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Integrating Guided Motor Imagery and Cross Education into Rehabilitation: Scientific Review and Clinical Application

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INTEGRATING GUIDED MOTOR IMAGERY AND CROSS EDUCATION INTO REHABILITATION: SCIENTIFIC REVIEW AND CLINICAL APPLICATION

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ABSTRACT

BACKGROUND: Guided motor imagery and cross education are two concepts that build upon motor programs. Guided motor imagery consists of imagining a specific action, thereby activating the respective motor program without an actual movement. Cross education incorporates contralateral training to activate the motor program of an action to the resting limb. These techniques yield neurological actions that can lead to improved performance outcomes when integrated into physical therapy programs. PURPOSE: This literature review investigated guided motor imagery and cross education within the scientific literature, identified and summarized evident themes and provided suggestions for incorporating these methods into rehabilitation programs. METHODS: An electronic search was conducted of peer-reviewed articles on guided motor imagery and cross education and their relation to rehabilitation. DISCUSSION: Despite the paucity of research, evidence exists for the effectiveness of these methods and provides insights regarding how these techniques may be successfully integrated into physical therapy regimens. A summary of evidence and suggestions are provided for physical therapists.

Keywords: Cross Education, Guided Motor Imagery, Physical Therapy, Mirror Therapy

Dedicated to my friends and family

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CHAPTER 1

INTRODUCTION

When a human body performs an action, the movement is selected and preplanned in the brain. Motor programs are the source of every possible movement. However, when a function impairing injury (orthopedic injury, stroke) occurs, quality of daily life is affected. Three types of injuries that affect quality of life are discussed next. Incorporating methods to take advantage of the functions of motor programs, such as guided motor imagery and cross education, can assist in the physical therapy treatments of these types of injuries and restore quality of life.

Stroke, musculoskeletal, and amputation injuries are particularly common events that detract from quality of life. Strokes are the third leading cause of death in the United States, the leading cause of adult disability, and each year 795,000 people experience a new or recurrent stroke.[1] Musculoskeletal injuries, also referred to as orthopedic injuries, are those involving muscles, bones, and joints. Musculoskeletal conditions rank as another leading cause of disability with more than 130 million patient visits to healthcare providers annually in the U.S.[2] These conditions are the number one reason people visit their physician and the incidence is nearly one in two Americans over the age of 18.[2] In the United States, there are nearly 2 million people living with a limb amputation.[3] When one sustains such an injury, quality of life and ability to function is negatively affected, as everyday routines become more complicated and frustrating. In addition to the financial burden these conditions may create, decreased income, due to loss of work time, can compound the problems associated with regaining function and resuming previous activities.

Rehabilitation can positively improve function and quality of life. There is evidence that physical therapy can have a positive influence on quality of life and perceived well-being in a wide range of patient populations requiring palliative care such as cancer, HIV, neurological disorders, cardiopulmonary conditions, mental illnesses and more.[4] Guided motor imagery and cross education are two methods that hold to potential to enhance physical therapy regimens. An extensive review of electronic databases, including PubMed, CINAHL, and SportDiscus suggests that some research has been done to test the effectiveness of these methods as rehabilitation modalities. As relatively few studies address these topics, most published studies involve rather small sample sizes and are relatively short term in duration. Also, there are few articles in existence that summarize and address the practical applications of this research. However, practicing clinicians can benefit greatly from exposure to these concepts, as this approach could foster widespread use in the clinical world. Therefore, this literature review addresses three major types of injuries - neurological (stroke), musculoskeletal, and amputation - and provides evidence-based guidelines on how guided motor imagery and cross education can be integrated into rehabilitation programs aimed at treating such conditions. The findings are summarized below in a manner which practicing clinicians may find valuable.

CHAPTER 2

BACKGROUND

BASIC HUMAN NEUROANATOMY: FUNCTIONAL ANATOMY TO FUNCTION

The Motor Unit

Initiating a movement of the human body takes multiple steps. Each skeletal muscle is composed of hundreds of thousands of smaller parts called muscle fibers.[5] Each muscle fiber has approximately one motor neuron located near the body of the fiber.[5] These neurons are peripheral neurons resulting from the spinal cord.[5] Motor neurons are the elements responsible for triggering a muscle to move. For an action to occur, the brain must send a signal through the spine via efferent pathways to the motor neurons. The neurons then stimulate their corresponding muscle fibers. When the fibers are activated, the muscle acts as a whole unit and performs the intended action.

The group of muscle fibers innervated by a motor neuron is a muscle unit, and the collection of muscle fibers together with their motor neurons are called a motor unit.[5] Action potentials are the signals sent from the brain responsible for initiating movement. A single action potential can be responsible for synchronous activation of hundreds of muscle fibers. Action potentials sent to motor units are responsible for every movement, from making a fist to performing a complicated dance.

Central and Peripheral Nervous Systems

The two parts of the nervous system are the central and peripheral systems. The brain and spinal cord compose the central nervous system, while the peripheral nervous system contains the nerve fibers that branch off of the spinal cord and extend to the limbs of the body. The primary motor cortex in the cerebrum of the brain is one of the principle areas responsible for generating neural impulses that control the execution of a movement.[6] Other regions of the cortex involved in motor function include the posterior parietal cortex, the premotor cortex, and the supplementary motor area.[6] A small area in the back of the brain called the cerebellum is responsible for modifying the motor commands to make the movements more adaptive and accurate.[7]

The corticospinal tract is the only direct pathway from the cortex to the spine and is the main pathway for control of voluntary movement in humans. It is composed of over one million fibers descending through the brainstem and continuing through the spine.[6] The peripheral nervous system is formed as these fibers branch off to continue to the extremities of the body. Motor neurons are these fibers originating from the spinal cord and are also a part of the motor unit. Motor programs are responsible for activating these neurons, which leads to movement.

Motor Programs

The signals sent from the brain to initiate and carry out a movement are called motor programs. Motor programs are “a set of muscle commands that are structured before a movement begins, and that allows a sequence to be carried out uninfluenced by peripheral feedback.”[8] Thus, human movements are preselected and planned by the brain.

Instructions for the motor units' movements are sent as signals through the motor neurons. For example, they provide information on how much the muscle should contract, how fast the action must be, when it should take place, how far a muscle or limb should move and more. Guided motor imagery and cross education rely on the way motor programs function. These theories are relatively new but are being found to have great practical function in daily clinical application.

Guided motor imagery is a complex self-generated cognitive action using sensory and perceptual processes.[9] It is defined as the mental simulation of a specific action without a corresponding motor output, and shares similar mechanisms underlying movement preparation and execution.[10] However, guided motor imagery does not require movement. In order to engage in guided motor imagery, an individual rehearses a situation or action voluntarily in his/her mind with the goal of gaining performance improvements. Imagery is cognitively driven, as the individual focuses on imagining the movement execution. This mental stimulation activates the same motor program and neural pathways for the specific movement.[11] Even though no movement occurs, the signals that contain the instructions for the envisioned movement still activate and travel from the brain to the motor neurons as if a movement were to be performed. During guided motor imagery, neural activation signals do not exceed the threshold levels required to cause muscle fiber activation.

Studies have shown with brain imaging, that when a movement or task is rehearsed mentally, the correlating parts of the brain are activated as if the movements or tasks were actually being performed.[12] Guided motor imagery can also be combined with physical therapy to enhance results.

Cross education describes the increase in voluntary force-generating capacity of the contralateral untrained limb occurring as a result of unilateral motion, such as resistance training.[13] Unilateral motion is when one side of the body moves, while the other remains stationary. When one limb is immobile, but the contralateral limb is resistance trained, the immobile limb increases force generating capacity, despite the fact that it was not trained. This result represents the "bilateral transfer of learning" aspect of cross education.[13] This transfer is thought to occur due to high-force unilateral voluntary contractions affecting the excitability of the spinal motor pathways projecting to the contralateral side.[13] For example, for a limb to be able to resistance train, motor programs have to be sent to that limb. However, these motor programs are also being sent to the opposite limb. Even though one limb is not being activated to move, both limbs are receiving the stimulation.

CHAPTER 3

RESEARCH

GUIDED MOTOR IMAGERY AND CROSS EDUCATION FOR NEUROLOGICAL CONDITIONS

Introduction to Neurological Conditions

Stroke is the neurological condition this paper focuses on. It is a common occurrence for millions of people worldwide, resulting in functional disability and impairment.[14] A stroke occurs when blood flow to the brain is interrupted due to a blood clot in a vessel, or artery, or if a blood vessel breaks.[15] Brain cells begin to die when blood flow is discontinued. This event results in abilities, such as movement or speech, controlled by the affected area of the brain to be lost.[15] The location and severity of the stroke typically correlate to the amount and type of functions lost. While a minor event may result in limb weakness, a severe stroke could lead to paralysis.

In the United States, stroke is the primary cause of long term disability.[15] Approximately 80% of acute stroke survivors suffer from some type of motor impairment.[14] Any type of motor impairment threatens to compromise quality of life, thus recovery is extremely important. Those who suffer from stroke often experience decreased balance, trouble walking, and loss of limb function.

Research on Guided Motor Imagery and Stroke

Guided motor imagery combined with physical training has been found to be beneficial when rehabilitating stroke patients.[16] One study reported post-stroke patients could improve after receiving a guided motor imagery intervention.[14] Thirteen patients, two to eleven months post-stroke, were involved. Eight received guided motor imagery training in addition to general physical therapy, while five received only general physical therapy. Those receiving the additional guided motor imagery training improved significantly more on motor impairment tests, compared to those in the control group.[14]

Another study investigated individuals suffering from brain damage due to a stroke in the middle cerebral region.[16] Participants were separated into two groups. Both groups performed five daily tasks including mobility functioning, balance, and upper-limb coordination combined with one hour of general muscle strengthening and walking.[16] However, one group received guided motor imagery training, in addition to the therapeutic rehabilitation, and was required to imagine performing their tasks. Picture cards were provided to help recall tasks and aide the imagery process. The group receiving guided motor imagery training had higher levels of performance after the one month follow up, compared to the therapy-only group. The authors concluded that guided motor imagery is beneficial for relearning motor functions in post-stoke patients.[16]

Research on Cross Education and Stroke

After a unilateral stroke, hemiparesis commonly occurs and is when one suffers from weakness and impaired motor control on one side of the body.[17] This condition requires mending in order to restore previous quality of life. Due to the unilateral nature of hemiparesis, cross education would likely be a beneficial technique to incorporate in physical therapy, as post-stroke patients can train the stronger side to strengthen the weak side.

A study involved 19 patients who were greater than six months post-stroke with one-sided dorsiflexor weakness.[17] The participants completed a unilateral training program on their less affected side to determine if the effected side would benefit. For six weeks, participants performed maximal isometric dorsiflexion training. Timed up and go test, timed ten minute walk, modified Ashworth Scale, Functional Ambulation Category, Berg Balance Scale, and Fugl-Meyer Assessment were administered one week prior to training and four days following training. When compared to baseline measures, an increase of strength and muscle activation of the more effected, non-trained dorsiflexors was evident.[17] It was concluded that cross education can benefit post-stroke patients suffering from hemiparesis.

Benefits of using Guided Motor Imagery and Cross Education with Treatment of Stroke

Guided motor imagery is beneficial for stroke patients because it allows for no actual movement of a weak or nonfunctioning limb. For example, one’s limbs may not be weight bearing or their hands may be unable to grip. This also allows for extra mental practice and stimulation of the motor programs without causing additional limb and muscle fatigue. No risk of injury is created when using guided motor imagery.

Since the effected side is not being exercised, cross education is also beneficial for stroke patients. The can perform higher intensity exercise much earlier in post-stroke rehabilitation, to gain benefits in the affected, non-trained side. An increased amount of repetitions can also occur without tiring the effected side. Solely focusing on rehabilitating the effected side results in a higher risk of injury and would require slower progression in exercises. Cross education has a very low risk of injury because the intensity performed is very moderate to low.

GUIDED MOTOR IMAGERY AND CROSS EDUCATION FOR MUSCULOSKELETAL CONDITIONS

Introduction to Musculoskeletal Conditions

Musculoskeletal or orthopedic injuries are very common and debilitating. In 2004, four out of every 100 persons reported that they were currently experiencing limitations in their ability to perform daily activities as a result of a fracture and/or bone or joint injury.[2] This reduction in ability results in a drastic threat to quality of life. For an injured adult, taking days off of work affects income, and if living alone, may prevent the ability to carry out personal care. For example, a broken leg affects mobility and may impede the ability to perform activities of daily living, such as being able to bathe properly. A shoulder injury can be devastating as dressing, bathing, cooking, and/or cleaning become increasingly difficult, or impossible, to perform. Therefore, a fast recovery from these conditions is desired and needed.

Research on Guided Motor Imagery and Musculoskeletal Conditions

The effectiveness of guided motor imagery on muscular endurance, dynamic balance, and functional stability over a period of four weeks was assessed in 26 athletes with grade II ankle sprains.[18] Half of the group received traditional physical therapy, while the other half received equal physical therapy combined with imagery rehearsal. The individual imagery sessions required participants to envision the content of the daily physical therapy session completed earlier that day followed by a period of quiet time. The researchers noted increases in muscular endurance in the group combining physical therapy and imagery, compared to the therapy-only group.[18] However, differences between the control and experimental groups, on measures of balance and stability, were not evident.

The effects of relaxation and guided imagery on knee strength, reinjury anxiety and pain following an Anterior Cruciate Ligament reconstruction were examined.[19] Thirty individuals, including seven intercollegiate athletes, were divided into three groups: treatment, placebo, or control. The treatment group received 10 individual sessions of relaxation and guided imagery in addition to six months of physical therapy. In addition to physical therapy, the placebo group was instructed to devote 10-15 minutes visualizing a peaceful scene. The control group only received the normal course of physical therapy. The treatment group had significantly higher knee strength, slightly less reinjury anxiety, and much less pain.[19] Even though this study incorporates the physiological side of rehabilitation, it provides evidence that guided motor imagery enhances a normal physical therapy regimen.

Research on Cross Education and Musculoskeletal Conditions

Cross education, combined with physical therapy, has also been found to be beneficial when treating musculoskeletal injuries. Thirty-nine women over the age of fifty with distal radius fractures were split into two groups of normal physical therapy and therapy combined with unilateral strength training in the uninjured arm.[20] The strength training was performed at home and consisted of exercises such as wrist curls and gripping a soft ball/sponge/play dough. They were also progressive in nature beginning with two sets of eight repetitions and working up to a maximum of five sets and eight repetitions. After a period of twelve weeks, it was found that the trained group was stronger than the therapy-alone group, however, there was no clear advantage in range of motion.[20]

Another study looked at cross education to strengthen the shoulder muscles.[21] An experimental group of thirteen participants received training to perform on one arm only. However, the strength training was performed using resistance tubing at home three times a week, not in a clinical setting. The exercises were chosen to strengthen all muscles surrounding the shoulder and consisted of both dynamic and isometric sets. The control group received no additional training outside their physical therapy regimen. Over a period of four weeks, those who completed the extra strength training, compared to the control group, were found to have overall significant increases in strength of external rotation and internal rotation, but not scapular strength.[21] From this study, it was concluded that an at-home, resistance tube strength training program for one shoulder can produce increases in strength of both shoulders.[21]

Benefits of using Guided Motor Imagery and Cross Education with Treatment of Musculoskeletal Conditions

Unfortunately, rehabilitation is typically delayed as mechanics of the injured limb can be compromised. As guided motor imagery involves no physical movement, it can be used while the limb is still injured, in a cast, or in a sling. It decreases any risk for injury and likely will not interfere with the healing process. For example, if someone has a pulled muscle and cannot walk, the major muscle groups in that leg will start to lose mass, strength, and neural drive.

Cross education is beneficial for very similar reasons. Utilizing it prior to traditional physical therapy methods can aid in preventing major muscle and coordination loss. Since the injured limb is not being used, there is very low risk of further injury or improper healing.

GUIDED MOTOR IMAGERY AND CROSS EDUCATION FOR AMPUTATION CONDITIONS

Introduction to Amputation Conditions

Difficulties that arise due to amputations are not as common as those previously noted, but are still significant and incapacitating. Most amputees report some presence of a lost limb, with most of them suffering from phantom limb pain.[22] Additionally, individuals with damaged afferent or sensory nerves in an intact limb, such as after a spinal cord injury, may experience this phenomenon. The phenomenon can range from non-painful, to slight sensations, to constant severe pain.[22] It can be centralized or spread out, while also being initiated, or exacerbated, by factors such as stress and weather changes. This situation is becoming more prevalent as the current estimation of 1.7 million amputees is projected to double by the mid-21st century due to demographic changes and higher rates of vascular diseases.[22]

Neuromas have been noted as the plausible etiology responsible for phantom limb pain in amputees. Neuromas are created when the peripheral nerves, cut during surgery, start to grow back towards each other. Improper growth results in a formation of tangled knots of neural tissue. These neuromas are known to show spontaneous and unpredictable activity potentially resulting in painful sensations.[22]

Mirror Therapy: Combining Guided Motor Imagery and Cross Education

A multitude of medications have been tried but have not been found as a dependable method to treat the pain sensations. However, a technique comprising guided motor imagery and cross education, mirror therapy, was developed in 1996.[23] Using a mirror beside the intact limb of the one suffering from phantom limb pain, the patient watches it move or stretch. The brain has mirror neurons and is basically "empathizing" with the amputated limb as it is being replaced with the virtual limb.[23] The technique is thought to help by resolving the visual-proprioceptive dissociation in the brain.[23]

Mirror therapy incorporates guided motor imagery as the individual is seeing an image allowing the brain to visualize the amputated limb as intact and moving. Thus, the motor programs responsible for that action are being activated down to the amputated limb. Cross education is also involved in this approach, as the motor programs are being activated for both the intact limb and amputated limb when the intact limb moves.

Research on Mirror Therapy and Amputations

A home-based study, using mirror therapy, was conducted on forty adults experiencing phantom limb pain due to a unilateral amputation.[24] Participants were educated about mirror therapy and asked to treat themselves for 25 minutes a day. Post-treatment was conducted after one and two months. A significant reduction in mean phantom pain intensity was found after each follow-up and the treatment was concluded to be feasible and efficient.[24]

Another study was conducted with eight patients with an above elbow amputation or a complete brachial plexus avulsion resulting in deafferentation and paralysis of the hand.[25] The treatment for this study was slightly different, as their uninjured limb movements were filmed and reflected back into a mirror placed above the missing or injured limb. The movements performed included extension and flexion of the elbow, wrist, and thumb, supination of the forearm, open and close fingers, and grasping objects.

The treatment lasted eight weeks, resulting in a 38% decrease of back ground pain. Additionally, five out of eight participants reported a pain reduction of greater than 30%. This decrease was maintained at four weeks post-intervention in four of the five participants previously noted. However, there was no evidence for long term relief.

Benefits of Using Mirror Therapy with Treatment of Amputation Conditions

A large benefit of using mirror therapy to treat phantom limb pain is the potential to reduce medicinal dependence. If phantom limb pain can be reduced and one can stop taking pain medication, return to their daily activities, and also save money. Mirror therapy does not require any strenuous movement, so there is little to no risk of injury. The method is also simple, costs very little, and can be performed at home.

RECOMMENDATIONS FOR INTEGRATING GUIDED MOTOR IMAGERY AND CROSS-EDUCATION INTO REHABILITATION PROGRAMS

Physical therapists tend to see a majority of common injuries such as total knee replacements, back injuries, and rotator cuff tears. There are plenty of injuries that are uncommon that therapists may only treat periodically. However, there tends to be a large portion of basic exercises that apply to a multitude of various injury treatments. As every injury and patient is different, these exercises are modified to fit each situation. Yet, there is still a common basis or background for similar injuries.

For example, for most knee injuries, therapists focus on improving strength in the leg, flexibility of the knee, and extension of the knee. These main goals occur regardless of what type of injury or situation has occurred. For a lower back injury in the lumbar area, therapists first treat any tissue irritation that could be causing pain. Then flexibility of the lower back is addressed and strengthening the muscles of the core. Trends across treatments are very common and even exist when applying guided motor imagery and cross education to physical therapy.

Using these techniques call for some type of regulation. After summarizing themes throughout the studies used in this paper, five application suggestions have been created. Each suggestion is supported by evidence in the literature and is considered necessary for successful implementation of these modes of treatment. The acronym RANES can be used to easily identify and remember these themes. It stands for relevant, application, novel, environment, and supplement. Below are the suggested guidelines for effective use of guided motor imagery and cross education in treatment of neurological, musculoskeletal, and amputation conditions.

- **RELAVENT:** In the studies discussed in this paper, the tasks imagined during guided motor imagery were the same, or similar, to tasks used for pre- and post-assessments. It was inferred that the tasks performed should be the same tasks that are envisioned during guided motor imagery to gain benefit.[10] Imagining actions that will not be performed as a daily activity or in physical therapy treatment will not provide any increase in ability.

- **ALIGNMENT:** To create the proper illusion for mirror therapy, precise alignment between the proximal limb and virtual image is necessary.[25] Without this alignment, the effects of mirror therapy may be reduced or non-existent. The alignment can be provided by mirror or video, but it must fully replace the vision of the amputated limb.

- **NOVEL:** In contrast to guided motor imagery, cross education works best with tasks that are new to the patient, as there appears to be a greater transfer of performance when exercises are novel and involve more learning.[21] Significant increases are seen when performing new exercises that vary from daily activities.

- **ENVIRONMENT:** Guided motor imagery should be used in a relaxed, quiet, and distraction-free setting. This environmental demand is necessary so the imagery can focus on the task details.[9] A stressed setting does not allow one to concentration, thus the activation of the motor programs for the imagined actions will not occur properly.

- **SUPPLEMENT:** In multiple studies, it is discussed that these techniques should be used as supplemental methods to physical therapy regimens, as they will not provide proper rehabilitation alone.[21,9] The studies state that cross-education should not be a replacement to physical therapy[21] and this limitation can be applied to guided motor imagery as well.[9]

CONCLUSION

These ideas are relatively new to the scientific community, therefore research and supporting evidence is sparse. Researchers investigating these topics conclude that more testing and research is needed and highly suggested. An exact measurement of how much these methods help, for how long, or in exactly what kinds of cases are still unknown. There is no guarantee that guided motor imagery and cross education will provide benefit across all types of therapeutic rehabilitation. However, most of the research included in this review of literature is encouraging that incorporating guided motor imagery and cross education is beneficial to the rehabilitation process.

RANES: relevant, alignment, novel, environment, and supplement are five suggestions to use for clinical application. Each suggestion was deducted and created from the influence of the research. When these are used properly, one has the potential to gain full benefits of incorporating guided motor imagery and cross education into physical therapy.

Guided motor imagery and cross education provide alternative approaches to enhance existing physical therapy regimens, and incorporating these methods cost little to no money. Since guided motor imagery requires no movement and cross education focuses on the uninjured limbs, both methods are extremely safe. When incorporated into mirror therapy, movement is very moderate and also safe. Since larger gains are found when using these approaches, therapy time could be reduced in some cases. Decreased healing time, combined with decreasing pain in some instances, could actually save money and reduce dependence on pain medications. Additionally, these methods are very safe and hold very little risk for increased injury because they either require no movement, or basic movements with a non-injured limb. However, it is not suggested to rely on guided motor imagery or cross education alone for rehabilitation. Gains would not be large enough to compensate for regular physical therapy. Thus, these approaches must be used in conjunction with typical therapeutic rehabilitation.

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