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Contemporary Motor Learning Approaches for Neurorehabilitation

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Course objectives:

1) Identify the rationale for the use of the motor learning theory to facilitate occupational performance and participation that is reflective of current and emerging practice, based on available evidence, and based on theoretical perspective.

2) List several current neurorehabilitation intervention strategies based on client needs for improved motor learning due to a neurological disorder.

3) Recognize the need to apply clinical reasoning to monitor, modify/adapt contemporary motor learning interventions based on client response and intervention effectiveness.

4) Select the appropriate therapeutic use of occupations, exercise, and activities within contemporary motor learning approaches that address underlying client factors that may influence occupational performance.

Agenda

- Motor learning theory
- Experience Dependent Neuroplasticity
- Constraint Induced Movement Therapy
- Task Specific/Oriented Training
- Interhemispheric Inhibition
- Other approaches (Bilateral Arm Training, Brain Stimulation, Action Observation, Mental Practice, Mirror Therapy, Functional Electrical Stimulation, Biofeedback, Robotic Devices, Virtual Reality, Strengthening and Exercise)
- Questions???
From Motor Control to Motor Learning

- **Motor Control**
  - The ability to regulate or direct the mechanisms essential to movement
  - CNS organization
  - Sensory information
  - Perceptions
  - Muscles and joints

- **Motor Learning**
  - Acquisition or modification of movement which is essential in occupation and adaptation
  - Individual
  - Occupation
  - Environment
  - Adaptation

Motor Learning

"...a process associated with practice or experience that leads to relatively permanent changes in the ability to produce skillful responses.”
- Schmidt

Dynamic Systems Theory

- Heterarchical Model

Shumway-Cook, & Woollacott, 2012

CONTINUED™
Motor Learning Theories

- Ecological (applied to motor learning by Newell, 1990’s)
  - search for optimal strategies to solve the task
  - find appropriate motor responses and appropriate perceptual cues
  - learn to distinguish relevant perceptual cues and match these to motor strategies
  - Perception: used to understand the task (goal and movements needed), and as feedback (both during and after movement)
  - learn to match appropriate movement dynamics to different conditions
  - learn how to solve motor problems, not perform a specific movement pattern

(Combined) Stages of Motor Learning

- Stage 1: Skill Acquisition
  - “Cognitive”
    - (Fitts & Posner)
  - “Novice”
    - (Systems)
  - “Understand the movement”
    - (Gentile)

(Combined) Stages of Motor Learning

- Stage 2: Skill Refinement
  - “Associative”
    - (Fitts & Posner)
  - “Advanced”
    - (Systems)
  - “Refine the movement”
    - (Gentile)
(Combined) Stages of Motor Learning

Stage 3: Skill Retention

- “Autonomous”
  - (Fitts & Posner)
- “Expert”
  - (Systems)
- (“Refine”...Gentile)

Motor Learning Requires Practice and Feedback

“Practice makes Perfect”
“Practice makes Perfect”
“Appropriate practice makes perfect”

• More is Better!!!

Errors are necessary for learning

• Practice doesn’t need to be ‘error free’
• Just don’t practice the errors
  – Practice recognizing & correcting them!

Feedback

• Error recognition
  – Actual vs. intended
• Error correction
  – Cues to improve
• Reinforcement & increased motivation
  – Increases attention to & duration of practice
• Guidance of ongoing movements
  – Only for very slow, especially novel movements
Feedback

- **Intrinsic**
  - Internal sources (self)

- **Extrinsic**
  - External sources (coach, therapist, etc.)
  - a.k.a. "augmented" or "supplemental"
  - Concurrent and/or terminal
  - Knowledge of results
  - Knowledge of performance

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"Fade" the Feedback

(“Guidance”)

- **Stage 1 - Acquisition:**
  - Continuous, immediate, prescriptive

- **Stage 2 - Refinement:**
  - Delayed, summary/brief intervals, descriptive

- **Stage 3 - Retention**
  - Delayed, summary/longer intervals,
  - questions vs. answers

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What about practicing parts of a task?

- May be effective for some tasks
  - If task can be naturally divided into units
  - Parts must be practiced in the context of the task
  - Must then practice the task as a whole, in appropriate environment
Practice Schedule

- Block: AAA-BBB-CCC-AAA-BBB-CCC

Does it matter where you practice?
Retention and transfer best when processing demands of practice environment match those of the "real" environment

Practice Environment

- Closed
  - Finite, constant, predictable
  - Promotes skill acquisition, impedes skill retention
  - Exception: task/environment constant
- Open
  - Infinite, changing, unpredictable
  - Delays skill acquisition, increases skill retention

continued
Vary Practice Schedule & Environment

• Stage 1 –
  Acquisition:
  – Single task
  – Self-paced
  – Drill schedule
  – Closed environment

Vary the Practice Schedule & Environment

• Stage 2 - Refinement
  – Multiple tasks
  – External timing demands
  – Blocked schedule
  – Open environment – limited

Vary the Practice Schedule & Environment

• Stage 3 - Retention
  – Concurrent tasks
  – Random schedule
  – Open environment

continued
Implications: Exam/Eval

• Identify the stage of motor learning for each task to be learned
  – After a neurological injury a common task may be in the acquisition phase when re-learning.

Implication: Intervention

• Increase practice variation & decrease feedback as learner improves

A few good points

• **Attentional focus** to effects of their movement better than focusing on details of the movement

• **Learner-control training** can enhance learning

• **Dyads/groups** can result in more effective learning
Summary

• Motor learning in ‘normal’ individuals is enhanced by progressively

  – increasing variation in practice schedule
    [memory demands] & practice environment
    [attentional demands]

  – decreasing the frequency of feedback
    [internalize problem solving process]

Summary

• As OT’s we should use the principles of motor learning to improve client treatments and maximize the effectiveness of our treatments

  – Recognize the stage of learning for each task to be learned

  – Match the type of practice & feedback to the learner’s level for each task

  – Change practice and feedback methods as the learner improves

What would you miss doing most if you did not have function in your dominant arm and hand?
Hemiparesis after Stroke

- "learned non-use" (Taub et al., 1993): Reluctance or unwillingness to use the "involved" limb prompted by encouragement from clinicians and family to use the "uninvolved" limb, resulting in learning how not to use the involved limb. A learned suppression of movement.

Neuroplasticity


<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Use it or lose it</td>
<td>Failure to use specific brain function can lead to functional deterioration</td>
</tr>
<tr>
<td>2. Use it and improve it</td>
<td>Training that does a specific brain function leads to an improvement of that function</td>
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<tr>
<td>3. Specificity</td>
<td>The nature of the training experience dictates the nature of the plasticity</td>
</tr>
<tr>
<td>4. Repetition Matters</td>
<td>Induction of plasticity requires sufficient repetition</td>
</tr>
<tr>
<td>5. Intensity Matters</td>
<td>Induction of plasticity requires sufficient training intensity</td>
</tr>
<tr>
<td>6. Time Matters</td>
<td>Different forms of plasticity occur at different times during training</td>
</tr>
<tr>
<td>7. Sequence Matters</td>
<td>The training experience needs to be sufficiently altered to induce plasticity</td>
</tr>
<tr>
<td>8. Age Matters</td>
<td>Training induced plasticity occurs more readily in younger brains</td>
</tr>
<tr>
<td>9. Time Domain</td>
<td>Plasticity is responsive to time training experience can affect the acquisition of skills behavior</td>
</tr>
<tr>
<td>10. Interactions</td>
<td>Plasticity in response to one experience can interfere with the acquisition of other behaviors</td>
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</tbody>
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Kleim & Jones. Principles of Plasticity. S227
Use it or Lose it!

- If physiological consequences of cortical infarct are use-dependent, then further loss of spared distal representation may be at least partially explained by disuse of affected musculatures.

Nudo & Milliken, 1996

Use it and Improve it!

- Rehabilitative therapy after a neurological insult can help prevent or overcome "learned non-use" of the hemiplegic upper extremity as well as improve its actual movement and function by recruiting other parts of the brain that are not damaged.

(Nudo, Plautz, & Frost, 2001)
(Nudo, Wise, SiFuentes, & Milliken, 1996)
(Liepert, Bauder, Miltner, Taub, & Weiller, 2000)

Specificity

- The motor cortex is critically involved in the acquisition and performance of skilled movement

Monfils, Plautz, & Klein, 2005
Repetition Matters

- In order to elicit neural mechanistic changes and subsequent adaptive responses, repetition of stimuli must occur. It cannot be elicited after one session.

(Racine, Chapman, Trepel, Teskey, & Milgram, 1995)

Intensity Matters

- For a change in motor output to occur, conditioning stimuli must be given repeatedly in intense measures.

Peinemann et al., 2004

Time Matters

- Initiating rehabilitation earlier rather than later provides significantly greater functional compensation/recovery (or adaptation) and enhanced structural plasticity within the undamaged motor cortex.

(Biernaskie, Chernenko, & Corbett, 2004)
Salience Matters

• Adaptive behavior involves a continual interplay between an organism and its environment, both of which are dynamic.

Age Matters

• Neurological age dependent changes underlie adaptations.
• Aging may interfere with neural plasticity processes in a number of ways

Transference

• Combining techniques of teaching/rehabilitation for adaptation places people at an advantage for further skill learning. The transference of multiple rehabilitation techniques leads to greater performance improvement than singular methods alone.
Interference

- Certain forms of explicit information delivered before task practice may not be as useful (or adaptive) for learning as discovering the solution to the motor task with practice alone. To facilitate adaptation, implicit learning is more advantageous than explicit teaching. In addition, explicit teaching can interfere with implicit learning.

Boyd & Winstein, 2006

Current Treatment Approaches

- Constraint Induced Movement Therapy
- Task Oriented/Specific Training
- Bilateral Arm Training
- Brain Stimulation
- Action Observation
- Mental Practice
- Mirror Therapy
- Functional Electrical Stimulation (FES)
- Biofeedback
- Robotic Devices
- Virtual Reality
- Strengthening and Exercise


Forced Use

- Requiring a patient to predominantly or exclusively use the impaired upper extremity by immobilizing the less impaired, homologous limb during most waking hours
  - Identified activities in multiple environments
  - No formal “one on one” training
    - adaptive task practice or repetitive task practice
Constraint-Induced Movement Therapy

The systematic application of shaping and repetitive use strategies without employing the contra-lateral limb over a defined time interval to improve (meaningful) functional use of an impaired limb

Evidenced Based Practice

Winstein, et al., 2003
Wolf, et al., 2006
Wolf, et al., 2008

THERAPEUTIC ASPECTS OF CI MOVEMENT THERAPY

- Restraint of less involved UE
- Constraint use of more involved UE
- Repetitive, task-oriented training
  - Adaptive task practice (shaping)
  - Repetitive task practice
- Adherence-enhancing behavioral strategies ("transfer package")
  - Behavior contract
  - Home diary
  - Home exercises
Therapeutic aspects of CIMT

• FORCED-USE (constraint)

Therapeutic aspects of CIMT

• INTENSIVE REPETITIVE PRACTICE

Types of intensive practice

Repetitive Task Practice
Practice of a full functional task that may have multiple steps for completion. Repeating tasks with continuous feedback from the trainer. Tasks selected by the patient, in collaboration with the trainer, on the basis of personal preference, relevance and interest.

- General practice of entire functional activity
- Periodic feedback
- Typically practiced over period of time

Shaping
(Adaptive task practice)
Training method in which a motor or behavioral objective is approached in small steps, by successive approximations or by making the task more difficult in accordance with the patient’s motoric capabilities.

- Grading and specificity of tasks
- Feedback and intensity of reps

..................................................
Goal: Make coffee

• Components
  – Pick up / open bag of coffee
  – Scoop beans into grinder
  – Grind coffee
  – Place filter and pour coffee into filter
  – Pour water into coffee maker
  – Pour coffee into cup
  – Drink!!!
Adherence-enhancing behavioral strategies (“transfer package”)

- Behavioral contract
- Caregiver contract
- Home diary
- Home skill assignment / Home practice
- Problem solving to overcome barriers of use of UE in home environment

Who is appropriate for CIMT?

**Movement criteria**

**WHY?**

The ExCITE Trial: Specific Aims

- Can a 2-week CI Therapy program be applied successfully to patients with sub-acute stroke?
- Do the therapeutic gains achieved through CI therapy persist over time? (12-24 months)
- Does the initial level of motor ability (higher/lower functioning) determine the extent to which sub-acute stroke patients improve with CI Therapy?
- Is the magnitude of response to CI Therapy different among patients with sub-acute stroke and chronic stroke?
ExCITE Results
CIMT before and after

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ExCITE Results Summary
Early CIMT vs Delayed CIMT
Higher vs Lower functioning

- Both groups improve in primary outcome measures at one year
- Magnitude of improvement at each time point favors the CI Therapy group
- Few serious adverse events that do not appear related to the intervention

No decline in:
- Time to complete WMFT
- Weight lifted in the WMFT
- WMFT grip strength
- Amount of use in the MAL
- How well the limb was used in the MAL

All groups showed improvements and retained improvements!!!

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What is the most important part?

- RTP (Repetitive Task Practice)
  - Continuous activity (e.g., eating, grooming, writing)

- ATP (Adaptive Task Practice) “shaping”
  - Coaching
  - Positive reinforcement for effort
  - Plotting task performance (Ex. 30 sec trials x 10)

- Grading of tasks
  - “How difficult should the task be?”
    - The level of difficulty should be slightly more challenging than “easy”

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What about the “real world”?

- What is the average number of repetitions a client performs during a typical rehabilitation session with their arm/hand? Leg/foot?
  - Upper limb rehab
    - ___ Reps/tx session
  - Lower limb rehab
    - ___ Gait steps/session


What does the evidence suggest?

- Upper limb rehab
  - Rats, Monkeys: ____ reps / tx session
  - Humans (behavioral studies): ____ of reps
    (Fine & Thoroughman, 2006, Boyd & Weinstein, 2006)

- Lower limb rehab
  - Cats: ____ steps/30 min treadmill sessions

Variations in application of CIMT

- Timing of administration
  - Acute/Subacute/Chronic
  - Clinic vs. home-based

- Wearing mitt
  - Forced use
  - 90% waking hrs ("signature CIMT/EXCITE")
  - mCIMT – 5 hrs/day
  - Distributed CIMT – 9.5 hrs/day

- Intensity of Practice
  - EXCITE: 6 hours/day, 5 days/wk for 2 wks
  - mCIT: 30 min/day, 3 days/wk for 10 wks
  - Distributed CIT: 3 hrs/day for 20 days

- Type of practice
  - Repetitive task practice
  - Shaping (adaptive task practice)
  - Traditional therapy
How to increase the intensity and repetitions in the “Real World”

– Groups
– Coordination with other disciplines:
  • Occupational Therapy
  • Physical Therapy
  • Speech Therapy
  • Recreational Therapy
  • Nursing
  • Aides
  • Others?

Motor Learning and Task Oriented/Specific Approach

• Neuro-facilitation approaches have evolved to include function not just suppression of reflex
• Task-oriented or motor learning approach
  – Developed from newer theories of motor control
  – Treatment based on functional tasks
  – Learn by solving problems
  – Must be able to adapt to changes in the environment

Task Oriented Training

- The active, repetitive practice of functional activities to learn or relearn a motor skill.
- Repeated, challenging practice of functional, goal-oriented activities
- Used for restoring or remediating upper extremity motor control

Principles of Task-Specific Training

- Practice of a movement results in improvement in that movement
  
  *(Use it and improve it)*

- Large amounts of practice are required to truly master a motor skill. The ideal dose of practice is unknown.
  
  *(Repetition and Intensity)*

- Learning requires solving the motor problem, not rote repetition of overlearned tasks.
- Learning does not occur in the absence of feedback.
- Intrinsic feedback is optimal for promoting self-learning and generalization.
  
  *(Specificity)*

Principles of Task-Specific Training (cont.)

- Optimal learning occurs with high levels of motivation and engagement.
  
  *(Salience)*

- Variable practice conditions are optimal for learning and generalization.
  
  *(Transference)*

- Within-session, massed practice promotes learning better than within-session distributed practice.
  
  *(Repetition and Intensity)*

- Practice of a whole task results in better learning than practice of parts of the task, unless the task can be broken down into clearly separable components.
  
  *(Specificity, Transference and Interference)*
Accelerated Skill Acquisition Program (ASAP)

- Skill – motor learning and self-management
- Capacity – impairment mitigation
- Motivation – intrinsic drive

Winston, Lewthwaite, Blanton, Wolf, & Wishart, 2014
Bilateral Arm Training


Interhemispheric inhibition


Brain Stimulation

Takeuchi and Izumi, 2012
Transcranial Magnetic Stimulation (TMS)

Mirror therapy

Action Observation

- Watch another person performing common functional actions (usually through a pre-recorded video) with the intention of imitating the observed actions.
- Followed by actual task performance.
Mental Practice

- A person cognitively rehearses a physical skill in the absence of actual movements.
- Often coupled with traditional task-oriented practice.

Example: "Eating apple"


Functional Electrical Stimulation (FES)

Popovic, Popovic, & Sinkjaer, 2002)

Biofeedback

Moreland & Thomson, 2994
Robotic Devices

Virtual Reality

Strengthening & Exercise

- Tai Chi
- Yoga
  - Balance
  - Mobility
  - Activity
  - Participation

Levin, Weiss, & Keshner, 2015
Stuart et al., 2009
Laver, et al., 2011
Questions???