frontiers FOR YOUNG MINDS

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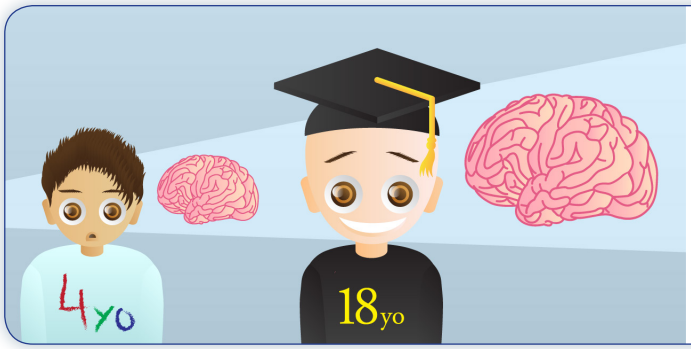

Going to school to sculpt the brain

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Reviewed by:

Darius
10 years old

When I was a kid, I thought of going to school as an obligation imposed by my parents, and I guess many kids feel the same. My father used to say, "you need to study hard to build a better future for yourself," but I think that if my father had told me "studying is good for your future brain," then I probably would have focused more on my learning at school. Here, I shall deal with the topic of how our school education can influence the brain, focusing particularly on the changes in the cerebral cortex that are induced by our surroundings. These findings will be explained using a historical perspective to support the ideas presented.

It is known that the cerebral cortex is the most "human" part of the nervous system because its activity is directly related to the emergence of those capacities that distinguish humans from other mammals. Of course, the brain works as a whole and the cerebral cortex is connected to many brain regions – and it is these connections that are also critical for the overall functioning of the cerebral cortex. Although we do not yet know exactly what it is that is special about our cerebral cortex, it is thanks to this part of the brain that we can carry out such amazing, complex tasks, like writing a book or flying to the moon. But how is this possible? Addressing the issue of mental processes from a biological standpoint is probably one of the most important contributions that modern neuroscience can make.

At present it is well established that the influence of culture and education is critical in enabling our brain to develop these skills. This has been clear since the time of the Ancient Greek philosophers, although they did not link these observations with changes in the structure of the brain (this happened many year later; see below). For example, Pythagoras of Samos, the famous philosopher and mathematician who lived five centuries before Christ, said "Educate the children and it won't be necessary to punish the men." Another interesting quote comes from the physician and philosopher Juan Huarte of San Juan (1529-1588) in his classic book *Examen De Ingenios Para Las Ciencias* in 1575, in which he included the following interesting thought:

> *... in two or three years a human being learns all that his (ancestors) did in two thousand years. Indeed, if man had to acquire such knowledge by experience, it would be necessary to live three thousand years and by experimenting with medicines, he would first kill an infinite number of men*

before defining their qualities. However, this could be avoided by reading the books of rational and experienced doctors who warn in writing of what they found during the course of their lives.

Certainly, the contributions of great men and women such as Marie Curie (1867-1934), Albert Einstein (1879-1955) and Pablo Picasso (1881-1973) would not have been possible if they had not been born in the cultural moment in which they were. This is the case because of our capacity to learn through observation or interaction with other individuals, with school being a perfect example of a place that provides opportunities to do so. Can you imagine how many people from the origin of our existence as human beings could have been outstanding in arts and in sciences if they had had the cultural tools and the intellectual atmosphere available at present? The words of the Phil Collins song "Another Day In Paradise" spring to mind, when he says "think twice, 'cause it's another day for you and me in paradise." Can you imagine if all of the children in the world had access to school as we do? We are lucky to be living in just such a paradise – and we must not waste this opportunity, not only for our own sakes, but to also try to change the world to help the next generation by convincing politicians that education is a national treasure that should be supported and valued.

We all know that a huge mental effort is needed to acquire knowledge when studying – it requires hard work, day after day! But the question is "why, or how, should education influence our brain?" This is where Santiago Ramón y Cajal (1852-1934), who is considered the father of modern neuroscience, comes in. One of the most important contributions of Cajal in this field was to try to explain these facts from a structural viewpoint based on his belief that the brain was susceptible to "plastic" (i.e., flexible) changes and that nerve cells were independent units. He said that nerve cells were independent units that are not physically joined, but rather they communicate with each other by cell-to-cell contact. This hypothesis, known as the neuron theory, contrasted with the most widely accepted idea at the time that the processes of contiguous nerve cells fused to form a continuous "net" of nerve fibers including dendrites and axons (the reticular theory). In 1894, Cajal wrote the following paragraph in the journal Revista de Ciencias Médicas de Barcelona where he described this idea beautifully:

As opposed to the reticular theory, the theory of the free arborization of the cellular processes that are capable of developing seems not only the most likely, but also the most encouraging. A continuous pre-established net — like a lattice of telegraphic wires in which no new stations or new lines can be created — somehow rigid, immutable, incapable of being modified, goes against the concept that all we hold of the organ of thought that within certain limits, is malleable and capable of being perfected by means of well-directed mental gymnastics, above all during its period of development. If we did not fear making excessive comparisons, we would defend our idea by saying that the cerebral cortex is similar to a garden filled with innumerable trees, the pyramidal cells, which can multiply their branches thanks to intelligent cultivation, sending their roots deeper and producing more exquisite flowers and fruits every day.

Cajal was a fervent supporter of cerebral gymnastics as a mechanism to increase the capability of our brain, clearly stating that the potential to increase neuronal connections occurred via a "plastic" mechanism in response to a continued stimulus. In this way he proposed that the higher intellectual capability observed among individuals who regularly do deep mental exercise was due to the fact that cerebral gymnastics would lead to the development of neuronal processes "beyond that normally observed, forcing the establishment of new and more extensive intracortical connections." Cajal proposed mechanisms and theories of plasticity that represented the starting point for some of our modern ideas about this fascinating subject that have now proved to be correct.

The idea of a link between the changing structure of the brain and the maturation of mental processes and motor skills (i.e., skills of movement) is strongly supported if we consider that, during development, our brain not only increases in size (as is obvious from the case of a newborn child) but, as shown in Figure 1, there is also an impressive development in the complexity of the neuronal processes which is linked to changes in the connections between neurons. Any of us who have a little brother, sister or child at home can witness first hand the huge, astonishing changes in their behaviors and skills that can be seen practically from one day to the next – like learning to speak and expressing more and more complex and abstract thoughts or learning to control themselves emotionally.

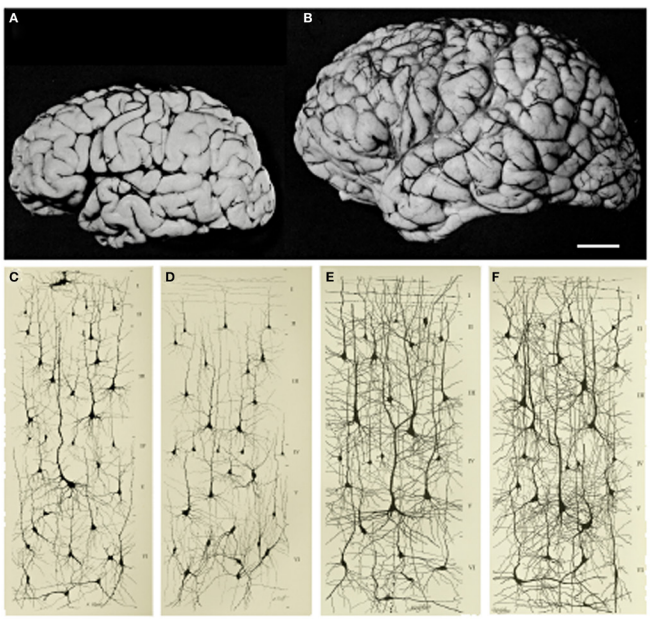

FIGURE 1 - Increase in brain size and the maturation of cortical circuits. The maturation of mental processes and motor skills is associated with an approximately four-fold enlargement in brain size [1].
A., B. Photographs of the brains of a 1-month and 6-year-old child, respectively. This size increase is accompanied by a dramatic development in the complexity of the neuronal processes, which in turn is influenced by the genetic background and the surroundings. This increase in the complexity is clearly evident in the drawings of Golgi-stained cortical neurons from the cerebral cortex of a 1-month-old child (C. showing the cortical area known as "pars triangularis of gyrus frontalis inferior"; D. showing "orbital gyrus") and a 6-year-old child (E. "pars triangularis of gyrus frontalis inferior"; F. "orbital gyrus"). Scale bar for A and B: 2 cm.

We (i.e., our brains) are still the same, but what changes is the structural and functional organization of the brain, in particular the morphology of the neurons and their connections, as well as other structural, molecular, genetic and physiological changes. However, these changes are not restricted to the early stages of development, as shown in Figure 1. Importantly, the surroundings (or conditions) that a person grows up in play an important role from the time of our birth through adolescence and even during our adult life.

At present, numerous neuroimaging studies, using different methods to image the structure (structural imaging) or function (functional imaging) of the human brain, have shown that culture and training changes the functional organization and anatomy of the brain of both young and adult individuals. For example, learning to read, changes in the way speech is processed, and the acquisition of motor skills have all been linked to changes in the volume of gray and white matter in specific brain regions.

There are numerous experimental studies using mostly mice and rats showing that, when these animals are reared in enriched environments, they outperform those reared in non-enriched cages in terms of learning, memory and visual acuity. These studies suggest that multiple circuits in the brain are modified, leading to improved cognitive abilities. At the micro-anatomical level, for example, an enriched environment has been shown to induce an increase in neuronal complexity in the cerebral cortex. Similarly, studies performed in the cerebral cortex of humans with different educational levels have reported an increase in neuronal complexity as educational levels increased.

Thus, the idea is not to try to sculpt our brain to become a genius, but rather to make the most of our own individual genetic make-up through education to increase our cognitive capabilities. In other words, sculpting our brain through our efforts at school would be amply rewarded with a greater brain capacity, benefiting us both during and beyond our school years.

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I am in fifth grade. In my free time I enjoy reading and computer programming. As a hobby, I make useful objects and experiment with devices. I am very interested in the environment and was one of the founders of my school's green committee. I enjoy reading about science, particularly chemistry, biology, and neuroscience.

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One of my principal interest is the study of the history of our current understanding of cortical organization and function. In particular, I am interested in the roots of cortical histology and circuitry. At present I am director of the Laboratorio Cajal de Circuitos Corticales (Centro de Tecnología Biomédica, UPM) and of the Laboratorio de Microorganización de la Corteza Cerebral Normal y Alteraciones de los Circuitos (Departamento de Neurobiología Funcional y de Sistemas, Instituto Cajal, CSIC).