Factors that affect movement

- The interaction of three factors:
  - The task to be completed
  - The environment it is to be completed in
  - The individual who is completing the task

Factors that affect movement

- Movement results from a dynamic interplay between the perception of sensory information, the processing through the CNS, and then the appropriate recruitment of muscles to generate the response
  - Groups of cells (not single cells) are the main units of activity in the nervous system
  - Functional synergies (not single muscles) are the main units of movement
  - The control of movement is distributed
- Changes or disruption to any of these components can potentially affect the ability to generate and coordinate movement

MOVEMENT – An organized system

- **Musculotopic maps** – orderly spatial arrangement between motor pools with the spinal cord and the muscles they innervate.
- **Cortical Motor maps** exist on a gross scale, while the representations of body regions are overlapping, non-continuous, and flexible
- Interconnectivity within the cortex
MOVEMENT – An organized system

We know there is organization of movement recruitment within the motor cortex, the spinal sensory system, spinal interneurons, and spinal motor neurons.


Sensory contributions

- **Sensory inputs stimulate reflexive movements** (spinal cord level of processing)
- 3 major sensory modalities
  - Nociception (pain)
  - Mechanoreception (touch)
  - Proprioception (position)
- Proprioceptive fibers have a specific, organized relationship with the motor neurons of the muscles they sense

Sensory contributions

- CNS reorganization occurs in response to musculoskeletal dysfunction
- Can be **adaptive** or **maladaptive**
- Changes in sensory input have been shown to produce alterations in the organization of motor activity leading to dysfunctional movement patterns
  - Examples: Changes in motor recruitment following ligament injury or the changes in motor recruitment in patients with pain symptoms
Movement control - How does this work?

- Control of movement involves a connected neural network of brain regions that select, coordinate, sequence, and refine muscle action.
- The regions are intrinsically connected but there is evidence that each individual region carries out distinct motor functions.
- Lateralization is the term that defines the functional and structural asymmetries between hemispheres found in the brain.


Movement control - How does this work?

- Inter-hemispheric connections between primary motor regions are important for selecting movements that result in the execution of complex actions.
- Inter-hemispheric communication consists of a complex balance of facilitory and inhibitory interactions, and the interactions vary with task complexity.


Movement control - How does this work?

- Some degree of inter-hemispheric inhibition is necessary to prevent interference between the two cortices.
- Inter-hemispheric inhibition increases during tasks where each limb has a different movement goal (independent spatial-temporal paths).
- Reduced motor performance has been identified in individuals with both an increased and a decreased amount of IHI.

Movement control- How does this work?

- Physical therapy is based on the science of movement
- Our job is to restore movement to maximize function
- Our patient evaluation and examination helps us to determine what patient specific components are contributing to their movement disorder (loss of function)
- Our understanding of movement control and motor learning drives our treatment intervention based on the deficits (impairments and functional limitations) we identify

Putting it all together -

- Optimal movement is based on both feedback and feedforward processing
- Rehabilitation interventions that attempt to maximize cortical neuroplastic changes have the greatest potential for success in motor dysfunction.
- Motor learning is task specific

Van Viet PM, Heneghan NR. Motor control and the management of musculoskeletal dysfunction. Man Ther. 2006;208-213.

Putting it all together

- PT can restore feedforward mechanisms through task specific training (training of a novel motor task)
- Task practice should be varied to ensure the cortical connections necessary for different task demands are developed and strengthened
- Practice has been associated with an increase in the strength of the functional connectivity within the motor regions
- Practice should be sufficient to cause changes in cortical activity

Van Viet PM, Heneghan NR. Motor control and the management of musculoskeletal dysfunction. Man Ther. 2006;208-213.
Putting it all together

- Anticipatory postural adjustments can be re-trained choosing an amplitude of movement that is **just beyond the patient’s control** (this challenges the CNS to increase postural activity)
- **Goal oriented training**, or training the involves **cognitive effort** impacts the extent of cortical neuroplastic changes
- Quality of training is more important than the volume (want to minimize fatigue and pain)
  - Change has been shown to take place with **60 in session repetitions** (approximately **10 to 15 minutes of training** – more repetitions did not change the outcome)


The goals in musculoskeletal rehab-

- **Restore ‘normal’ motor strategies** through sensory and motor skill training (reorganization is reversible)
- **Ours in 2 stages:**
  - **Within session** (early fast learning stage which results in considerable improvement in performance)
  - **Across session** (slower learning stage which results in continued evolvement of neuroplastic change)
- **What to identify interventions that:**
  - Enhance cortical excitability and promote reorganization
  - Promote sensorimotor control strategies
  - Increase function

Optimizing success

- **Skill or precision tasks** facilitate cortical neuroplastic changes (early learning stages to incorporate **performance of a movement component** rather than a sequence of movements)
- Pain can hinder motor learning, suggesting training should be performed in a **pain-free** manner to optimize success (patient specific mode, intensity, frequency)
- Novel motor skill training may **reduce** the risk of further **maladaptive neuroplastic changes** associated with pain
- Slowly increase the **complexity of the task** to encourage **cognitive effort** and enhance neuroplastic changes
Optimizing success

• **Repetitive practice** of functional movement
  – Part and whole practice
  – Use of mental imagery
  – Repeat movements in varying contexts

• **Focus of attention**
  – **External** (affect of the action, what needs to be done)
  – **Internal** (action itself, how a movement needs to be executed)
  – Role of FOA in phases of learning (coordination; control; skill)


Defining what we do-

• Somatosensory training (conscious proprioception)
  – **Kinesthesia and joint position sense training**: postural alignment, ability to detect motion, ability to recreate joint position
  – **Strengthening exercises**: isometric, eccentric, isokinetic training, co-activation training

• Neuromuscular training (unconscious proprioception)
  – **Joint stability and feed-forward control**: reactive muscle activation exercises

Hagert E. Proprioception of the wrist joint: a review of current concepts and possible implications on the rehabilitation of the wrist. JHT. 2010.

Desensitizing the CNS in chronic pain

• **Cognition targeted exercise therapy**
  – **Exposure without danger** (stopping the take over of the amygdala, hippocampus, and anterior cingulate cortex)
  – **Graded, repeated exposure** treatment model
  – Other components:
    • Prescription is not determined by pain symptoms (shift of focus)
    • Emphasis is on patient perception
    • Stress is not avoided but balance

Putting it to practice

Patient Cases

Patient Case 1

• 23 year old female graduate student with complaints of low back and left LE and thigh pain. Previous history includes a lumbar laminectomy and fusion at L5S1 4 years prior from an injury sustained during a basketball game. Current symptoms, progressively increasing over past year, include pain ranging from consistent localized low back pain 2/10 to 8/10, referring to her posterior and anterior thigh.

Patient goal

• Patient goal is to be able to stand for longer periods of time, she is currently able to tolerate <10 minutes of standing without aggravation of pain symptoms.
Examination findings:

• Lumbar ROM increases pain symptoms (flexion ++, extension ++++, SB R>L +, R rotation ++)
• Neural tension testing + on L
• Segmental hypermobility noted at L3/4 and L4/5 with instrumented fusion at L5/S1

Patient Case 2

• 29 year old male with a 3 year history of R ankle pain and instability in addition to R knee pain. Past history includes multiple ankle sprains (2 to 3 per year). He is unable to participate in sports related activities and has continual foot pain with work related activities.

Patient goal

• Patient goal is to be able to run with confidence (fear of ankle giving way) and without an aggravation of ankle and knee pain symptoms
Examination findings:

• Positive talocrural instability tests on R
• + navicular drop and too many toes sign
• + findings of poor motor control and coordination in functional movement screens (squat, single limb stance, single limb stance)
• Primary loading through the rearfoot with callus formation at heel and lateral border of foot