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Graded Motor Imagery in Hand Therapy Practice

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Graded Motor Imagery in Hand Therapy Practice

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OTD 8494: Doctoral Capstone and Exit Colloquium

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Introduction to Capstone Project

My final culminating project will be focused on Graded Motor Imagery (GMI) and its effectiveness in the hand therapy setting. My capstone experience will be completed at Select Physical Therapy, an outpatient clinical setting under Select Medical where the population served includes adults, older adults, and geriatric patients who suffer from traumatic injuries to the hands, elbows, or shoulders or insidious pain that hinders patients from engaging in various occupations either at home or at work. The Accreditation Council for Occupational Therapy Education focus area is clinical practice.

My Capstone Experience mentor is Christa Riccio, OTR/L. She is an occupational therapist that specializes in hands and upper extremities and has been practicing for over 5 years. She requested that I complete my final culminating project on GMI because it has been a topic of interest for her and she wanted to learn more about it and how to implement the program with her patients who experience functional limitations caused by chronic and acute injuries. The project will include a presentation on GMI and how it can be used for outpatient hand therapy. I will also be providing Neuro Orthopedic Institute Group’s (NOI) ‘Recognise’ flash cards (Neuro Orthopaedic Group, 2021) and a mirror box; images will be included in the appendix.
Literature Review of Capstone Project

GMI is an intervention technique utilized by both physical and occupational therapists for patients suffering from complex regional pain syndrome (CRPS), phantom limb pain, stroke, and chronic musculoskeletal pain (CMP). GMI is defined as “a complex series of treatments including implicit motor imagery, explicit motor imagery, and mirror therapy for targeting neuropathic pain problems” (Moseley et al., 2012, p. 3) and promotes cortical reorganization within the brain’s motor networks (Osborne et al., 2018).

The brain encompasses cortical representations or ‘neurotags’ that are distributed throughout the brain and are believed to be responsible for output when activated (Moseley, 2012). Neurotags include an activation threshold or levels of excitement at which the output is produced and requires activation of the member (involved) brain-cells and inhibition of the non-member (uninvolved) brain cells (Moseley, 2012). For example, a neurotag that excites back pain, or a neurotag that excites familiar smells.

When pain remains constant, the neurotags become sensitized and disinhibited causing pain to become more easily evoked by different internal and external stimuli (Moseley, 2012). Disinhibition causes neurotags to become disrupted and lose precision which could “manifest as spreading pain, pain that moves, or pain that is less precisely defined qualitatively” (Moseley, 2012, p. 26). Disinhibition occurs through cortical reorganization in the primary sensory cortex (S1) (Moseley, 2012). The S1 is responsible for processing somatic sensations (touch, pain, temperature, proprioception, and vibration) (Unknown, 2016). According to the Graded Motor Imagery Handbook, the majority of data was collected from those suffering from CRPS and phantom limb syndrome (Mosely, 2012). In patients who suffer from CRPS, the area S1 that corresponds to the activation of the hand decreases and becomes less precise which explains why
people diagnosed with CRPS “overestimate the size of their affected limb or the feeling of a clenched fist in those with upper limb amputations” (Mosely, 2012, p. 28).

According to Priganc and Stralka (2011), GMI is a treatment technique that uses a “top down” approach to treat chronic pain through cortical reorganization, or in other words, “retrain the brain”. As previously mentioned, GMI includes a series of treatments including implicit motor imagery, explicit motor imagery, and mirror therapy. When used properly, by the end of a GMI treatment patients should be able to use his or her affected limbs with significantly decreased pain or no pain and discomfort (the after-effects of retraining the brain). However, the keyword here is “graded”. This means that based on patients’ pain levels and his or her ability to complete the activities, each portion of the treatment series can be graded up or down to ensure patients master each activity before progressing to the next stage.

Stages of Graded Motor Imagery

Implicit motor imagery or laterality training is the first stage of GMI. It is performed through unconscious discrimination between left and right body parts or movements. This portion of GMI is completed with the use of flash cards, magazine images, or the Recognise application (Neuro Orthopaedic Institute, 2021) that displays different parts of the body that correspond to the patients’ affected limb (a left hand, a right leg, or a neck turned to the right). During this portion of GMI, a patient is shown a group of images that correspond to the affected limb. The patient then must immediately determine whether it is a left or right body part or movement (Moseley, 2012). According to the GMI handbook, average response times greater than 2.5 seconds may indicate difficulty processing the image and incorrect responses (less than 80% accuracy) may indicate disinhibited or decreased precision of the neurotags of the affected limb (Moseley, 2012).
There is more and more evidence being produced which supports practicing left/right discrimination to decrease response times and increase accurate judgements; once the response times and accuracy improves to greater than 90%, the patient can then progress into explicit motor imagery (Moseley, 2012). The idea behind implicit motor imagery is to re-establish left and right concepts in the brain which is why it is the first step of GMI. Priganc and Stralka (2011) state “until patients have an accurate representation of the body, it is counterproductive to progress with cortical retraining”. In this stage, grading includes but is not limited to changing the context of images, response time for each image, number of images, and the time-of-day GMI is completed.

The second stage of the GMI program is explicit motor imagery which involves imagining movements without actually completing the imagined movement. Explicit motor imagery works by disassociating movement and pain through the use of the primary motor cortex (M1) which stimulates the neurotags for movement (Mekonen, 2019). Imagining movements using the affected limb may overstimulate the neurotag causing pain so, it is recommended to begin imagining pain-free movements using the unaffected limb (Mekonen, 2019). The use of explicit motor imagery following implicit motor imagery allows patients to use his or her imaginations without triggering the pain neurotag. “To the brain, imagining movements is the same as doing it” (Mekonen, 2019, p.46).

Once that patient is able to imagine pain-free movements in his or her affected limb, they can then move on to the third stage of GMI which is mirror therapy. Mirror therapy involves the use of a mirror box or full-length mirror; the patient places his or her unaffected limb in front of the mirror and the affected limb inside the mirror box or behind the full-length mirror. The object of mirror therapy is to “trick” the brain into believing the patient has two unaffected limbs. When
the patient moves the unaffected hand in the mirror, an illusion is created that the affected limb is moving without pain (Priganc & Stralka, 2019). Mirror therapy is shown to be successful once the patient is able to move the affected limb without experiencing pain.

GMI has been researched and tested by numerous therapists who have all found positive outcomes after treating patients with chronic pain diagnoses such as CRPS, shoulder pain and frozen shoulder, phantom limb pain, and distal radius fractures. Many of the GMI treatments have been done in conjunction with an established rehabilitation program.

**Distal Radius Fractures and Complex Regional Pain Syndrome**

According to McGee, Skye, & O’Brien (2018), 1 in 5 fractures in older adults occur at the distal radius after low impact injuries to the wrist and hand and could have after-effects that include weakness, immobility, edema, and CRPS. CRPS is a painful disorder that can emerge after a stroke, trauma, or insidiously (Méndez-Rebolledo et al., 2017). It is classified as two types: after a noxious event or after a nerve injury (Mendez-Rebolledo et al., 2017) and affects 1 to 5% of patients after limb trauma and 20% of patients with hemiparesis (Mekonen, 2019).

A systematic review conducted by Méndez-Rebolledo et al. (2017) used 3 studies that compared pain and function in patients with CRPS before and after a complete GMI treatment that lasted up to 6 weeks. It was found that patients’ pain had decreased by up to 25 points on the neuropathic pain scale (NPS) and increased function by up to 3 points on the numeric rating scale (NRS). Swelling and response times for left/right judgment also significantly decreased.

Quintal et al. (2018) conducted a case study using a 39-year-old patient diagnosed with CRPS. The purpose of this study was to demonstrate that some patients suffering from CRPS may need a more tailored program to address experienced pain and functional limitations. According to Quintal et al. (2019), the patient mentioned in this study received traditional
rehabilitation for more than a year with no symptomatic improvement. However, after a 22-month program consisting of traditional rehab in addition to GMI, the patient was able to demonstrate improvements in all areas which eventually allowed him to return to work (Quintal et al., 2019).

Dilek et al. (2017) conducted an 8-week single-blinded randomized controlled trial with 36 participants post distal radius fracture (DRF) who were randomly assigned to a GMI treatment group and a control group who received traditional rehabilitation. It was found that the GMI group showed significant improvements in pain, AROM of the wrist and forearm, and overall function (Dilek et al. (2017). In addition, a case study conducted by Priganc and Stralka (2011) on a 57-year-old woman diagnosed with CRPS after a DRF found a 25 degree increase in active range of motion (AROM) for wrist flexion, extension, and ulnar and radial deviation as well as a 15-pound increase in grip strength and a 9-pound increase in pinch strength after 5 months of GMI. Her GMI treatment was combined with desensitization techniques, cervical and thoracic mobilization, and therapeutic exercises (Priganc & Stralka, 2011).

**Chronic Shoulder Pain Syndrome and Frozen Shoulder**

Chronic shoulder pain syndrome is the third most common musculoskeletal condition and is described as non-specific and persistent pain in the shoulder (Araya-Quintanilla et al., 2020) whereas frozen shoulder is noted with equal limitations in both passive and active range of motion (Sawyer et al., 2018). Frozen shoulder is known to have 4 stages including sharp pain with range of motion (ROM) and at rest during stage 1, freezing and pain during stage 2, completely frozen with limited to no ROM at stage 3, and prevailing stiffness with decreased pain during stage 4 (Sawyer et al., 2018).
Araya-Quintanilla et al. (2020) conducted an open single-arm prospective study involving 107 patients with chronic shoulder pain syndrome who participated in a complete GMI program that lasted 6 weeks. Pain was assessed using the visual analogue scale (VAS), fear of movement was assessed using the Tampa Scale of Kinesiophobia (TSK), and shoulder flexion AROM was assessed before and after treatment. The VAS showed a decrease of 4.2 centimeters, the TSK showed a decrease 17 points, and shoulder flexion AROM increased by 30 degrees at the end of treatment (Araya-Quintanilla et al., 2020).

In a case report completed by Sawyer et al. (2018), a 54-year-old woman diagnosed with frozen shoulder from gradual onset reported pain at rest as 7 out of 10 on a numeric pain scale and had a Shoulder Pain and Disability Index (SPADI) score of 64%. A Fear-Avoidance Beliefs Questionnaire was administered to assess the patient’s fear related to physical activity and work (FABQ-PA and FABQ-W) in which the patient scored 22 for the FABQ-PA and 34 for the FABQ-W which indicates high levels of fear during functional occupations (Sawyer et al., 2018). The patient was also noted to have 61 degrees of active shoulder flexion in the right shoulder compared to 165 degrees in the left shoulder. After a 12-week complete GMI treatment combined with tactile discrimination training, the patient reported her pain as 0 out of 10 at rest and active shoulder ROM increased significantly to 162 degrees. The patient’s SPADI and FABQ scores decreased by more than 50%.

**Phantom Limb Pain**

Limakatsu et al. (2019) defines phantom limb pain as debilitating and is characterized by painful sensations in the missing portion of the amputated limb. A randomized controlled trial conducted by Limakatsu et al. (2019) compared the effects of a complete GMI treatment to routine physical therapy treatments for patients experiencing phantom limb pain using the Brief
Pain Inventory (BPI) as the primary outcome measure after a 6-week program involving 21 adults post unilateral upper and lower limb amputations. According to Limakatsu et al. (2019), the results of this study show that GMI is more effective than routine physical therapy treatments for reducing phantom limb pain.

The articles referenced have shown that the use of GMI to treat chronic pain has been proven effective in terms of decreased pain and increased function during preferred occupations. Previous research also provides justification on how GMI can produce better outcomes in hand therapy and how it could be used when treating patients who are limited functionally due to long-lasting pain.

**Needs Assessment**

In an outpatient hand therapy setting, patients with hand and upper extremity injuries or insidious pain are seen due to the functional and occupational limitations experienced. Numerous patients seen at Select Physical Therapy experience shoulder pain and shoulder injuries as well as finger, wrist, and arm fractures which can lead to the development of guarding behaviors and fear of moving his or her affected limbs to avoid pain. GMI would be a treatment program that would greatly benefit patients who experience both chronic and acute pain after an injury and are no longer able to engage in routine occupations in his or her everyday life. GMI could enable patients to learn how to use his or her affected limbs in desired occupations without triggering a previously experienced sensation of pain.

A needs assessment was completed by analyzing the strengths, weaknesses, opportunities, and threats of implementing GMI in the hand therapy setting. Strength: results from previous studies indicated decreased pain and decreased fear of movement, increased AROM of the affected limb, and increased participation in desired occupations. Weakness:
implicit motor imagery or laterality training was found to be more effective when completed 4-6 times a day meaning the patient would need to purchase the ‘Recognise’ application that corresponds to the affected limb (hands, back, neck, knee, shoulder, or feet) with each application costing $5.99 (Neuro Orthopaedic Institute, 2021). This is considered a weakness due to patients who may not be willing to purchase the application to use outside of therapy, therefore prolonging the GMI treatment series. Opportunity: the use of GMI gives clinicians the opportunity to help patients overcome prolonged pain and fear involved with moving his or her affected or injured limb. Threat: GMI being ineffective due to lack of knowledge on how the program works or the inability to complete the entire treatment series as suggested.

**Goals and Objectives Achieved During the Capstone Project and Experience**

1. Learn and understand different hand and upper extremity injuries and syndromes including how they affect future occupational performance.
   a. Demonstrate proficiency and competency performing evaluation components of the upper extremity.
   b. Demonstrate an understanding of basic principles of cumulative trauma disorders as well as treatment of upper extremity injuries and diagnoses.

2. Learn to provide appropriate treatment interventions to injuries (splinting, wounds care, modalities, etc.).
   a. Demonstrate knowledge and understanding of the use and application of physical agent modalities.
   b. Demonstrate competency in basic joint and soft tissue mobilization techniques.
   c. Successfully fabricate upper extremity orthoses according to clinical standards.
3. Demonstrate appropriate time management by evaluating, assessing, and providing treatments in a timely manner.
   a. Demonstrate the ability to treat and manage a caseload of 10 patients per day including correct documenting procedures according to Select Physical Therapy (SPT) standards.
   b. Demonstrate awareness and compliance with billing and coding standards according to SPT standards.
   c. Demonstrate awareness of insurance/payor constraints, limitations, and discharge planning from initial evaluation.

   a. Provide a presentation on GMI including results from recent studies.
   b. Provide SPT Zephyrhills NOI flash cards for hands and a hand-made mirror box.
   c. Collaborate with my mentor to implement GMI for hand therapy patients with CMP.

Due to the variety of diagnoses seen at SPT, the objectives for goals 1-3 remained in progress throughout my entire 16-week capstone experience and the objectives for goal 4 began during the last four weeks. Additional learning included Certified Hand Therapy “Questions of the Day” which were provided by my mentor and the completion of a resource binder that includes information on different upper extremity diagnoses, a list of interventions/activities that can be completed for each diagnosis, treatment and surgical protocols, what to include in initial evaluations, and patterns for orthosis fabrication. By the end of my capstone experience, I was able to demonstrate competency with treating patients with upper extremity injuries/diagnoses and effectively use GMI as a treatment intervention for patients with CMP. When addressing the identified need, becoming competent in understanding various diagnoses and providing
treatment interventions according to protocol led me to easily determine which patients would be appropriate for GMI. I was also able to provide my mentor with information on how to implement the program with her patients. Although the patients chosen to participate were not able to purchase the Recognise app for his or her own personal reasons, they did agree to participate throughout each treatment session in hopes of seeing improvements in pain levels and AROM. Each patient receiving GMI is currently working to improve his or her accuracy for implicit motor imagery.

**Summary**

During the final 4 weeks of my capstone experience, I was able to collaborate with my mentor to begin implementing GMI with patients experiencing chronic pain and functional limitations. To begin the final stage of my capstone experience, I purchased NOI Group’s ‘Recognise’ flash cards (Neuro Orthopaedic Institute, 2021) for hands to complete the first two stages of GMI: implicit and explicit motor imagery (see Appendix A). I then completed a hand-made mirror box for mirror therapy, the final stage of GMI (see Appendix B). Finally, I provided a presentation on GMI for my mentor and other therapists currently working at SPT Zephyrhills (see Appendix C). This presentation included background information on GMI, how it is used, and its efficacy through recently completed studies. My completed capstone project will be sustained by my mentor through the use of the provided flash cards and mirror box.
Appendix A. Neuro Orthopaedic Institute Group’s Recognise Flash Cards

Appendix B. Hand-made Mirror Box
Appendix C. Graded Motor Imagery Presentation

WHAT IS GMI?

- Complex series of treatments including graded left/right judgement exercises, imagined movements, and the use of mirrors targeting neuropathic pain problems (Mosely, 2012)
  - Positive effects with stroke, CRPS, phantom limb pain, and chronic musculoskeletal pain (Mekonen, 2019)
- Aims to improve cortical reorganization "retraining the brain"
  - Top-down approach to emphasize neuroplasticity (Priganc & Straka, 2010)
- Neurotags- networks of interconnected neurons that are distributed throughout the brain (Moseley, 2012)
  - Responsible for output when activated
  - Requires sufficient activation of member brain-cells and inhibition (precision) of non-member brain cells
WHAT IS GMI? (CONT.)

• Disinhibition- neurotags become disrupted and lose precision
  • Spreading pain, pain that moves, pain that is less precisely defined
• Primary sensory cortex (S1)- responsible for somatic sensations (temperature, proprioception, and vibration)
  • Patients with CRPS tend to overestimate the size of their affected limb
  • Amputees with the feeling of a clenched fist in the amputated limb

WHAT IS GMI? (CONT.)

• Top-down approach to treat chronic pain through cortical reorganization
• Includes:
  • Implicit Motor Imagery
  • Explicit Motor Imagery
  • Mirror Visual Feedback (Mirror Therapy)
• ***Always start away from the affected limb so the patient can experience mastery***
IMPLICIT MOTOR IMAGERY

Tip: Explain to patients that L/R judgements can aggravate pain at first (which is expected), but once the brain learns how to do the task without imagining the movements, the pain will decrease.

Stage 1: L/R Discrimination or Laterality Training
- Unconscious discrimination between right/left movements or body parts
- Response Times:
  - >2.5 seconds may indicate difficulty processing the image
  - <80% accuracy may indicate disinhibited or decreased precision of the neurotags (smudging)
- Practice L/R discrimination to improve response times and accuracy
  - Re-establish L/R concepts in the brain prior to progressing with cortical retraining
- Grading:
  - In app: change image context, decrease response times, # of images, # of times completed
  - Images: complete while listening to different types of music, different emotions

Figure 2.3A Acute left hand injury looking at right hand
Figure 2.3B Acute left hand injury looking at left hand
**Explicit Motor Imagery**

Tip: Progress the patient from vanilla to context images when progressing from IMI to EMI. Monitor symptoms to identify which images are aggravators. Then find the specific image that aggravates symptoms and de-threaten the image!

- **Stage 2:**
  - Imagining movements without completing them
  - The person is aware of themselves thinking about what they are doing
  - Activates the primary motor cortex (M1) which activates the neurotags for movement
    - Engages the brain with contextual and other factors that may contribute to difficulty with movement
    - Movements are organized functionally, not anatomically
      - Drinking from a cup= one brain cell activates elbow flexion, one brain cell activates wrist deviation
• **Stage 3:**
  - General principle: perform movements with both hands, but look at the reflected image of the good hand rather than the bad hand
  - The mirror will give the illusion that the person is looking at the limb that is hidden
  - Brain activation is less during this stage, but more than imagining the movement

1. Have the clinician demonstrate
2. De-threaten the environment
3. Have the patient remove jewelry, watches, and cover tattoos
4. Start with a simple exercise as neurotags may be sensitive

**Tip:** Those who experience the greatest pain relief are those who can imagine using their affected limb. Therefore, patients need to have intact motor imagery before performing mirror therapy!
NEEDS ASSESSMENT

• Strength
  • Positive results after a complete GMI treatment

• Weakness
  • Recognise App $5.99 each (hands, shoulder, back, neck, knee, feet)
  • Should be completed 4-6 times per day

• Opportunity
  • Help patients overcome prolonged pain and fear movement

• Threat
  • Lack of therapists' knowledge causing GMI to be ineffective
• CRPS:
  1. Méndez-Rebolledo et al, 2017 [SR]: Pain decreased by up to 25 points on the neuropathic pain scale (NPS) and increased function by up to 3 points on the numeric rating scale (NRS). Swelling and response times for left/right judgment also significantly decreased (6 week GMI Tx)
  2. Quintal et al., 2019 [CS]: Patient able to return to work after a 22-month program (GMI and traditional rehab)
  3. Priganc and Stralka, 2011: 25 degree increase in active range of motion (AROM) for wrist flexion, extension, and ulnar and radial deviation as well as a 15-pound increase in grip strength and a 9-pound increase in pinch strength after 5 months of GMI

• DRF:
  1. Dilek et al, 2017: 8 week single-blinded RCT- GMI group showed significant improvements in pain, AROM of the wrist and forearm, and overall function

• Chronic Shoulder Pain/ Frozen Shoulder:
  1. Araya-Quintanilla et al., 2020: VAS showed a decrease of 4.2 cm, the TSK showed a decrease 17 points, and shoulder flexion AROM increased by 30 degrees at the end of treatment. (6 week program)
  2. Sawyer et al., 2018: After a 12-week complete GMI treatment combined with tactile discrimination training, the patient reported pain as 0/10 at rest and active shoulder ROM increased significantly to 162 degrees. The patient’s SPADI and FABQ scores decreased by more than 50%

• Phantom Limb Pain
  1. Ukimakatsu et al., 2019: RCT shows that GMI is more effective than routine therapy treatments for reducing phantom limb pain
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