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A Decade Old Revolution of the Revealation on the Brain Plasticity

KULWANT SINGH
RESEARCH SCHOLAR CMJ UNIVERSITY, SHILLONG

ABSTRACT

Brain plasticity means to refer the extraordinary ability of the brain to modify its own structure and function following changes within the body or in the external environment. The large outer layer of the brain, known as the cortex is especially able to make such modifications.

Normal brain functions under plasticity such as our ability to learn and modify our behavior. It is strongest during childhood — explaining the fast learning abilities of kids — but remains a fundamental and significant lifelong property of the brain. Adult brain plasticity has been clearly implicated as a means for recovery from sensory-motor deprivation, peripheral injury, and brain injury. It has also been implicated in alleviating chronic pain and the development of the ability to use prosthetic devices such as robotic arms for paraplegics, or artificial hearing and seeing devices for the deaf and blind.

Since a decade, brain plasticity has been implicated in the relief of various psychiatric and neurodegenerative disorders both in humans and in animal models. These disorders include obsession, depression, compulsion, psychosocial stress, Alzheimer's disease, and Parkinson's disease. Furthermore, recent research suggests that the pathology of some of these devastating disorders is associated with the loss of plasticity. Collectively, there is a growing recognition that brain plasticity plays a fundamental role in either the deterioration to, or the alleviation of, psychiatric and degenerative brain disorders.

KEYWORDS: neuroplasticity, paraplegics, Alzheimer, Pearkinson's, Psychosocial, Neurogenesis

Brain plasticity, can also be termed as the Neuroplasticity which refers to changes in neural pathways and synapses which are due to changes in behavior, environment and neural processes, as well as changes resulting from bodily injury Neuroplasticity has replaced the formerly-held position that the brain is a physiologically static organ, and explores how - and in what manner the brain will change in the whole span of a life.

Neuroplasticity can be realized under different levels, ranging from cellular changes due to learning, to large-scale changes involved in *cortical remapping* in response to injury. The role of neuroplasticity is widely recognized in healthy development, learning, memory, and recovery from brain damage. During most of the 20th century, the consensus among neuroscientists was that brain structure is relatively immutable after a critical period during early childhood. This belief has been challenged by findings revealing that many aspects of the brain remain plastic even into adulthood

Hubel and Wiesel had demonstrated that ocular dominance columns in the lowest neocortical visual area, V1, were largely immutable after the critical period in development. Critical periods also were studied with respect to language; the resulting data suggested that sensory pathways were fixed after the critical period. However, studies determined that environmental changes could alter behavior and cognition by modifying connections between existing neurons and via neurogenesis in the hippocampus and other parts of the brain, including the cerebellum.

More than a decade of research has shown that substantial changes occur in the lowest neocortical processing areas, and that these changes can profoundly alter the pattern of neuronal activation in response to experience. Neuroscientific research indicates that experience can actually change both the brain's physical structure (anatomy) and functional organization (physiology). Neuroscientists are currently engaged in a reconciliation of critical period studies demonstrating the immutability of the brain after development with the more advance research showing how the brain changes.

Randy Nudo's group found that if a small stroke (an infraction) is induced by obstruction of blood flow to a portion of a monkey's motor cortex, the part of the body that responds by movement will move when areas adjacent to the damaged brain area are stimulated. In one study, intracortical micro stimulation (ICMS) mapping techniques were used in nine normal monkeys. Some underwent ischemic infarction procedures and the others, ICMS procedures. The monkeys with ischemic infarctions retained more finger flexion during food retrieval and after several months this deficit returned to preoperative levels. With respect to the distal forelimb representation, "post infarction mapping procedures revealed that movement representations underwent reorganization throughout the adjacent, undamaged cortex." Understanding of interaction between the damaged and undamaged areas provides a basis for better treatment plans in stroke patients. Current research includes the tracking of changes that occur in the motor areas of the cerebral cortex as a result of a stroke. Thus, events that occur in the reorganization process of the brain can be ascertained. Nudo is also involved in studying the treatment plans that may enhance recovery from strokes, such as physiotherapy, pharmacotherapy and electrical stimulation therapy.

Neuroplasticity is gaining popularity as a theory that, at least in part, explains improvements in functional outcomes with physical therapy post stroke. Rehabilitation techniques that have evidence to suggest cortical reorganization as the mechanism of change include Constraint-induced movement therapy, functional electrical stimulation, treadmill training with body weight support, and virtual reality therapy. Robot assisted therapy is an emerging technique, which is also hypothesized to work by way of neuroplasticity, though there is currently insufficient evidence to determine the exact mechanisms of change when using this method.

TREATMENT OF LEARNING DIFFICULTIES

Michael Merzenich developed a series of «plasticity-based computer programs known as Fast Forward." Fast-forward offers seven brain exercises to help with the language and learning deficits of dyslexia. In a recent study, experimental training was done in adults to see if it would help to counteract the negative plasticity that results from age-related cognitive decline (ARCD). The ET design included six exercises designed to reverse the dysfunctions caused by ARCD in cognition, memory, motor control, and so on after use of the ET program for 8–10 weeks, there was a "significant increase in task-specific performance." The data collected from the study indicated that a neuroplasticity-based program could notably improve cognitive function and memory in adults with ARCD.

NEUROPLASTICITY DURING OPERATION OF BRAIN-MACHINE INTERFACES

Brain-machine interface (BMI) is a rapidly developing field of neuroscience. According to the results obtained by Mikhail Lebedev, Miguel Nicolle's and their colleagues operation of BMIs results in incorporation of artificial actuators into brain representations. The scientists showed that modifications in neuronal representation of the monkey's hand and the actuator that was controlled by the monkey brain occurred in multiple cortical areas while the monkey operated a BMI. In these single day experiments, monkeys initially moved the actuator by pushing a joystick. After mapping out the motor neuron ensembles, control of the actuator was switched to the model of the ensembles so that the brain activity, and not the hand, directly controlled the actuator. The activity of individual neurons and neuronal populations became fewer representatives of the animal's hand movements while representing the movements of the actuator. Presumably as a result of this adaptation, the animals could eventually stop moving their hands yet continue to operate the actuator. Thus, during BMI control, cortical ensembles plastically adapt, within tens of minutes, to represent behaviorally significant motor parameters, even if these are not associated with movements of the animal's own limb

PHANTOM LIMBS

A diagrammatic explanation of the mirror box. The patient places the good limb into one side of the box (in this case the right hand) and the amputated limb into the other side. Due to the mirror, the patient sees a reflection of the good hand where the missing limb would be (indicated in lower contrast). The patient thus receives artificial visual feedback that the "resurrected" limb is now moving when they move the good hand.

The experience of Phantom limbs is a phenomenon in which a person continues to feel pain or sensation within a part of their body which has been amputated. This is strangely common, occurring in 60-80% of amputees. An explanation for this refers to the concept of neuroplasticity, as the cortical maps of the removed limbs are believed to have become engaged with the area around them in the post central gyrus. This results in activity within the surrounding area of the cortex being misinterpreted by the area of the cortex formerly responsible for the amputated limb.

The relationship between phantom limbs and neuroplasticity is a complex one. In the early 1990s V.S. Ramachandran theorized that phantom limbs were the result of cortical remapping. However, in 1995 Herta Flor and her colleagues demonstrated that cortical remapping occurs only in patients who have phantom pain. Her research showed that phantom limb pain (rather than referred sensations) was the perceptual correlate of cortical reorganization. This phenomenon is sometimes referred to as maladaptive plasticity

CHRONIC PAIN

Individuals who suffer from chronic pain experience prolonged pain at sites that may have been previously injured, yet are otherwise currently healthy. This phenomenon is related to neuroplasticity due to a maladaptive reorganization of nervous system, both peripherally and centrally. During the period of tissue damage, noxious stimuli and inflammation cause an elevation of nociceptive input from the periphery to the central nervous system. Prolonged nociceptionfrom periphery will then elicit a neuroplastic response at the cortical level to change its somatotopic organization for the painful site, inducing central sensitization. For instance, individuals experiencing complex regional pain syndrome demonstrate a diminished cortical somatotopic representation of the hand contra laterally as well as a decreased spacing between the hand and the mouth. Additionally, chronic pain has been reported to significantly reduce the volume of grey matter in the brain globally, and more specifically at the prefrontal cortex and right thalamus. However, following treatment, these abnormalities in cortical reorganization and grey matter volume are resolved, as well as their symptoms. Similar results have been reported for phantom limb pain, chronic low back pain and carpal tunnel syndrome

MEDITATION

A number of studies have linked meditation practice to differences in cortical thickness or density of gray matter. One of the most well-known studies to demonstrate this was led by Sara Lazar, from Harvard University, in 2000. Richard Davidson, a neuroscientist at the University of Wisconsin, has led experiments in cooperation with the Dalai Lama on effects of meditation on the brain. His results suggest that long-term, or short-term practice of meditation results in different levels of activity in brain regions associated with such qualities as attention, anxiety, depression ,fear, anger, the ability of the body to heal itself, and so on. These functional changes may be caused by changes in the physical structure of the brain.

FITNESS AND EXERCISE

In a 2009 study, scientists made two groups of mice swim a water maze, and then in a separate trial subjected them to an unpleasant stimulus to see how quickly they would learn to move away from it. Then, over the next four weeks they allowed one group of mice to run inside their rodent wheels, an activity most mice enjoy, while they forced the other group to work harder on minitreadmills at a speed and duration controlled by the scientists. They then tested both groups again to track their learning skills and memory. Both groups of mice improved their performances in the water maze from the earlier trial. But only the extra-worked treadmill runners were better in the avoidance task, a skill that, according to neuroscientists, demands a more complicated cognitive response.

The mice that were forced to run on the treadmills showed evidence of molecular changes in several portions of their brains when viewed under a microscope, while the voluntary wheel-runners had changes in only one area. "Our results support the notion that different forms of exercise induce neuroplasticity changes in different brain regions," Chauying J. Jen, a professor of physiology and an author of the study, said.

HUMAN ECHOLOCATION

Human echolocation is a learned ability for humans to sense their environment from echoes. This ability is used by some blind people to navigate their environment and sense their surroundings in detail. Studies in 2010 and 2011 using Functional magnetic resonance imaging techniques have shown that parts of the brain associated with visual processing are adapted for the new skill of echolocation. Studies with blind patients, for example, suggest that the click-echoes heard by these patients were processed by brain regions devoted to vision rather than audition

RESEARCH AND DISCOVERY

In 1923, Karl Lashley conducted experiments on rhesus monkeys which demonstrated changes in neuronal pathways, which he concluded to be evidence of plasticity, although despite this, as well as further examples of research suggesting this, the idea of neuroplasticity was not widely accepted by neuroscientists. However, more significant evidence began to be produced in the 1960s and after, notably from scientists including Paul Bach-y-Rita, Michael Merzenich along with Jon Kaas, as well as several others.

In the 1960s, Paul Bach-y-Rita invented a device that allowed blind people to read, perceive shadows, and distinguish between close and distant objects. This "machine was one of the first and boldest applications of neuroplasticity." The patient sat in an electrically stimulated chair that had a large camera behind it which scanned the area, sending electrical signals of the image to four hundred vibrating stimulators on the chair against the patient's skin. The six subjects of the experiment were eventually able to recognize a picture of the supermodel Twiggy

It must be emphasized that these people were congenitally blind and had previously not been able to see. Bach-y-Rita believed in sensory substitution; if one sense is damaged, your other senses can sometimes take over. He thought skin and its touch receptors could act as a retina (using one sense for another In order for the brain to interpret tactile information and convert it into visual information, it has to learn something new and adapt to the new signals. The brain's capacity to adapt implied that it possessed plasticity. He thought, "We see with our brains, not with our eyes."

A tragic stroke that left his father paralyzed inspired Bach-y-Rita to study brain rehabilitation. His brother, a physician, worked tirelessly to develop therapeutic measures which were so successful that the father recovered complete functionality by age 68 and was able to live a normal, active life which even included mountain climbing. "His father's story was firsthand evidence that a 'late recovery' could occur even with a massive lesion in an elderly person." He found more evidence of this possible brain reorganization with Shepherd Ivory Franz's work. One study involved stroke patients who were able to recover through the use of brain stimulating exercises after having been paralyzed for years. "Franz understood the importance of interesting, motivating rehabilitation: 'Under conditions of interest, such as that of competition, the resulting movement may be much more efficiently carried out than in the dull, routine training in the laboratory". This notion has led to motivational rehabilitation programs that are used today

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