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
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.
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
- Rise in the incidence of stroke with an aging population
- 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
Implicit learning - ability to acquire complex information without awareness of what has been learned

- Develops over time with numerous exposures to information or practice of a skill

- Distributed throughout various regions of the cortex
  - Cerebellum
  - Sensorimotor cortex
  - Supplemental motor cortex
  - Prefrontal cortex
  - Thalamus
  - Basal ganglia

Implicit learning is an element for motor learning
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**
  - Ability to locate objects in space or direct extremities to the correct location
  - Involves the motor cortex

- **Temporal Accuracy**
  - 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
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\textsuperscript{7,13-15}

- has been demonstrated without explicit information\textsuperscript{15}

- may be disrupted if explicit information is provided concurrently in stroke subjects\textsuperscript{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)\textsuperscript{16}

Ethics

- Ethics approval from the UBC Clinical Ethics Research Board
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

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

If acceptable:
Read & sign informed consent

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

[Diagram showing a tracking task with a target cursor and a participant cursor over time (sec)].
Each consenting participant will be subjected to the following timeline:

<table>
<thead>
<tr>
<th>Day</th>
<th>Duration</th>
<th>Experimental Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60 min</td>
<td>Consent; Screening tests; Baseline testing</td>
</tr>
<tr>
<td>2-6</td>
<td>60 min</td>
<td>Task practice</td>
</tr>
<tr>
<td>7</td>
<td>60 min</td>
<td>Retention testing</td>
</tr>
</tbody>
</table>
Experimental Protocol

Day 1 & Day 7
Block 1 & 3
Rest 36sec  Repeated 144sec  Rest 36sec  Random 144sec  Rest 36sec

Block 2 & 4
Rest 36sec  Random 144sec  Rest 36sec  Repeated 144sec  Rest 36sec

Day 2 - 6
Block 1
Random 90sec  Rest 36sec  Random 90sec

Block 2 - 5
Repeated 90sec  Rest 36sec  Repeated 90sec

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)

(1)
Outcome Measures

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Outcome Measures

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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

<table>
<thead>
<tr>
<th>T-Test: Overall</th>
<th>T-Test: Spatial</th>
<th>T-Test: Temporal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeated</td>
<td>0.0003</td>
<td>Repeated</td>
</tr>
<tr>
<td>Random</td>
<td>0.0025</td>
<td>Random</td>
</tr>
</tbody>
</table>

Random 0.0025

p = 0.008
Effect Size

Components of Sequence-Specific Implicit Motor Learning

- Overall Tracking Error
- Spatial Accuracy
- Temporal Accuracy

Repeated vs Random
# Effect Size

<table>
<thead>
<tr>
<th>Effect Size (0.2=small, 0.5=moderate, 0.8=large)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeated Overall Tracking Error</td>
<td>0.757</td>
</tr>
<tr>
<td>Random Overall Tracking Error</td>
<td>0.621</td>
</tr>
<tr>
<td>Repeated Spatial</td>
<td>0.669</td>
</tr>
<tr>
<td>Random Spatial</td>
<td>0.633</td>
</tr>
<tr>
<td>Repeated Temporal</td>
<td>0.790</td>
</tr>
<tr>
<td>Random Temporal</td>
<td>0.577</td>
</tr>
</tbody>
</table>

0.2 small effect, 0.5 moderate effect, 0.8 large effect\textsuperscript{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
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

<table>
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<tr>
<th>Generalized Motor Learning</th>
<th>Sequence-specific Implicit Motor Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>If random and repeated sequences display equal effect sizes, generalized motor learning can be inferred.</td>
<td>If random and repeated sequences display different effect sizes, more effect due to implicit sequence-specific motor learning can be inferred.</td>
</tr>
</tbody>
</table>

#### Effect Size

- 1.000
- 0.800
- 0.600
- 0.400
- 0.200
- 0.000

#### Metrics

- Overall Tracking Error
- Spatial Accuracy
- Temporal Accuracy

**Legend:**
- Red: Repeated
- Blue: Random
MCA vs. Cerebellar Infarcts

- In this study, MCA infarcts shows:
  - Temporal accuracy was improved
  - Spatial accuracy shows less improvement

- Cerebellar infarcts showed the opposite:\cite{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
The authors would like to thank Lara Boyd, PT, PhD, Janice Eng, PT, PhD and Elizabeth Dao, BA for their support and guidance. This work was made possible by the Brain Behaviour Lab at UBC. We would also like to thank the Department of Physical Therapy at UBC in Vancouver, Canada.
REFERENCES


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Questions...
Overview of Strokes
Functionally Equivalent to MCA

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.

Pontine Stroke with atrophy of sensorimotor cortex
Statistics

T-tests

Compared repeated Baseline data to repeated Retention data

Overall Tracking Error
<table>
<thead>
<tr>
<th></th>
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<td>0.0234</td>
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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

![Graph showing sample size calculation for different effect sizes (ES) and power levels (for two-tailed alpha = .05).]