Neuromodulation: Harnessing Neuroplasticity with Brain Stimulation and Rehabilitation

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Course/session description: This session will describe forms of non-invasive and invasive brain stimulation as it relates to rehabilitation in different neurologic diagnoses across the lifespan. The methods covered in this session will include: transcranial magnetic stimulation (TMS), repetitive TMS (rTMS), transcranial direct current stimulation (tDCS), deep brain stimulation (DBS), and vagal nerve stimulation (VNS). The advantages, disadvantages, safety principles and risk factors associated with each form of brain stimulation will be identified. The concepts of excitability, inhibition, facilitation and neuroplasticity will be discussed. Finally, current applications of brain stimulation methods in rehabilitation research and future impact in clinical practice will be explored.

Course/session learning objectives:
At the completion of the session, participants will:
1. Be familiar with forms of non-invasive and invasive brain stimulation
2. Be able to identify the safety and feasibility of each technique
3. Understand current issues regarding dosing parameters of brain stimulation
4. Translate brain stimulation research into clinical implications

Course outline:

1. Introduction
   a) What is neuromodulation?
   b) Current tools for brain neuromodulation:
      • Non-invasive: transcranial magnetic stimulation (TMS), repetitive transcranial magnetic stimulation (rTMS), transcranial direct current stimulation (tDCS), transcranial alternating current stimulation (tACS), theta burst stimulation (TBS), ultrasound (US)
      • Non-invasive: deep brain stimulation (DBS), vagus nerve stimulation (VNS)
   c) Mechanisms of action of neuromodulation tools
   d) Safety considerations

2. How and why can the brain be downregulated? Dystonia as an example
   a) Dystonia and the concept of decreased inhibition
b) **Downregulation tools for dystonia**
   - tDCS
   - rTMS

c) **Potential targets and outcomes for neuromodulation interventions in dystonia**
   - Primary motor cortex, premotor cortex, cerebellum

3. **How and why can the brain be upregulated? Stroke as an example**
   a) **Typical Development**
      - Corticospinal Tract Development- Competitive Withdrawal
        - Neural Plasticity
          i. Defined: Any observable change in neuron structure or function
          ii. Behavior is not neural plasticity
          iii. Not all plasticity is “good”
      - Hebbian Postulate – “Cells that fire together, wire together”
      - Potentiate versus Depress
   b) **Corticospinal Tract Projections**
      - Crossed Corticospinal Tract Integrity
      - Ipsilateral Tract Reorganization
   c) **Double-disablement**
      - Adult Stroke Models
   d) **Tricky Triad in Pediatric Stroke**
      - Interhemispheric Inhibition
      - Doubly-Disabled
      - Developmental Disuse
   e) **Consideration of forms of non-invasive brain stimulation researched in adult and perinatal stroke with resultant hemiparesis**
      - rTMS as an intervention
      - tDCS as an intervention
      - Synergistic Applications of Neuromodulatory Interventions and Non-Invasive Brain

4. **Hijacking neural firing patterns and harnessing neuroplasticity to improve motor function**
   a) **The neuronal basis for neuromodulation approaches (harnessing synaptic, homeostatic and non-homeostatic plasticity)**
      - changing the excitability (facilitation/suppression) of neural elements and networks
altering neuronal firing rates (increased/decreased)
altering neuronal firing patterns (spatial, temporal and frequency domains)

b) The Rate vs. Pattern Hypothesis in Parkinson’s disease

c) Deep Brain Stimulation in Parkinson’s disease: Restoring function or functionality?

- DBS – mechanisms of action (the “informational lesion”)
- The “ripple effect of DBS”
- DBS for Parkinson’s disease
  - What motor features are improved with DBS?
  - What motor features are resistant or worsened by DBS?

Deep Brain Stimulation for Dystonia

- The homeostatic response pattern seen in healthy adults is altered in dystonia. Using DBS to treat abnormal plasticity.
- DBS for dystonia
  - What motor features are improved with DBS?
  - What motor features are resistant or worsened by DBS?
- DBS for dystonia – mechanisms of action?

d) Advances and new targets for DBS

- Closed-loop stimulation (movement- or brain activity-related stimulation)
- Coordinated Reset (neuroplastic effects DBS)
- DBS for stroke, obesity?

f) Neurorehabilitation as a critical adjunct to DBS therapy

5. Where are we now, where are we going, and how do we get there?

a) How close are we?

- Neuromodulation has the potential to prime rehabilitation effects
  - Vagus nerve stimulation (VNS)
    - Animal model
    - First in human results
    - Pilot efficacy
  - Current psychiatry model
    - Clinics, fee for service
  - Commercial availability
    - Self-treatment

b) Considerations to move forward

- Responders / non-responders – may be helpful to predict response
o What factors should be measured?
  • Mechanism of Action
    o Are assessments measuring what is changing?
  • Vision for the future
    o Precision medicine/rehabilitation = Individualized approach

References


