Neuroplasticity, Motor Relearning, and its Application in Rehabilitation

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The material in this presentation is for general clinical knowledge, and it is not considered treatment recommendations for specific patients.
Overview

• Define neuroplasticity
• Review basic anatomy and physiology
• Clinical application of neuroplasticity in rehabilitation
• Describe the underlying theory of Learned Non-use and Cortical Reorganization
• Evidence for effectiveness
Rehabilitation is Changing

• For the past 75 years, compensation for loss of function was the primary focus of rehabilitation.

• The brain and spinal cord were thought to be unresponsive to change and incapable of recovery.

• However, research has shown that the brain and spinal cord are indeed plastic and can develop new neuronal interconnections so that new functions can be acquired and restored.
Basic anatomy and physiology

Cells in the brain send signals to cells in the spinal cord which in turn connect with the muscles.
What is Neuroplasticity?

• The capacity for continuous alteration of the neural pathways and synapses of the Central Nervous System in response to injury or repetitive experience.

• The CNS may respond to this stimuli by reorganizing its structure, function, and/or neural connections.

• New neural connections may form in order to compensate for injury/loss of function or it may be a response to changes in one’s environment.

• Present in both healthy and damaged CNS.
What is Neuroplasticity?

- Synaptic connections are continually being modified (re-organisation of circuitry)
  - In response to demand – learning, repetition
  - After damage to the CNS
  - Disuse
Neuroplasticity in Healthy CNS

• Musicians – how do I get to Carnegie Hall? “Practice, practice, practice.”

• Athletes – practice fundamentals – over and over and over.

• Why does this work? Muscles can’t think – it’s the hardwiring of the CNS through repetition of activity that leads to improvement in performance.
Neuroplastic Stages of Feeding

A) Rejecter of New Foods
Neuroplastic Stages of Feeding

B) Ejector of New Foods
Neuroplastic Stages of Feeding

C) Messy Eater
Neuroplastic Stages of Feeding

D) No way am I eating that
Neuroplastic Stages of Feeding

E) Picky Eater
Neuroplastic Stages of Feeding

E) Happy Meal Eater
Neuroplastic Stages of Feeding

F) Accomplished Eater
Mechanisms of Neuroplasticity

- **Hebbian Learning** - neurons active together create strong connections leading to behavior adaptations. Explains the adaptation of neurons in the brain during the learning process.

- Repetition of a reverberatory activity tends to induce lasting cellular changes that add to its stability (Hardwiring concept).
What determines whether a cell fires?

Hebbian learning rule (Hebb - 1949):

Repetitive activation of a presynaptic neuron together with simultaneous activation of a neighbouring postsynaptic neuron leads to an increase in synaptic strength between them.
Mechanisms of Neuroplasticity

• **Axonal Sprouting** - Undamaged axons grow new nerve endings to reconnect damaged neuron links

• **New Neural Pathways** - Undamaged axons sprout to other undamaged nerve cells forming new neural pathways to accomplish a needed function

• **Cortex Changes** – Use of dependent competition among neurons can alter brain network in both the sensory and motor cortex.
Cortical maps – ‘use it or lose it’

• The sensory and motor cortex also is not fixed but flexible and adapts to learning and experience (Donoghue 1996).

• Areas with more connections – fine motor control or more acute sensation - have larger representation.

• Factors that promote change:
  1. Exposure to an enriched environment after ischaemic stroke increases cortical activity
  2. Amputation of a limb results in a shrinking of the cortical representation
  3. Immobilization of an extremity – for example in a splint results in a decrease in cortical activity (Liepert 1995)

• Increase in size is related to increase in skill/functional performance.
Experience Alters Somatosensory Maps in the Cortex

Before Rehabilitation

After Rehabilitation

Area of cortex devoted to fingers
Rehabilitation Impact on Neuroplasticity

• Behavioral Level – recovery of sensory, motor, or autonomic function

• Physiological – normalization of reflexes

• Structural – axonal/dendrite strengthening

• Cellular – synaptic strengthening
Longitudinal changes in single subjects

<table>
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<th>GRIP</th>
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<td>20/20</td>
<td>57/57</td>
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Importance of Sensory Input

Learned Non-use in Animals

• Substantial neurological injury leads to reduction in motor and/or perceptual function

• Animal attempts to use the involved limb

• Continued attempts to use involved limb produces failure, pain, poor coordination, falling, etc.

• Animal begins to function adequately with 3 limbs, reinforcing 3 limb function
Learned Non-use in Animals

• Non-use response tendency persists, preventing animals from learning that after several months, the limb is potentially usable.

• Conclusion: the animals never learned they could eventually use the limb - (Learned Non-use or Learned Helplessness)
Learned Non-use in Humans

- When a person's brain is damaged by a stroke, it often becomes more difficult to move an extremity.
- The person therefore tends to use the extremity less.
- This leads to shrinkage of the regions of the brain that control movement of that extremity.
- Movement of the extremity becomes even more difficult.
Process of Learned Non-use

1. Decrease in the size of cortical representation of the extremity

2. Punishment of use of involved extremity (pain, frustration)

3. Reinforcement of use of intact extremity
   - The three processes interact to produce a cycle during which the person uses the extremity less and less
   - It is potentially reversible and can be overcome by the application of appropriate interventions
Childhood vs. Adult Response to CNS Damage

- Children with early CNS damage (prenatal and early postnatal) differ from adults with a sudden CNS lesion.
- Underlying neural framework for movement with complex cortical pathways has not yet developed.
- Results in atypical movement patterns, which include ignoring or disregarding one’s body parts.
- Unlike the adult who once had normal movement patterns then loses them, the child never acquired typical movement.

Deluca, Echols, and Ramey, 2007
What can be done to enhance Neuroplasticity and functional recovery potential?

• Today rehabilitation protocols are being based on motor learning to induce neural plasticity

• Training should be:
  - task specific
  - meaningful and challenging
  - repetitive and intensive
  - provided in an enriched environment
  - movements performed in a relatively normal biomechanical position and manner
Skill Acquisition: Implicit and Explicit Learning

- Explicit learning:
  - ‘How to’ – associated with memory, cognition, etc.
  - Learning may be very rapid and is tested by questioning

- Implicit learning:
  - Motor skills are examples of implicit learning
  - Demonstrated by ‘doing’

- Therapists often use explicit learning in training motor skills

- Evidence suggests this may not be effective
The potential influence of neuroplastic interventions on functional performance

- Unable to perform task
- Neuroplastic therapies
  - Movement & Sensory input
    - Stiffness / ROM
    - Spasticity
    - Muscle strength
  - Intense, varied repetition at limit of performance
  - Feedback from successful performance
- Neuroplasticity
- Motor Learning
  - Reduce support
- Improved Performance

Improved Performance

Motor Learning

Intense, varied repetition at limit of performance

Feedback from successful performance

Reduce support

Movement & Sensory input

- Stiffness / ROM
- Spasticity
- Muscle strength

Neuroplastic therapies

Unable to perform task

Improved Performance
Summary

• Evidence that intensive practice and repetition leads to better outcomes
  • Evidence for neuroplasticity in animal models has been demonstrated in human subjects
  • Neuroplastic changes are associated with improved function
  • Complex interventions may add value to improve functional outcomes
  • Proper environment and biomechanical position are critical
Three rehabilitation interventions to enhance neuroplasticity

(afternoon session)

• Constraint Induced Movement Therapy (CIMT)

• Body Weight Support Treadmill Training (BWSTT)

• Exoskeleton Training
Assistive and Rehabilitative Technology

• Rehabilitative Technology is designed to train individuals to regain function.

• Assistive Technology is devoted to the facilitation of function.
Our Inspiration

Professor of Theoretical Physics – Dr. Steven Hawking – Cambridge University

“Dr. Stephen Hawking continues to be active in his research and personal lives because he has developed effective strategies for personal care, speaking, writing, and research activities that compensate for functional limitations imposed by ALS.”

http://www.washington.edu/doit/Faculty/articles?370

http://www.hawking.org.uk/
Assistive or Adaptive Technology commonly refers to "...products, devices or equipment, whether acquired commercially, modified or customized, that are used to maintain, increase or improve the functional capabilities of individuals with disabilities..."

Assistive Technology Act of 1998


Bridging the GAP!!!
“For people without disabilities, technology makes things easier.

For people with disabilities, technology makes things possible.”
What is the Purpose of AT?

• TO HELP PEOPLE WITH DISABILITIES PARTICIPATE IN LIFE ACTIVITIES AND TO INCREASE THEIR INDEPENDENCE

• Simple to Complex Examples:
  – Play a board game
  – Make a call
  – Read the paper
  – Communicate wants and needs
  – Mobility