Objectives:

1) Participants will be able to identify motor learning principles that should be considered when designing PT interventions for persons with neurologic disease or damage.

2) Participants will be able to identify patient characteristics that should be considered when applying motor learning principles to PT interventions for persons with neurologic disease or damage.
Motor learning underlies rehabilitation

Practice → New Behavior → Consolidation → Retention

Motor Learning

implicit vs. explicit
procedural vs. declarative

Kleynen et al. 2014; Kleynen et al. 2015; Taylor and Ivry 2014
Procedural Learning

- Develops slowly
- Requires repetition
- Traditionally thought to not require awareness, attention or other higher cognitive processes, however, because learning exists on a continuum, it is difficult to find tasks where this is completely true

Declarative Learning

- Results in knowledge that can be consciously recalled
- Significant repetition can move declarative learning into procedural knowledge (e.g.- initially patient has to tell themselves each step of a transfer, but eventually, with enough practice, they can just complete the transfer without consciously going through the steps)
- Traditionally thought to require awareness, attention or other higher cognitive processes, however, because learning exists on a continuum, the level of awareness varies
Different forms of motor learning fall on different parts of the continuum

More Implicit

Stereotypical sensorimotor adaptation function

Taylor and Ivry 2014

Different forms of motor learning are impacted differently by instruction

Implicit Sensorimotor Adaptation

Explicit Strategic Learning

Taylor and Ivry 2014; Mazzoni and Krakauer 2006; Morehead et al. 2015; Morehead et al. 2017
Different forms of motor learning engage primarily different areas of the brain

Implicit Sensorimotor Adaptation

Explicit Strategic Learning

- Use-dependent learning
  - repetition-based
  - Hebbian learning??

- Reward based learning
  - dopaminergic systems??
  - basal ganglia??


Tasks can involve multiple forms of learning

McDougle et al, 2016
The instructions given can influence how much one form of learning contributes.

French et al, 2018
What do these types and forms of learning all have in common?

Participants make and correct errors

Practice in situations that reduces errors results in less retention

(Williams et al, 2016)

(Marchal-Crespo et al, 2017)
Split-belt treadmill
- Two treadmill belts controlled by two independent motors
- Legs can be made to move at two different speeds

This type of learning is thought to be quite implicit

Resistance Paradigms

Resisting the lower leg during swing


**Error Augmentation**

- If the stroke survivor has the capacity to use trial & error practice to correct gait deviations, why don’t they?
- **What is an error to the damaged nervous system?**
• Error and error correction appear to be important in the process of learning in both neurologically intact subjects and those with neurologic damage

• Movements that appear “erroneous” to the observer may not be detected by a damaged nervous system (“new normal”) and those errors may need to be augmented in order for typical trial and error practice to occur

Considerations for practice with error:
• Error size and number of errors
  • Errors that are too large may limit learning (Sanger, 2004; Guadagnoli and Lee, 2004)
  • Too many errors may limit learning (Domingo & Ferris, 2010; Guadagnoli and Lee, 2004)

• Task accomplishment
  • What is task completion for walking?
    • Continuous reciprocal stepping?, positive step lengths?, plantar surface contact?, limb support during loading? All of these?
Considerations for practice with error:

- Error size and number of errors
  - Errors that are too large may limit learning \((\text{Sanger, 2004; Guadagnoli and Lee, 2004})\)
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- Task accomplishment
  - What is task completion for walking?
    - Continuous reciprocal stepping?, positive step lengths?, plantar surface contact?, limb support during loading? All of these?
  - For reaching?
    - Make contact with object on at least 2/3 of trials? complete at least ½ of trials for the complete task?
• Encourage students to identify *a priori* the size and number of errors that would indicate that the task is too challenging

• This requires them to identify what it means to accomplish the task

• Example: If patient kicks the box on the obstacle course more than 50% of the time, box height will be reduced.
Guidance Assist-as-needed Unassisted Error augmentation

Variability

At the task level At the movement level

Based on ideas from
Guadagnoli and Lee, 2004; Winstein et al, 1994

How does this relate to typical concepts of practice structure discussed in motor learning (e.g.-blocked vs variable/random practice)?
At the task level

Variable practice

At the movement level

Blocked practice

What about the error and variability occurring at the movement level?

Variability/Error relative to Practice Structure

Discuss with students:

• By structuring practice such that there is variability at the task level, they are also achieving variability at the movement level.

• Blocked practice that results in movement variability of one task.

• This may be appropriate if errors are too many/too great when practicing with substantial task variability or when patient requires guidance in order to complete movement.
Guidance Assist-as-needed Unassisted Error augmentation

Trial and Error Practice

Based on ideas from
Guadagnoli and Lee, 2004; Winstein et al, 1994

Feedback/Instructions

More Implicit More Explicit

< cognitive resources > cognitive resources
Cognitive deficits may influence ability to learn more for certain forms of learning than others.
<table>
<thead>
<tr>
<th>More Implicit</th>
<th>More Explicit</th>
</tr>
</thead>
<tbody>
<tr>
<td>“walk” (e.g.-no instruction)</td>
<td>“I want you to try to step over the obstacle by bending your hip and knee and not by swinging your leg around the obstacle”</td>
</tr>
</tbody>
</table>

**Summary**

- There are different types and forms of learning
- Error and error correction are critical for learning and treatment should be structured with error in mind
- Interactions between patient characteristics and type/form of learning may influence learning
- Feedback and instruction influence the type of learning and this should be considered when structuring practice (see point 2)
Cerebellar Damage/Disease

Motor Learning

Implicit Sensorimotor Adaptation  Explicit Strategic Learning

Taylor and Ivry 2014; Bastian 2008; Morton and Bastian 2006
- Damage to cerebellum impairs motor learning and adaptation (Horak & Diener, 1994; Lang & Bastian, 1999; Morton & Bastian, 2006).

**UE example**

*Lang & Bastian, 1999*
Gait example

- Persons with a cerebellar disorder have difficulty controlling interaction torques (Morton et al, 2004)

- Those with cerebellar damage tend to do worse when multiple degrees of freedom need to be controlled simultaneously (Charles et al, 2013)
• Difficulty with adaptation and learning and deficits in controlling multiple degrees of freedom impact the treatment planning concepts discussed previously

• Variability and trial and error practice may not be as useful in those with cerebellar disease/damage.

• Treatments that increase interactions torques (e.g., moving fast) may not be as useful in those with cerebellar disease/damage if result is too many/too large error.

Summary

• Damage to the cerebellum negatively impacts more implicit forms of motor learning such as sensorimotor adaptation. Discuss this with students relative to considerations of what and how to practice

• Damage to the cerebellum results in difficulty controlling multiple degrees of freedom and this must considered when thinking about error number and size
REFERENCES


