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Neuroplasticity: Putting principles into practice

Guest Editor: Mike Studer, PT, MHS, NCS, CEEAA, CWT

Apr 23: Neuroplasticity and Rehabilitation
Jim Lynskey, PT, PhD
Apr 24: Applying Cutting-edge Neuroplasticity Research for Functional Restoration after Spinal Cord Injury
Edelle Field-Fote, PT, PhD, FAPTA
Apr 25: Neuroplasticity in Stroke Across the Spectrum
Kelsi Smith, PT, DPT, NCS, and Erin McMullen, PT, DPT, NCS
Apr 26: Neuroplasticity in Vestibular Impairment: The Foundation and Facilitatory Techniques for Optimizing Healing
Janene M. Holmberg, PT, DPT, NCS
Apr 27: Neuroplasticity in Degenerative Diseases
Diane Huss, PT, DPT, NCS, and Herb Karpatkin, PT, DSc, NCS, MSCS

Neuroplasticity in Stroke Across the Spectrum

Erin McMullen, PT, DPT, NCS
Kelsi Smith PT, DPT, NCS
April 25, 2018

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Erin McMullen
PT, DPT, NCS:

- Erin McMullen received her Doctorate in Physical Therapy from University of Nebraska Medical Center and became a Neurologic Certified Specialist in 2011. She has treated stroke survivors throughout her 10-year career, and has been able to see clients through the entire spectrum of care.

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Kelsi Smith
PT, DPT, NCS:

- Kelsi graduated from Washington University in St. Louis in 2014. She quickly found her passion for treating individuals with neurologic conditions and began working in outpatient neurology soon after graduation. In 2017, she became a Neurologic Certified Specialist. She treats individuals across the spectrum with a passion for: stroke, multiple sclerosis, vestibular/concussion, and healthy aging.

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Objectives

As a result of this course, participants will be able to:

- Obtain working understanding of proper dosage at various stages of stroke
- Identify barriers to learning
- Prioritize outcome measures to focus interventions for individuals at various stages of stroke
- Identify how to integrate principles of neuroplasticity in daily practice
- Describe different modes of rehabilitation through the spectrum of CVA

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Review of Neuroplasticity

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

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Table 2: Core principles of experience-dependent neuroplasticity

1. Use it or lose it	Neural networks not actively engaged in training can degrade
2. Use it & improve it	Training can induce dendritic growth and synaptogenesis within specific brain regions that enhance task performance
3. Specificity	The nature of training dictates the nature of the plasticity
4. Repetition matters	Repetition is required to induce lasting neural change (skill instantiation)
5. Intensity matters	A sufficient intensity if stimulation is required to induce plasticity
6. Time matters	Different forms of plasticity occur at different times during training
7. Salience matters	The training experience must be sufficiently rewarding to induce plasticity
8. Age matters	Training-induced plasticity occurs more readily in the younger brain
9. Transference	Plasticity induced by one training experience can enhance the acquisition of similar behaviours
10. Interference	Plasticity induced by one training experience can interfere with the acquisition of similar behaviours

Note. This table summarises key principles by Kleim & Jones (2008) and is not intended as an exhaustive list.

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Stroke Statistics

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Causes

- Ischemic - 70%
  - Cerebral infarction (thrombosis or embolism) is most common
- Hemorrhagic - 20%
- Unspecified - 10%

Risk Factors

- MOST COMMONLY recognized risk factors
  - Hypertension
  - DM II
  - Heart disease
- Other recognized risk factors
  - Obesity
  - Lack of exercise
  - Smoking
  - Recent TIA
  - Elevated hematocrits
  - Age

Statistics

- 5th ranking cause of death—more than 140,000 people die each year (1 every 20 minutes)
- Leading cause of adult disability—4 million Americans
- Improved stroke care has resulted in greater survival, but >50% of patients have chronic disabilities and 33 % are institutionalized. (stroke SIG article)
- 795,000 new or recurrent each year
- Prevalence (% of population affected)
  - 2.6% of the population in the US
  - 5,400,000 survivors

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Statistics

- Risk rises with age, 2/3 of all strokes occur in people 65+ and after age 55, risk doubles every 10 years
- Men > women
- Black 2x vs. white, and latino > white
- Of those with stroke:
  - 31% need assistance
  - 20% need help walking
  - 16% are in LTACs
  - 71% are vocationally impaired after 7 years

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Mortality & Morbidity

- Sharp drop in mortality rates of CVA in 1974, likely associated with use of hypertensive drugs in 1960-70's
- 14% die within one year
- 1/3 are functionally dependent after a year
- Higher mortality with:
  - Loss of consciousness at stroke onset
  - Lesion size
  - Hemorrhagic Stroke
  - Persistent severe hemiplegia
  - Multiple neurological deficits
  - History of previous strokes

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Time Matters

- There is level 1a evidence that earlier admission to rehabilitation results in improved overall functional outcomes.
- There is level 1a evidence that very early mobilization (VEM) post stroke (within the first 24 hours) results in improved outcomes when there are more frequent short in duration out-of-bed sessions and that VEM results in poorer outcomes when early mobilization session are more prolonged.

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Appropriate Levels of Care

Evidence Based Review of Stroke Rehabilitation

- Sub-acute rehabilitation
  - Severe stroke patients have reduced mortality with specialized stroke rehabilitation, but not functional outcomes
  - Moderately severe stroke patients have improved functional outcomes with specialized stroke rehabilitation, but not mortality
  - No benefits for mild stroke patients

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Appropriate Levels of Care

- Level 1a evidence for:
  - Specialized stroke care is associated with reduced mortality, combined outcome of death or dependency
  - Need for institutionalization and the length of hospital stay
  - Earlier admission to rehabilitation results in improved functional outcomes
  - Mild-moderate stroke patients discharged early from acute care hospital can receive community rehabilitation by interdisciplinary team and achieve similar to superior functional outcomes compared to inpatient rehabilitation

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Appropriate Levels of Care

- Outpatient Rehabilitation Provided Within the First 6 Months of Stroke Onset
  - Additional outpatient therapy improves performance of ADLs (conflicting 1a)
- Outpatient Rehabilitation Provided at Least One Year Following Stroke
  - Conflicting level 1a evidence regarding the association between home based therapy for chronic stroke survivors and improvements in performance on ADLs and mobility
- Rehabilitation in the Home or in the Hospital
  - There is level 1a and level 2 evidence that home-based and hospital-based outpatient stroke rehabilitation programs are equally effective in achieving modest gains in ADL following inpatient rehabilitation

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Predictors of Functional Outcomes

- Most powerful predictors of functional recovery and eventual discharge status home
  - Initial stroke severity
  - Patient's age
  - These two alone can be used to determine appropriate stroke rehabilitation triage, although it does not preclude the use of additional factors.
- Mild strokes benefit the least because of a "ceiling effect"
- Moderate to severe stroke improve the most on stroke rehab
- Severe strokes appear to benefit the most when compared to controls

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Outcomes and Age

- Incidence of Stroke for Younger Individuals
  - The incidence of stroke in young patients is notably lower than in older patients. Variable incident rates have been reported, ranging from 3/100,000 to 44.3/100,000 and 3/1,000 to 25/1,000 for younger versus older individuals, respectively.
  - The incidence of stroke in young patients has increased over time.
  - The incidence of ischemic stroke tends to be greater than the incidence of hemorrhagic stroke.

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Outcomes and Age

- Recovery and Prognosis for Young Stroke Patients
  - Young stroke patients make better neurological recoveries with less disability.
  - Young stroke patients have a better long-term survival rate.
  - Impaired cognitive performance, recurrent stroke and epilepsy may be associated with post-stroke recovery in young adults.

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Outcomes and Function

- The amount of therapy needed to result in a significant improvement in motor outcomes is 17 hours of physiotherapy and occupational therapy over a 10 week period of time.
- Five years post-stroke functional outcomes plateau and may decline.
- Walking speed: The 5th vital sign
- Participants that performed well on Fig8 and BBS had a significantly lower risk of cognitive impairment 1 year after stroke. (Ursin and Bagland, etc)

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Intensity Matters

- Level 1a evidence for:
  - Improved functional outcomes with greater intensities of PT and OT
  - 17 hours of PT and OT over a 10 week period of time results in significant improvement in motor outcomes
  - Caregiver supported therapy results in improved functional outcomes compared to conventional therapy alone

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Recurrence

- 25% of stroke survivors will experience another in 5 years after 1st stroke
- Greatest risk post-stroke and decreases over time
- Increased likelihood of disability and death with each recurrent stroke
- 3% experience recurrent stroke within 30 days
- ~30% experience 2nd stroke within first 2 years

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Anatomy Review

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Middle Cerebral Artery (MCA)

- Most commonly affected territory in a cerebral infarction
- Symptoms may include:
  - Contralateral hemiparesis
  - Contralateral hemisensory loss
  - Hemianopsia
  - Aphasia: Broca's and Wernicke's
  - Neglect: non-dominant hemisphere

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Posterior Cerebral Artery (PCA)

- Contralateral loss of pain and temperature sensations
- Contralateral hemianopsia with macular sparing
- Challenges with facial recognition
- Weber's syndrome
- Ipsilateral - oculomotor nerve (CN 3)
- Contralateral - facial nerve (CN 7), vagus nerve (CN 10) and hypoglossal nerve (CN 12)
- Horner's Syndrome

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Anterior Cerebral Artery

- Rare - 2% of infarcts
- Symptoms may include:
  - Dysarthria, aphasia
  - Contralateral motor weakness (LE > UE)
  - Minimal sensory changes (two-point discrimination) in the same distribution as above
  - Left limb apraxia
  - Urinary incontinence

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Posterior Inferior Cerebellar Artery (PICA):

- Considered the most common territory involved in cerebellar infarction
- Symptoms may include:
  - Vertigo
  - Nausea
  - Truncal ataxia
  - Signs of a lateral medullary syndrome may coexist in ~30%

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Right Brain Stroke

- Anomia
- Attention span
- Denial
- Neglect
- Perseveration
- Visual/spatial problems
- Emotional lability
- Left hemiplegia
- Impulsivity
- Problems with short-term memory

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Left Brain Stroke

- Language apraxia
- Paralysis on the right side of the body (right hemiplegia)
- Aphasia
- Memory problems, such as shortened attention spans, difficulty in learning new information
- Problems with concept and generalization
- Development of a slow and cautious behavioral style

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Zones of cellular injury

- Core ischemic zone
  - An area of severe ischemia (blood flow below 10% to 25%) where the loss of oxygen and glucose results in rapid depletion of energy stores
  - Severe ischemia can result in necrosis of neurons and also of supporting cellular elements (glial cells) within the severely ischemic area.

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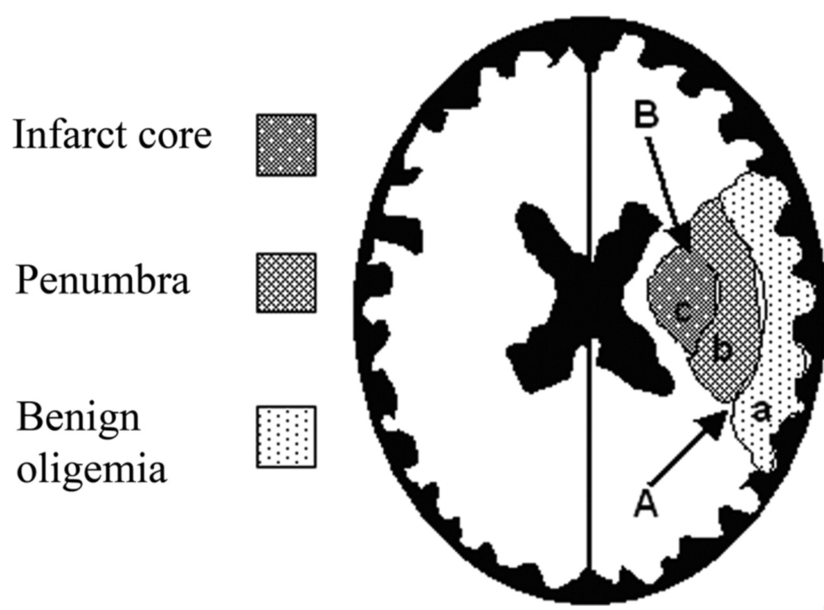

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Zones of cellular injury cont

- The ischemic penumbra
  - A rim of mild to moderately ischemic tissue lying between tissue that is normally perfused and the area in which infarction is evolving, may remain viable for several hours.
  - It is supplied with blood by collateral arteries anastomosing with branches of the occluded vascular tree (see inset).
  - Cells in this region will die if reperfusion is not established during the early hours since collateral circulation is inadequate to maintain the neuronal demand for oxygen and glucose indefinitely.

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Evaluation

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Evaluation - Subjective

- Location of CVA
- Co-morbidities
- Medications - interactions
- Patient goals

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Medications

- Antispastics:
  - Baclofen: Acts on the CNS; Fatigue, weakness are common side effect
  - Botox: Decrease muscle tone and increase range of motion at injection site
  - Tizanidine hydrochloride (Zanaflex): Blocks nerve impulses, short lasting
- Anticoagulants: Blood thinners, prevent clots from forming
  - Aspirin (ASA)
  - Heparin: Lovenox (Enoxaparin) is an example
  - Coumadin (Warfarin)
- Beta Blockers (Beta-adrenergic block agents): Block the effects of adrenaline (epinephrine), blunts heart rate and blood pressure responses
  - Atenolol
  - Metroprolol

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Medications cont

- Calcium Channel Blockers: Prevent calcium from entering the blood vessel walls, dilating blood vessels; decreases resting and exercise blood pressure response
- Digitalis: Increase cardiac contractility, most often used for heart failure; may cause dysrhythmias, tachycardia
- Bronchodilators: May increase heart rate and blood pressure; may cause dysrhythmias
- Diuretics: May cause dysrhythmias, dehydration
- Vasodilators: Open blood vessels, reducing blood pressure
  - Hydralizine
  - Minoxidil
- Keppra: Anti-epileptic; holds off post-stroke seizures (22% of survivors)

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Evaluation - Objective

- Vitals
- Motor function
- Sensation
- Activity
- Gait and balance
- Trunk Control
- Arm Function
- Posture
- ADL/IADL

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Contraindications for Exercise

- Resting HR >100 bpm, or <50 bpm
- Resting SBP >200 or <90 mmHg
- Resting DBP >110 mmHg
- Oxygen saturation <90%
- Cyanosis, diaphoresis, bilateral edema in a pt with CHF, pallor, fever, weight gain > 4-6 lbs/day, abnormal change in breath sounds or heart sounds
- Increase in symptoms: SOB, angina, dizziness, severe headache, sudden onset of numbness or weakness, painful calf suggestive of DVT

Indications to Terminate Exercise

- HR: sudden drop > 15 bpm, change from regular to irregular rhythm, or exceeds HR maximum
- SBP: > 200 mmHg, decreases to <90 mmHg, drop > 10 mmHg from resting or with increasing exercise
- DBP: >110 mmHg
- O2 saturation: <90%*
- See above symptoms

Objective Measures-Acute

- **Functional Mobility—even if you don't have an objective measure**
- Functional Independence Measure (FIM)
- Berg Balance Scale (BBS)
- Five times sit to stand
- 6-minute vs. modified 2-minute walk test
- Mini-Balance Evaluation Systems Test (BEST)

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Objective Measures-Acute

- 10-meter walk test
- Tinetti: Performance oriented mobility assessment
- Postural Assessment Scale for Stroke (PASS)
- Modified Ashworth Scale (MAS)
- Timed up and Go (TUG)

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Objective Measures-Subacute/Chronic

- TUG
- Stroke Impact Scale (SIS)
- 6-minute vs. modified 2-minute walk test
- Mini-BEST
- 10-meter walk test
- BBS

Objective Measures-Subacute/Chronic

- Postural Assessment Scale for Stroke Patients (PASS)
- Dynamic Gait Index (DGI)
- Fugl-Meyer (FM)
- Functional Reach Test
- Motor Activity Log (MAL)
- Stroke Rehabilitation Assessment of Movement

Objective Measures-Considerations

- Mini-Mental
- MoCA
- 9 Hole Peg Test
- Trail Making A and B

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Training

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Training Plan - Intrinsic Feedback

- Inherent feedback
  - Feedback that comes to the individual through various systems as a result of the normal production of movement
- Includes:
  - Visual information (check if movement was accurate)
  - Somatosensory information (check the position of the limb)

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Training Plan - Extrinsic Feedback

- Augmented feedback
  - Information that supplements intrinsic feedback
    - Ex: When you tell a patient they need to lift the foot higher during gait
- Can be given:
  - Concurrently (concurrent feedback)
    - Verbal and manual cues while doing PNF
  - At the end of a task (Terminal feedback)
    - Telling a patient to push on the armrest harder NEXT TIME after practicing a sit to stand trial

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Training Plan - Feedback

- Knowledge of Results (KR)
  - Terminal feedback about the outcome of the movement, in terms of the movement goals
  - Verbalized feedback presented in terms of environmental goal
  - Example: “you have walked 20ft in 95 seconds”

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Training Plan - Feedback

- Knowledge of Performance (KP)
  - Feedback relating to the movement pattern used to achieve goal
  - Verbalized feedback presented in terms of movement pattern
  - Example: “you need to pick your left foot up higher when walking”

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Training Plan - Feedback Frequency

- Relative frequency
  - Percentage of trial where augmented feedback was provided
  - Performance is better with constant feedback
  - Reduced frequency is more effective for learning than 100% relative frequency
  - RECOMMENDATION: feedback be given no more than 50% of trial

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Training Plan - Feedback

- Fading schedule
  - Winstein & Schmidt, 1990
    - Subjects (undergraduate students) were given KR
    - Compared 2 groups
      - 1: More KR in early practice (50% frequency)
      - 2: KR after every trial (100% frequency)
    - RESULTS:
      - No difference in performance during acquisition of skill
      - 50% frequency group had better scores on delayed retention test

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Training Plan - Feedback

- Summary KR
  - Schmidt et al., 1989
  - Summary KR= KR given after an ENTIRE block of trial
  - Compared 3 groups
    - 1: IMMEDIATE KR—KR feedback after every trial
    - 2: SUMMARY KR—KR feedback after a block of 20 trials
    - 3: Both types of feedback
  - RESULTS:
    - Performance at acquisition was best in groups 1&3
    - Performance on transfer test was best in group 2
  - Conclusion: Summary KR is best, KR is detrimental to learning since it allows subjects to rely on information

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Training Plan - Feedback

- Summary KR - Guadagnoli & Kohl, 2001
  - Simple force production task
  - (a) required, or not required, to estimate error about their previous response
  - (b) provided KR either
    - After every response (100%)
    - After every 5th response (20%) during acquisition
  - 100% KR + required to error estimate during acquisition = BEST during retention
  - 20% KR performed less well
  - 100% KR + not required to error estimate during acquisition = poorest during retention
  - Motor learning is an increasing function of the degree to which participants use KR to test response hypotheses

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Training Plan - Feedback

- Summary KR - Schmidt & Lee, 2005
    - For simple movement timing task
    - KR was given after 1 trial, 5 trials, 10 trials, or 15 trials
        - Performance on acquisition:after 1 trial
        - Performance on transfer test: after 15 trial (summary KR)
    - For more complex task
        - Pattern of moving light have to be intercepted by arm movements (similar to intercepting ball with bat)
    - Performance on transfer test: after 5 trials

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Training Plan - Feedback

- Massed practice
- Distributed practice
- Variable practice
- Constant practice

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Training Plan - Feedback

- Massed practice
  - Practice >> Rest between trials
  - May lead to fatigue in some tasks
  - For continuous task: decreases performance markedly
  - After a transfer test: slight improvement
- Distributed practice
  - Rest > or = to practice time for trials
  - May be better for patients who fatigue easily

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Training Plan - Feedback

- Variable practice
  - Task or environment is NOT EXACTLY the same in every trial
  - More EFFECTIVE learning
  - Increase the ability to adapt & generalize learning
- Constant practice
  - Task or environment is THE SAME in every trial
  - Performance is better

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Training Plan - Feedback

- Practice Schedules:
  - Blocked practice
  - Serial practice
  - Random practice
  - Context effect

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Training Plan - Feedback

- Blocked practice
  - AAA, BBB, CCC
  - Best for acquiring NEW skill
  - Performance is better

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Training Plan - Feedback

- Serial practice
  - ABC, ABC, ABC
  - Learning is better

Training Plan - Feedback

- Random practice
  - ACBAABCBC
  - Able to TRANSFER to novel situation better

Training Plan - Feedback

- Context effect
  - Factors that make performing a task difficult initially often makes learning more effective in the long run
  - Random practice = MOST effective when used with skills that use different patterns of coordination thus different underlying motor program (Magill & Hall, 1999)
  - Random practice may be INAPPROPRIATE until the learner understands the dynamics of the task being learned (Del Ray et al., 1983, Goode, 1986)

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Training Plan

- Whole vs. Part Training
  - Task analysis—process of identifying the components of a skill or movement and then ordering them into a sequence
  - Part-task training can be an EFFECTIVE way to retrain some task, IF the task can be naturally divided into units that reflect the inherent goals of the task (Schmidt, 1991; Winstein, 1991)

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Training Plan - Feedback

- MCA stroke
  - Boyd & Weinstein, 2003
  - Random practice= retention of learning
  - Explicit information= declines in learning
  - Control subjects improved with explicit information

Training Plan - Feedback

- Cerebellar lesions
  - Explicit information= beneficial

Training Plan - Feedback

- Basal Ganglia lesions
  - Boyd & Weinstein, 2004
  - Explicit information= interferes with learning

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Barriers to Learning

- Cognition, Aphasia
  - Knowledge of Results
  - Knowledge of Performance/insight
- Vision
- Co-morbidities
- Sensory/proprioceptive deficits
- Visuospatial awareness
- Lack of practice
- Memory

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Interventions

Interventions: Acute

- Spontaneous Recovery
- Functional Activity/Task Specific Training
- Locomotion
- Dual tasking
- Virtual Reality
- Robotics
- Neuromuscular Electrical Stimulation/Functional Electrical Stimulation (NMES/FES)
- High Intensity Interval Training (HIIT)
- Aquatics
- Mental imagery
- Mirror therapy
- Transcranial Magnetic Stimulation (TMS)

Spontaneous Recovery

- Limited research performed in the acute phase partly due to spontaneous recovery
- Spontaneous neurological improvement occurred in 16.2% of 1473 consecutive patients with ischemic stroke collected in a stroke registry that included data from 2000 patients

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Task Specific Training

- Basic Activities of Daily Living
- Instrumental Activities of Daily Living
- Developmental sequence
- Focus on returning home, or reducing caregiver burden

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Locomotor Training

- Overground
- Treadmill
- Bodyweight Supported Treadmill Training
  - STEPS: Strength Training Effectiveness Post-Stroke
    - 4 sessions/week x 6 weeks
    - 1 hour of moderate-intensity, task-specific gait training or strengthening
    - Initial BWS of 30-40% reduced over sessions
    - Four 5-minute training bouts, 1.5-2.5 mph; also received gait instruction in an overground setting over a 50 ft distance to reinforce training from treadmill

Locomotor Training

- Benefits of BWS: “Active” ingredient;
  - Unweighting provides added support and positive reinforcement to the pt, reduces fear
  - BWS is progressively decreased which allows therapist to progressively increase biomechanics demand with improving motor control and power during swing and stance
  - Use of harness and progressive manipulation of BWS result in more intense practice of walking
  - Self-report higher confidence in walking skills, enjoyment

Locomotor Training - Interference

- Exercise programs in young adults that combine high-volume and high-intensity endurance and resistive exercise programs can **REDUCE** the strengthening effects
- In older adults, CV training alone resulted in LE strength gains comparable to those achieved through either a low- or high-resistance or combined program

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Robotic Assisted Gait

- Enables patients with severe lower limb paresis to start walking early after stroke
- HAL training:
  - 4 days/week x 4 weeks
  - TM with BWS

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Robotic Assisted Gait

- Ekso in acute
- Designed to help patients get back on their feet supporting re-learning of correct step patterns, weight shifting, and potentially mitigating compensatory behaviors
- Flaherty et al. utilized the Ekso a mean number of 7.33 sessions distributed over a period of 5 to 35 days. The mean number of steps in Ekso was 416 and mean up time was 30 minutes

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Robotic Assisted Gait

- The Lokomat
  - Autonomously provides a predefined walking motion that is not related to the user's voluntary drive
  - The user generates force along the autonomous motion pattern generated by the Lokomat and is encouraged to generate as much effort as possible

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Electrical Stimulation - NMES

- Those who benefit from NMES:
  - Acute survivors with no volitional finger extension
  - Emergent muscle contraction – EMG-NMES
  - No volitional ankle movement - cyclic peroneal nn or with gait training
  - Shoulder NMES is effective in reducing postroke shoulder subluxation, increasing pain free lateral rotation ROM and facilitating motor recovery in acute phase
    - Apply to supraspinatus and posterior deltoid for those with flaccid hemiplegia and subluxation during acute phase of CVA to prevent pain
    - Unclear if this helps with pain without subluxation
    - 6 hours/day, 6 weeks

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Electrical Stimulation - FES

- Nonuse in one extremity coupled with heavy reliance on the contralateral extremity has been shown to result in major imbalances of cortical excitation and inhibition
- FES: Rehabilitation strategy that temporally couples electrical stimulation of motor and sensory nerve fibers during the performance of a functional motor task and may target neural pathways that could restore post stroke hemispheric imbalances
  - There is Level 1a and Level 2 evidence that functional electrical stimulation during conventional rehabilitation improves gait, balance, and independence when compared to rehabilitation alone

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Robotic Assisted - UE

- Armeo + Virtual Reality
  - Self-initiated repetitive hand and arm therapy; exoskeleton embraces whole arm
  - Utilizes activities of daily living in virtual world
  - Provides closed-loop online feedback of the 3D movement in virtual reality
  - Creates the possibility to detect compensation strategies and may provide a tool to achieve the rehabilitation goals in accordance with the individual capacity for genuine functional restoration

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Mental Practice

- Act of performing the skill in one's imagination, with no action involved
- Hird et al., 1991 - Results:
  - Group given 100% mental practice was MORE EFFECTIVE at the task than control
  - Group given 100% physical practice was MORE EFFECTIVE at the task than 100% mental practice and control group
- Suggests:
  - Physical practice is the BEST TYPE of practice
  - Mental practice is an effective way to enhance performance and acquisition of a task without physical constraints

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Mirror Therapy

- Act of observing the reflection of the unaffected limb positioned as the affected limb; this reflection often can be perceived as the affected, paretic limb
  - This strong visual cue from the mirror can therapeutically be used to improve motor performance and the perception of the affected limb
  - Likely due to activation of mirror neurons as well as the superior temporal gyrus
- Perform at least once daily with a minimum duration of ten minutes, maximum duration around 30 minutes

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Interventions: Subacute

- Body worn sensors
- CTSIB
- Constraint Induced Movement Therapy
- Functional Activity/Task Specific Training
- Locomotion - BWSTT
- Dual tasking
- Virtual Reality
- Robotics
- Neuromuscular Electrical Stimulation/Functional Electrical Stimulation (NMES/FES)
- High Intensity Interval Training (HIIT)
- Aquatics
- Mental imagery
- Transcranial Magnetic Stimulation (TMS)

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Locomotion- Cardiovascular + TM Training

- Mackay et al., 2013
  - BWSTT improved VO2 peak by 30%, which was significantly greater than the 8% improvement observed for usual care (P = .004 between groups).
  - BWSTT elicits greater improvements in cardiovascular fitness and walking endurance than usual care in the subacute poststroke period.
  - These gains are largely sustained for 1 year

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Locomotion - HIIT + CV training

- Leddy et al., 2016
  - Secondary analysis from a RCT comparing HIIT to conventional interventions in sub-acute population
    - 1-6 mo post stroke
    - < 40 sessions of HIIT or conventional interventions

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FES Assisted Gait

- Long-term use of FES during rehabilitation activities improved motor function, increased portico motor drive to the paretic limb, and shifted the focus of brain activity from the non lesion to the lesion sensorimotor cortex during a paretic hand motor task.
- Palmer et al. Conclusions:
  - Typical post stroke asymmetrical walking patterns may strengthen corticomotor imbalances between hemispheres and could potentially amplify gait asymmetries in some people
  - This study demonstrates that neuroplastic changes in the LE are detectible following a single session of rehabilitation

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Transcranial Magnetic Stimulation

- Repetitive transcranial magnetic stimulation (rTMS) demonstrated beneficial effect for motor recovery after stroke by either increasing excitability of the primary motor cortex (M1) of the affected hemisphere, or by inhibiting the M1 of the unaffected hemisphere
- Takeuchi et al. presented results that have demonstrated that rTMS over the contralesional M1 could lead to an improvement of motor function in the affected hand of patients with chronic stroke

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Interventions: Chronic

- Aquatics
- Balance training
- Body worn sensors
- Constraint Induced Movement Therapy
- Dual task training
- Functional Activity/Task Specific Training
- High Intensity Interval Training (HIIT)
- Locomotion- overground vs. BWSTT
- Mental Imagery
- Neuromuscular Electrical Stimulation/Functional Electrical Stimulation (NMES/FES)
- Progressive Resistance Exercises
- Robotics
- Transcranial Magnetic Stimulation (TMS) or Transcranial Direct Current Stimulation
- Virtual Reality

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Aquatics

- Zhizhong et al., 2016
  - Water temperature of between 33 °C to 34°C could:
    - Increase skin temperature
    - Expand blood vessels in the peripheral skin
    - Increase blood supply
    - Accelerate muscle relaxation
    - Decrease sensitivity to pain or muscular spasm
    - Enhance balance function
  - Motor and sensory stimuli during water exercises can potentially induce plasticity
  - Aquatic exercise improves motor function, and static and dynamic balance in people who suffered stroke.
  - Objective measures:
    - 2MWT, BBS, TUG, FRT

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continued

Aquatics cont'd

- AQUATIC
  - Stretching of all joints/major muscle groups (on land): 5 min
  - Strengthening exercises (holding side of the pool): 1 x 15
  - Balance/coordination exercises
  - Aquatic treadmill exercises:
    - Began at an individual's comfortable turning speed on level ground
    - Increased by increments of 0.05 m/s every 5 minutes as tolerated
    - Walking 10 minutes or 500 meters
  - Cool-down period - Stretching, deep breathing, and floating: 10 minutes

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continued

Aquatics cont'd

- LAND
  - Stretching of all joints and major muscle groups(on land)
  - Strengthening exercises: 1 x 15
  - Trunk mobility exercises
  - Treadmill training
    - Began at an individual's comfortable turning speed on level ground
    - Increased by increments of 0.05 m/s every 5 minutes as tolerated
    - Walking 10 min or 500 meters.
  - Cool-down period (10 minutes): Stretching of all joints and major muscle groups

- Clinical message: Hydrotherapy increased balance and mobility more than an equivalent amount of land-based therapy in people after stroke.

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Balance Training

- There is Level 1a evidence that sit-to-stand with asymmetrical foot positioning improves balance when compared to symmetrical foot positioning.
- There is Level 1a and Level 2 evidence that aquatic therapy improves balance when compared to conventional rehabilitation.
- There is Level 1b and Level 2 evidence that motor imagery-enhanced balance training improves balance when compared to standard balance training.

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CIMT

- Hakkennes, Keating, 2005
- Only small amount of pts may be appropriate for CIMT:
  - Preserved cognition
  - 10 active finger exension
  - 20deg wrist extension
- Restraint of the intact limb over and extended period, in combination with a large number of repetitions of task-specific training of the affected limb
- Treatment:
  - Training for 6hrs/day x 2 week
  - Constraint for 90% of waking day for 14 days
- Learned non-use can't use the affected UE and never regain the function
- The effect sizes across the meta-analysis were all moderate to large in favor of the CIMT group

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Dual Task

- There is Level 1a and Level 2 evidence that dual task training improves gait and stability when compared to single task training
- Cognitive-Motor
  - Processing information during gait
- Motor-Motor
  - Manipulating an item during gait
- Relative measures: dual-task effect (cost/benefit)
  - DTE % = ±(dual task –single task)/single task × 100

Dual Task

- Yang, Wang, Chen, & Kao, 2007
  - Subjects in the experimental group participated in 30 minutes of a ball exercise program
    - 3x/ week x 4 weeks
    - Subjects walked while manipulating either 1 or 2 balls. (45, 55, 85, and 95cm and basketball)
      - Walking while holding 1 or 2 balls on both hands
      - Walking to match the rhythm of bouncing 1 ball with 1 hand or both hands
      - Walking while holding 1 ball on 1 hand and concurrently bouncing another ball with the other hand
      - Walking in time while kicking a basketball (the basketball was put into a net, and the net was held by the subject)
      - Walking while holding 1 ball and concurrently kicking another basketball within a net
      - Walking while bouncing 1 ball and concurrently kicking another basketball within a net
      - Walking while reciprocally bouncing 1 ball with both hands
    - Variable practice for the walking condition involved walking forward, walking backward, walking on a circular route, and walking on an S-shaped route. The subject was challenged with increasingly difficult tasks.

Dual Task

- Liu, Yang, Tsai, & Wang, 2017 - pilot trial
  - Participants (n = 28) were randomly assigned to
    - Cognitive dual task gait training (CDTT) - serial subtraction
    - Motor dual task gait training (MDTT) - tray-carrying
    - Conventional physical therapy (CPT) group
    - Participants in CDTT or MDTT group practiced the cognitive or motor tasks respectively during walking
    - Participants in CPT group received strengthening, balance, and gait training
  - 30 min/session, 3 x/week for 4 weeks
  - CDTT - gait performance (stride length and DTC-speed) was improved
  - MDTT - gait speed, stride length, and DTC-speed) was improved
  - NO BETWEEN group differences
    - Different types of dual task gait training can be adopted to enhance different dual task gait performance in stroke

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HIIT

- Within-Session Responses to High-Intensity Interval Training in Chronic Stroke
  - > 6mo post stroke (chrobic)
  - 3 different 1-day HIIT sessions, randomized 1 week apart
  - Repeated 30-s bursts of treadmill walking at maximum tolerated speed, alternated with rest periods.
  - Three HIIT protocols were different on the basis of the length of the rest periods, as follows:
    - 30 s (P30), 60 s (P60), or 120 s (P120)
  - Exercise tolerance, oxygen uptake (V˙O2), HR, peak treadmill speed, and step count were measured.
  - P30 achieved the highest mean V˙O2, HR, and step count but with reduced exercise tolerance and lower treadmill speed than P60 or P120
  - P60 achieved treadmill speed and exercise tolerance similar to those in P120, with higher mean V˙O2, HR, and step count
- For treadmill HIT in chronic stroke, a combination of P30 and P60 may optimize aerobic intensity, treadmill speed, and stepping repetition, potentially leading to greater improvements in aerobic capacity and gait outcomes in future studies.

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Robotic Assisted Gait

- HAL in chronic stroke
- 16 locomotor training sessions using the HAL within 2 days/week as tolerated by each patient.
  - Ninety minute sessions: Included setup of the HAL, rest periods, and assessments.
  - The total duration of training with the HAL was between 20 and 30 min in each session.

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Robotic Assisted Gait

- Lokomat in chronic stroke
- Hornby et al. reported a 0.07 m/s increase (d = 1.0) in gait speed from the mean baseline value of 0.45 m/s.
- Initial walking speed between 0.1 to 0.6 m/s
- Twenty-four 60-minute sessions of either Lokomat or conventional gait training.

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Robotic Assisted Gait

- Ekso in chronic stroke
- Twelve 1-hour sessions over 4 weeks
- Molteni et al. concluded that in both sub-acute and chronic stroke patients, improvement in ambulatory function is shown after 12 sessions of gait-training with the Ekso exoskeleton.

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Task Specific

- Livingston-Thomas et al., 2016
  - Environmental Enrichment (EE) - form of rehabilitation that encourage sensorimotor stimulation
- Level 1a and Level 2 evidence that task-specific training for the lower limbs improves gait and balance when compared to conventional training or task-specific training of the upper limbs.
- Level 2 evidence that task-specific training on stairs/ramps improves aspects of balance when compared to training on flat surfaces
- Conflicting Level 1b evidence as to whether task-specific circuit training improves gait and balance when compared to conventional training.

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Durability of Rehabilitation Gains

- Level 1a: relatively greater functional improvements are made who attend rehabilitation on specialized stroke units
- Level 1a: functional outcomes achieved through stroke rehabilitation are maintained for up to 1 year post stroke
- Level 1b: 5 years post-stroke plateau in functional outcomes and may decline
- Level 1b: 10 years overall functional outcome scores significantly decline although it is unclear to what extent natural aging and comorbidities may contribute to declines

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Equipment

- Functional Electrical Stimulation/Neuroprosthetics
  - LE: Bioness L300 or L300 Go, Ottobock MyGait, WalkAide
  - UE: Bioness H200
- Saebo
- Armeo
- Robotic assisted gait
  - Rewalk Exoskeleton
  - Ekso Bionics
  - Cyberdyne Hybrid Assisted Limb

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Videos

Summary

- Anatomical variations and statistics will guide decision making on evaluation, training, and interventions
- Literature helps to identify how neuroplastic changes can be facilitated with appropriate therapeutic interventions while treating acute, subacute and chronic CVA
- Use underlying principles of neuroplasticity and research to be creative with interventions.

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Thank you!

Questions?

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