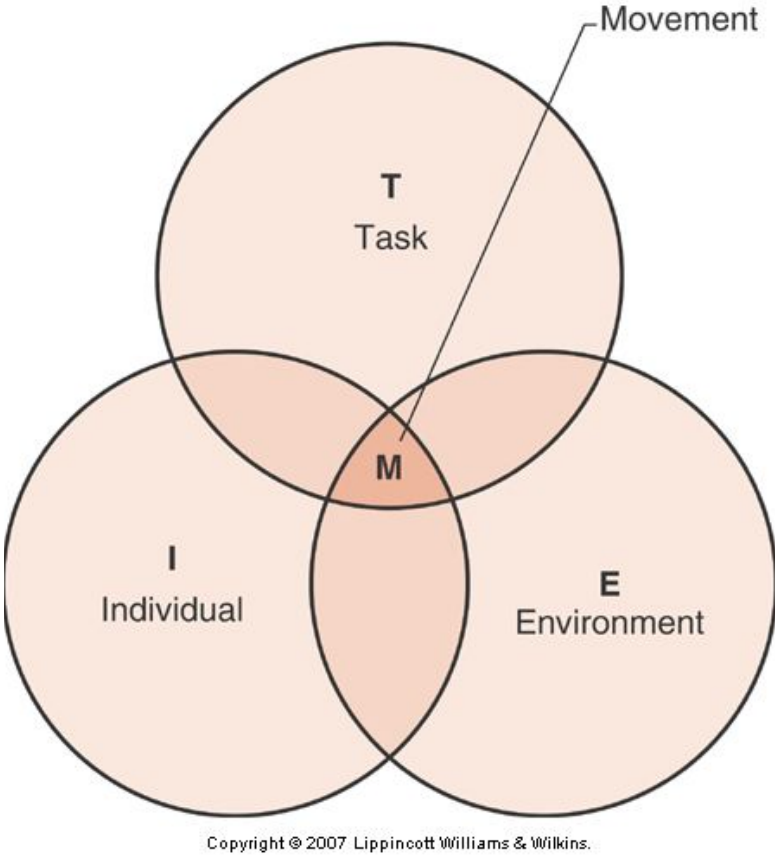
Factors that affect movement



- 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

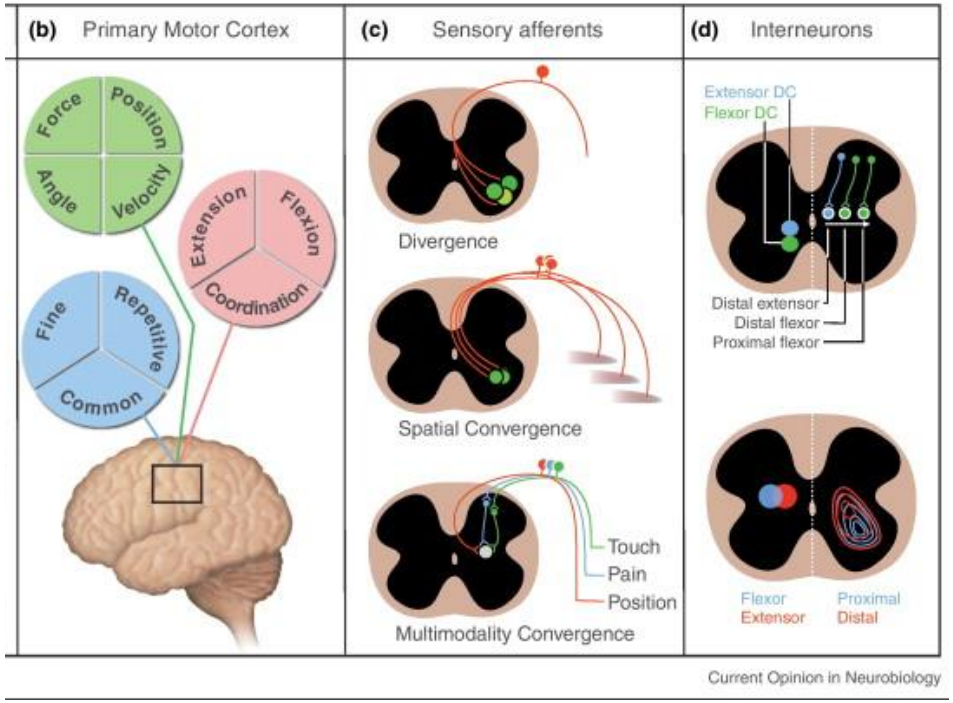
Factors that affect movement

- 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

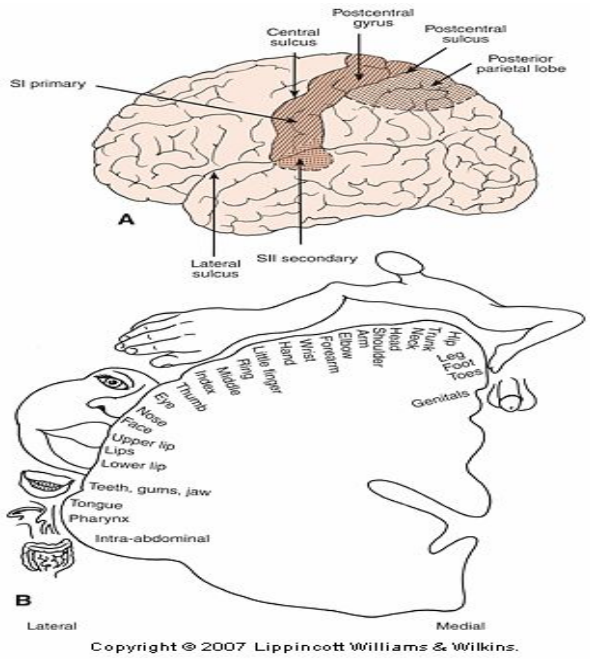


We know there is organization of movement recruitment within the motor cortex, the spinal sensory system, spinal interneurons, and spinal motor neurons.

Levine AJ et al. Spatial organization of cortical and spinal neurons controlling motor behavior. Current Opinion in Neurobiology. 2012;22:812-821.

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.

Barber AD et al. Motor dexterity?: evidence that left hemisphere lateralization of motor circuit connectivity is associated with better motor performance in children. Cerebral Cortex; 2012;22(1):51-59.

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

Fling BW, Seidler RD. Task dependent effects of interhemispheric inhibition on motor control. Behavioral Brain Research. 2012;226:211-217.

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

Fling BW, Seidler RD. Task dependent effects of interhemispheric inhibition on motor control. Behavioral Brain Research. 2012;226:211-217.

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**

Boudreau SA et al. The role of motor learning and neuroplasticity in designing rehabilitation approaches for musculoskeletal pain disorders. Man Ther. 2010; 15:410-414.
Van Vliet 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

Boudreau SA et al. The role of motor learning and neuroplasticity in designing rehabilitation approaches for musculoskeletal pain disorders. Man Ther. 2010; 15:410-414.
Van Vliet 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)

Boudreau SA et al. The role of motor learning and neuroplasticity in designing rehabilitation approaches for musculoskeletal pain disorders. Man Ther. 2010; 15:410-414.

The goals in musculoskeletal rehab-

- **Restore 'normal' motor strategies** through sensory and motor skill training (reorganization is reversible)
- Occurs 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)

Snodgrass SJ et al. Recognizing neuroplasticity in musculoskeletal rehabilitation: a basis for greater collaboration between musculoskeletal and neurological physiotherapists. Man Ther. 2014.

Defining what we do-

- Somatosensory training (conscious proprioception)
  - **Kinesthesa 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

Nijs j et al. Exercise therapy for chronic pain: innovation by altering pain memories. Man Ther. 2014.

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 an 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