Neural Plasticity and Stroke Rehabilitation

Can a new brain (re-)learn old tricks?

Christine Nelson, MBA, MOT, MEd, CBIS
CEU Objectives:

This presentation will discuss:

- What is neural plasticity?
- Principles of neural plasticity
- Implications for motor recovery
- Implications for learning/cognition
- Research/Evidence
Neuroplasticity is:

“the brain’s ability to modify, change, and adapt both structure and function throughout life and in response to experience”

Voss, et al., 2017
Another definition:

- “neural plasticity is the mechanism by which the brain encodes experience and learns new behaviors. It is also the mechanism by which the damaged brain learns lost behavior in response to rehabilitation.”
Critical Periods for Experience-Dependent Plasticity

- Important changes in the brain tend to occur early in life during time-limited episodes of plasticity known as “Critical Periods”
- These episodes are stimulus-driven
- There is growing evidence that critical periods can be re-opened later in life due to factors that are still being uncovered
- This suggests that plasticity can occur throughout the lifespan and is not entirely dependent on the developmental “critical periods”
A little history

1800s - Autopsies revealed people with speech problems had brain damage in the lateral frontal lobe. Wernicke’s area was discovered to control interpretation of written and spoken language.

1950s - Treated epilepsy by using electricity to destroy part of brain causing seizures, and scientists 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
New understanding of Neuroplasticity

- Neuroplasticity is a relatively new concept.
- It was previously believed that after a certain age, the brain stopped adapting and changing.
- New research shows that changes can occur throughout the lifespan.
- Neural plasticity does not happen in a vacuum.
10 Principles of Neuroplasticity

- 1. Use it or lose it
- 2. Use it and improve it
- 3. Specificity
- 4. Repetition matters
- 5. Intensity matters
- 6. Time matters
- 7. Salience matters
- 8. Age matters
- 9. Transference
- 10. Interference
Principles...

- **Use it or lose it**
  Failure to drive specific brain functions can lead to loss of abilities.

- **Use it and improve it**
  Training that drives a specific brain function can lead to improving abilities.

- **Specificity**
  The nature of the training experience dictates the nature of the change in the brain (plasticity)
Principles...

- **Repetition matters**
  Change (plasticity) requires sufficient repetition.

- **Intensity matters**
  Change (plasticity) requires intensive training.

- **Time matters**
  Different forms of change (plasticity) in the brain happen at different times during training.
Principles...

- **Salience matters**
  The training experience must be meaningful to the person in order to cause change (plasticity).

- **Age matters**
  Training-induced change (plasticity) occurs more readily in younger brains.

- **Transference**
  Change in function as a result of one training experience can even lead to learning other similar skills.

- **Interference**
  Brain changes (plasticity) that result in bad habits can interfere with learning good habits.
Cortical Mapping
Advances in Imaging—how we know

Cortical Activity during Hand Movement

Contralateral Hemisphere

Ipsilateral Hemisphere

Healthy Subjects (Right Hand)

Stroke Patients Affected Hand (Right Hand)
2006 Study on London cab drivers’ hippocampus -- the part of the brain that holds spatial representation capacity -- is measurably larger than that of a bus driver.

By driving the same route every day, the bus drivers don't need to use this part of the brain as much. The cabbies, on the other hand, rely on it constantly for navigation.

(Maguire, Woollett and Spiers, 2006)
Targeted Training for Positive Neuroplasticity

- Use it or lose it
- With learned non-use (natural recovery) the territory may become smaller and smaller and eventually be taken over by other areas
Mechanisms of recovery after Stroke

Recovery:
1. Restoration of the neural tissue initially perturbed after the injury (neural level)
2. Restoration of movement exactly as it was performed prior (behavioral level)
3. Restoration of activity exactly as it was performed prior (activity level)

Compensation:
1. Recruitment of new neural circuits (neural level)
2. Training of new movement sequences (behavioral level)
3. Training of activity in a new way after injury (activity level)
Rehab interventions that Promote Neuroplasticity for improved function

- Music therapy
- Mental Imagery
- Action observation
- Body weight support treadmill training
- Mirror therapy
- Functional electrical stimulation
- Constraint induced movement therapy
Music Therapy

**Description:** Various modalities - improvisation, receptive listening, song writing, lyric discussion, imagery, performance, and learning through music.

**Parameters:** Implemented as early as 1 week post stroke for 8 weeks

**Clinical applications:**
- Thaut et al. found a significant difference in gait velocity, stride length, cadence and symmetry at 3 weeks post treatment in a group that received Rhythmic Auditory Stimulation gait therapy compared to a group that received NDT based therapy.
- Schneider et al. assessed the use of a music supported training program compared to conventional therapy to improve upper limb motor skill recover post-stroke. Significant improvements in the group given music supported training.
- Sarkamo et al. examined the effect of music listening on recovery of cognitive functions in acute stroke and found improved focused attention and verbal memory in that group versus other non-music groups.

**Considerations:** Ipad/cellphone - use to access YouTube and search their favorite artist (stand for length of song, swing arm to the beat, name that song, tell me about your life when..)
Motor Imagery/Mental Practice

**Description:** Repeated mental rehearsal of an action without actually physically performing it.

Brain scanning techniques have shown that similar areas of the brain are activated during MI and physical movement. MI has been shown to help the brain reorganize its neural pathways, which may help promote learning of motor tasks after stroke.

**Clinical Applications:**

- Reviews by Braun et al. (2006), Nilsen, Gillen and Gordon (2010) and Barclay-Goddard (2011) concluded that mental practice used in combination with another treatment is more effective than the other treatment alone.

**Considerations:** Create a script of common ADLs, grasp and release, stair climbing, etc. Play the script and have client/family perform MI 10 minutes before therapy. It has been show that while MI is beneficial by itself, it is most effective when used in addition to physical practice.
Mirror Therapy

**Description:** A mirror is placed at 90 degrees close to the midline of the patient and the affected limb is positioned behind the mirror. Watching the non-affected limb in the mirror while performing the exercises, the pt receives positive visual impression that the limb in the mirror (the affect limb) is fully functioning.

**Parameters:** The movements in front of the mirror must be done simultaneously on the affected and non-affected sides. This encourages bilateral use of the UEs.

**Clinical Applications:** Beneficial for sensory deficits and stimulates recovery from hemi-neglect. Improved performance noted in most measures, except ADL’s. Cortical changes were noted even when there is no movement in the affected limb.
Action Observation

Description: Watching the performance of someone else or themselves on video or watch the unaffected limb perform the task. The actions are mapped into the motor system. Combine observation of action with physical performance of the same action.

Can be used to prime neurons. Pre-training enhances outcomes. Significant enhancement of motor activation in the pre-motor cortex.

Clinical Applications: One study had participants watch 6-minute videos of sequences of arm/hand movements, then had them perform the movements with their hemiparetic limb. This group did better than the control group and functional MRI studies show a positive additional impact on the recovery of motor functions by reactivation of the motor areas.

Considerations: Therapists can start a photo/video library in the patient’s phone for the patient to watch prior to therapy or task completion.
Body-Weight Supported Treadmill Training

**Description:** Facilitates normal gait after stroke. Patient is suspended in a harness to reduce weight and provide postural support for treadmill walking. The amount of support can be gradually decreased as the patient practices “normal” gait patterns and motor functioning improves.

**Parameters:** Patient should be able to sit indep. for 3 minutes and stand with our without assistance.

**Clinical Considerations:** Typically requires 2 therapists, one for helping with weight-shifting, and one for limb advancement. BWS is errorless learning- instead of practicing “abnormal” gait patterns, BWS helps patients achieve many repetitions of “normal” gait patterns.
**Functional E-Stim**

**Description:** Application of electrical stimulation over key muscle groups, combined with task-oriented practice

**Clinical Applications:** There is moderate evidence that FES in addition to conventional therapy is more effective than conventional therapy alone, but only for improving hand function and dexterity in patients with acute stroke. There is moderate evidence that EMG-triggered FES in combination with conventional therapy is more effective than conventional therapy alone in sub-acute stroke. FES should be considered for use in improving muscle force, strength and functional gait is select in some patients.

**Considerations:** To maximize benefits after stroke, FES should be used for at least 6 weeks
Constraint Induced Movement Therapy

- **Description:** Forced use of the affected extremity by limiting the use of the non-affected extremity.

- **Parameters:** Concentrated, repetitive training for 5hrs/day, plus wearing constraint for 90% of waking hours for 10-15 days. Modified CIMT therapy is 1/2hr, 3x/week, plus forced use 5 hours /day for 5 day/week. (there are other protocols as well)

- **Clinical Implications:** Found to be effective 3-21 months post stroke with mild-moderate impairments. Evidence does not support this in the acute phase (<1month).

- **Considerations:** Functional benefits appear to only pertain to individuals with some active wrist extension and hand movement. Must meet inclusion criteria (wash cloth or towel test). Patient should be cognitively able to sign a behavioral contract.
Applying principles in Cognitive Therapy

- **ACRM Cognitive Rehab Manual:**
  - Attention Process Training
  - Predicting Performance
  - Goal-Plan-Do-Review
  - Spaced Retrieval for Memory
  - Lighthouse Technique
Attention Process Training

- Based on the assumption there are 5 types of attention: Focused, sustained, selective, alternating, and divided.
- 1. Therapist assesses the attention problem - identify which type(s) of attention are impaired
- 2. Complete attention tasks in order of difficulty - start with the easiest tasks and progress to more difficult tasks as warranted.
- Individualize tasks to the patient's needs
Predicting Performance to address impairments with insight and awareness

- Particularly for impairments to the right hemisphere or parietal regions, and/or frontal lobes.

- Steps:
  - Therapist chooses a task
  - Patient is asked to:
    - Define task goals
    - Predict task performance
    - Anticipate and pre-plan for any types of errors or obstacles that may come up
    - Choose a strategy to overcome any barriers
  - Patient performs task
  - Patient self-estimates how well they did
  - Discuss the actual performance with the patient
Goal-Plan-Do-Review for Problem Solving (Exec. Functioning)

- **Acquisition** – patient learns the rationale for the model and how it works
- **Application** – patient begins to use the model of various tasks
- **Adaptation** – patient applies the skills to tasks outside the clinic
Goal-Plan-Do-Review Sheet

GOAL
What do I want to accomplish?

PLAN
How am I going to accomplish my goal?

<table>
<thead>
<tr>
<th>MATERIALS/EQUIPMENT</th>
<th>STEPS/ASSIGNMENTS</th>
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PREDICTION
How well will I do? How much will I get done?

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<thead>
<tr>
<th>Self rating</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td>Teacher Rating</td>
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<td>2</td>
<td>3</td>
<td>4</td>
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DO

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<th>PROBLEMS ARISE?</th>
<th>FORMULATE SOLUTIONS!</th>
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REVIEW

<table>
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<tr>
<th>HOW DID I DO?</th>
<th>WHAT WORKED?</th>
<th>WHAT DIDN’T WORK?</th>
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<tr>
<td>Self rating</td>
<td>1</td>
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<tr>
<td>Teacher rating</td>
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WHAT WILL I TRY DIFFERENTLY NEXT TIME? ____________________________
Spaced Retrieval for Memory

> Start with errorless learning:
>  > Make a statement and ask the patient to recall the statement without a delay
>  
> Spaced retrieval is like errorless learning except the patient is asked to retain the information for progressively longer periods of time (e.g., immediate, 15-second delay, and 30-second delay)
>  
> Adjust the delay according to patient performance
Lighthouse Technique

- Used in the treatment of Hemispatial Neglect

- Patient is asked to imagine that they are a lighthouse. The therapist places a picture of a lighthouse in the farthest aspect of the left field. The patient is then asked to imagine their eyes are like the light of the lighthouse and make their gaze sweep all the way to the left and right of the horizon.

- First practice the task with a simple letter cancellation activity—Acquisition and Application of skill

- Next, use the technique with magazines, the whole room, then the community—Application and Adaptation of the Skill
Enriched Environment

- EE: model that provides multiple possibilities
  - Social stimulation
  - Interaction with objects
  - Requires physical activity


