Plastic Brains

Cerveaux plastiques

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Abstract

Memories fade, alas, and more rapidly with age, though the aging brain holds more tenaciously to the longer past. Or does it? The brain may be continually editing those seemingly clear memories. That the immature brain constructs, "sculpts" itself by configuring its neural linkages to make best use of the sensory input received in early life has been known for decades. The more recent news is that mature brains also re-arrange these linkages as sensory inputs change. So what? Well, by some estimates inadequate stimulation in early childhood leaves 25% of Canadians neurally challenged by the modern world. Countries with systematic early child development programs show better results. Are there also opportunities for exploiting the plasticity of adult brains? (Or is that already happening, all around us?)

Résumé

Les souvenirs s'estompent, hélas, et encore plus rapidement avec l'âge, bien que le cerveau vieillissant ait davantage tendance à se rappeler le passé plus lointain. Est-ce réellement le cas? Il se pourrait que le cerveau soit continuellement en train de modifier

des souvenirs apparemment clairs. On sait depuis des décennies que le cerveau encore en développement se construit et se « façonne » en configurant ses liens neuronaux de manière à faire le meilleur usage possible des données sensorielles reçues tôt dans la vie. Selon les données récentes, les cerveaux pleinement développés réorganisent ces liens à mesure que les données sensorielles changent. Et alors? D'après certaines estimations, 25 % des Canadiens affichent des déficiences neuronales qui les limitent dans le monde moderne en raison d'une stimulation inadéquate dans la première enfance. Les pays dotés de programmes systématiques de développement des jeunes enfants présentent de meilleurs résultats. Y a-t-il aussi des occasions d'exploiter la plasticité des cerveaux adultes? (Ou cela se produit-il déjà tout autour de nous?)

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"T'aint what a man don't know as makes him ignorant, it's what he knows that aint so."

– variously attributed

I seem to be forgetting things lately. My memory used to be excellent – at least that's how I remember it – and my (very) long-term memory remains pretty good. But it is not clear how great an advantage that is. As the late middle-aged chap in the *New Yorker* cartoon says wistfully, "I think I've learned quite a few things over the years. But there doesn't seem to be much demand for them." Remembering what my wife told me this morning might be more useful.

This seems to be the common experience of aging, just part of the general decay (a.k.a. golden years). My mother-in-law referred to it as "CRAFT." (It's an acronym.)

But there is something else, perhaps a bit more interesting. The contents of the long-term memory, still apparently very clear, seem to shift over time. If I go back to check the sources, they do not always exactly match. Memory tells a simpler, neater, more consistent story than the originals. It seems to have been edited – selectively.

There is an obvious way of dealing with such lapses: assert confidently and never look things up. As Satchel Paige said, "Don't look back. Something might be gaining on you." If you are fortunate, no one else will remember, or still have the originals.

Occasionally, however, some other scholarly pack-rat does. Milton Friedman's famous claim to have distilled his 1950s monetary doctrines from some deep-rooted and subtle "oral tradition" at the University of Chicago ran into just that problem. The equally distinguished, though much less celebrated, monetary scholar Don Patinkin, a contemporary of Friedman's at Chicago, had kept his graduate class notes. These contained no trace of the doctrines that Friedman had attributed to their eminent instructors. Paul Samuelson, an undergraduate at Chicago in those years, later made the same

observation: "I believe that this nominated myth should not be elevated to the rank of plausible history of ideas" (Barnett 2004: 526).

Friedman was engaged in constructing a set of economic doctrines to advance his political ideology – not the first to do that! To add weight and plausibility in a then relatively hostile intellectual environment, he recruited an array of distinguished (and conveniently defunct) supporters. But was he deliberately lying? Perhaps not. The more interesting possibility is that he sincerely believed his own myth. His brain may have been editing his memory to create the story that assisted his ideological agenda. Thank heavens you and I never do that.

This could be scary stuff. But the fact that Friedman appears to have made up the story – and his doctrines – from whole cloth has had no apparent bearing on their subsequent impact. Maybe Satchel Paige got it right.

One-Eyed Kittens

That the immature brain edits itself has long been known. Hubel and Wiesel shared the Nobel Prize in 1981 for demonstrating that the developing brain organizes its own neuronal wiring in response to the information being received from peripheral sense organs – eyes, ears and so on. In the classic experiment, the lids of one of a kitten's eyes are sewn together when the animal is four weeks old, and opened again at six weeks. The kitten will now have only monocular vision; it will not able to see out of the perfectly normal and healthy eye that was temporarily sewn shut during this critical period of neural development.

Subsequent microscopic examination of the experimental animal's visual cortex shows that the neurons are now linked dendritically so as to process information only from the eye that was not sewn up. The kitten is blind not in the sewn-up eye itself, but in the brain that is no longer capable of responding to electrical signals from that eye. Processing capacity had been reallocated, during the critical four- to six-week period of development, away from the apparently non-functioning peripheral organ. Once that period is past, the brain does not go back to revisit the allocation; the kitten is permanently monocular. The brain has organized itself – establishing the connections between neurons – to make best use of the sensory data coming in during the critical period.

Research ethics committees are unlikely to approve replication of this experiment in humans; there might also be legal complications. But everyone is aware that there is a critical period, perhaps somewhat less well mapped, for the learning of languages. Early exposure to two or several languages results in children becoming multilingual as easily and naturally as they learn their "native" language. But try it yourself: for an adult to learn another language is certainly possible, but the task is much more difficult and is rarely as well achieved.

There are two fundamental points here. First, the brain is "plastic" for a more or less extended period after birth. The immature brain is busy organizing itself – establishing the pattern and density of neuronal linkages (more is better) in response to the patterns of sensory data coming in. Neuronal linkages that are not receiving input are pruned away. The mature brain is "sculpted," in Cynader's (1994) felicitous phrase, from a huge initial oversupply of neurons in a process of competitive cooperation. Those that are successful in becoming active links in networks processing sensory input survive; the others do not.

Second, however, this sculpting process takes place according to a relatively precise sequence, so that different phases of development are coordinated. Critical periods, once missed, are gone forever – like the kitten's binocular vision. Other brain processes may be mobilized to remedy deficits – like the learning of a language in adult life – but they will never work as well. These two fundamental ideas drive the efforts in Canada to establish public policies and institutions to promote early childhood development (ECD), to which we will return below.

All this is interesting enough, but what does it have to do with me or with Milton Friedman? The plasticity of the developing brain would seem to lead naturally to the mature brain, with all its neuronal linkages in place and, for better or for worse, impervious to further external input. (There seems to be a lot of casual empirical support for this view.) But in fact, it is possible to teach an old dog new tricks – and it had better be, if the rhetoric of "lifelong learning" is to have any correspondence to the real world.

There are optimistic examples. London taxi drivers must "do the knowledge," learn the intricacies of the city's streets, to qualify to drive one of those big black cabs. Subsequent brain scans of drivers found that this demanding task was associated with enlargement of the hippocampus, a region associated with learning (Maguire et al. 2000). The adult brain apparently created the extra neuronal capacity to acquire and store all this new information.

The Monkey's Finger

The plasticity of the adult brain is addressed by Doidge (2007). He highlights in particular the work of Michael Merzenich, whose research program uses techniques that go back to the pioneering work of Wilder Penfield at the Montreal Neurological Institute in the 1930s. Penfield used electrical probes to stimulate particular areas of the exposed brains of conscious patients. As patients reported their sensations, he was able to "map" the brain, identifying the regions in which different types of information were processed and stored, and their linkages via the nervous system to other parts of the body. With much finer instrumentation, Merzenich and his associates have been able to "micro-map" areas of the adult monkey brain exposed in living experimental animals.

The striking finding is that these maps do not stay still. The boundaries between

micro-areas shift, over relatively short periods of time, depending upon how intensely they are being used.

As a leading example, a monkey's hand, like the human hand, is linked to the brain by three main nerves (radial, medial and ulnar) that transmit electric signals to specific and adjacent areas of the brain. Viewed by magnetic resonance imaging, these areas "light up," indicating neuronal activity, in response to stimulation of the corresponding regions of the hand. Modifying or blocking the transmission of signals from hand to brain not only changes or shuts down the neuronal activity in that micro-region, but also leads to rearrangement of the linkages among the neurons themselves.

In one experiment, the medial nerve was cut; in a more extreme intervention, the middle finger served by that nerve was amputated. The corresponding brain area became inactive. But, some months later, that area was remapped in the experimental animal and found to respond (light up the MRI image) to stimuli in adjacent areas of the hand served either by the radial or by the ulnar nerve. The neurons no longer receiving signals from the medial nerve had been appropriated by the networks responding to signals from the other, still functioning nerves. Just as in the developing kitten brain, unused neuronal processing capacity in the adult monkey brain was reassigned, and over quite a short time interval.

Another intriguing result emerged when two of the fingers of an experimental animal, served by different nerves, were linked together so that they could only be moved simultaneously. Later micro-mapping indicated that the separate neuronal networks that had previously responded to the signals from the distinct fingers/nerves were now merged into a single network, responding to the signals from what was now in effect one "finger."

Merzenich's monkey experiments demonstrate that the mature brain rearranges itself in response to external stimuli. This finding would appear to provide an increasingly secure neurological basis for the common wisdom, "Use it or lose it." Why does one have to keep practising a foreign language, or a physical skill? Because if the neurons that support it are left unused, they will be recruited by some other network.

But there is clearly more to the story. High levels of skill – in professional athletes, musicians or surgeons, for example – do require very frequent practice. It is well established that surgeons who operate infrequently have on average poorer outcomes. But if the "edge" is lost for lack of practice, it is also regained by further practice. And that further practice builds on a basic level of skill that, once acquired, remains for a long time, perhaps for life. Important neuronal linkages apparently persist, even without continuing stimulation. One never forgets how to ride a bicycle, for example. Nor does one's native language require constant practice.

All this is very interesting, but the findings for both immature and mature brains show self-reorganization in response to external stimuli, or lack of it. That is still some considerable distance from explaining the mechanisms whereby the brain quietly goes

about editing its own contents to make them more compatible with its proprietor's interests, purposes or ideological agenda. The human heart may be "deceitful above all else, and desperately wicked"; I suspect the human brain is only trying to be helpful. How does the internally driven editing process work?

Kids and Kittens: ECD and the Children Left Behind

Furthermore, what does all this have to do with health policy? In the case of the developing brain, quite a lot. Here is where we come back to ECD, and the evidence assembled by McCain and Mustard in the Early Years Studies (McCain and Mustard 1999; McCain et al. 2007).

The socio-economic gradient in health status is well known: higher income, education and social status are closely associated with better health and longer life expectancy. Perhaps less widely known is that the gradients in adult health correspond to earlier gradients in readiness to learn at school entry, in school performance, in post-secondary education, in contacts with the justice system, in attachment to employment and quality of jobs (Keating and Hertzman 1999). These self-reinforcing life trajectories are strongly influenced by the early life experiences that promote or inhibit the neural development of the immature brain – even including the expression or suppression of particular genes. Experiences become embedded in "coping styles," or patterns of behavioural and biological responses, to the later opportunities and challenges of life. The so-called "lifestyle choices" by which socio-economic health gradients are so often trivialized have deep roots in early environments and neural development.

These social gradients in health, literacy, school and work performance are much steeper in some societies than in others, meaning that they can be modified through public policies. Societies with flatter gradients are not only healthier but have higher literacy and educational attainment, lower poverty rates and smaller prison populations, and just plain work better. And they have serious ECD programs.

This is now all pretty well understood, though the evidence has yet to penetrate our political leadership. By some estimates, about 25% of Canadian children reach adulthood without the competencies they need to cope in the modern economy. The result is a large burden of social overhead costs, and of sheer human distress. It does not have to be this way. But ideology and economic interest trump science.

Messing with Your Head – To What End?

Well and good, but what about the mature brain? The evidence for continuous neuronal reorganization is intriguing, but how far does it take us? Presumably I too can reorganize my own neurons by duct-taping two of my fingers together for six months, but the operational significance is unclear.

The fact that the micro-map of the brain changes in response to particular external stimuli suggests the possibility of therapies for some forms, at least, of brain injury or illness, though these may be a long way off.

There are indications from brain scans that rigorous training in meditation enables adepts to modify their own brain functions. The Dalai Lama has an understandable interest in these observations, but I no longer have 20 years to spare. (I used that time studying economics – wonder what *that* did to my brain?)

There is also evidence that cultural norms, habits of thought, ideological preconceptions, even perceptions themselves may be neuronally embedded ("I wouldn't have seen it if I hadn't believed it"). This has rather disturbing implications.

If the Jesuits' insight ("Give me the child until he is seven and I will show you the man") is as solidly rooted neurologically as the one-eyed kittens, that suggests pretty radical limitations on the communicative and, *a fortiori*, the motivational power of "fact and argument" – evidence, as we might call it. In particular, school systems fragmented along sharply divergent religious or cultural lines may produce a citizenry whose brains are actually wired differently. And immigration … let's not go there. No wonder politics is such a difficult art.

So what does it all mean? Frankly, I don't know. And I still don't know why or how my brain is editing my memory – in response to some sort of internal stimulus, I guess. To support further wholesale returns of conjecture, we probably need a greater investment of fact. Stay tuned.

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