help others understand the self-construction of the child and young adult, I believe we have to turn to the hard evidence. There is a superb book, *The Brain That Changes Itself,* published in 2007 and now out in paperback, to help the layperson become familiar with recent discoveries in neuroscience. The author is Norman Doidge, a psychiatrist, psychoanalyst, and researcher at Columbia University and the University of Toronto. In the first chapter, he recounts an anecdote about Paul Bach-y-Rita, a physician and researcher, whose father, a poet and scholar at The City College of New York, suffered a massive stroke at the age of sixty-five. He was completely paralyzed on one side, including his face, and unable to speak. Paul and his brother, George, were told that their father would never recover. George, a medical student in Mexico, took his father home to live with him. After four weeks of the routine rehabilitation offered at the American British Hospital in Mexico, his father showed no progress. George set out on his own to rehabilitate his father by trial and error. He chose as his model the way babies develop. First, he supported his father on all fours. When he could manage this position almost on his own, he encouraged his father to try to crawl with his weak side supported against a wall. After many months, they began to try standing and taking steps in the same way. To motivate his father, George encouraged him in his efforts at independence. He broke down activities of everyday life into step-by-step exercises, just as Montessori did for the youngest children in the infant and primary classrooms with the practical life exercises.

Miraculously, by the age of sixty-eight, Professor Bach-y-Rita had recovered his abilities, including speech, sufficiently to return to full-time teaching at City College. This is not the end of the story, however. In 1965, at the age of seventy-two, he was in Bogota, Columbia, hiking in the mountains at high altitude when, sadly, he had a heart attack and died soon after. Paul was working in California, and he brought his father's body there for an autopsy. In the days before brain scans, autopsies were key to learning about the brain and the manner of death. A friend who performed the autopsy at Stanford Hospital called Paul in great agitation. The autopsy showed that the lesion from the stroke had never healed. In fact, 97% of the nerves from the cerebral cortex to the spine were destroyed. The brain had somehow reorganized itself to regain all those functions!

Paul Bach-y-Rita changed his career to specialize in neuroscience and rehabilitation medicine. In his work at the University of Wisconsin at Madison and in Mexico and other parts of the world, he has been a major force in our present understanding of the brain's plasticity. In particular, through his knowledge of nerve growth, he recognized early on that plateaus in learning regularly occur in rehabilitation and are an integral part of a learning cycle that is based on the brain's plasticity. There are no

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outward signs of progress, but nevertheless these "plateaus" are periods of consolidation and intense learning. They are necessary in order for neuronal change to take place and thus allow for permanent learning. In Montessori education, we recognize this pattern of plateaus in the learning process and use it to the student's advantage.

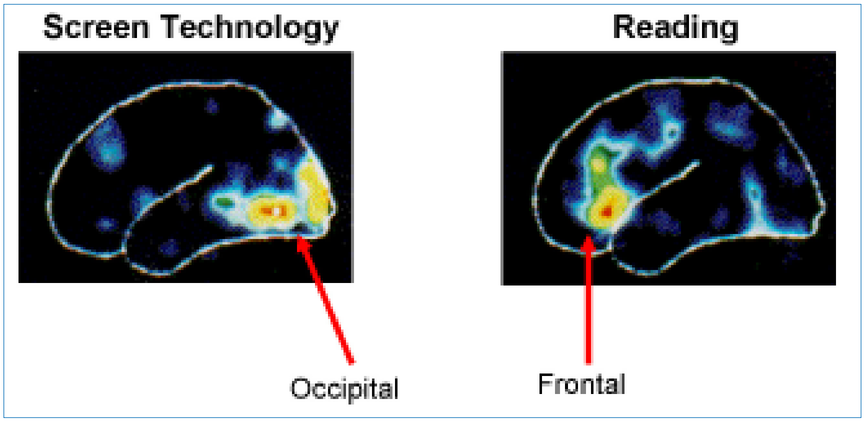

Figure 2. Brain use in screen technology versus reading.

I have chosen the work of three researchers to highlight the historical context of the recent discoveries in neuroplasticity and the relationship of these discoveries to Montessori practice. Michael Merzenich, who was trained at Hopkins and became a professor at the University of California at San Francisco, was one of the first researchers to become convinced of the brain's ability to change itself. As a young post-doctoral fellow, he conducted experiments using a new technology that was a thousand times more precise than a brain scan. It involved tedious surgery under a microscope with microscopic instruments. A microelectrode was inserted into or beside a neuron. It could detect each individual cell's signal to the next neuron. The model at this time indicated that each point on the body traveled directly to a point in the brain. The brain was hardwired from birth for this connection. Merzenich crossed the neurons in monkeys' hands so they would not be able to make this connection. Seven months later, he did brain maps of the monkeys using the new technology. He expected to see confused maps of crossed signals. Incredibly, the brain maps were almost normal. The brain had somehow rearranged the signals and sent them to the right spot. It was directing itself; it could not be hardwired!

Later experiments of Merzenich demonstrated that plasticity is competitive. In one study, he cut median nerves in monkeys' hands and found that after several months, remaining neurons had invaded their space. There was a "use it or lose it" principle at work. In other words, we have to practice an activity to be certain map space is not lost to a competing activity. This is one reason for concern over the amount of time children are spending currently with screen technology (see Figure 2). Screen technology requires viewing holistically with the back part of the brain. Reading requires forebrain use. It involves directional order: left to right, top to bottom, a process that must be practiced and a new skill in evolution. The cave man's brain was not organized for literacy.

Still other experiments showed that neural speed is plastic. We can learn to think faster and more clearly, but these changes occur for the long term only when close attention is paid. This conclusion gives strong support for Montessori's emphasis on concentration and interest in the learning process. Concentration and interest cannot be forced. You must have structured freedom in a prepared environment in order to maximize the opportunities for their occurrence. This is why it is so important to protect the integrity of the three-hour work period in all Montessori classrooms. The children simply cannot follow their interests into deep, concentrated work without it. This challenge becomes more difficult at the high school level, and for some Montessori schools even at the upper elementary level, but a way simply must be found if we are to work *with* the brain's plasticity, and not against it.

The second researcher, Alvaro Pascual-Leone, is associated with Harvard Medical School. In the 1990s he did an experiment using new non-invasive technology called Transcranial Magnetic Stimulation (TMS). It involves a helmet that transmits an electric current. This current changes the magnetic field acting upon the brain, causing neurons to fire. Through this process TMS can be used to map the brain without the tedious microsurgery used in the earlier decade by Merzenich. Pascual-Leone taught subjects Braille, sometimes referred to as "reading fingers" because it involves a motor activity translated into language. He mapped his subjects' brains on Mondays and, after intensive practice for five days, again on Fridays. The subjects then had two days off, and the process was repeated.

Figure 3. Progressive study of geography.

Rapid expansion of the brain maps showed on Fridays as expected. However, Pascual-Leone was shocked to see that they returned to their previous size on Mondays. This pattern continued for six months. The Friday maps showed dramatic growth; the Monday maps went back to their original position. After six months, expansion in the Friday maps began to slow very gradually and Monday maps started to slowly conserve the Friday changes. It was not until ten months had passed, however, that the Monday maps showed complete and permanent changes. Pascual-Leone hypothesized that the Friday changes showed strengthening of existing neuronal structures while the Monday maps revealed the creation of brand new ones. Thus a "tortoise and hare" effect could reflect the process of learning in slower and quicker learners. It also suggests why cramming is an ineffectual way to learn for the long term and is best characterized as an "easy come, easy go" approach. Learning permanently requires steady, slow work.

Clearly self-construction is a process that takes place over time and needs a dynamic environment to be optimal and solid. Therefore in Montessori education the three-year-old is introduced to the globe with a model showing land represented by sandpaper shapes and water by smooth surfaces, and later a model of the continents and oceans in differing colors. Eventually, puzzle maps of each continent are presented, at first only as individual country pieces to put together but later with accompanying nomenclature. By elementary age, the child has had a three-year experience with the world's countries, oceans, and major seas as well as principal land and water forms (introduced with hands-on materials representing lake and island, isthmus and strait, and so forth). At ages six to seven, the children begin the discovery of the world's capitals as well as rivers, lakes, mountains, deserts, tropics, and forests. Finally, nine-year-olds research economic geography, laying a foundation for the study of global markets a few years hence. In Montessori environments all knowledge in every discipline fits into the whole in this way and is explored by the children following their interests within a structure of freedom and continuous social life. It is the exact opposite of the artificial separation of knowledge into different subject matter that then is force-fed in the "cram, test, forget" sequence so common in schools today.

In other experiments, Pascual-Leone demonstrated that thoughts alone have an effect on the physical structure of the brain. Using trained pianists as subjects, he showed that imagining playing specific music has the same effects as actually playing it. Athletes, actors, and other performers now use the process of mental imaging and rehearsing to enhance their performances, knowing that they are indeed making a difference in outcomes.

To my mind, the third researcher, Eric Kandel of the Center for Neurobiology and Behavior at the College of Physicians and Surgeons of Columbia University, is responsible for the most dramatic evidence of all that human beings construct their own selves. In his early work, for which he received the Nobel Prize in 2000, he demonstrated for the first time that neuronal structures and synaptic connections in human beings are altered through learning and long-term memories. More recently, he even showed that we might affect our own genes! For the past one hundred years it was assumed that our genes dictate who we are: our behavior and our mental capacities. Kandel produced strong evidence that in fact we turn our genes on, or not. Each neuron contains a complete set of our DNA. Genes do two things. They replicate themselves, preserving themselves from generation to generation, and they also have an expressive function. This expressive function is regulated in two ways, by what we think and by what we do, both of which are strongly influenced by our environment. Thus we find ourselves back to Montessori's original proposal. Human beings construct their own brains, their own selves, in collaboration with the environment. Kandel wrote a book in 2006 both autobiographical and a fascinating history of recent neuroscience and microbiology for the layman. Entitled *In Search of Memory,* it is widely acclaimed and now available in paperback.

So far we have considered research focused on the molecular action of neurons and synaptic connections between them in the so-called "gray matter" of the brain. Gray matter represents the outer portion of the brain and is made up of the six layers of the cerebral cortex. It does our thinking and our calculating. Neuroscientists are just now turning their attention to the other almost half of the human brain that the cerebral cortex rests on and that is referred to as "white matter." New technology called Diffusion Tensor Imaging (DTI) enables scientists for the first time to observe white matter in action. This is particularly important for our understanding of the adolescent and young adult because DTI shows that there are significant changes in white matter throughout our twenties.

In the March 2008 issue of *Scientific American*, R. Douglas Fields, chief of the Nervous System Development and Plasticity Section of the National Institute of Child Health and Human Development, summarizes the research on white matter to date in an article titled "White Matter Matters." He states that neuroscientists were wrong to consider white matter as having an essentially passive role in mental functioning.

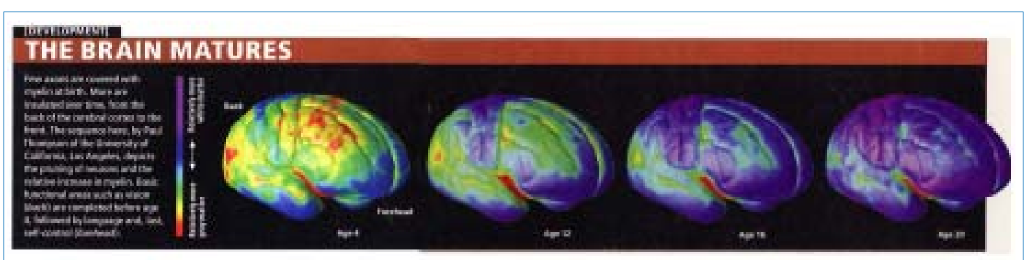

Figure 4. Myelination (dark shading) progresses with age, from back to front of the brain.

In fact, it actively affects how the brain learns and also accounts for many tragic brain dysfunctions. White matter consists of nerve fibers, or axons, that project inward from the cerebral cortex. They are eventually wrapped with myelin, a white gelatinous substance produced by two types of glial cells. This myelin coating protects the integrity of the signals that each axon carries to a neuron. White matter as a whole connects various regions of the brain, thus allowing the brain to "talk" to itself. It is responsible for coordinating signals so they arrive together, thus creating a message that makes sense. Depending on the length of the axon involved, some signals have to slow down. Others have to speed up. The degree of myelination, plus a series of nodes, or relay stations, along each axon, influences this regulation.

There are three factors that are important for us to remember. The environment affects myelination. For example, researchers have found that the white matter of professional pianists differs from that of non-musicians and that there is a higher development in white matter in children with high IQ. Myelination is barely started at birth. It proceeds over time and in a back-to-front pattern in the brain. In Figure 4, myelination is represented by the darkest shade. Notice the forebrain and at what age myelination occurs there. Lastly, myelination plays a major role in dysfunctions such as schizophrenia, helping to explain the prevalence of its first symptoms often appearing in adolescence. Other dysfunctions possibly related to myelination are bipolar disorders, dyslexia, autism, and mental loss in aging.

Concentration and independence for the First Plane.

Social collaboration and imagination for the Second Plane.

Exploration and discovery of the world and human society for the Third Plane.

As we plan our Montessori high school programs, it is essential to remember that the forebrain is where judgment and self-control originate. This area is not complete during adolescence. Neuronal structures, or the gray matter of the brain, are largely there. However, the process of myelination is not finished. This reality has major implications for the prepared environments that we propose for the Third Plane of Development.

Again, what a special time for Montessorians! We can now have hard evidence that human beings construct their own brains in collaboration with their environment, just as Montessori proposed one hundred years ago. We also know a good deal about what those optimal environments should embody:

· concentration and independence for the First Plane

· social collaboration and imagination for the Second Plane

· exploration and discovery of the world and human society for the Third Plane

What does all this mean for you and me? It means that we have the opportunity to get it right from the beginning for our students, children, and grandchildren. For those of us fortunate enough to be working with adolescents, who knows who this new being will be?

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