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# Understanding Neuroplasticity and Recovery: Insights From Current Research

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# UNDERSTANDING NEUROPLASTICITY AND RECOVERY: INSIGHTS FROM CURRENT RESEARCH

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## INTRODUCTION

- This presentation will discuss the following:
  - A framework for understanding principles of neuroplasticity.
  - Contemporary theories of cortical reorganization following injury.
  - Current evidence supporting neuroplastic change following injury.
  - Selected current treatment research relating outcomes to neuroplasticity.

## A FRAMEWORK FOR NEUROPLASTICITY

- Neuroplasticity occurs throughout the lifespan.
- The nature of neuroplasticity is *change* whether it is positive or negative.
- We tend to think about neuroplasticity in terms of recovery, but it is important to consider pre-injury variables.
- Both extrinsic factors and intrinsic factors drive neuroplastic change (Cramer et al, 2011; Hotting & Roder, 2013; Plowman & Kliem 2010).
  - Extrinsic: Motor learning and skills, experiences, behavior modification, exposure to drugs, exercise
  - Intrinsic: Age, gender, stage of development, genotype

## A FRAMEWORK FOR NEUROPLASTICITY

- Skills are not discrete, isolated events but rather a distribution of interconnections to other areas supporting the function (Kolb, Muhammad & Gibb, 2011).
  - We can see this more readily in motor movements through the networks of the direct activation pathway (pyramidal tract) and indirect activation pathway (extrapyramidal tract).
  - However, language functions also require intricate connections for lexical storage, phonemic representation, auditory/visual memory, etc.
- Experience and practice impacts assignment of the amount of cortical area dedicated to the skill even though the general topography remains constant (Chen, Epstein & Stern, 2010; Grafman, 2000; Kerr, Cheng & Jones, 2011; Mateer & Kerns, 2000; Nudo, 2011; Plowman & Kliem, 2010).
  - Movement from discrete events to smooth interconnected functions.
  - The type of cortical change is specifically tied to the functions of the task.

## A FRAMEWORK FOR NEUROPLASTICITY

- Plowman & Kliem (2010): Cortical maps are dynamic. Behavior occurs first, followed by increased synaptic connections (synaptogenesis) and finally cortical change
- True learning can only occur if the brain changes (Kolb).
  - Long-term potentiation.
  - Anything can cause change, including exercise and thoughts.
- Mateer & Kerns (2000):Circuits that fire together build interconnections that are at first temporary, but “wire together” over time (Mateer).
  - Association learning is an example of the establishment of interconnections.
- Attention is gaining importance in facilitating neural connectivity and regulating cognition and perception.

## THEORIES OF CORTICAL REORGANIZATION

- Grafman (2000): Four Types of Neuroplasticity
  - Homologous Area Adaptation
    - Relevant to early, critical stage human development.
    - Injury causes shifting of functions to homologous opposite hemisphere locations.
    - Complicates function originally assigned to the location especially if it occurs before full development.
    - Makes dual-task performance difficult.

# THEORIES OF CORTICAL REORGANIZATION

- Grafman (continued)
  - Cross-Modal Reassignment:
    - If an area is deprived of the input that it would normally receive, other areas invade it.
    - Example: Blindness deprives the area of input allowing input from new areas.
  - Map Expansion:
    - The size of the area dedicated to a function is dependent on frequency of use.
    - Dynamic and temporary unless the skill is repeated long enough.
    - Nudo (2011) refers to this as Temporal Contiguity Hypothesis.

# THEORIES OF CORTICAL REORGANIZATION

- Compensatory Masquerade:
  - Instead of actual recovery of functions, different processes are used to accomplish the task.
  - Grafman presents this example: More than one route to get from home to work. One is automatic with little effort (routine, implicit, covert). Other routes require more effort (needs more cues, explicit, overt processing).
  - After injury spared and preexisting neural networks are reorganized.

## THEORIES OF CORTICAL REORGANIZATION

- Thompson (2000) and Raymer et al (2008)
  - Research evidence seems to support two of these types of reorganization following injury relevant to language recovery.
  - Homologous Area Adaptation
    - Shift of language functions to homologous right hemisphere locations.
    - Research has also shown that some healthy adults activate right hemisphere locations as well, but not to the same extent.
    - Tends to be more related to comprehension than production.
  - Map Expansion
    - Expansion to spared adjoining areas.

## THEORIES OF CORTICAL REORGANIZATION

- Mateer & Kerns (2000) cautions that damaged areas may be dominated by intact connecting areas causing suppression of function even if residual skills are present.
  - May seem facilatory at first but becomes detrimental over time.
- Nudo (2011) proposes 3 mechanisms that facilitate spontaneous recovery:
  - The theory of diaschisis and its reversal
  - Functional improvement rather than actual “recovery” of lost skills.
  - Substantial physiological and neuroanatomical change occurs.

## THEORIES OF CORTICAL REORGANIZATION

- Kliem et al (2004) & Kliem (2011) demonstrate a time course for motor reorganization in rats that may be relevant to human recovery.
  - 3 days post injury: Improvement in *behavior* on trained skills only.
  - 7 days post injury: An increase in the number of *synapses* per neuron.
  - 10 days post injury: Increase in *cortical representation*.
  - The change in behavior alone is not indicative of cortical change. Cortical changes occur in late stage learning.
  - The change observed is specific to the task demands.

## THEORIES OF CORTICAL REORGANIZATION

- Raymer et al (2008) provide a literature review outlining principles important to recovery of language.
  - Timing is critical: Intensive treatment immediately following injury may have a negative impact on recovery.
  - The specific “safe” time is not yet known.
  - At the chronic stage of recovery, intensity and an enriched environment is the desirable approach.
  - Use it or lose it: Language has to be used to be improved.
  - Repetition, consistency and experience are important.
  - Meta analysis by Robey demonstrated those patients beginning treatment early had the best outcomes overall.
  - Start early but keep tasks simple; increase intensity over time.

## THEORIES OF CORTICAL REORGANIZATION

- Ludlow et al (2008) published a literature review tackling the same question from the motor reacquisition point of view.
  - Speech movements improved with practice, but nonspeech movements did not.
  - Diadochokinetic rates may not translate to speech unless speech is used in the training.
  - Early learning engages more cortical activation than routine tasks.
  - Reiterated: experience, repetition, intensity, timing, salience and age all impact outcomes.

## RESEARCH DEMONSTRATING CHANGE

- Saur & Hartwigsen (2012) Examined 14 patients with lesions associated with middle cerebral artery infarct over 3 time periods.
  - Less than 4 days post onset: Poor language scores, little left hemisphere activation
  - Approximately 2 weeks post onset: Improved language scores, more left hemispheric activation and significant homologous right hemisphere activation.
  - 4-12 months post onset: Decreased right hemisphere activation, increase in left hemisphere activation.
  - Supports a 3 phase model of recovery: Diaschisis, Subacute and Chronic

## RESEARCH DEMONSTRATING CHANGE

- Meinzer, Rodriguez and Rothi (2012) examined results of Constrained-Induced (CI)Treatment Approaches over the last 10 years.
  - 4 main principles: Nonuse, massed practice, shaping and behaviorally relevant treatment settings.
  - Nonuse: Thought to be related to diaschisis, but can be overcome by forcing use of the area to tap into residual skills. In the beginning very strict practice was followed.
  - Massed Practice: The more the engagement of the area, the stronger the neural connections leading to actual cortical change. As high as 3 hours per day over 10 consecutive days.

## RESEARCH DEMONSTRATING CHANGE

- Meinzer (continued)
  - Shaping: Through practice, behavior is gradually shaped closer to the desired behavior.
  - Relevant Settings: Activities must be relevant to real life, everyday functions, in the beginning.
  - Generally, CI treatment shows significant improvement over other treatments -- especially if the control treatment does not use the same intensity schedule.
  - Gains appear to be retained over 6 months.
  - No evidence to clarify how long the treatment should continue.

## RESEARCH DEMONSTRATING CHANGE

- Hamilton, Chrysikou and Coslett (2011).
  - The role of the right hemisphere activation in language recovery is somewhat controversial.
  - Some researchers argue that it has a facilatory impact while others suggest that it has a negative impact on long term recovery.
  - The size of the lesion in the left hemisphere impacts the amount of right hemisphere activation.
  - The age at which the injury occurs impacts right hemisphere proficiency.
  - The lack of balance between the hemispheres may reduce inhibition, causing the right hemisphere to inhibit residual left functions.

## RESEARCH DEMONSTRATING CHANGE

- Heath et al (2013) used fMRI to examine the impact of auditory repetition on naming in patients with aphasia at two time frames.
  - 21 control participants with an average age of 56.9, no significant medical history, right handed.
  - 6 participants with chronic aphasia from a single left CVA with an average age of 57.6
  - Picture stimuli were digital photographs.
  - Aphasia group: Pictures were chosen based on consistent naming ability in a trial task.

## RESEARCH DEMONSTRATING CHANGE

- Heath, et al. (continued): 4 tasks
  - Facilitation phase: Participants were required to look at the picture, listen to the name and repeat.
    - These pictures were presented again in the scanner as long-term facilitation task during the experimental phase.
  - Experimental phase: Pictures were presented while in the fMRI scanner.
  - Participants were prompted to either name or repeat the name heard.
  - For the short-term facilitation task new pictures were presented twice in the scanner - once repeated and once not repeated.
  - Unfacilitated task: Naming with no auditory prompt.
  - Follow-up one week after scanning: Naming with no prompt.

## RESEARCH DEMONSTRATING CHANGE

- Heath, et al. (continued)
  - All participants with aphasia showed improved naming from baseline to post-testing.
  - Repetition facilitated more accurate naming for all in both the short-term and long-term tasks.
  - fMRI did not show facilitation of phonological networks.
  - Patterns of activation were different for each aphasic participant.
  - Patterns of activation for aphasic participants were different than controls.
  - Activation patterns for both groups employed both phonologic and semantic cortical regions.

## RESEARCH DEMONSTRATING CHANGE

- Marcotte et al (2013) examined semantic feature analysis treatment relative to default-mode network connectivity in aphasics and controls.
- Default-mode network: Two main hypotheses
  - DMN regulates attention to internal and external stimuli, monitors the external environment and supports diffuse attention.
  - DMN regulates introspective functions, linked to episodic memory, attention and working memory.

## RESEARCH DEMONSTRATING CHANGE

- Marcotte et al (2013)
  - 10 healthy controls and 9 individuals with aphasia from a single left hemisphere incident, all right handed, French speaking adults.
  - In order to compare learning across groups, the control group were asked to complete a computerized Spanish word learning task.
  - Controls - Two fMRI scans: 5 days after training (early learning phase) and after 14 training sessions (consolidation phase).
  - During scans, pts named pictures in both Spanish and French.
  - Participants with aphasia: Probed at baseline. Only words incorrectly named over two trials were selected for inclusion in the task.
  - Pts were scanned, then received SFA treatment 1 hour/3 times a week to reach either 80% accuracy or a maximum of 6 weeks.
  - Two post-treatment scans involved only naming.

# RESEARCH DEMONSTRATING CHANGE

- Marcotte et al (2013) - continued
  - Of specific interest were the interactions both within the anterior and posterior parts of the DMN and between them.
  - All participants with aphasia improved naming and some generalization to untrained stimuli with SFA treatment.
  - Imaging results showed significantly different results for both groups in DMN activation. The control group was stable across participants while the individuals with aphasia showed individual patterns.
  - SFA treatment did result in greater activation of posterior regions.
  - Anterior-posterior disconnection was seen with the aphasia group. SFA did not improve this disconnection.
  - However, a significant correlation between DMN activation and treatment outcome was not found.

# RESEARCH DEMONSTRATING CHANGE

- Vallila-Rohter and Kiran (2013)
  - Examined nonverbal learning in individuals with aphasia in an effort to better understand the process of learning.
  - Does aphasia occur in the absence of any cognitive learning deficits or is the language deficit compounded by deficits in learning?
  - 2 groups: 18 individuals with aphasia following a single left hemispheric CVA, all right handed, all tests at least 6 months post onset.
  - 13 control participants matched for age and education level; one was left handed.
  - Stimuli: Cartoon character drawings varying by 10 characteristics.
  - The task was to sort the pictures into two groups.

## RESEARCH DEMONSTRATING CHANGE

- Vallila-Rohter & Kiran (continued)
- Each participant completed two category tasks.
  - Task 1 - Feedback-based Training: Picture was presented, participants guessed which category it should belong to by pressing a button, feedback was given regarding category and correctness of response.
  - Testing Phase: 45 new examples + 16 seen above were presented with no training.
  - Task 2 - Paired-Association Training: Picture was presented with its category affiliation included. Participants pressed the button after seeing the correct answer.
  - Testing Phase: 45 new examples + 16 seen above were presented with no training.

## RESEARCH DEMONSTRATING CHANGE

- Vallila-Rohter & Kiran (continued)
  - No effect of task or group, but a group x task interaction did occur.
  - The two groups demonstrated different patterns of learning.
  - For the control group: The more features a character had, the more likely it was categorized correctly. All controls met standards of learning the tasks.
  - Performance for controls did not change as a function of training.
  - Aphasic group: Only 11 participants met the standards of learning (60% accuracy).
  - Aphasic group: 3 performed the same regardless of instruction.

# SUMMARY

- Even though emerging evidence shows neuroplastic changes following CVA, the correlation to observable behavior remains unclear.
- More evidence validating animal research as applicable to human neurological function is being demonstrated.
- The brain continues to change in both positive and negative ways in response to behavior and environment.
- Individual characteristics and experiences appear to impact recovery.
- Timing, intensity and task demands play important roles in facilitating functional outcome.
- It remains unclear at this time if “recovery” or “compensation” are responsible for improved outcomes.
- Neuroplastic change is not restricted to a specific time period post injury.
- The role of the right hemisphere in language recoupment remains unclear.

# REFERENCES


1. Chen, Halwen, Epstien, Jane and Stern, Emily (2010). *Neural plasticity after acquired brain injury: Evidence from functional neuroimaging.* American Academy of Physical Medicine and Rehabilitation, Suppl. 2, S306-S312.
2. Cramer, Stephen C., et al. (2011) *Harnessing neuroplasticity for clinical applications.* Brain, 134, pp 1591-1609.
3. Grafman, Jordan (2000) *Capitalizing functional neuroplasticity,* Journal of Communication Disorders, 33, 345-356.
4. Hamilton, Roy H., Chrysikou, Evangelia G. and Coslett, Branch (2011) *Mechanisms of aphasia recovery after stroke and the role of noninvasive brain stimulation.* Brain & Language, 118, 40-50.
5. Heath, Shiree, et al. (2013) *Facilitation of naming in aphasia with auditory repetition: An investigation of neurocognitive mechanisms.* Neuropsychologia, 51, 1534-1548.
6. Hotting, Kristen and Roder, Brigitte (2013) *Beneficial effects of physical exercise on neuroplasticity and cognition.* Neuroscience and biobehavioral reviews. 37, 2243-2257.
7. Kerr, Abigail L., Cheng, Shao-Ying, Jones, Theresa A. (2011) *Experience-dependent neural plasticity in the adult damaged brain.* Journal of Communication Disorders, 44, 538-548.

# REFERENCES


8. Kiran, Swathi, et al. (2013) *Neuroimiaging in aphasia treatment research: Standards for establishing the effects of treatment.* NeuroImage, 76, 428-435.

9. Kliem, Jeffery A., *Neural plasticity and neurorehabilitation: Teaching the new brain old tricks.* Journal of Communication Disorders, 44, 521-528.

10. Ludlow, Christy L., et al. (2008) *Translating principles of neural plasticity into research on speech motor control recovery and rehabilitation.* Journal of Speech, Language, and Hearing Research, 51, S240-S258.

11. Marcotte, Karine, Perlbarg, Vincent, Marrelec, Guilaume, Bernali, Habib and Ansaido, Ana, I. (2013). *Default-mode network functional connectivity in aphasia: Therapy-induced neuroplasticity.* Brain & Language, 124, 45-55.

12. Mateer, Catherine A. and Kerns, *Kimberly* A. (2000) *Capitalizing on neuroplasticity.* Brain and Cognition, 42, 106-109.

13. Meinzer, Marcus, Rodriguez, Amy D. and Gonzalez-Rothi, Leslie J. (2012) *First decade of research on constrained-induced treatment approaches for aphasia rehabilitation.* Archives of Physical Medicine Rehabilitation, 93, Suppl 1, S35-S44.

14. Nudo, Randolph, J. (2011) *Neural bases of recovery after brain injury.* Journal of Communication Disorders, 44, 515-520.


# REFERENCES


15. Plowman, Emily K. and Kliem, Jeffery A. (2010) *Motor cortex reorganization across the lifespan.* Journal of Communication Disorders, 43, 286-294.

16. Raymer, Anastasia M., et.al. (2008) *Translational research in aphasia: From neuroscience to neurorehabiitation.* Journal of Speech, Language, and Hearing Research, Vol. 51, S259-S275.

17. Saur, Dorothee and Hartwigsen, Gessa (2012) *Neurobiology of language recovery after stroke: Lessons from neuroimaging studies.* Archives of Physical Medicine Rehabilitation, 93, Suppl 1, S15-S23.

18. Thompson, Cynthia K. (2000) *Neuroplasticity: Evidence from aphasia.* Journal of Communication Disorders, 33, 357-366.

19. Vallila-Rohter, Sofia and Kiran, Swathi (2013) *Non-linguistic learning and aphasia: Evidence from a paired associate and feedback-based task.* Neuropsychologia, 51, 79-90.