Plasticity

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Plasticity

The dictionary defines plasticity as the capacity to change. Neuroanatomists define plasticity as, the presence of morphological evidence of an altered state of organization. Electrophysiologists define plasticity as a change in the efficiency of a synapse. Psychologists define plasticity as the ability of the animal to respond in a new way.

- The most appropriate definitions relate to the anatomical and electrophysiological changes in the CNS following injury.
- The concept of plasticity include the ability of the nervous system to make structural and functional changes in response to internal and external demand.
- Two type of neural plasticity:

1)Experience expectant.

2) Experience dependent neural plasticity.

Experience expectant

In the course of typical prenatal and postnatal development , the infant is expected to be exposed to sufficient environmental stimuli at appropriate times.

Experience dependent neural plasticity.

- Allows the nervous system to incorporate other types of information from environmental experience that are relatively unpredictable.
- Motor learning as apart of motor development is an example of experience- dependent neural plasticity

Recovery following injury to the nervous system occurs in one of two ways. One is a result of spontaneous recovery and the other way is function induced recovery. Function-induced recovery is also known as use-dependent cortical reorganization.

Injury induced plasticity and recovery of function

Mechanisms underlying recovery of function after neural injury have been categorized as either **restorative (direct)** or **compensatory (indirect)**

Direct mechanisms involve the resolution of temporary changes and recovery of the injured neural tissue itself. In addition, nearby neural tissue takes over identical neural functions to the original damaged tissue, resulting in restitution of function.

In indirect, or compensatory, recovery completely different neural circuits enable the recovery of lost or impaired function. Compensatory neural reorganization can include both function-enabling and function disabling plasticity.

Research suggest that there are a variety of events occurring within the nervous system following injury. These events may contribute to the recovery of function:

- **Neural Shock Resolution.**
- Recovery of Synaptic Effectiveness.
- Presynaptic Hypereffictivenes.
- **Denervation Supersensitivity**.
- Persistance of Hyperinnervation.
- Recruitment of Silent Synapses.
- Sprouting.
- Vicarious Function Theory.
- Compensation (behavioral substitution).

Neural Shock Resolution

One of the first events following nervous system injury is neural shock or diaschisis that include the short term loss of function in neural pathways at a distance from the site of the lesion itself. Damage to the nervous system deprives other intact regions of normal afferent inflow, blood supply, or metabolism that had previously come from the injured area. So, the symptoms will be produced from the intact as well as from the injured areas. The resolution of diaschisis may account for some of the return of function following injury .

Edema

Cerebral edema commonly follows brain injury. **Cytotoxic cerebral edema** involves the accumulation of intracellular fluid, whereas **vasogenic edema** entails leakage of proteins and fluid from damaged blood vessels. Cerebral edema can be local (i.e., adjacent to the primary injury site) or remote and produces a functional depression in brain tissue that is not part of the primary injury .

Edema at the site of neuronal injury may lead to a compression of axons and physiological blocking of neuronal conduction Reduction of the edema would then restore a portion of the functional loss.

Diaschisis

is a transient CNS disorder involving loss of function in a structurally intact brain area because of loss of input from an anatomically connected injured area of the brain

The sudden functional depression of brain regions distant from the primary site of injury can be due to a reduction in blood flow and/or metabolism

Denervation Supersensitivity

- Can occur when neurons show loss of input from another brain region leading to the post synaptic membrane of a neuron becomes hyperreactive to a realesed transmitter substance.

Persistence of Hyperinnervation (silent neurons)

- During maturation, the brain over produce neurons, possibly twice as many as needed. So , this may assist in the recovery of injury for younger age .There is evidence using younger animal models that two recovery mechanisms may occur because of hyperinnervation:

1) axons may not follow the maturational order to extract in the presence of injury.
2) growing axons may reroute to a different location in the presence of injury.

Recruitment of Silent Synapses

- Recruitment of previously silent synapses also occurs during recovery of function. This suggests that structural synapses are present in many areas of the brain but were masked and not functionally working under normal conditions due to competition within the neuronal pathways.
- However, experiential factors or lesions may lead to their being unmasked when they are realesed from these previous effects

Sprouting

➢There are two types of sprouting :

a) Regenerative Synaptogenesis (Regenerative Sprouting) : occurs when the injured axons responds by providing side branches .
b) Reactive Synaptogenesis (Collateral Sprouting) : occurs when neighboring normal axons sprout to innervate synaptic sites that were previously activated by injured axons .

➢ The sprouting has been reported to begine between 4 days and 2 weeks following injury.

Effect of training on cortical reorganization

- Each sensory and motor area in the cerebral cortex has a separate map (sensory and motor maps) of the body. Research has shown that these maps of the sensory and motor cortex vary from individual to individual according to past experience.
- They suggest that we have multiple pathways innervating any given part of the sensory or motor cortex, with only the dominant pathway showing functional activity. However, when a lesion occurs in one pathway, the less dominant pathway may immediately show functional connections. This leads us to the conclusion that cortical maps are very dynamic. Even in adults there is competition among neurons for synaptic connections. So, when one area becomes inactive, a neighboring area can take over its former function.

sensory and motor maps in the cortex are constantly changing in accordance with the amount to which they are activated by peripheral inputs. Since each one of us has been brought up in a different environment and has practiced very different types of motor skills, the maps of each of our brains are unique and constantly changing as a result of these experiences.

Non-plastic factors that influence recovery

- age
- Past and present experience.
- Motivation to learn .
- Health of the body at time of injury (Risk Factors)
- Genetic factor
- Site of the lesion .
- Extent of the lesion .
- Rapidity of the insult.

Age

- The age of the individual at the time of the lesion affects recovery of function ,but in a complex manner . It was proposed that brain injury during infancy caused fewer deficits than damage in the adult years . But with more understanding about the function of different brain areas researchers c**oncluded that not all areas show the same capacity for regeneration.**
- Therefore when considering the effect of age on recovery , several variables should be considered:

l)the area of the brain that is injured.

2)the maturity of the brain region rather than the age of the individual.

3) the task being tested.

4) the time following insult.

Nature of the lesion

- This includes the site the size and the rapidity of the insult. A small lesion has a greater chance of recovery, as long as a functional area hasn't been entirely removed .

Effect of Experience on Recovery

- Research literature suggests that an enriched environment leads to improved performance.
- An enriched environment includes multisensory stimulation.
- Morphological changes are reported to associate this **improved behavior , such as an increase in the amount of dendritic branches , larger synaptic boutons , an increased protein synthesis and an increase in brain weight.**
- It was suggested that **enriched subjects** may have developed **functional neural mechanisms** that are more varied than that of **restricted subjects** , and this could provide them with **a greater ability to reorganize the nervous system after a lesion , or simply to use alternate pathways to perform a task.**

Health of the Body at the Time of Injury

It is very important factor that affects the recovery of function after CNS injury. We should also consider the predisposing or risk factors that include hypertension , hypotension, diabetes mellitus , cardiac diseases , hyperlipaemia , smoking , old age and sedentary life. All of these factors predispose to cerebral atherosclerosis that finally leads to cerebrovascular accidents (CVA).

Recovery from stroke

- The most significant recovery in neurologic function occurs within the first 3 months after the injury, although movement patterns may be able to be improved with goal-directed activities for up to 2 to 3 years after the initial injury.
- Neurological recovery is defined as recovery of neurological impairments. These are determined primarily by the site and extent of the stroke.
- The return of motor power is not synonymous with recovery of function; function may be hampered by the inability to perform skilled coordinated movements, apraxias, sensory deficits, communication disorders as well as cognitive impairment.
- Recovery after a stroke is associated with cortical reorganization. Motor recovery is a complex process combining:

1. Neurological or Spontaneous Recovery.

2. Functional Induced Recovery.

Mechanisms of Neurological Recovery

➢Neurological recovery is defined as recovery of neurological impairments and is often the result of a number of factors:

Post-Stroke Edema:

- Edema surrounding the lesion may disrupt nearby neuronal functioning. Some of the early recovery may be due to resolution of edema surrounding the area of the infarct and as the edema subsides, these neurons may regain function.
- This process may continue for **up to 8 weeks but is generally completed much earlier.**
- **Cerebral hemorrhages** tend to be associated with **more edema**, which **take longer to subside**, but which may in turn be associated with a more dramatic recovery.

Reperfusion of the Ischemic Penumbra:

- Reperfusion of the ischemic penumbra is another local process which can facilitate early recovery.

Resolution of Diaschesis:

- Diaschesis is a state of low reactivity or depressed function as a result of a sudden interruption of major input to a part of the brain remote from the site of brain damage.
- Neuronal function may return following the resolution of diaschisis, particularly if the connected area of the brain is left intact.

Mechanisms of Functional Induced Recovery

Function-induced recovery (use-dependent cortical reorganization) refers to the ability of the nervous system to modify and repair itself.” itself in response to changes in activity and the environment, known as **Neuroplasticity.**

Mechanisms of neuroplasticity include

- **Neural regeneration**: release of trophic molecules (nerve growth factors) play a key role in growth and repair processes.
- **Regenerative synaptogenesis** refers to sprouting of the injured axons to innervate previously innervated synapses.
- **Reactive synaptogenesis** (collateral sprouting) refers to the reclaiming of synaptic sites of the injured axon by dendritic fibers from neighboring axons.
- **Synaptic plasticity**: improve neurotransmitter release, receptor sensitivity and Nerve cells change their physiological interactions with each other, at the level of the synapses.
- **Long-term potentiation**: Changes in synaptic strength firm up neuronal connections and serve as a basis for all memory and learning.
- **Cortical remapping:** Different and underutilized areas of the brain (e.g., cortical supplementary and association areas) can take over the functions of damaged tissue.
- Activation of brain areas that previously is not active. It is important to remember that the brain is organized with parallel and distributed circuits that provide multiple inputs to many areas with overlapping functions.

How to enhance plasticity.

- Dual task.
- Feedback (intrinsic &extrinsic).
- Enriched environment.
- Experience.
- Learning.
- Skills.
- Improve cognition (memory/attention/concentration).
- Motivation.
- Competition.
- Identify abilities & disabilities.

Intervention based on motor control, motor learning & plasticity

Previously, interventions have been based on neurophysiologic approaches, which focus on the impairments seen in individuals with neurologic dysfunction. More recently emphasis is placed on the activity limitations and participation restrictions encountered by those with neurologic dysfunction.

More functionally based view of interventions and the impact of those interventions on the quality of life of the individual.

The motor activities selected must be engaging and meaningful to the person. The therapist selects the task to be performed and the environment as well as determines the type of practice and when feedback is given. Active participation is required for motor learning.

Principles of forced use of an extremity that might be ignored have been extremely effective in adults and children with hemiplegia. **Constraint-induced movement therapy (CIMT)** involves both constraint of the noninvolved upper extremity of an individual with hemiplegia and repetitive practice of skilled activities or functional tasks.

The mass practice in CIMT is thought to induce cortical reorganization and mapping, which increases efficiency of task performance in the hemiplegic upper extremity. These findings reflect the influence of CIMT on activity-dependent neural plasticity.

Use of partial body weight support treadmill training (PBWTT) as a form of gait practice does not require the person to have postural control of the trunk before attempting to walk. Task- specific practice has been shown to positively affect outcomes in adults with hemiplegia, incomplete spinal cord injuries found that PBWTT significantly increased gait velocity and walking velocity during rehabilitation.

Summary

First, it means that whenever a patient experiences a neural lesion , the cortical maps show both a)immediate reorganization , due to the unmasking of previously nonfunctional synaptic connections from neighboring areas , and b) a longer-term change , where the inputs to the neighboring areas take over the parts of the map that were previously occupied by damaged cells.

Second , it tells us that experience is very important in shaping cortical maps . Thus if we leave patients without rehabilitation for many weeks or months , their brains will show changes in organization reflecting disuse, which will be so bad for these patients .But, it has been proved that training appears to make a difference no matter when it is given , since the brain continues to be plastic throughout our lives .