It's All In Your Brain: Graded Motor Imagery for Pain Modulation

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DESCRIPTION: Graded Motor Imagery is an emerging therapeutic strategy for treating complex pain patients. It integrates established principles of graded exposure and response prevention with current theories in the neuroscience of pain. Grade Motor Imagery consists of laterality training, imagery and mirror therapy with the aim of exposing the brain to movement related therapies to induce positive reorganization of the brain.

OBJECTIVES
Upon completion of this course, you will be able to:
1. Discuss current theories on normal and abnormal peripheral and central pain mechanisms.
2. Explain the cortical reorganization associated with complex and/or chronic pain.
3. Describe the neuroscience principles behind the use of a graded motor imagery program (GMIP).
4. Identify the practical applications of a GMIP with various patient populations in which pain is a primary impairment.
3. Develop treatment strategies using GMIP to improve function in the involved upper limb.
4. Integrate the use of laterality reconstruction, visual and motor imagery, and mirror therapy into the plan of care for complex pain patients to achieve pain management and functional outcomes.

SELECTED REFERENCES:
Normal and Abnormal Pain Mechanisms: Concepts for Clinical Decision Making
Jane Fedorczyk, PT, PhD, CHT, ATC
Drexel University Philadelphia, PA

"Pain is considered one of the most challenging impairments to remediate due to the complex physiologic mechanisms involved in the normal response to pain as well as maladaptive pain states that frequently occur in persistent or chronic pain conditions... A comprehensive assessment of pain will enhance the development of an appropriate plan of care including the judicious use of modalities and other rehabilitation techniques."

Jane Fedorczyk, 2005

Definitions of Pain and Nociception

Pain
An unpleasant sensory and emotional experience associated with actual or potential tissue damage. (IASP). Serves as a warning signal. Behavior associated with painful stimuli is an adapted behavior and involves learning and memory.

Nociception
The reception of sensations carried by nociceptors (free nerve endings) in response to tissue damage. Nociceptors located in periphery; carry signals from noxious stimuli.

Review of “Normal” Pain Mechanisms
- Nociceptors: Sensitization and Activation
- Primary Peripheral Afferents
- Dorsal Horn Activity
- Ascending Pain Pathways and Modulation
- Descending Pain Pathways and Modulation

Sources of Pain Mediation

Mediated by Inflammatory Response
Peripheral Nociceptive: Injury to musculoskeletal tissues
Peripheral Neurogenic: Injury within the peripheral nervous system

Pain Not Mediated by Inflammatory Response
Central Pain
- Lesion or dysfunction within CNS
- Presence of Abnormal Pain States
Characteristics:
Poor response to medication, even opioids
Presence of abnormal pain states
Pain comes out of nowhere
Pain does not follow a distinct or reasonable pattern
Inconsistent behaviors

Abnormal Pain States
**Alldynia**: Pain response to non-noxious stimuli
**Hyperalgesia**: Exaggerated or spontaneous response to noxious stimuli

Neuroplasticity
Cortical Reorganization
Spinal Cord (Dorsal Horn) Changes

*Pain Related to Sympathetic Nervous System*
Complex Regional Pain Syndromes

**Affective Pain**
Primarily involves pathways concerned with affect or emotion
Limbic system involvement

**Threshold vs. Tolerance**

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Tolerance</th>
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<tbody>
<tr>
<td>Sensory Component</td>
<td>Affective Component</td>
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<tr>
<td>Does This Hurt?</td>
<td>How Much Can You Take?</td>
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<tr>
<td>Consistent</td>
<td>Variable due to</td>
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<td></td>
<td><strong>Fatigue</strong></td>
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<td></td>
<td><strong>Stress/Anxiety</strong></td>
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<td><strong>Lack of Control</strong></td>
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Role of Therapy in Pain Modulation
Address both threshold and tolerance
Pain Impairment

Primary Source of Pain Mediation

Peripheral Nociceptive or Peripheral Neurogenic

Plan of Care May Include:
- Physical Agents
- Exercise
- Manual Techniques
- Orthotic Intervention
- Positioning
- Education
- Pharmacologic Agents to modulate pain

Central Pain or Affective Pain

Plan of Care May Include:
- Neuromuscular Retraining
- Exercise
- Graded Motor Imagery
- Behavior Modification
- Education
- Pharmacologic Agents
- Psychological Interventions to modulate pain

Promote tissue healing

down peripheral pain inputs
Global Tactics for Nerve and Tissue Healing

- Increase Bloodflow
- Increase Oxygen
- Promote Stressfree Use of Hand and UE
- Aerobic Exercise
- Drink Water
- Avoid Static Postures
- Avoid Caffeine and Nicotine
- Diaphragmatic Breathing
- Joint Protection and Energy Conservation
**It’s All In Your Brain**
*Graded Motor Imagery*

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**Hello from Memphis, Tennessee**

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**Neuro Science Revisited**

- Cortical change - chronic pain
- Bottom Up – peripheral nociceptive stimuli
- Top Down – cortical central processing
- GMI – retrain the brain
Sculpting the Brain

• Contribution of CNS to pain
• Cognitive reeducation
• Neuroplasticity
• Cortical Reorganization

Why Train the Brain

• Cognitive
• Behavioral
• Brain Changes
• Neglect & Ownership
• Disrupted Bodily Awareness


Primary Sensory Cortex

http://faculty.etsu.edu/curelm/images/neu10.jpg
Brain Neuroplasticity

- Persistent anatomical or physiological changes in a neuron that occurs during development, regeneration, experimental manipulation or repeated activity across a synapse
- Throughout life, the brain is able to restructure itself to change by adapting
Neural Plasticity

Good Neuroplasticity

- Persistent anatomical or physiological changes in a neuron that occurs during development, regeneration, experimental manipulation or repeated activity across a synapse
- Throughout life, the brain is able to restructure itself to change by adapting

Principle: Neural Plasticity

- Not purely motor but partially due to a sensory deficit or a sensory motor disconnection
- Maximize neural adaptation behaviors which drive changes in central nervous system require attention and repetition over time positive feedback
- Behaviors goal directed
- Accurate and progressed in complexity
- Goal increases progressive firing of neurons
Rewiring the Brain
Graded Motor Imagery Program

• Laterality Reconstruction
  – Restoration of brain’s concept of left and right
  – Try to imagine your hand in that position.

• Visual and Motor Imagery
  – Conscious access to brain which are involved in
    intention, preparation and then carrying out the
    movement

• Mirror Therapy
  – The brain is tricked into thinking that the limb is better
    than the brain thinks it is

Mirror Therapy

• Mirror conveys visual stimuli to the brain

• Observation of one’s unaffected part

• Principle states affected limb can be
  stimulated by visual cues originating from
  the opposite side of the body.

Graded Motor Imagery Program

Laterality Reconstruction → Visual & Motor Imagery

→ Mirror Therapy

• Non-threatening
• Normal somatosensory input to over-come altered motor
  control or dysfunctional movement pattern.
• Emphasis is on intervention of the non-painful movement.
• Helps to restore the disruption of normal interaction
  between intention to move the limb in absence of
  appropriate sensory feedback
**Graded Motor Imagery (GMI)**

- Sequentially graded, progressing from easy to difficult and non-threatening to threatening
- Hand representation in mirror will change synapses in the brain
- With hand in box, begin with less aggressive movement then the outside hand can move more aggressively and review symptoms

**Mental Imagery**
*Capacity to imagine objects or events that are not there*

**Motor Imagery**
*Process of imagining a movement of your own body without actually moving your body*

**Movement Observation**
*Perception of action of others*

**Top Down Training**

- Visual imagery used for relearning cognitive and planning aspect of movement
- Mirror and motor imagery used to re-educate or retrain the brain for basic motor skills by concentrating on the non-painful movement
- Smooth and controlled movements must act as example for brain to reset circuitry that mediates voluntary movement
Neural Plasticity Happens

- Sensory discrimination and fine motor task enhanced
- Neuron show structural change
- Cortical representations are expanded
- Receptive fields smaller than normal
- Number of excitable neurons is increased
- Specificity of feedback is enhanced
- Myelination is increased
- Synapse input is strengthened
- Integration time is shortened
- Complexity of dendritic branching is enhanced

Rebirth-Imaging

Functional Magnetic Resonance Imaging (fMRI)

fMRI provides a means to observe which structures participate in specific functions.

- Increase blood flow of the brain areas that are recruited for a task
- 30% neuron can be recruited to fire when one thinks about the image of the task
- Visual imaging recruits neuronal activity
- Magnetic resonance imaging can be used to map changes in brain hemodynamics that correspond to mental operations of neural activity as detected by a blood oxygen level dependent signal.
Rizzolotti, et. al. found that when a monkey reached for a peanut or watched an experimenter reaching for a peanut, that the mirror neuron involved in coding of goal using actions.

Mirror Neurons
- Activated by observing and executing movement
- Located in premotor cortex and inferior parietal lobe

Mirror Neuron System
- In humans, this is the mechanism that fires neurons when both observation and execution of movement occur
- Higher cognitive process
- Individual ability to learn from other actions - imitate and understand their intentions
- Premotor neurons
  - Fire when you observe someone doing a task
  - Imagining a task
  - Mirror imaging


Research
- Activated by performance
- Located in premotor cortex and inferior parietal lobe
- Monkey – premotor cortex
  - Discharge when performs a given motor act and when observe the same motor act
- Human – ample evidence
  - Cortical network that discharges in some way – observing and executing movement

Mirror Neuron Role in Rehab

- Improve motor performance by using visual & motor imagery
- Motor imitation and motor execution excite the corticospinal pathway

Hand Therapy and the Mirror Neuron System

- Movement observation may be an alternative way to activate the motor system based on the mirror neuron system
- May be used during immobilization or deafferentiation
- Hand transplants – retraining

Research The Netherlands

- Mirror neurons fire not only when action is executed, but also when one observes another person performing the same action
- Encode both our actions and actions of others

Research by Stefan

- Mirror neuron system firing is instrumental in motor learning
- Overt motor practice may not be totally necessary for implicit motor learning
- Observing movements may facilitate motor performance


Brain Rewiring

- Our brain is, in fact, a learning machine, capable of rewiring itself
  - Increasing myelination
  - Making new synapses
  - Enhancing the complexity of the dendrites
  - Secreting more neurotransmitters/neurohormones
  - Increasing attention


"The Clinical Approach Focuses On:

- Decreasing all inputs that imply that body tissue is in danger
- Then on activating components of the pain neuromatrix without activating its output
- Rehabilitation progresses to increase exposure to threatening input across sensory and non-sensory domains."

Goal - Sensory reintegration

Graded Sequential Protocol

Laterality Reconstruction
- Imagery (not moving)
- Imagery moving
- Mirror Work (imagery then movement)

Laterality Reconstruction
- Restoration of brain's concept of left and right
- Clinically, until you can identify left and right, there is usually pain

Laterality Reconstruction
Motor Imagery

• Conscious access to brain
• Think - preparation and carrying out movement
• Imaging or watching an activity
• Start static posture then imagine it moving
Mirror Imagery Treatment Regime

- Mirror to view healthy limb and reflection of same healthy limb mimics the involved limb
- Told to concentrate hard on the image as if both limbs were normal

Mirror Imagery and Mirror Therapy

- Tricks the brain into correcting its distorted image of the body
- Pain results from a mis-match in the way the brain perceives the body and the actual condition of the body
- Brain is tricked into thinking that the limb is actually better than the brain thinks it is
- Affected limb inside box
- Unaffected limb outside box

Mirror Movement
Top - Down Therapy

- The mirror reflection permits the subject to rehearse movements of the affected limb without having to directly activate those parts of maladaptive central process that typically produce pain.

Pain is Not a Happy Tune

- Dominates every aspect of life, work, family, relationships, emotions and beliefs.
NeuroMatrix Model of Pain

- Models the theory that the brain has a neural network that integrates information from multiple sources to produce the "experience that is labeled pain."
- Pain and cortical mechanisms are involved not just one single pain center
  - Anterior cingulate cortex
  - Thalamus
  - Sensorimotor

Melzack R. From the gate to the neuromatrix. Pain, 1999.

"The NeuroMatrix Theory integrates new findings from brain imaging studies, including:
- Pain brain mapping
- Pain and pharmaceutical interventions
- Cortical reorganization and pain
- Studies on the effect of stress on pain
- Research on cognitive-behavioral factors and pain

The Paths of Pain, Merskey, Loeser, Dubner, 2005

Pain Experience
The Brain is in Control = no brain no pain

Pain:
- "A multiple system output, activated by and specific pain neuromatrix. This neuromatrix is activated whenever the brain concludes it is in danger and action is required and pain is allocated an anatomical reference in the virtual body."

Pain experiences can create change in the Brain

- Pain memories—through the same mechanisms that enable humans to learn and retain memories.
- Pain memories can form through sensitization of the nervous system and is apparent on brain imaging studies.
- The pathways that transport painful stimuli may change, the structural changes may lead to increased excitation in the brain in the presence of non-painful stimulus.

Tracy Hampton PhD, JAMA, June 2005

Mind and Body

Pain is a “feeling” via activation of various neurotags.


Pain experience is not hard-wired

- It is more complex than the traditional pain pathway theories
- Pain:
  - “A multiple system output, activated by and specific pain neuromatrix. This neuromatrix is activated whenever the brain concludes it is in danger and action is required and pain is allocated an anatomical reference in the virtual body.”
Pain and Associative Learning

- Conditioned Response
  - Pain memories can form when movements and sensations that signal onset of pain elicit anticipation of pain.
  - Eventually, this can work in reverse
    - Anticipation of pain can elicit a pain response
  - Just thinking about a movement may hurt

Rehabilitation of Pain Patients
Fundamental Principles

- Pain is an output of the brain that is produced whenever the brain concludes that body tissue is in danger and action is required.
- Pain is a multisystem output that is produced when an individual-specific cortical pain neuromatrix is activated.
- Pain becomes chronic, the efficacy of the pain neuromatrix is strengthened via nociceptive and non-nociceptive mechanisms, which means that less input, both nociceptive and non-nociceptive, is required to produce pain.
Why Train the Brain

- **Cognitive** – patient must understand the problem
- **Behavioral** – function and movement hierarchy
- **Brain changes** – S1 reorganization
- **Neglect & Ownership** – it doesn’t feel like mine
- **Disrupted bodily awareness** – change and disruption in higher order due to cognitive representation

Pain Research

- Not single hard-wired dedicated pathway
- Converging evidence - physiological and functional imaging studies
- Move diffuse and plastic system - Cord, brainstem, thalamus and cortex
- Psychological studies - Attention, anticipation, preparation for action

Chronic Pain Syndromes
Chronic Pain

- 3 independent mechanisms contribute to chronicity
  - Nociceptive
  - Non-nociceptive
  - Central sensitization - allodynia

Chronic Pain

- Associated with reduced tactile acuity

- Relationship = pain intensity, tactile acuity and cortical reorganization

- Research by Moseley, Zalucki, etc., tactile stimulation can decrease pain and increase tactile acuity when patients are required to discriminate between type and location of tactile stimuli

Fear Avoidance Model

- Mind - Body Connection
- Pain causes altered motor control which leads to development of dysfunctional movement patterns
- Developing of protective movement and fear of movement causes musculoskeletal impairment

  ROM
  
  Muscle length changes
  
  Strength

  Treat the uninvolved side
Cognitive Restructuring Through Education

• Help patients understand that pain may not be giving an accurate account of their tissues

• There are clear physiological effects and changes in the brain when subjects think differently about their pain. (Flor. Adv Neurol. 2003)

Brain Maps

• The brain maps our experience and the maps represent our skills and our knowledge

• When a skill develops or changes the neuro pools, neurotags will change and the brain maps will change.

• When we approach learning or an experience seriously, we:
  - Attend to the task
  - We practice
  - And we become emotionally involved

Dr. Erthele Chang, Consultant Neurologist and Neurosurgeon
Adapted by Prof. S. Mathew: Brain and the Function -- Part 2

Pain Treatment (Multi-disciplinary)

• Shift from pain focused approach to function-based approach

• Motivation = explain, encourage, motivate

• Coping strategies = anxiety/depression

• Empower the patient
  - Educate on brain and pain so family and patients change their belief system about pain
  - Understand mind and brain are connected
  - Family education between hurt and harm
  - Relaxation — Relaxation — Relaxation
Effective Treatment

- Treat the WHOLE person
- It is stored in the nervous system as emotional and physical wants

**Goal:**
Learn your way out of the disability because you learned your way in

Clinical Value of Physical and Emotional Dualism

- Both need integrating and managing early on in patient care

Can't have one without the other

Understanding Pain and Motor Impairment
Cognitive Restructuring through Education

- Help patients understand that pain may not be giving an accurate account of their tissues
- There are clear physiological effects and changes in the brain when subjects think differently about their pain.
Work-Related Musculoskeletal Disorder (WMSD)

- Systemic response
- Neurological reorganization centrally
- In spinal cord and cerebral cortex
- Neuroplastic reorganization may precede onset of motor decrements

Why Patients Don't Get Well with Repetitive Stress Injuries

- **Signs**: abnormality of the normal homuncular organization of the fingers representation in primary somatosensory cortex
  - Chronic pain, intermittent and vague control problems or somatosensory dysfunction may be early signs of focal dystonia
  - Treatment must consist of discriminative sensory motor skills

Outcomes: Negative Learning

- Important cortical representations shrink and
- Adjacent cortical areas expand and become dysfunctional
- Imbalances develop in neurotransmitters and neurohormones
- Focused attention can be reduced
- Imbalance develops between sensory inputs (feed forward and feedback) and motor outputs
- Sensory system becomes abnormally sensitive (decreased threshold for excitation, chronic pain and/or neuropathic pain)
Aberrant Learning

- Cortical sensory changes after excessive repetitive movement
- Cortical representation reduced receptive field, now very large and overlap adjacent digits and dorsal glabrous surface hand
- Brain can no longer differentiate individual digits and control their movement

Byl, Merzenich, et al. Research

- Change neural structure by attended repetitive practice
- Expansion of cortical representation of digits after sensory attended training program
- Normal receptive fields on hand become smaller with training, more dense and numerous so representation is more specific


Limb Dystonia
Risk Factors Dystonia

- Type A
- Perfectionists
- Long working, under-stress, poor biomechanics

Don't Continue with BAD habits

Neurologically Induced Behavior in Highly Repetitive Task

- Centrally mediated

- Maybe unresponsive to intervention that address only localized injury – Add to program:
  - Laterality
  - Mirror imaging
  - Motor control

Byl's 5 Phases for Treatment of Dystonia

1. Imagine hand or foot are normal
2. Improve sensory discrimination
3. Perform and concentrate on small graded controlled movements
4. Work on sensory motor skills
5. Restore fine motor control

Dr. Nancy Byl, Ph.D., OLY, LGPT, APTA
Professor of Physical Therapy and Health Sciences
CSO/AFSE – Graduate Program in Physical Therapy
University of California – San Francisco
Byl’s Principles of Basic Science to Clinical Learning-Based Training

• Stop abnormal movements
• Attention to movements
• Repetition
• Positive feedback

• Non-stereotypical movements
• Progression of task difficulty to opposite limb
• Practice periods spread out
• Make learning fun

GMIP
(CRPS Research – Mirror Therapy)

CRPS Research

• Altered CNS activity with persistent pain
• Changes cortical topography of involved part
• Relationship between cortical reorganization and pain intensity
• Changes in body schema influenced by pain can change hand performance
• Cortical changes return to normal as pain reduces
• Functions of mirror neurons
CRPS I and II

- Persistent pain, which is disproportionate to the original injury
- Patient reports
  - Extra skin sensitivity (hyperesthesia)
  - Color or skin temperature change
  - Sweating - increase or decrease
  - Edema
  - Decreased ROM
  - Motor planning difficulty
- Non-painful stimuli is painful - (allodynia)
- Swelling or sweating (asymmetry)
- Abnormal movement
- Trophic changes in hair, nail or skin

Clinical Signs

CRPS Patients

- Often tend to neglect their affected limb despite the pain
- Often position it out of field of vision similar to neurological neglect or motor neglect
- Some view limb as foreign or strange or larger than it is
- Recent brain imaging studies show CRPS patients have disrupted cortical reorganization. This can effect how an individual perceives their own body
- Amount of pain and degree of cortical disorganization
CRPS

- Strong negative feeling or strong body dysmorphic

- Novel treatment CRPS –
  - mirror visual feedback
  - motor imagery

Delay in Hand Actions Recognition in People with CRPS

- Disrupted body schema

- Neglect like effect

- Cortical change and perceptual aspects of body sense

Laterality Test

CRPS in Hand Takes Longer to Recognize

- Mentally maneuver own hand to match
- Imagined and actual movement is reaction time (RT)
- Brain activity changes in excitability of spinal motor neuron pool and EMG
- Hand laterality relies on body schema or real time dynamic representation from sensory input ends integrates with motor systems for control of action
Graded Motor Imagery for Pathologic Pain: A Randomized Controlled Trial

- N = 51 patients with phantom limb pain or CRPS I
- Performed 2 weeks each of laterality recognition
- Imagined movements and mirror movements then progressed to PT and ongoing medical care

Moseley GL. Neurology. 2006; Dec 26; 67(12):2129-2134.

Research
Graded motor imagery for pathologic pain: a randomized controlled trial.
Moseley GL. Neurology. 2006; Dec 26; 67(12):2129-2134

Result:
- Pain and Function: There was a main statistical effect on the treatment group but not the diagnostic group
- Mean decrease in pain between pre- and post-treatment for the two groups:
  - Motor Imagery group - 23.4 mm
  - Control group - 10.5 mm
- Improvement function for both groups was similar and was maintained at the 6-month follow-up

**Motor imagery reduced patients' pain and disability with CRPS but the mechanisms of the effect are not clear**

Graded Motor Imagery for Pathologic Pain: A Randomized Controlled Trial

<table>
<thead>
<tr>
<th>Phase</th>
<th>Day 1-4</th>
<th>Day 5-8</th>
<th>Day 8-14</th>
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<tbody>
<tr>
<td>Limb laterality recognition imagined movements</td>
<td>Categories 1-2 (60 trials)</td>
<td>Category 1 (20 trials)</td>
<td>Cat. 1-2 (100 trials)</td>
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<tr>
<td>Motor movements</td>
<td>Cat. 1-2 (60 trials)</td>
<td>Cat. 1-2 (60 trials)</td>
<td>Cat. 1-2 (80 trials)</td>
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<table>
<thead>
<tr>
<th></th>
<th>NNT to get a 50% decrease in pain</th>
<th>NNT to get a 6-point increase in function</th>
<th>NNT for both criteria</th>
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<tbody>
<tr>
<td>Response at post-program</td>
<td>3 (2-6)</td>
<td>4 (2-11)</td>
<td>4 (2-17)</td>
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<tr>
<td>Response at 6-mo. Follow-up</td>
<td>2 (1-5)</td>
<td>2 (1-5)</td>
<td>3 (2-4)</td>
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</table>

Moseley GL. Neurology. 2006; Dec 26; 67(12):2129-2134.
Graded Motor Imagery is Effective for Long-Standing CRPS: A Randomized Controlled Trial

- N = 13 chronic CRPS 1 patients.
- Non-moving, MIP or ongoing management for 12 weeks.
- MIP group – 2 weeks of hand laterality, recognition tasks, imagined hand movement and mirror therapy.


Results

- Mirror Imaging Program (MIP) without movement support. The hypothesis that MIP is more effective than other ongoing medical management.
- 50% of the patients no longer met the criteria for CRPS after 6 weeks of MIP.
- During the program of the MIP and maintained status for at least 6 weeks after completion of treatment.
- There was no change in the controls in any measure.
- Crossover gains in the control group were the same as above for the experiment group.


Progression of Program

- Progression based on:
  - Reaction time is equal to that of the unaffected time for 2 consecutive days
  - Imagined motions do not increase symptoms
  - Imagine moving the limb slowly and to adopt the position in the picture
  - Smoothly return to resting position
  - Imagine doing this with out pain
  - Graded exposure to activity, i.e. Quota based therapy

Tactile discrimination, but not tactile stimulation alone, reduces chronic limb pain


- Chronic pain causes reduced tactile acuity.
- Relationship exist between pain intensity, tactile acuity and cortical reorganization.
- **Results**: Tactile stimulation at 3 months caused decreased pain and increased tactile acuity when patients were asked to discriminate between the type and location of tactile stimuli.

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Tactile Discrimination, but not tactile stimulation alone, reduces chronic limb pain.

**Results:**

*Discriminating the location and diameter of tactile stimuli to the affected limb of CRPS patients can decrease pain and two point discrimination (TPD) threshold*


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<tr>
<th>Sex</th>
<th>Age</th>
<th>Body part</th>
<th>MOA</th>
<th>Dur.</th>
<th>NRS</th>
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*Correlates that the subject reduced analgesic medication during the review period*

CRPS Research – Motor Imagery Program (MIP)

- Graded Motor Imagery is effective for long-standing CRPS.
- A randomized controlled study:
  - 26 CRPS Type I chronic patients s/p non-complicated wrist fx. 6 months
  - Allocated to 2 groups
    - Traditional ongoing therapy
    - MIP program: 2 weeks of laterality, 2 weeks of imagery
    - 2 weeks of mirror therapy
  - Assessments: Initial – 2, 4, 6 and 12 week intervals
  - Outcome measures:
    - Neuropathic Pain Scale (NPS)
    - Swelling
    - Response times to recognize the affected hand

Exercise and Function

- Introduce exercise slowly and start with the least feared movements
- Patient needs to feel in control of what they are doing
- As a therapist, do not harshly challenge the patient’s beliefs about movement and pain
- Explain what happens in a normal limb that is immobilized and then starts to move again
- Understanding information like this helps improve patient confidence with movement

Object Identification
Active Stimulation

- Read Braille and play card game in Braille
- Match symbols, letters, figures, shapes
- Play games with eyes closed – dominos
- Put shapes into matched holes – eyes open and closed
- Choose letters and alphabet in sand
- Find matching objects on floor, sand and beans

Adapted from Nancy Byl
Nontarget Sensory Motor Tasks

- Identify different alphabet letters with eyes opened and closed
- Spell words with alphabet letters - write letters with toes
- Remove small objects from a box and identify and time the task - move objects with toes and feet
- Eyes closed - feel pegs, sense the touch by holding them and put pegs in holes without (no pain or abnormal movement) - attempt with feet
- Increase speed
- With arms resting on thighs, shoulder and hands relaxed - move finger to identify part of the body with light touch or use toe to touch and identify parts of the body.

Research

- CRPS Type I
  - Visual input from moving unaffected limb reestablishes the pain-free relationship between sensory feedback and motor execution

Laterality and CRPS

- Delayed recognition of hand laterality is related to the duration of symptoms and to the pain that would be invoked by executing the movement
- Both involve cortical reorganization of body schema
- Guarding type response occurs upstream from the motor cortex at a motor planning level
CRPS Theoretical Models

- Disruption of sensory cortical processing and shrinkage of cortical representation in the primary sensory cortex. (Juttonen 2002)
- Disinhibition of the motor cortex (Schwenkreis 2003)
- Disrupted Body Schema (Schoebel 2009)

CRPS Research – Mirror Therapy

- A controlled study of the utility of mirror visual feedback in the treatment of CRPS Type I

- Hypothesis:
  - CRPS is a consequence of disruption of central sensory processing and that congruent visual feedback from the moving unaffected limb as provided by a mirror would restore the integrity of cortical processing thereby relieving pain and restoring function in the affected limb

McCabe CS, et al., Rheumatology 2003

CRPS Type I Research – Mirror Therapy

- A controlled study of the utility of Mirror Visual Feedback

- Eight subjects; diseases duration ≥ 3 weeks to ≤ 3 years, allodynia
  - Six weeks study
  - 2 controls:
    - No device to view
    - Non-reflective surface
  - Intervention: Mirror visual feedback
  - Measured outcomes: Pain severity, Visual Analog scales, Vasomotor changes (infrared thermography)

McCabe CS, et al., Rheumatology 2003
CRPS Therapy Treatment Plan

- Motivation, mobilization, desensitization and GMIP
- The process of desensitization may involve both a pharmacologic approach to reduce pain and sensitivity and a process of gentle controlled nonnociceptive stimulation
  - Using heat, massage, pressure, cold, vibration, movement, etc., to help restore normal sensory processing.
- Overcome kinesiophobia (fear of movement)
- Patient needs to begin to move and allow the limbs to be touched

Protocol – CRPS I or II with or without Dystonia

- Limb Laterality Recognition
  - Photographs of right or left limb recognition
  - Positions of limb
  - Imagined movements
  - Mirror movements

  > Daily for 2 weeks each program – 4 times
  > 20 recognitions and time them

Case Study
Disability of the Arm, Shoulder and Hand (DASH)

Pacing/Reactivation

- Make a plan – write it down
- Start with low baselines. Build up tolerance gradually and systematically
- Take regular rests between activities
- Do small amounts often rather than doing everything at once
- Avoid prolonged activity and avoid prolonged rest

- Do not rush to increase activity or exercise levels. Just maintaining the program can be beneficial
- Slow gradual approach enables long-term change

CRPS Success

GMIP
Imagery Training

- **Research**
  Perform imagined motions of 28 pictures of the affected hand
- **Our clinic program**
  Imagine doing the motion regardless of right or left
- Imagine adopting the position shown, 3 times.
- Repeat the task of 28 pictures 3 times per hour 15 min.

Mirror Therapy

- **Mirror box — make your own**
  - 12 X 12 cardboard collapsible box
  - Must have reflective outer surface
  - Don’t have bowed mirror — makes hand look bigger
  - Make sure space is large enough inside
  - Correct illusion
  - Take off watch, ring, sleeve
  - Focus on mirror image

Mirror Exercises

- Exercise cards are selected with the patient
- **Research design:**
  20 copies of pictures of the unaffected hand
- **Our Clinic Program:** either extremity as determined by the exercise card selection, generally 6 to 10 exercises
  - Slowly adopt each position with both hands concurrently 10 times = 60 — 100 motions
  - Try not to exceed 10 per hour
  - Very the context around the patient (music, emotion)
Phantom Limb
Research on Brain’s Paradigm Shift

- Monkeys and human studies
- Sensory inputs from one sense can substitute for another sense
- Cold and vibration on face can mimic the response on the phantom limb
- Why – if phantom hand cortex is denervated, then face input activates

Phantom Limb Pain

Touching specific areas on the face of a person with an amputated arm will often evoke precisely localized sensations in the fingers.


Phantom Limb

- 3 weeks post amputation upper extremity – sensations from ipsilateral face are referred to the amputated limb
  - Ice will elicit cold
  - Vibration will elicit vibration
- This effect caused by sensory input from face invading and activating deafferented hand zones in cortex and thalamus
- See that the phantom limb is moving in response to brain command from the non-involved side
Research

• Ramachandran hypothesized that the disruption of the normal interaction of motor intention to move the limb and the absence of appropriate sensory feedback resulted in phantom limb pain.

• They speculated that visual feedback would interrupt this pathological cycle.

Ramachandran Research

• N = 9
• Mirror – use normal hand
• Eyes open is KEY – later on...eyes closed
• 7/9 - felt limb move with imagery and there was no pain


Phantom Limb Pain
Neurorehabilitation and
Neural Repair

• Arm amputees use mirror reflection of intact arm or leg to get movement of the other limb
• Used for somatosensory deficits
• Increased functional use
• Blinded rating

**Sathian K, Greespan AI, Wolf SL. Doing it with Mirrors: A Case Study of a Novel Approach in Neurorehabilitation. Neurorehabilitation and Neural Repair. 2000; 14 (1) 52-76.
Phantom Limb Pain

• Strong relationship between the amount of plastic change in the primary sensory cortex and the amount of phantom pain. (Flors 1995).

• Interventions that activate cortical areas that subserve the affected limb lead to symptomatic and functional improvements and observable cortical reorganization. (Flors, 2001)


Research

• Neurons in the brain that use to represent sensation in the lost limb were functional but driven by other body parts. Usually parts closest to the amputated limb.

• Patients experiencing phantom pain the sensation can be recreated with stimulating in the brain.

• Phantom sensation could not be elicited in amputees without phantom sensation.

Phantom Limb Pain

• Sensations relate cortical representation or map inside the brain

• Neurological
  - Illusory body experience since change in amputated area

• Migration of neighboring somatosensory receptor sites into these vacant areas
Phantom Arm – Mirror Visual Feedback

- "Paralyzed" in painful position
- Treatment using mirror – see normal hand or foot
- Move normal hand or foot to comfortable resting position - may relieve painful cramps

Mirror Therapy

- Using a mirror enabled amputees to superimpose the visual image of their normal limb to their affected limb.
- Exercises involving the "virtual limb" rapidly decreased pain and phantom spasms in six of twelve cases.

Laterality

Phantom Limb Pain Intervention
“Imaging”

1. Slowly straighten and then bend your arms or legs
2. Point your fingers and toes upward, and then point your fingers and toes downward at the same time
3. Turn your hands or feet in toward each other and then away from each other at the same time
4. Move your hands and feet around in a circle to the left and to the right

Phantom Limb Pain Intervention
Imaging

5. Lift your hands and feet off the table or stool
6. Clench and unclench your fist and toe
7. Spread your fingers and toes and then relax them
8. Point one thumb or toe up and one thumb or toe down then reverse it


CSM 2011
Ramachandran hypothesized that the disruption of the normal interaction of motor intention to move the limb and the absence of appropriate sensory feedback resulted in phantom limb pain. They speculated that visual feedback would interrupt this pathological cycle.

Graded Motor Imagery Therapy

- **Phase I**
  - Discuss disorder – establish rapport
  - Discuss distortion of limbs representation in the brain
  - Understanding what has or has not worked

Graded Motor Imagery Therapy

- **Phase II**
  - Laterality Flash Cards
    - 3-4 times daily for 15 minute sessions
    - Identify right or left limb
  - Timed identification to monitor improvement
  - Decrease time to look at right or left
  - Room identification for right or left in human subjects
  - Circle pictures in magazine
    - Timed and number of correct answers
Graded Motor Imagery Therapy

- Phase III – Mirror therapy
  - Motor imagery tasks in mirror box
  - Motor movement

Program Description (MIP)

- The MIP is a process to "retrain the brain". There are 6 major components to the program.

1. A dedicated client that is committed to a home program utilizing a computer program at a duration of 10 min. and a frequency of 10 X per day.

2. Education to understand "Pain and the Brain": The MIP is a process to "Retrain the Brain". It is essential to have some understanding of brain function to be successful in the MIP program. Each of your sessions will include instruction to understand how one reorganizes the somato-sensory cortex that can change pain representation in the brain.

Program Description (MIP) (cont’d)

3. Laterality training utilizes a computer program "Recognise®" to improve recognition of the involved limb and will occur over approximately a two week period.

4. "Imagined movements" prepare the body for movement and are practiced with either the "Recognise®" program or the use of exercise cards at home for a two week period.
5. Mirror box exercise home program
   • When using the mirror, one can trick the brain into believing that an injured part is actually okay.
   • For example, if the left hand was the problem, it would be hidden and by using the mirror image of the right hand, the brain would construct that the left hand was somehow okay. It signals the brain that the hand is fine and now its time to represent it properly.

   ✔ Clients will generally attend therapy one time per week, for approximately 10 sessions.
   ✔ Equipment requirements: Computer, "Recognise" CD-ROM, Mirror Box

5 Steps to Teach and Upgrade the Patient's Imagery Technique
   • Assess mental capacity to learn imagery technique
   • Establish nature of mental practice
   • Teach imagery technique
   • Evaluate and monitor imagery technique
   • Develop self-generated treatment

Implications on Neuroplasticity for Clinical Practice
1. Client must be committed to learning that education of patients is critical to carry out the task at home
2. Drive spontaneous and purposeful change by attended, repetitive and rewarded behavior
3. By focused, selective and goal-oriented repetitive behaviors, we should be able to reverse negative output

Tips of the Trade

- Graded motor imagery must be graded
- Laterality must show improvement in recognition and speed
- Motor imagery must start thinking about movement with eyes open first then eyes closed
- Movement of uninvolved limb must not cause pain in involved limb
- Mirror work always starts with involved limb in box or hidden from view
Thank You