IMPLICIT SEQUENCE-SPECIFIC MOTOR LEARNING IN INDIVIDUALS WITH CHRONIC STROKE : SPATIAL AND TEMPORAL ACCURACY

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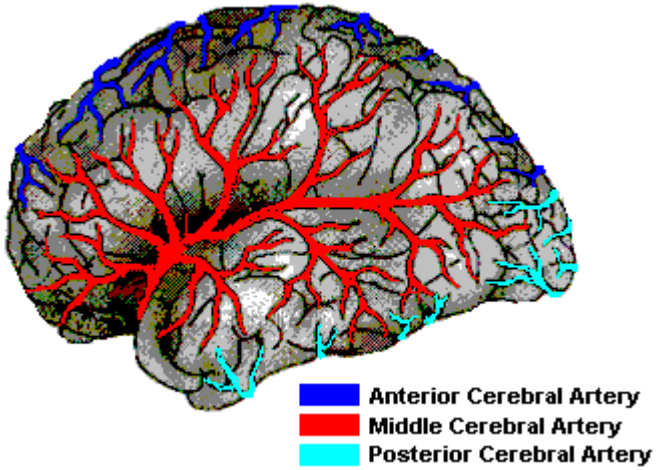
Overview

- Background & Purpose
- Methods
- Results
- Discussion
- Implications for Physical Therapists
- Q & A

PURPOSE

The purpose of this study was to verify if sequence-specific implicit motor learning occurs in individuals with chronic middle cerebral artery (MCA) stroke and to investigate the affect of an MCA stroke on the spatial and temporal components of implicit learning on a sequence-specific motor task.



BACKGROUND

Stroke - Burden of Disease

- Leading cause of adult disability in North America[1]
- Affects over 300,000 Canadians[2]
- $43 billion yearly burden in USA[3]
- 67% left with permanent disability[4]
- 60% have impaired function of their hand[4]
- Self reported decrease in Quality of Life[1]

Study Rationale

- MCA is the most common site for infarct[5]
- Rise in the incidence of stroke with an aging population[2]
- Need effective rehabilitation techniques focused on improving motor function
  - As the ability to learn motor skills is essential for rehabilitation

Motor Learning

Motor Learning:

"A set of processes associated with practice or experience leading to relatively permanent changes in the capability for responding." [6]

Learning

Two components:

- **Explicit learning** - ability to accurately recall information even after one exposure[7]
  - Consciously accessible via recall memory
  - Used in cognitive processes
  - Stored in the medial temporal lobe

Learning

- **Implicit learning** - ability to acquire complex information without awareness of what has been learned[8]
  - Develops over time with numerous exposures to information or practice of a skill[8]
  - Distributed throughout various regions of the cortex[9]
    - Cerebellum[7]
    - Sensorimotor cortex[8,10]
    - Supplemental motor cortex[8,10]
    - Prefrontal cortex[8,10]
    - Thalamus[8,10]
    - Basal ganglia[8,10]

    Areas supplied by the MCA[11]
  - Implicit learning is an element for motor learning[8]

How Do You Teach Someone to Walk?

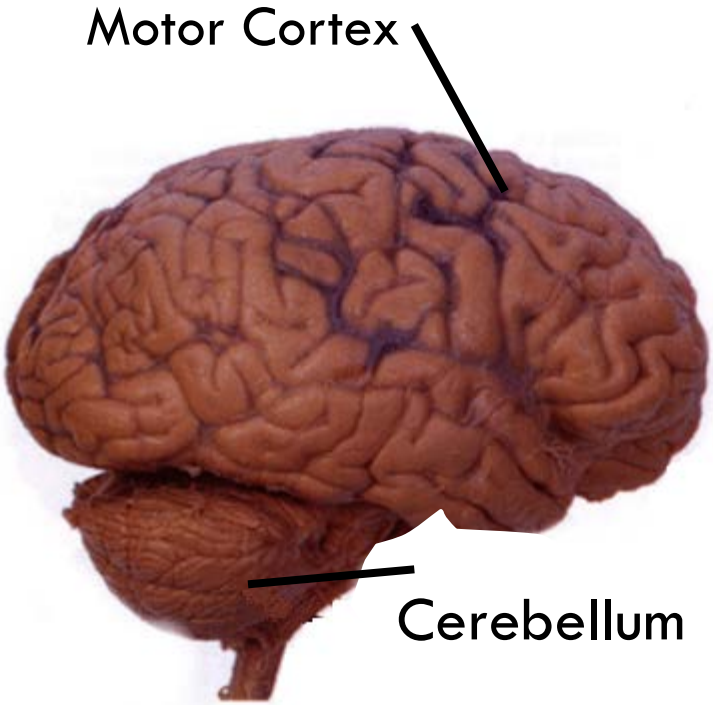
Explicit Instructions – At toe off, activate hip flexors to accelerate limb through first 20 degrees of hip flexion. At this point, allow momentum to carry limb until hip is at approximately 20 degrees of flexion. During this time, engage tibialis anterior to dorsiflex….

Implicit Instructions – Give it a go!

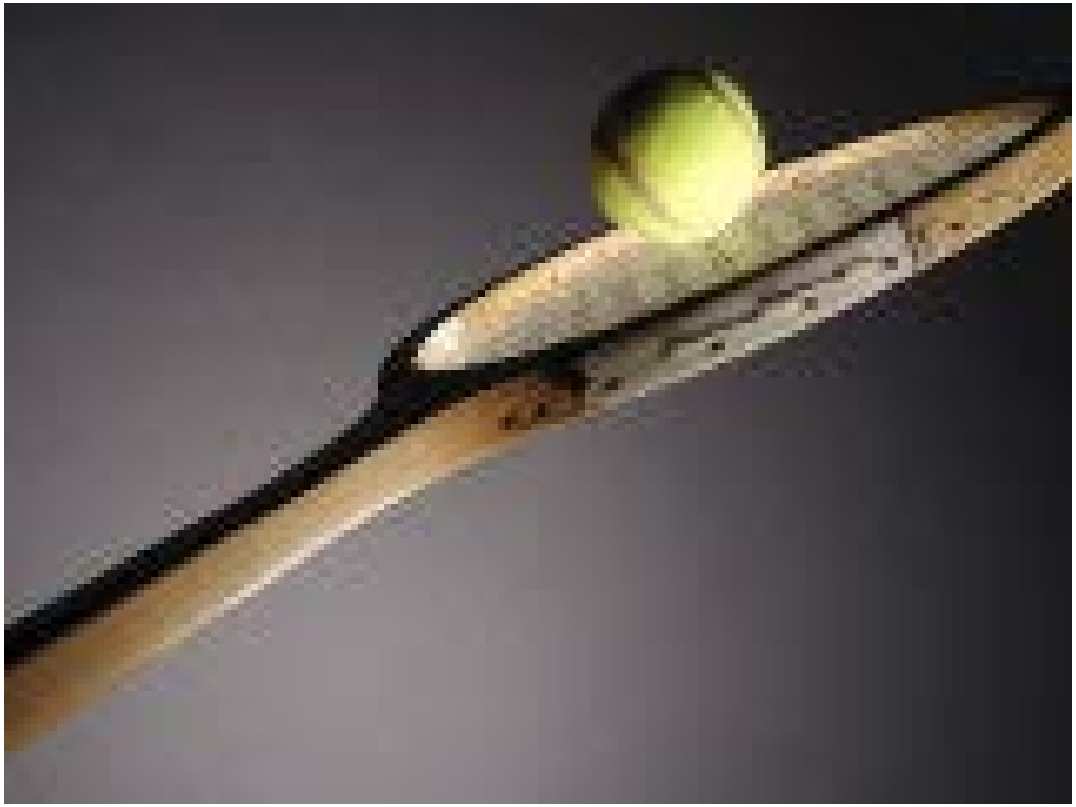
Implicit Motor Learning

Two distinct components:

- **Spatial Accuracy**[12]
  - Ability to locate objects in space or direct extremities to the correct location
  - Involves the motor cortex
- **Temporal Accuracy**[12]
  - Relates timing of movements
  - Involves the cerebellum



Spatial vs. Temporal Motor Learning



Spatial: Getting the racket into the same space as the ball

Temporal: Swinging the racket at the right time to match the speed of the ball

Combined = Right Place at the Right Time

Implicit Motor Learning in MCA Strokes

- Little research has been done to determine the effect of MCA strokes on the temporal and spatial components of sequence-specific implicit motor learning
  - may be referred to as implicit learning
- Cerebellar infarcts showed:[14]
  - Temporal accuracy impaired
  - Spatial accuracy improved
- More research into sequence-specific implicit motor learning is warranted to enhance treatment strategies

Relevance for Physical Therapists

Sequence-specific implicit motor learning…

- has been demonstrated in people with MCA infarcts[7,13-15]
- has been demonstrated without explicit information[15]
- may be disrupted if explicit information is provided concurrently in stroke subjects[14]

Study Aim and Hypothesis

Aim:

- Examine changes in temporal and spatial accuracy of sequence-specific implicit motor learning in individuals with chronic stroke in the MCA distribution

Hypothesis:

- Sequence-specific implicit learning will be demonstrated with a difference in spatial versus temporal accuracy

METHODS

Present Study

- Present study is part of a larger study currently in preparation entitled "Promotion of Brain Reorganization after Stroke" (Boyd & Eng et al., 2011, Grant # G072750:PILAB)[16]

Ethics

- Ethics approval from the UBC Clinical Ethics Research Board

Study Flow Chart

Participants recruited from:
- GF Strong
- VGH
- Lion's Gate
- Dr. Eng's database

Screened with inclusion & exclusion criteria

Undergo specific tests:
Fugl Meyer
Frenchay Aphasia Screen
MOCA

If acceptable:
Read & sign informed consent

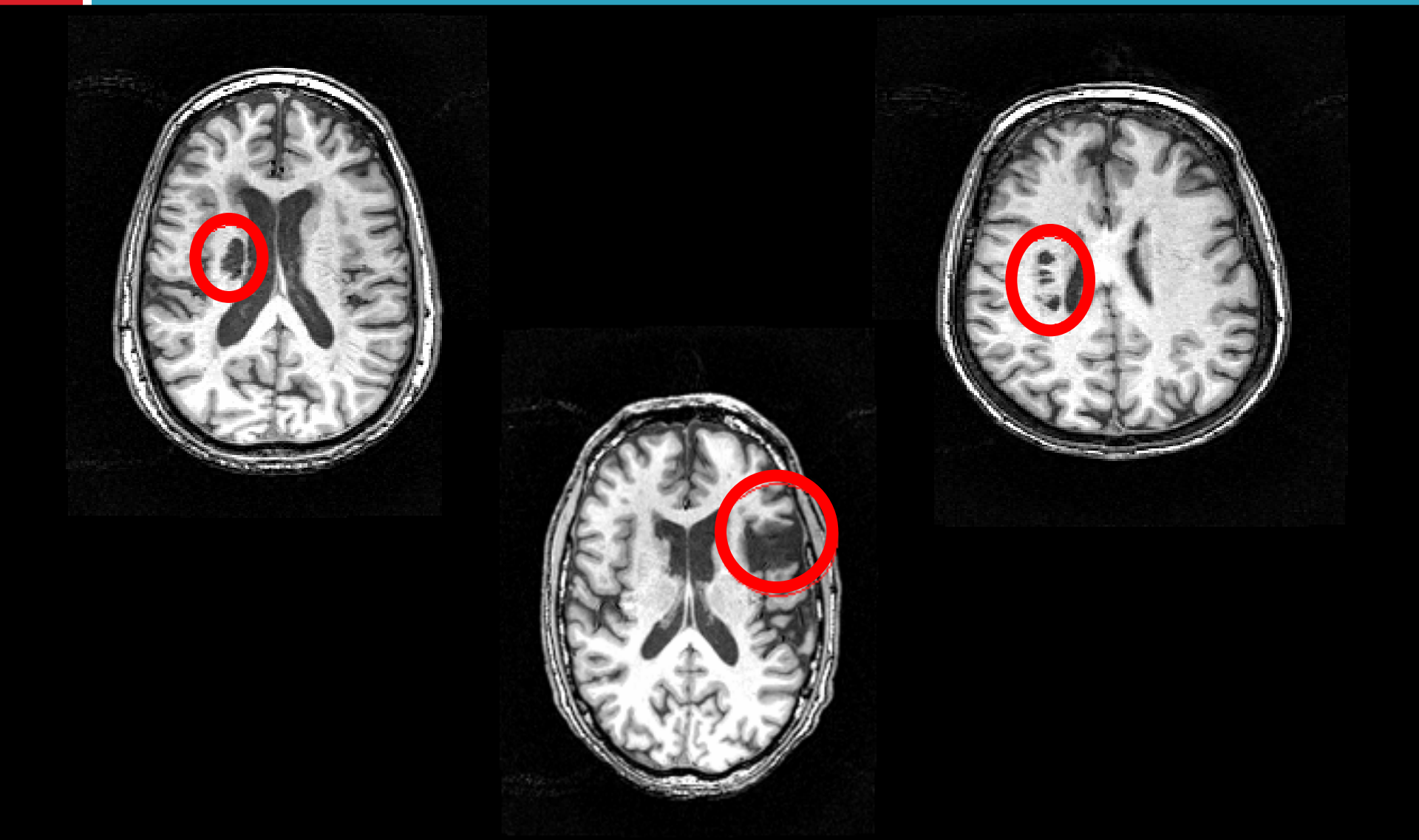
Randomized into 1of 3 treatment groups with block randomization & computer software based on CONSORT statement[17]

We used the control group as our experimental group

Inclusion Criteria

- ≥18 years old
- First clinically diagnosed stroke
  - Ischemic stroke in the middle cerebral artery or functional equivalent
  - > 6 months post-stroke onset
- Motor output impaired in upper extremity
- Passing scores on screening tests
  - Fugl-Meyer UE score
  - MOCA
  - Frenchay Aphasia Screen

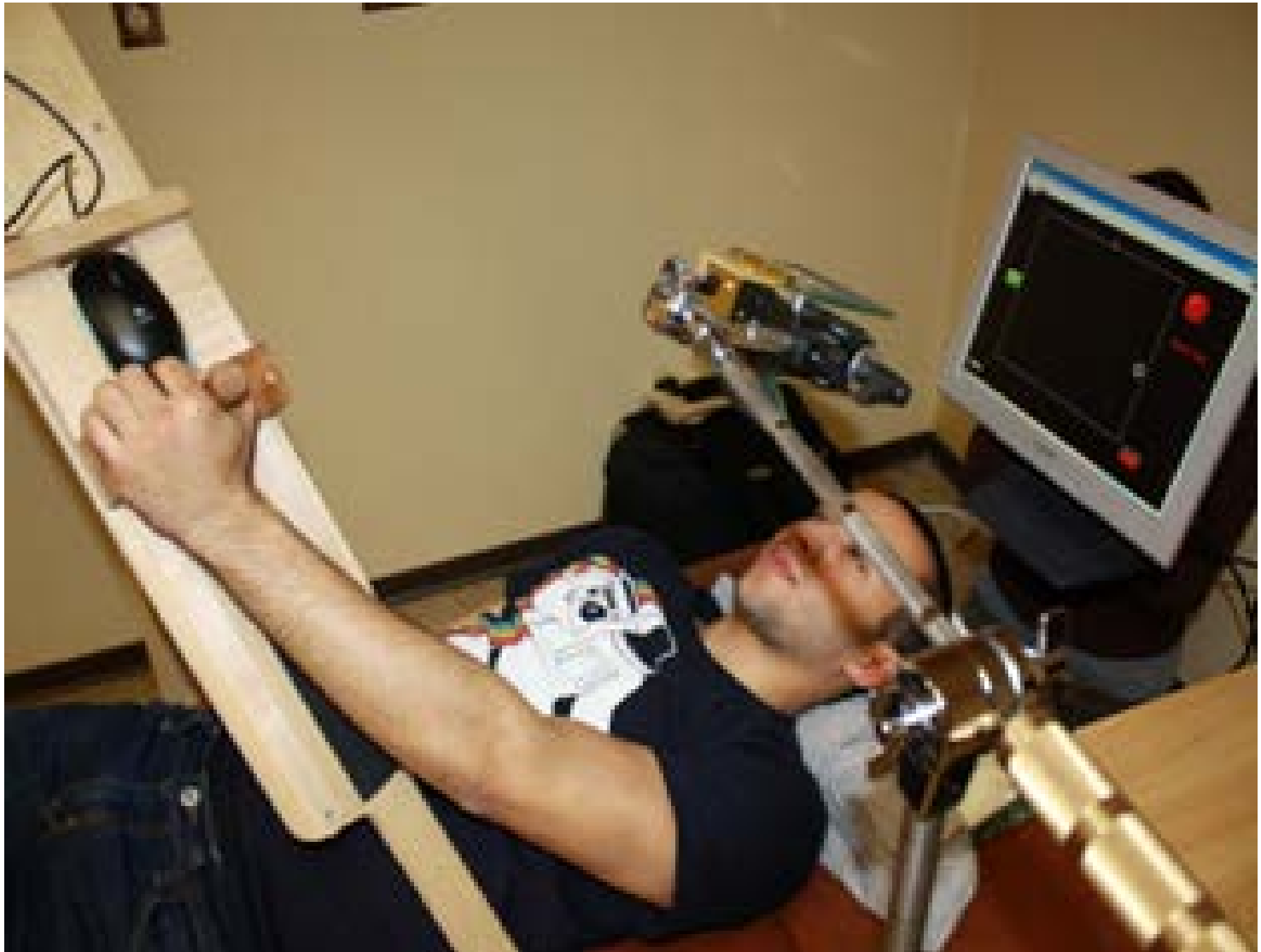
MCA Strokes



Exclusion Criteria

- Major psychiatric diagnosis
- History of substance abuse
- Neglect
- History of seizures or epilepsy
- Pregnancy
- Obesity
- Metal in body
- Claustrophobia
- Score of $\leq$13 on expression and comprehension sections of Frenchay Aphasia Screening Test
- Drugs that impair brain plasticity
  - Anticholinergics, GABAergics, NMDA-receptor blockers
- History of tumor, head trauma, neurodegenerative disorder
- U/E impairment that limits participation in experimental motor skill task

Novel Motor Tracking Task

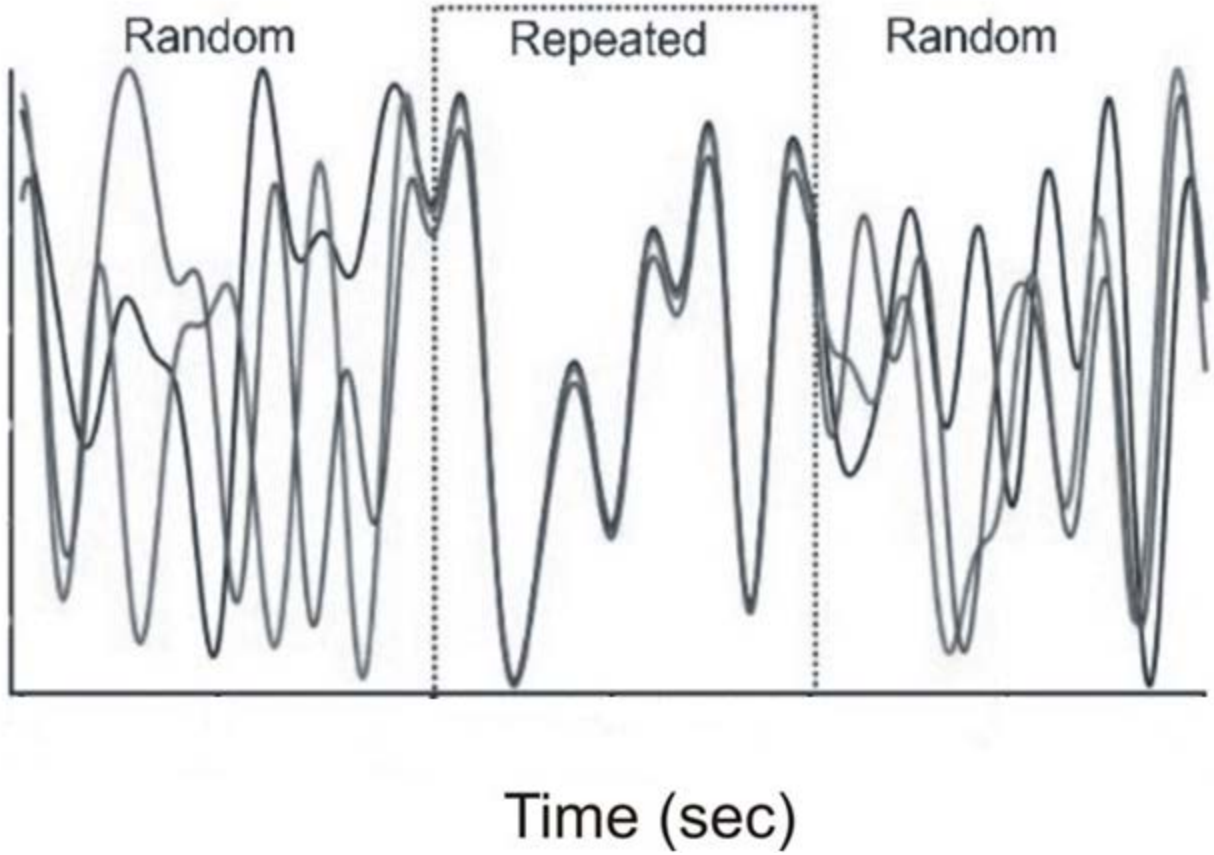


Tracking Task

- Motor Task Example

Target Cursor

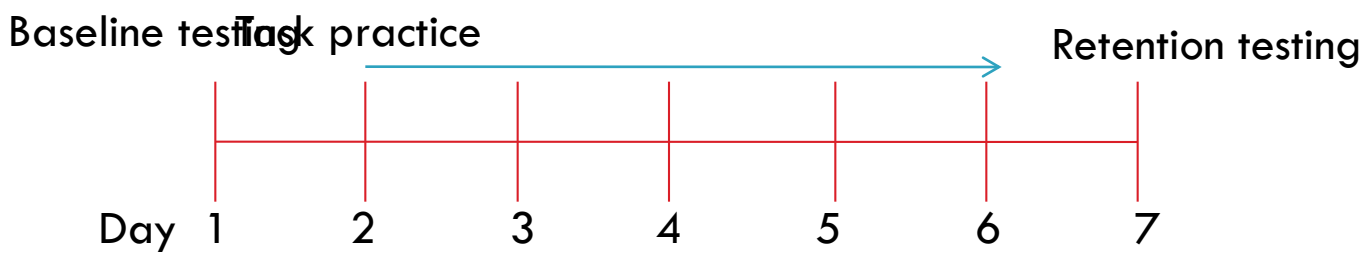
Participant Cursor



Experimental Protocol

- Each consenting participant will be subjected to the following timeline:

Day	Duration	Experimental Task
1	60 min	Consent; Screening tests; Baseline testing
2-6	60 min	Task practice
7	60 min	Retention testing



Experimental Protocol

Day1 & Day7

Block1 & 3

Block2 & 4

Day2 - 6

Block1

Block2 - 5

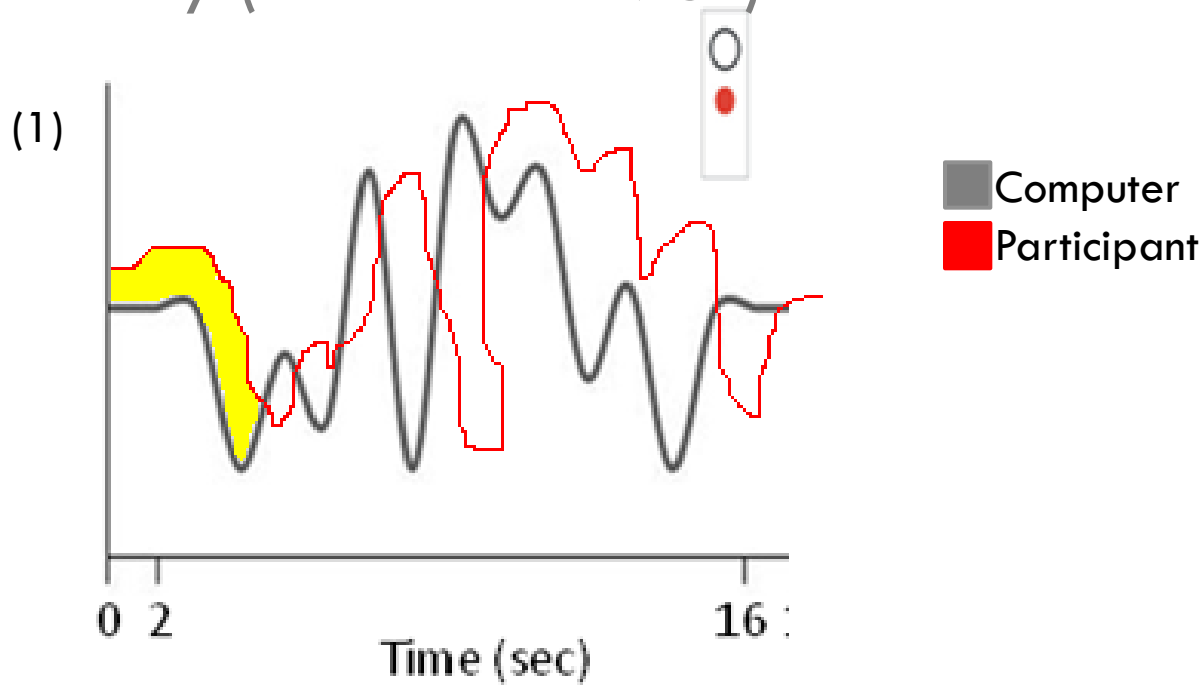
Blocks consist of trials

Trials are 18 seconds long

Outcome Measures

Learning is inferred by a decrease in any of these:

1. **Overall tracking error (RMSE)**
2. Temporal Lag (ms)
3. Spatial accuracy (corrected RMSE)



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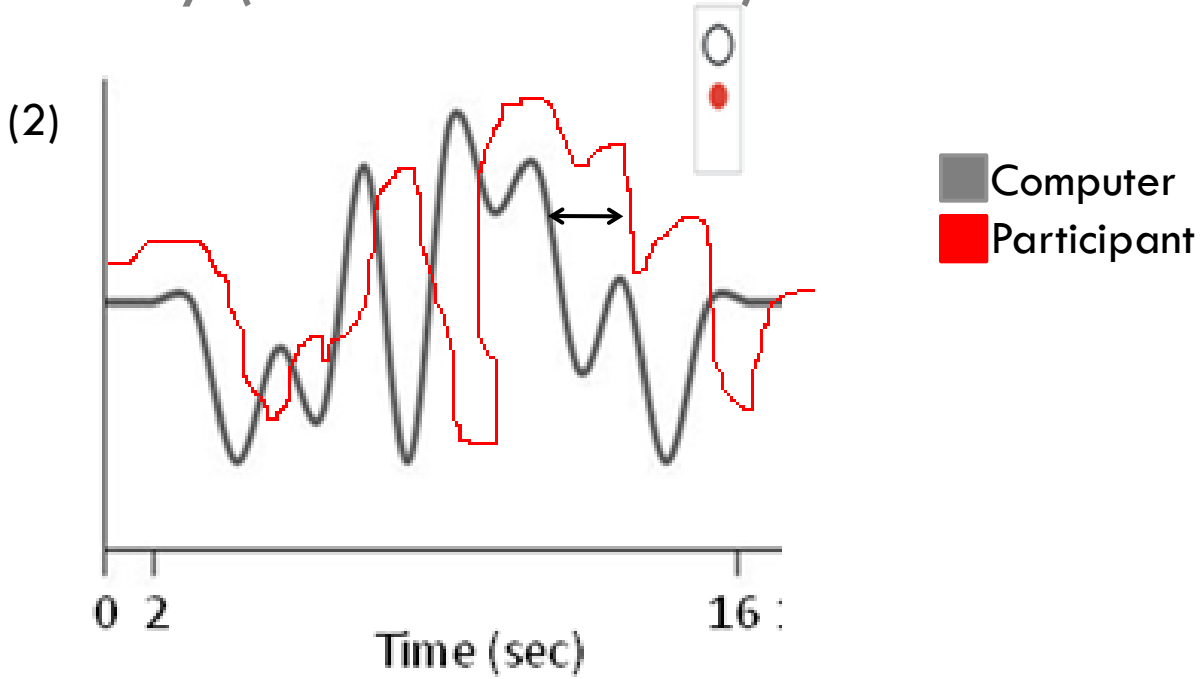
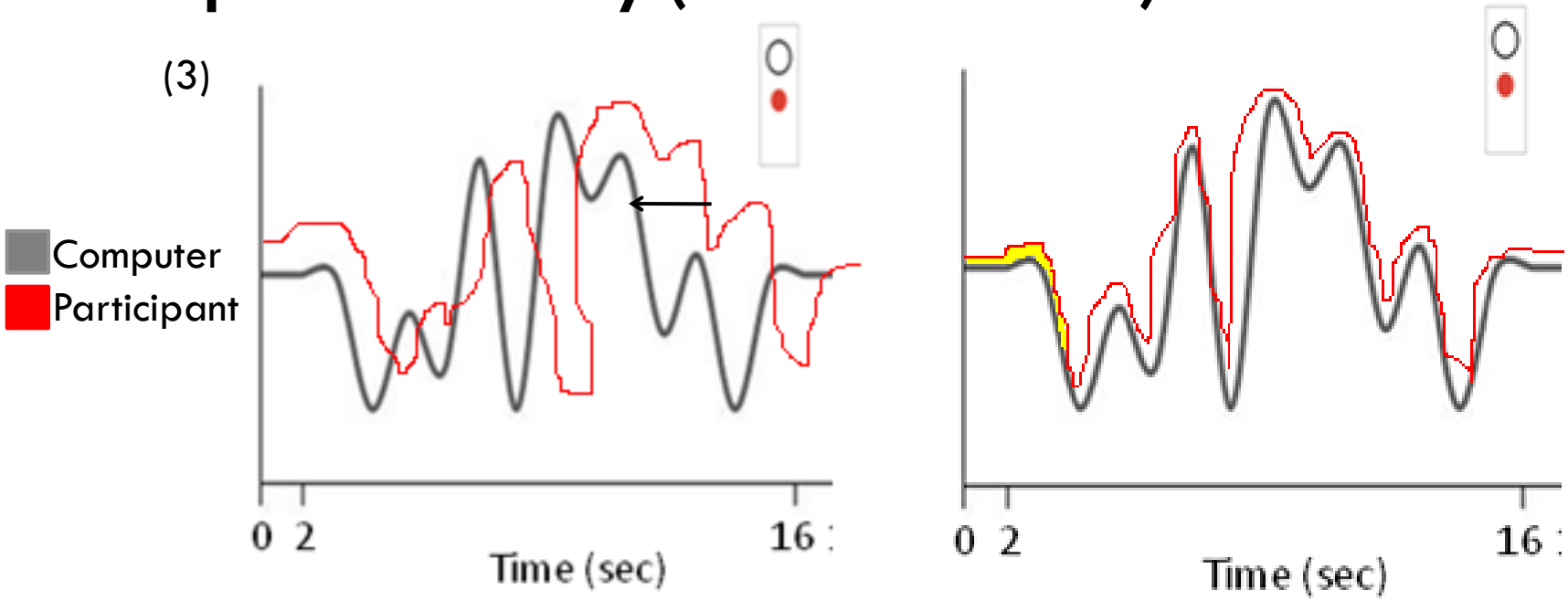


Outcome Measures

Learning is inferred by a decrease in any of these:

1. Overall tracking error (RMSE)
2. Temporal Lag (ms)
3. **Spatial accuracy (corrected RMSE)**

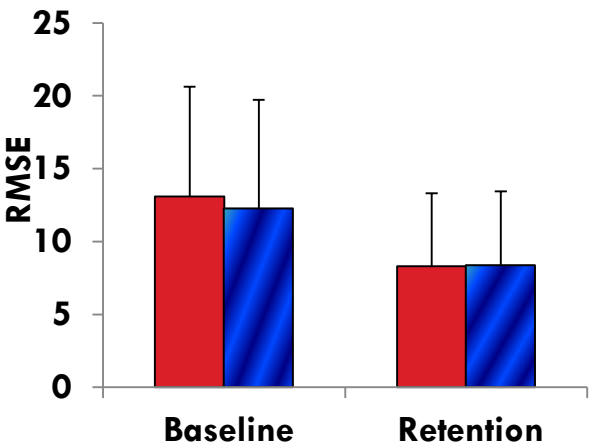


RESULTS

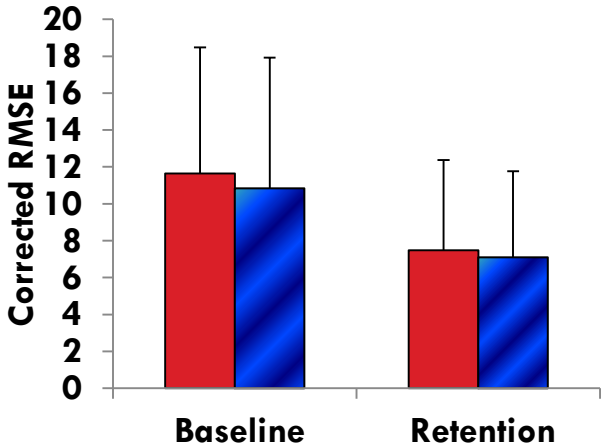
- 11 complete data sets were analyzed
- Averages (SD), T-tests, and Effect Size were calculated
- T-tests significance level: $p = 0.008$
  - 6 tests were run
  - New critical p-value is $p = 0.05/6$
    - Corrects for multiple comparisons

Results Overview

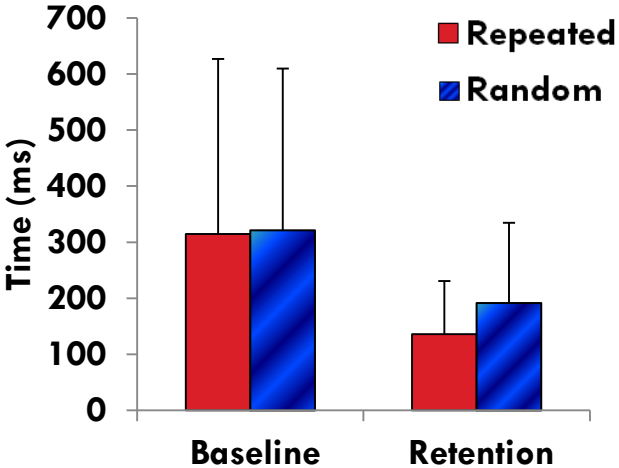
Overall Tracking Error



Spatial Accuracy



Temporal Accuracy



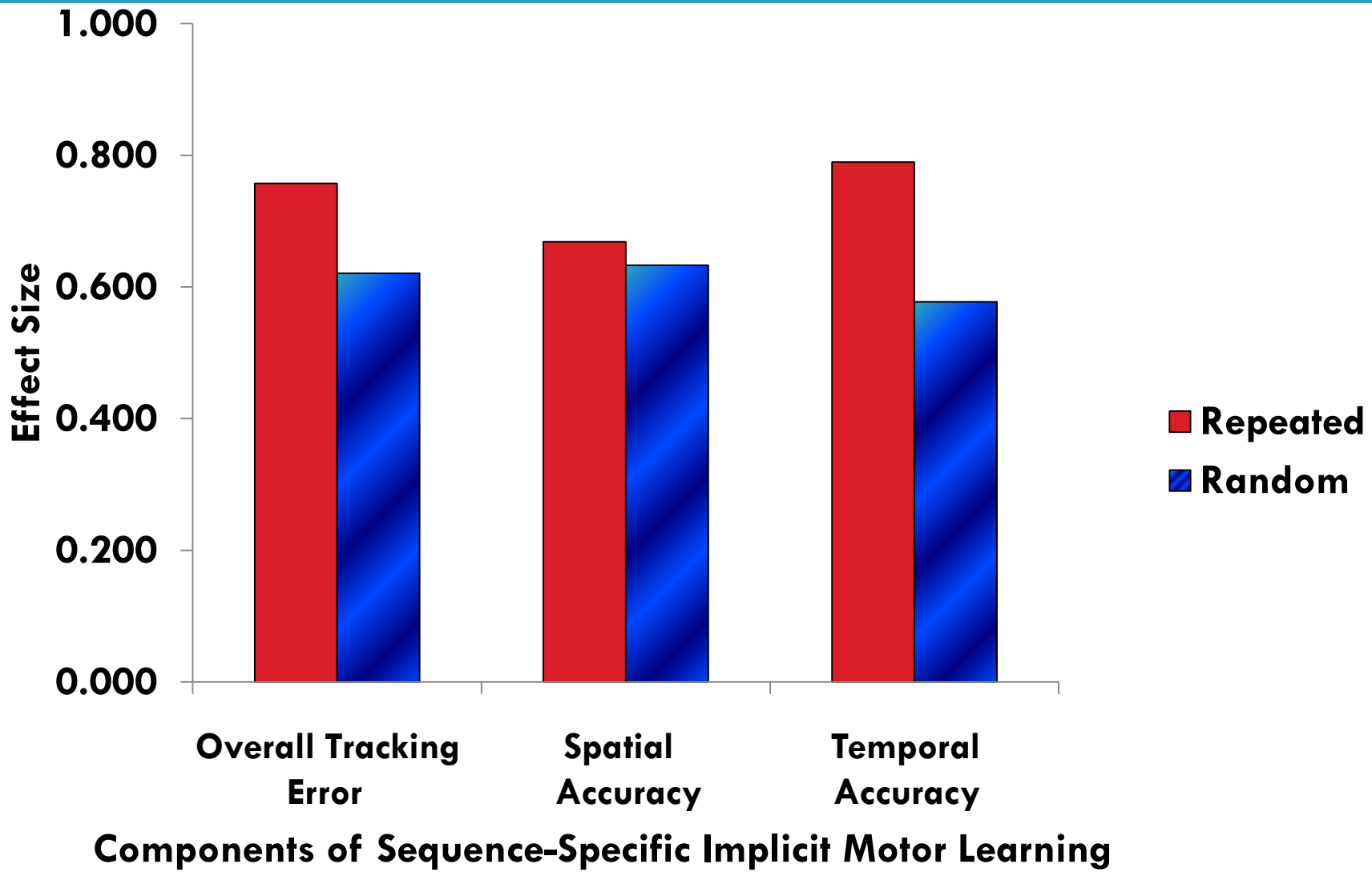
T-Test: Overall	
Repeated	0.0003
Random	0.0025

T-Test: Spatial	
Repeated	0.0002
Random	0.0025

T-Test: Temporal	
Repeated	0.0193
Random	0.0234

$p = 0.008$

Effect Size


1.000
0.800
0.600
0.400
0.200
0.000
Effect Size
Repeated
Random
Overall Tracking Error
Spatial Accuracy
Temporal Accuracy
Components of Sequence-Specific Implicit Motor Learning

Effect Size

Effect Size (0.2=small, 0.5=moderate, 0.8=large)	
Repeated Overall Tracking Error	0.757
Random Overall Tracking Error	0.621
Repeated Spatial	0.669
Random Spatial	0.633
Repeated Temporal	0.790
Random Temporal	0.577

0.2 small effect, 0.5 moderate effect, 0.8 large effect[18]

Summary of Results

- This study confirms that sequence-specific implicit motor learning is possible with damage to the MCA
- Our data suggests participants showed a greater change in the temporal domain compared to spatial

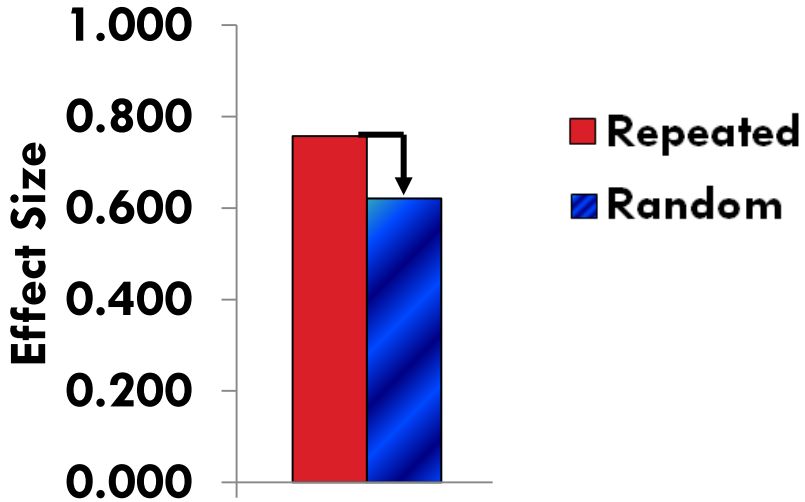
DISCUSSION

Generalized Motor Learning[7] (aka Practice Effect)

- Learning is expected with any novel motor task as task familiarity increases performance and decreases error

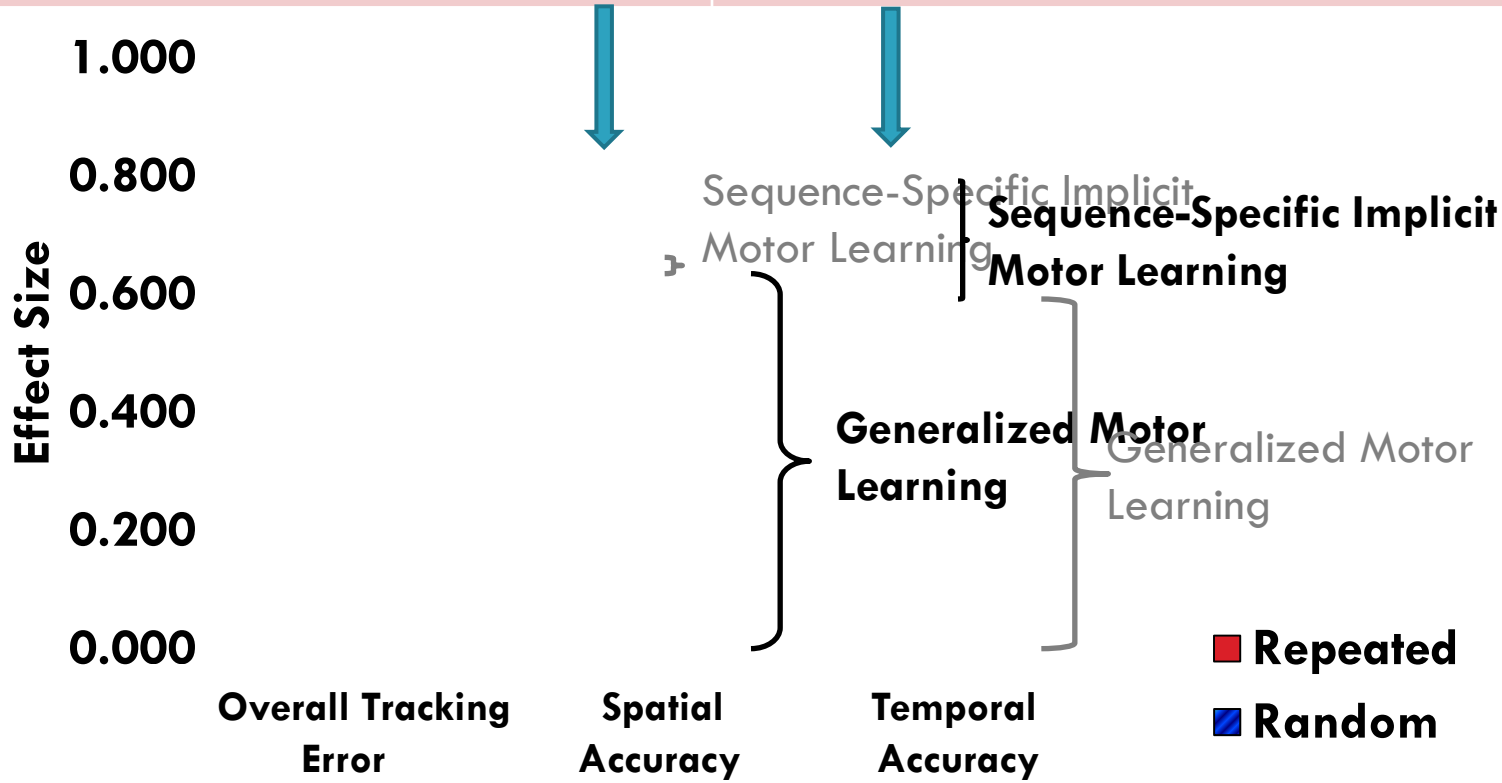
Sequence-Specific Implicit Motor Learning

- Generalized motor learning can be differentiated from sequence-specific implicit motor learning by comparing the effect size of repeated and random sequences
- Sequence-specific implicit motor learning is inferred by an increase in repeated effect size (vs. random)



Generalized vs. Implicit Motor Learning

Generalized Motor Learning	Sequence-specific Implicit Motor Learning
If random and repeated sequences display equal effect sizes, generalized motor learning can be inferred	If random and repeated sequences display different effect sizes, more effect due to implicit sequence-specific motor learning can be inferred



MCA vs. Cerebellar Infarcts

- In this study, MCA infarcts shows:
  - Temporal accuracy was improved
  - Spatial accuracy shows less improvement
- Cerebellar infarcts showed the opposite:[14]
  - Temporal accuracy impaired
  - Spatial accuracy was improved
- Neural networks supplied by the MCA are more involved in spatial accuracy than temporal accuracy

Implications for Physical Therapists

- Motor learning is capable with no explicit instructions
- For individuals with strokes in MCA distribution:
  - Focus rehabilitation on spatial accuracy distribution as this appears to be lagging (Remediation)
  - Focus rehabilitation on temporal accuracy as this appears to improve with task specific practice (Compensation)
- More research into sequence-specific implicit motor learning is warranted to enhance treatment strategies

Limitations

- Limited number of participants
- Participant fatigue: 3 participants unable to complete all blocks of baseline and retention testing
  - Data averaged and imputed
- One participant eliminated due to erroneous results
  - Data imputed from average of all remaining participants

CONCLUSION

1. Individuals with MCA stroke are able to learn new motor sequences implicitly without explicit instructions
2. Generalized motor learning can be seen in both spatial and temporal components
3. Greater gains were seen in temporal accuracy compared to spatial accuracy
4. Neural networks supplied by the MCA are involved in spatial accuracy to a greater extent than temporal accuracy

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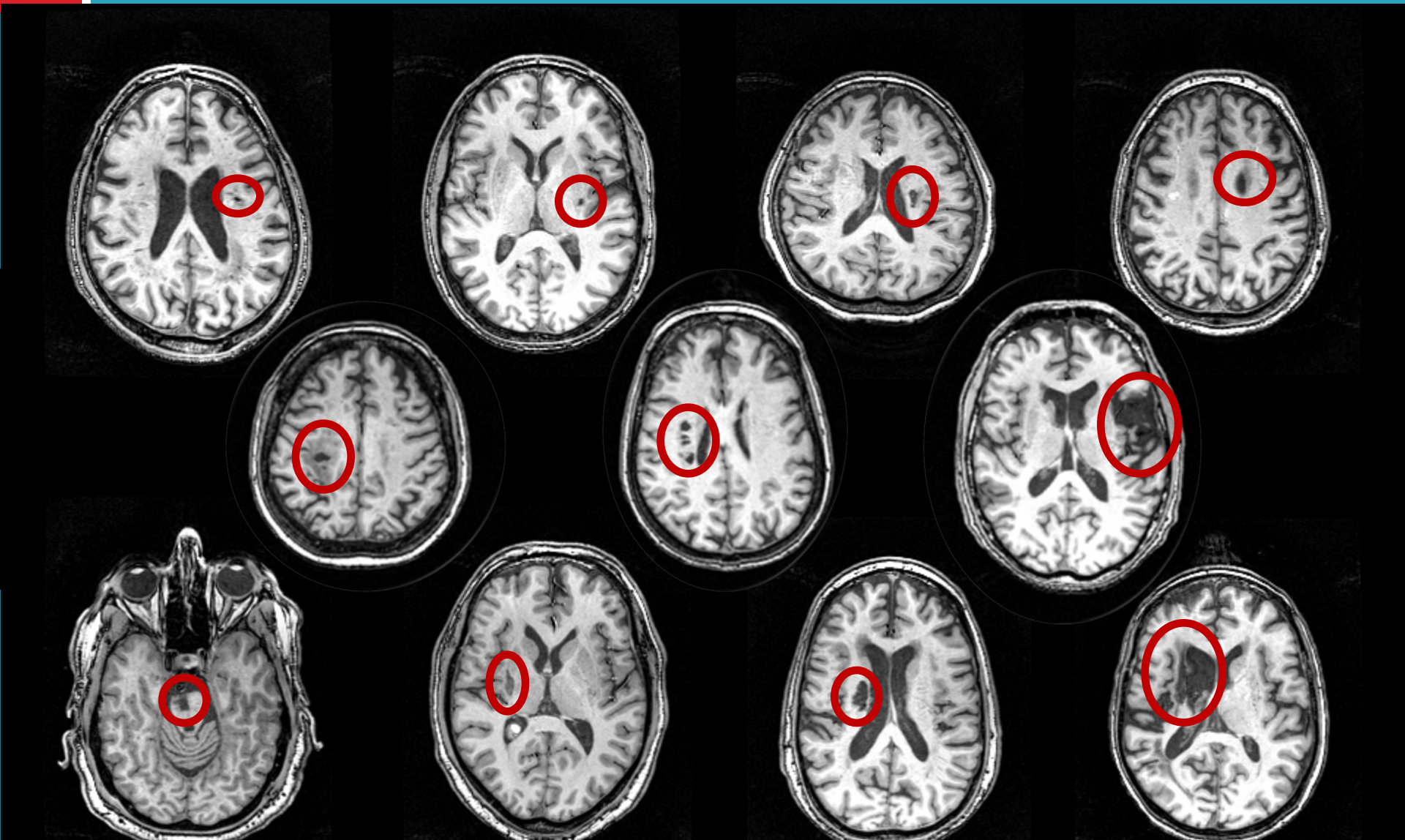
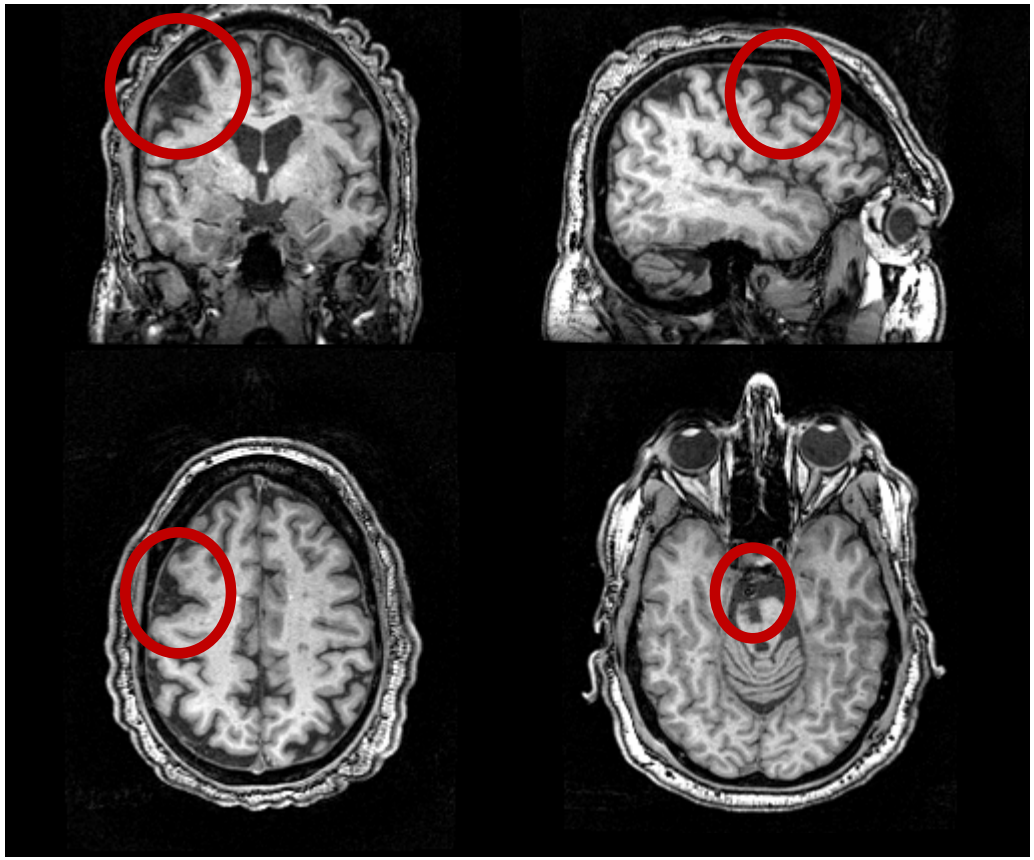
Questions…

Overview of Strokes



Functionally Equivalent to MCA



Pontine Stroke with atrophy of sensorimotor cortex

Diaschisis Definitions:

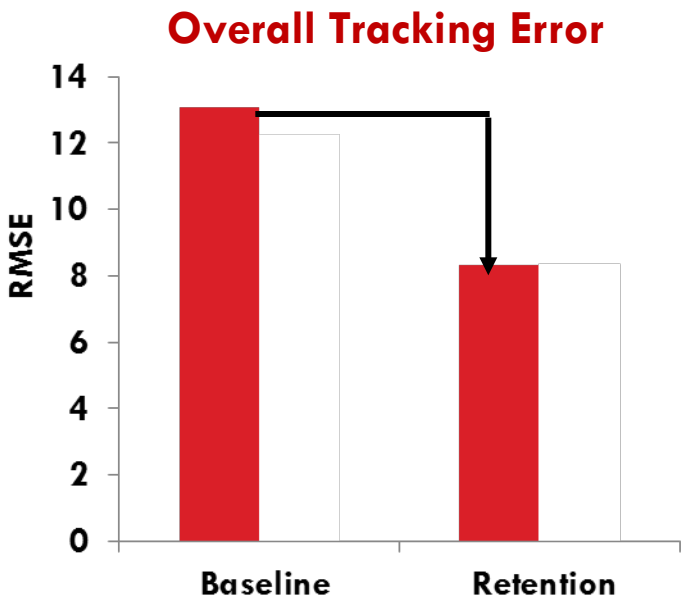
A sudden loss of function in a portion of the brain that is at a distance from the site of injury, but is connected to it by neurons.

A loss of function and electrical activity in an area of the brain due to a lesion in a remote area that is neuronally connected with it

Statistics

T-tests

Compared repeated Baseline data to repeated Retention data



T-test results (p=0.008)	
Repeated Overall Tracking Error	0.0003
Random Overall Tracking Error	0.0025
Repeated Spatial	0.0002
Random Spatial	0.0025
Repeated Temporal	0.0193
Random Temporal	0.0234

Effect Size (0.2=small, 0.5=moderate, 0.8=large)	
Repeated Overall Tracking Error	0.757
Random Overall Tracking Error	0.621
Repeated Spatial	0.669
Random Spatial	0.633
Repeated Temporal	0.790
Random Temporal	0.577

Sample Size Calculations

- $\alpha = 0.05$
- Power = 0.8
- Effect size = 0.8
  - Pilot study by Boyd & Linsdell (2009) suggests effect size for treatment of 1.2
- Required 12 subjects for each of the 3 groups
  - Eleven suitable participants were assigned to the control group of the larger study; this group is our experimental group

Sample Size Calculation