Neuroplasticity: Evidence Based Clinical Applications

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Objectives

1. **Concept of neuroplasticity**

2. **Essential principals**
   - Basic theories and principles
   - History
   - Positive vs. Maladaptive neuroplasticity

3. **Recent evidence**
   - Incorporate recent evidence into clinical application
   - Eliciting good neuroplastic changes
   - Share research articles
Objectives (cont.)

4. Evidence based interventions
   • Explain enriched environment
   • Provide a description of environmental structure that Pate provides in accordance with neuroplasticity principles
   • Present interventions to promote brain activation
   • Present future possibilities

5. Evaluation and Discussion
   • Facilitate questions and discussion
   • Handout evaluation form
**Neuroplasticity**

**Defined:** The property of the brain to adapt to environmental pressure, experiences, and challenges including brain damage. Life long capacity of the brain to change and rewire itself in response to the stimulation of learning and experience.

**History of science**

- **450 BC:** Greek physician brain dissections led to discovery that heart was not the center of intelligence.
- **1861:** Dr. Broca’s autopsies revealed people with speech problems had brain damage in the lateral frontal lobe. 1874- Wernicke’s area discovered to control interpretation of written and spoken language.
- **1950s:** Treated epilepsy by electrically zapping to destroy part of brain causing seizures, Created maps of sensory & motor maps still used today. Over the years- neuroscientists began plotting areas of the brain as ONLY controlling a specific function - no changing.
- **1980s-90s:** Taub experiments on animals show that if given purposeful brain injury resulting in hemiparesis, that the brain can reorganize itself to recover the lost function of a limb if the environment demands it. **THE BRAIN CAN CHANGE**
Functional MRI

Cortical Activity during Hand Movement

Contralateral Hemisphere

Ipsilateral Hemisphere

Healthy Subjects (Right Hand)

Stroke Patients Affected Hand (Right Hand)
Cortical Mapping

Broadmann’s Areas

Homunculus
Targeted Training for Positive Neuroplasticity

• Use it or lose it
• Keep control of real estate
• Prevent a take over
“One practice variable that dwarfs all the others in terms of importance and is so obvious that it need hardly be mentioned at all—practice”.

-Schmidt and Lee
Brain Injury Rehab

BI is the leading cause of chronic disability.\(^7\)

- **Cognition** - one study showed that 91% of survivors failed in at least one cognitive domain, mainly: memory and executive functions.
  - **Language** - 25-40% of CVA survivors have aphasia.
- **Physical** - Two-thirds of survivors have impaired gait and 6 months later more than 30% still need assistance to walk. 80% of stroke survivors have hemiparesis. In 2005, nearly 1.1 million stroke survivors reported difficulty performing basic activities of daily life.

**Cost**
- The annual cost of TBI to society exceeds $76.5 Billion.
- The estimated cost of stroke in the United States was $53.9 billion in 2010.
Brain Injury Rehab

Environmental Design
• Duration & Intensity
• Structure and Distraction
• Multidisciplinary
• External Support Systems
• Therapeutic Use of Self

Influences on Neuroplasticity
• Time since onset
• Age
The benefit is a combination of optimal care, task oriented, and meaningful training in an environment that gives confidence, stimulation, and motivation. Environmental enrichment has many functional and biological effects and significantly enhances the effect of other interventions.

–Johansson, BB.
Promoting Neuroplasticity in an Enriched Environment

EE: model that provides multiple possibilities

We do this 3 ways:

1. Social stimulation
2. Interaction with objects
3. Physical activity dependent

Emotional Climate

- Interaction with therapists and other survivors
- Relaxation/Stress management
- Sleep
Functional Approach in an Enriched Environment

• Client Driven Schedules
• Job Task Simulation
• Work site evaluations
• Community & Home Based Treatment
Considerations for Acute and Inpatient Rehab\textsuperscript{15}

The brain is vulnerable in the first 7 days post injury

- Managed care wants functional changes
- Fine line to discover the ideal challenge to prevent complications and also to promote functional changes to create optimal rehab opportunities

Evidence

In animal models:

- Voluntary exercise in the first 7 days decreased plasticity.
- Voluntary exercise in days 14-20 after injury increased plasticity.
Enriched Environment Enhances other Interventions, but on its own.. 15, 16

**Functional Effects**
- Improves working memory, spatial learning
- Greater opportunity to engage in stimulating activities- motor
- Meeting new people/creating relationships helps restore language, emotional intelligence, and sense of self
- Promotes independence through task specific activities of daily living

**Biological Effects = MORE**
- Dendrites
- Dendritic branching
- Synapses
- Glial processes
- Brain weight
- Cortical thickness
Structuring Interventions

- Task Specific
- Repetitive 300-1000 per day!
- Relevant

- Engaging: Multisensory Interaction, Biofeedback
- Challenging and Progressive
Evidence Based Therapeutic Interventions

- Aerobic Exercise
- Bilateral Arm Training
- Constraint-Induced Movement Therapy
- Body-Weight Supported Treadmill Training
- Mirror Therapy
- Action Observation
- Motor imagery / Mental practice
- Electrical Stimulation
- Biofeedback
- Cognitive Therapy
- Oral Motor Therapy
- Music Therapy
Aerobic Exercise

Basic description: any activity that uses large muscle groups, can be maintained continuously, and is rhythmic in nature. It is a type of exercise that overloads the heart and lungs and causes them to work harder than at rest.\textsuperscript{8}

Parameters: 3-7 days/wk, 20-60 minutes (can be broken into 10 minute increments), 50-80\% of HRmax\textsuperscript{1}

Clinical applications: Even when a pt may not present with need for skilled PT/OT, they need to have an aerobic ex program for ideal healing, prevention, cognitive benefits. Needs to be part of the recovery program. If possible do it before cognitive tx.

Considerations: Releases BDNF, promotes neurogenesis & angiogenesis
\begin{itemize}
\item Decreased incidence of depression, greater chances for social interaction, improved emotional function, better QOL
\item Positive impact on attention/concentration, executive function, memory, visual-perceptual deficits, language deficits.\textsuperscript{2}
\end{itemize}
Aerobic Exercise\(^2\)

**Influence of Timing of Post-Injury Exercise on Stroop Task Performance**

![Graph showing the influence of timing of post-injury exercise on Stroop task performance.](image)

**Table 3: Symptom Questionnaire: Most Highly Endorsed Rating Category (% of Participants Endorsing)**

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<th>Sometimes</th>
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Bilateral Arm Training\textsuperscript{14}

Basic description: “Good trains the bad”, promotes lateralization- activation undamaged side increased activation of damaged hemisphere. Shown to reduce motor impairment & improve spatiotemporal control of affected arm in both bilateral and unilateral tasks.

Parameters: 2hrs/day, 5 days a week for 3 weeks. 1 hr/day, 2 wks Effective in subacute & chronic phases. Bilateral movement alone or paired with rhythmic auditory cuing or estim.

Clinical applications: 6-67months after onset. (proven superior to traditional equally intense but less task specific therapy). Greater gains in proximal upper limb than traditional and CIMT.

Considerations: Good for severe functional deficits and at all levels.
Constraint Induced Movement Therapy

Basic description: forced use of the affected extremity by limiting use of the non affected extremity with mitt or other constraint device\textsuperscript{17, 13}

Parameters: Therapy 5 hrs/day + wear mitt 90% of waking hrs. 10-15 days mCIT Therapy $\frac{1}{2}$ hr, 3X/wk + forced use- 5 hrs/day, 5 days/wk during active productive times. Other protocols - 1-6 hrs/day, 3-5 days/week, 2-12 weeks \textsuperscript{13}. 6 hrs/day, 7days/wk, for 2 wks.\textsuperscript{11}

Clinical applications: effective 3-21 mo. post injury\textsuperscript{17}. Mild-mod impaired\textsuperscript{14}. Higher intensity in acute care =negative effects.

Considerations: Must meet inclusion criteria (washcloth or towel test); client must be fully vested, behavioral contracts are common. In animal models, forced use in the first 7 days compounded the injury and led to decreased function.
Body Weight Supported Treadmill Training

**Basic description:** A task-specific intervention that is used to provide an environment that facilitates relearning normative gait after stroke.⁹

**Parameters:** No GT in acute care, 30 mins/day, 5 days/wk for 2-8 weeks with double upright AFO. Initial BWS 30%, speed .7 mph, no UE support, 2 therapists- one for weigh shift, other for limb advancement. After 2 consecutive bouts of at least 3 minutes, speed was increased by .1 mph and BWS decreased by 5% until pt reached 10 mins at 1.5 mph with 0 BWS and minA or less for involved leg advancement. Overground gait use of STC. (all s AFO/AD by 6 months post).¹⁰

**Clinical applications:** Start in inpatient rehab, if BWS unavailable, use B platform walker and rolling stool. Must be able to sit independently for 3 minutes and stand with or without assistance.

**Considerations:** One prelim study on chronic CVA shows overground may be superior to BWS.
Mirror Therapy

Basic description: a mirror is placed at 90 degrees close to the midline of the pt and the affected limb is positioned behind the mirror. The pt watches the non-affected limb in the mirror and performs exercises. Receiving positive visual impression that the limb in the mirror (the affected limb) is fully functioning.

Parameters: 1 hr/day in addition to conventional rehab\(^5\). Chronic CVA- 1.5 hrs/day, 5 days/week, 4 weeks. Chronic- regain more distal function vs. traditional tx\(^{14}\). 15 min 2X/day, 6 days/wk- proximal-> distal.

Clinical applications: beneficial for sensory deficits & simulates recovery from hemi-neglect. Improved performance in all measures, but not necessarily ADLs\(^6\). Related to action observation as it activates motor and premotor areas. Multi-sensory interaction. Cortical changes even when no movement in the affected limb!

Considerations: Low cost. Ability to carry over at home.
Action Observation

Basic description: Watching the performance of someone else or themselves on a video. The actions are automatically mapped into the motor system without sophisticated perceptual analysis (mirror neurons). Combine observation of daily action with physical training of the same movements\textsuperscript{14}.

Parameters: 4 weeks- significant enhancement of motor activation in pre-motor cortex\textsuperscript{14}.

Clinical applications: good priming task, providing feedback on performance, all levels of severity, easy. Gestures may facilitate word retrieval in aphasia. Listening to speech actually modulates tongue muscles\textsuperscript{17}

Considerations: combined with physical training enhances outcomes\textsuperscript{14}. Can be used to prime neurons, using as pre-training enhances outcomes.
Motor Imagery/Mental Practice

Basic description: imagining planned movements requires areas of the brain to activate that control movement preparation and execution\textsuperscript{14}.

Parameters: in chronic CVA, imagery vs. placebo had significant effect on motor outcome. Move non-affected side, then close eyes, imagine affected side doing movement, then attempt to move affected side.

Clinical applications: can start early in rehab. Implemented 4 years post had significant effect on motor outcome\textsuperscript{14}

Considerations: good in severe cases, can be combined with other treatments. Lesions in L parietal/frontal may have difficulty with this technique.
Functional Electrical Stimulation

Basic description: Application of electrical stimulation over key/affected muscle groups combined with task-oriented practice.

Parameters: Chronic Stroke: 3 hours per day, 5 days per week, for 4 weeks\(^3\). 120 minutes superior (compared to 30 and 60)\(^4\).

Clinical applications: All levels of motor deficits, even just sensory deficits (TENs). Can be carried over into home use. Emerging use in acute care.

Considerations: Cortical plasticity modulation continues up to several hours after stimulation is removed\(^{13}\).
Music Therapy

Basic description: rhythmic auditory stim & musical motor feedback

Parameters: implemented 1 week post stroke (long term plastic changes) lasting for 8 weeks-combined music with other therapies.

Clinical applications: acute phase +, singing = greater word repeat and recall. Melodic intonation- “Leads to remodeling of the right arcuate fasciculus (fiber bundle that combines the anterior and posterior language area in the left hemisphere demonstrating that plasticity can be induced in the contra-lateral homolog tract”. Gait rhythmicity, cadence, velocity, stride length. Increased ROM, flexibility, + mood, increased frequency and quality of relationships.

Considerations: improves executive function, emotional adjustment, attention, verbal memory. Just listening activates pre-motor and motor pathways; with movement, improves activation and connectivity of cortical cells. Multi-sensory. Great for providing feedback and cueing motions.
Evidence Based Cognitive Therapy


Oral Motor therapy- Frasier Method (errorless learning) protocol for improving swallowing in aphasic patients without compensating ie: promoting return of skill through neuroplasticity-repetitive sipping of clean water opposed to thickening liquids. 15
Technologies offer an amazing opportunity for therapists to refine practice, enhance science, and most importantly become even better at restoring the function and quality of life of our clients.

- Lara Boyd PT, PhD
Promising New Research

Robotics
• Measured performance
• Feedback
• Intensive practice
• Normal movement
• Interactive

Virtual Reality – Based Therapies
• Multisensory, Multidimensional, Functional, Safe, Individualized, Interactive, Motivating
Promising New Research

Cortical Stimulation
- Transcranial Magnetic Stimulation
- Transcranial Direct Current Stimulation

NeuroPharmacological Adjuncts

Brain Computer Interface
Implications Without Intervention

Less social interactions - structural changes with isolation
Decreased life expectancy (physical sequelae)
Increased caregiver/society burden ($$$)
Learned non-use
Depression/Decreased QOL

“Ideally, the rehab process is continuous until the return of the individual to the family, reintegration into the community, and resumption of the patient’s professional activities”.
-F.J. Carod-Artal
Discussion

• Questions
• Discussion
• Evaluation
References


   A four-week, task-specific neuroprosthesis program for a person with no active wrist or finger movement because of chronic stroke.

   Longer versus shorter daily durations of electrical stimulation during task-specific practice in moderately impaired stroke.
   Page SJ, Levin L, Hermann V, Dunning K, Levine P.


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