Dual Task Paradigms and Context Dependent Learning to Modify Functional Motor Performance, Balance, and Fall Risk

Part 1: Theoretical Background and Interpretive Considerations

Beth Crowner PT, DPT, NCS, MPPA
Washington University, Program in Physical Therapy

Valerie E. Kelly, PT, PhD
University of Washington, Department of Rehabilitation Medicine

Joanne Wagner PT, PhD
St. Louis University, Department of Physical Therapy and Athletic Training

Ya-Yun Lee, MSPT
University of Southern California, Division of Biokinesiology and Physical Therapy

Combined Sections Meeting 2013, San Diego, CA
January 21–24, 2013
Dual-Task and Context-Dependent Learning to Modify Functional Motor Performance, Balance, and Fall Risk

Part 1: Theoretical Background and Interpretive Considerations

OBJECTIVES

- Describe how context affects motor performance, dual-task balance, and walking paradigms, and their use in research and clinical practice.
- Discuss the theoretical background as well as methodological and interpretive considerations surrounding the use of dual-task paradigms.
- Explain potential mechanisms and neural substrates associated with context-dependent learning.
- Discuss the relationship among impaired dual-task balance and walking performance and functional deficits, fall risk, and disability in the geriatric and neurologic populations.

OUTLINE

1. Introduction
   Beth Crowner PT, DPT, NCS, MPPA
2. Dual-task deficits in PD & TBI
   Valerie E. Kelly, PT, PhD
3. Dual-task balance and gait changes in MS
   Joanne Wagner PT, PhD
4. Context-dependent learning
   Ya-Yun (Alice) Lee, MSPT

Dual-Task Balance and Gait in PD & TBI

Theoretical & Interpretive Considerations

Valerie E. Kelly, PT, PhD
Division of Physical Therapy
vekelly@uw.edu

OBJECTIVES

1. Define dual-task balance and gait.
2. Describe dual-task balance and gait deficits in people with PD, including contributing factors.
3. Describe treatments for dual-task balance and gait deficits in people with PD.
4. Describe dual-task balance and gait deficits in people with TBI.

This material is the property of V.E. Kelly and should not be copied or otherwise used without express written permission of the author.
Dual Task Performance
- Simultaneous performance of two tasks that can be performed discretely

Dual Task Postural Control
- DT performance in which one of the tasks requires postural control
  -- Postural Tasks
  - Standing
  - Walking
  -- Concurrent Tasks
  - Cognitive
  - Motor

DT Postural Control Deficits
- Older adults (Hollman et al., 2006; Kelly et al., 2008; Priest et al., 2008)
- Mild Cognitive Impairment (Muir et al., 2011)
- Stroke (Cockburn et al., 2003; Plummer-D'Amate et al., 2008)
- Traumatic Brain Injury (McCulloch et al., 2010)
- Dementia (Sheridan et al., 2003)
- Multiple Sclerosis (Hamilton et al., 2009; Kalra et al., 2010)
- Parkinson’s Disease (Morris et al., 2000; O'Shea et al., 2002)

GAIT IMPAIRMENTS IN PD
- Decreased independence (Muslimovic et al., 2008; Post et al., 2007)
- Falls: Fear of falling, injuries, hospitalization (Gray & Hildebrand, 2000; Wielinski et al., 2005; Pickering, 2007)
- Reduced quality of life (Gomez-Esteban et al., 2007; Shibley et al., 2008)

COGNITION IN PD
- Cognitive function WNL
  - No cognitive impairment
- Cognitive impairment that falls short of clinical criteria for dementia
- Dementia diagnosed >1 year after diagnosis of PD

COGNITION IN PD
- 19–30% of people with newly-diagnosed PD present with cognitive impairment (Aarsland et al., 2009; Elgh et al., 2009; Muslimovic et al., 2005)
- Increases with disease progression (Muslimovic et al., 2005)
- Associated with development of dementia (Muslimovic et al., 2005)
- 26–44% of people with PD have dementia (Aarsland et al., 2007; Holm & Meza, 1999)
Dual Task Paradigms and Context Dependent Learning: Part 1

January 22, 2013

This material is the property of V.E. Kelly and should not be copied or otherwise used without express written permission of the author.

Dual-Task Deficits in PD

• Observed for speech, upper extremity movements, balance, and walking
• Potential mechanisms:
  – Reduced automaticity (Takakusaki et al., 2004; Wu & Hallett, 2008)
  – Cognitive involvement
  – “Posture second” prioritization (Bloem et al., 2006)

Dual-Task Walking Deficits in PD

• Dual-task walking deficits are common, but not uniform, in people with PD
• Appear to differ based on individual, task, and environmental factors
  – Individual: Disease severity? Cognitive impairments?
  – Task: Motor or cognitive? Difficulty?
  – Environment: Clinic? Home? Lab?

Dual-Task Walking in PD

<table>
<thead>
<tr>
<th>Plotnik et al., 2011</th>
<th>Lord et al., 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gait speed DT cost = -17%</td>
<td>Gait speed DT cost = -32%</td>
</tr>
<tr>
<td>Moderate PD</td>
<td>Moderate PD</td>
</tr>
<tr>
<td>Off medication</td>
<td>Off medication</td>
</tr>
<tr>
<td>6.4 m walk</td>
<td>6.4 m walk</td>
</tr>
<tr>
<td>Counting auditory tones</td>
<td>Counting auditory tones</td>
</tr>
<tr>
<td>Home environment</td>
<td>Home environment</td>
</tr>
</tbody>
</table>

Effect of Different Tasks

Motor task:
• Button press

Cognitive tasks:
• Serial-3 subtractions
• Verbal fluency

More complex tasks → greater dual task deficits

Motor Contributions

• Disease severity
  – DT gait speed & variability
    (Lord et al., 2010; Rochester et al., 2004; Lord et al., 2011)
• Postural control (Rochester et al., 2004)
• Single-task walking
  – DT gait speed & stride length (Plotnik et al., 2011)
COGNITIVE CONTRIBUTIONS

• Executive Function
  – Set-shifting
  – Attention
    (Lord et al., 2010; Plotnik et al., 2011; Rochester et al., 2004)

• Mechanism
  – Limit use of cognition to compensate
  – Contribute to inappropriate prioritization
    (Kelly, Eusterbrock, Shumway-Cook, 2012)

Posture-second prioritization is not invariant. People with PD can improve gait speed when instructed to focus on walking, but it may come at a cost to the cognitive task.

Kelly et al., unpublished data

Dual-Task Training in PD

• General approaches:
  – External cues (Rochester et al., 2010)
  – Cognitive strategies (Canning, 2005; Lohnes & Earhart, 2011)
  – Dual-task training (Fok et al, 2010, 2011; Canning et al., 2008; Brauer & Morris, 2010; Brauer et al., 2011)

Evidence that all can improve dual-task walking deficits, at least in the short term.

Dual-Task Deficits in TBI

• Dual-task walking:
  – Speed (McCulloch et al., 2010)
  – Stability (Parker et al., 2005, 2006)

• Cognitive deficits in TBI

• Dual-task training?

(for review see McCulloch, 2007)
Dual-Task-Related Changes in Persons with Multiple Sclerosis: Postural Control and Gait

Joanne M. Wagner, PT, PhD
Program in Physical Therapy
Doisy College of Health Sciences
Saint Louis University
jwagne34@slu.edu
Objectives

1. **Provide a brief overview of multiple sclerosis**
   - Disability scales
   - Balance and walking dysfunction, accidental falls
   - Sensorimotor & cognitive impairment

2. **Discuss dual-task-related deficits in people with MS (pwMS)**
   - Evidence of dual-task-related deficits in postural control in pwMS
   - Evidence of dual-task-related gait changes in pwMS

3. **Discuss Implications of Dual-Task-Related Deficits in pwMS**
   - Implications of dual-task-related deficits in postural control in pwMS
   - Implications of dual-task-related gait changes in pwMS

4. **Discuss the cognitive tasks used in dual-task-paradigms in pwMS**
   - Does the type of cognitive task effect dual-task-related changes in pwMS?

5. **Discuss dual-task-related training in pwMS**
   - Can dual-task deficits in pwMS be improved?

6. **Highlight the gaps in knowledge regarding dual-task-related deficits in pwMS**
Multiple Sclerosis

Multiple sclerosis (MS) is a chronic, progressive disease of the central nervous system characterized by inflammation, demyelination and destruction of the motor and sensory axons within the brain and spinal cord.

Lassman, 1999
Expanded Disability Status Scale (EDSS)

Pyramidal
Cerebellar
Brain Stem
Sensory
Bowel and Bladder
Visual
Cerebral (Mental)
Other

Balance Dysfunction in pwMS

Impaired postural control has been documented in pwMS using clinical and instrumented assessments of standing posture.

- Decreased ability to maintain position
- Limited and slow movement toward limits of stability
- Delayed responses to postural displacements or perturbations

Balance dysfunction observed in 50% to 90% of pwMS using standardized clinical measures of standing balance.
Walking Dysfunction in pwMS

Approximately 75% of adults with MS will experience a deterioration in ambulation (Hobart et al, 2001)

- Standing: No Difficulty (90%), A Little Difficulty (10%), A lot of Difficulty (0%)
- Keeping Balance: No Difficulty (80%), A Little Difficulty (20%), A lot of Difficulty (0%)
- Running: No Difficulty (60%), A Little Difficulty (30%), A lot of Difficulty (10%)
- Walking Short Distances: No Difficulty (70%), A Little Difficulty (20%), A lot of Difficulty (10%)
- Walking Long Distances: No Difficulty (50%), A Little Difficulty (30%), A lot of Difficulty (20%)
- Climbing Stairs: No Difficulty (40%), A Little Difficulty (30%), A lot of Difficulty (30%)

LaRocca, 2011

n = 1,011
Accidental Falls in pwMS

Accidental falls are common in pwMS

Injurious falls are frequent in pwMS (Peterson et al, 2008)

354 pwMS, aged 55-94 years

*Difficult to compare studies due to different definitions for falls and time frame of assessment
Fear of Falling in pwMS

Fear of falling (FOF) is common in pwMS (Peterson et al, 2008)
354 pwMS, aged 45-90 years

Fear of falling (FOF) in pwMS curtails activity (Peterson et al, 2008)
Heterogeneous impairment of multiple functional systems contributes to imbalance and walking difficulty

- Visual
- Pyramidal: Weakness, Spasticity
- Multiple Sclerosis: Dorsal Column, Sensory Loss, Ataxia, Tremor
- Cerebellar: Impaired Balance, Ataxia, Tremor
- Cognitive

Impact on Individual

Reduced Walking

Personal Factors

Environmental Factors

Adapted from Pearson, 2004
Cognitive Impairment in pwMS

Cognitive Impairment occurs in 30-70% of patients with MS (Rao et al, 1991; Amato et al, 2001)

– Deficits in attention, information processing speed, working memory, verbal and spatial memory, and executive functions

Evidence of cognitive impairment in early MS (Feuillet et al, 2007)

Cognitive impairment is related to disease burden, white and gray matter neuropathology (cortical atrophy, thalamic atrophy) (Rovaris et al, 1998; Benedict et al, 2004, 2006)
It is plausible that cognitive impairment, alone in combination with sensorimotor impairment, contributes to dual-task-related deficits in pwMS.

Dual-task-related deficits may contribute to the fear of falling, accidental falls, and mobility disability.

WHAT IS THE EVIDENCE?
Evidence of Dual-Task-Related Postural Control Deficits in pwMS

Effects of dual tasking on the postural performance of people with and without multiple sclerosis: a pilot study

Jesse V. Jacobs · Susan L. Kasser

Postural control in multiple sclerosis: Effects of disability status and dual task

Morgan K. Boes a, Jacob J. Sosnoff a,b,*, Michael J. Socie c, Brian M. Sandroff b, John H. Pula d, Robert W. Motl b

Effect of a cognitive task on postural control in patients with a clinically isolated syndrome suggestive of multiple sclerosis

A. Kalron 1, Z. Dvir 2, A. Achiron 3
Participants:
19 mild clinical disability: 2-3.5 EDSS
26 moderate clinical: EDSS: 4-6.5 EDSS

Paradigm:
ST-Motor: Quiet standing
ST-Cognitive: None
DT: Quiet standing with modified word list generation

Results:
Moderate group greater imbalance than mild group (SA, RMS AP)
DTC = greater imbalance (SA, MV AP, RMS ML)
No significant difference in DTC between mild and moderate disability groups

Limitations: No control Group, No ST-cognitive
Effect of a cognitive task on postural control in patients with a clinically isolated syndrome suggestive of multiple sclerosis

A. KALRON 1, Z. DVIR 2, A. ACHIRON 1

Participants:
CIS: 52; EDSS: 1.7 (0.2)
WD: 28

Paradigm:
ST-Motor: Quiet standing EO & EC
ST-Cognitive: None
DT: Quiet standing EO & modified Stroop test

Results:
Sway rate: Significant increase DTC vs. EO both groups
Plane SD: No significant change DTC vs. EO for both groups
No comparison of DTC between groups
Greater % of CIS patients received low scores during DT vs. EO and EC

Limitations: No ST-cognitive task

DTC– Sway Rate
Healthy: 34%
MS: 43%

DTC– Plane SD
Healthy: 5%
MS: 8.5%
Effects of dual tasking on the postural performance of people with and without multiple sclerosis: a pilot study

Jesse V. Jacobs · Susan L. Kasser

Participants:
pwMS: 13; EDSS: 2.5 (0-4.5)
WD: 13

Paradigm:
ST-Motor: step initiation, forward lean LOS, toes-up rotations of support surface
ST-Cognitive: Verbal response to auditory Stroop test
DT: Motor tasks + auditory Stroop test
Clinical DT: TUG-cognitive

Results:
multiple kinetic and kinematic variables reported (CoP, CoM)
DTC – step initiation: latency of APA posterior component and step lengths differed between MS and WD group
DTC –forward lean and postural responses: did not differentially affect the groups
DTC – TUG: MS group greater DTC TUG vs. TUG-cognitive than WD group

Limitations: small sample
Implications of Dual-Task Postural Control Deficits in pwMS

In pwMS or CIS there is no direct evidence of a link between dual-task postural control deficits and

- Accidental falls
- Fear of falling
- Reduced community mobility

PwMS report that states of confusion or performing tasks under divided attention are associated with falling (Finlayson et al, 2006, Nilsagard et al, 2009)

Limited information regarding the mechanisms contributing to dual-task postural control deficits in pwMS

- Dual-task postural control deficits are associated with fatigue (Jacobs and Kasser, 2012)

DTC might be a useful tool for identifying postural control deficits not identified by standard tools

- A greater percentage of CIS patients received low scores during DT vs. ST (EO and EC) postural tasks (Kalron et al, 2011)
Evidence of Dual-Task-Related Gait Deficits in pwMS

Walking and talking: an investigation of cognitive–motor dual tasking in multiple sclerosis

F Hamilton¹, L Rochester²,³, L Paul⁴, D Rafferty², CP O’Leary⁵ and JJ Evans¹

Walking while talking—Difficulties incurred during the initial stages of multiple sclerosis disease process

Alon Kalronᵃ,c,*, Zeevi Dvirᵇ,c, Anat Achironᵃ,c

Walking and Thinking in Persons With Multiple Sclerosis Who Vary in Disability

Jacob J. Sosnow, PhD, Morgan K. Boes, BS, Brian M. Sandroff, BS, Michael J. Socie, BS, John H. Pula, MD, Robert W. Motl, PhD
Walking and talking: an investigation of cognitive–motor dual tasking in multiple sclerosis

F Hamilton¹, L Rochester²,³, L Paul¹, D Rafferty², CP O’Leary³ and JJ Evans¹

Participants:
pwMS: 18; EDSS: 2.7, (1.6)
WD: 18

Paradigm:
ST-Motor: walking preferred speed
ST-Cognitive: fixed and titrated digit recall
DT: walking & fixed digit recall, walking & titrated digit recall

Results:
MS group: greater DTC for W+F but not W+T; greater DTC for walking speed during fixed and titrated digit recall; greater DTC for swing time variability during fixed task (MS ↑; WD ↓) compared to WD group
No group differences in DST

Limitations:
Walking while talking—Difficulties incurred during the initial stages of multiple sclerosis disease process∗

Alon Kalron a,c,* , Zeevi Dvir b,c , Anat Achiron a,c

Participants:
CIS: 52; EDSS: 1.7 (0.2)
WD: 28

Paradigm:
ST-Motor: Walking self-selected speed, walking fast speed
ST-Cognitive: None
DT: Walking + modified word list generation

Results:
CIS group: significantly slower walking speed, reduced cadence, greater double support time (% GC) during DT vs. ST
WD group: no significant differences DT vs. ST

No calculation or comparison of DTC between groups

Limitations: No ST- Cognitive
Participants:
21 mild clinical disability: 2-3.5 EDSS
25 moderate clinical disability: EDSS: 4-5.5
32 severe clinical disability: EDSS: 6.0-6.5

Paradigm:
ST-Motor: Walking self-selected speed
ST-Cognitive: None
DT: Walking self-selected speed + modified word list generation

Results:
Severe disability group had significantly greater DTC for FAP, velocity and cadence compared to mild disability group
Moderate disability group had significantly greater DTC for FAP, velocity and cadence compared to mild disability group
No differences between severe and moderate groups

Limitations: no control group, short distance walk -limited opportunity for word generation (< 1.2)
Implications of Dual-Task Related Gait Changes in pwMS

In pwMS or CIS there is no direct evidence of a link between dual-task-related gait changes and

- Accidental falls
- Fear of falling
- Reduced community mobility

Limited information regarding the mechanisms contributing to dual-task-related gait changes in pwMS

- Dual-task-related related gait changes are associated with fatigue and general cognitive functioning (Hamilton et al, 2009)

Performance on the Timed Up and Go – Cognitive is a significant predictor of future falls in pwMS (Nilsagard et al, 2009b)
Does the Cognitive Task Matter?

- Word list generation
- Stroop Test
- Digit Recall Task
- Serial subtraction
The Effects of Task Difficulty on Walking and Talking in Multiple Sclerosis

DA Wajda, JH Pula, RW Motl, JJ Sosnoff

Participants:
pwMS: 10; EDSS: 3.0
WD: 10,

Paradigm:
ST-Motor: Forward and backward walking self-selected speed
ST-Cognitive: None
DT: FW-WLG, FW-S3, FW-S7, and BW-WLG

Results:
MS group showed no significant change in DTC with increasing task difficulty
WD control group displayed a significant task effect for walking velocity and cadence with DTC increasing with cognitive task difficulty.

Limitations: no ST cognitive, short distance walk - limited opportunity for word generation, WD group not age and gender matched to MS group.
Dual-Task Training in pwMS?

There is no direct evidence in pwMS that dual-task-related deficits in postural control or dual-task related gait changes can been remediated by training.

There is no information regarding dual-task training parameters.

Clinical judgment?

- Do you screen for dual-task deficits? If so, how?
- Have you observed dual-task-related changes in postural control or gait in pwMS?
- Do these changes negatively impact mobility?
- Have you attempted dual-task training to remediate these dual-task deficits?
Take Home Messages

Emerging but incomplete evidence of dual-task-related postural deficits and gait changes in pwMS

It is likely that not all pwMS will exhibit DTC greater than those WD

Consider screening for dual-task deficits

Will combining balance or walking performance with a cognitive task (e.g., dual-task) capture irregularities not revealed during standard assessment (e.g., single-task)?

Additional research is needed
- Identifying the mechanisms underlying dual-task-related changes in pwMS
- Understand the clinical significance dual-task-related changes in pwMS
- Develop clinical measures of dual-tasking in pwMS
**CONTEXT-DEPENDENT LEARNING**
(PARKINSON’S DISEASE, MULTIPLE SCLEROSIS, AND TRAUMATIC BRAIN INJURIES)

Ya-Yun (Alice) Lee, PT, MS
University of Southern California (USC)
Division of Biokinesiology and Physical Therapy

**Objectives**
- To describe how contextual information affects motor performance in people with PD → context-dependent learning
- To understand potential mechanisms associated with context-dependent learning
- To discuss clinical applications for physical therapists

---

**What Are the Optimal Training Strategies for Individuals with PD?**

- **Training goals**
  - Decrease motor impairment
  - Enhance functional capabilities
- **Common treatment strategies**
  - Gait training, balance training, cueing strategy, etc.
- **Individuals respond differently to training**
- **How to achieve the best training effect?**
  - Motor learning matters

---

**Do Individuals with PD Have Motor Learning Deficits?**

- **Controversial results in the literature**
- **Related to**
  - Stage of learning
  - Disease severity
  - Medication usage
- **Acquisition is preserved in PD, but transfer is limited**

---

**Determining the Optimal Challenge Point for Motor Skill Learning in PD**

- **Individuals with PD demonstrated comparable motor learning to healthy adults, even under high cognitive demand conditions**
- **However, comparable learning only occurred when the testing condition was the same as that during practice**
- **This context-dependent behavior may be related to motor set inflexibility**

  1. Are individuals with PD more context-dependent than healthy individuals during motor learning?
  2. What is the neural mechanism associated with this behavior?
Are Individuals with PD More Context-Dependent Than Healthy Individuals during Motor Learning?

What is Context-Dependent Learning?

Real life examples:
- Home field advantage
- Foul shots

Context-Dependent Learning in PD?

The Effect of a Home Physiotherapy Program for Persons with Parkinson’s Disease

- Main findings
  - Physical training at home led to effective performance of functional activities
  - The effect of training seemed to be most convincing in the context in which training took place

- Limitations
  - High drop out rate
  - Two contexts were tested on different days and time
  - Video taped the performance in hospital, but not at home testing

- Implication: context may play an important role in PT training

The Effect of a Home Physiotherapy Program for Persons with Parkinson’s Disease

<table>
<thead>
<tr>
<th>Group</th>
<th>PD Group (n=9)</th>
<th>Control Group (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>63.67 ± 10.14</td>
<td>62.89 ± 13.76</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>6M/3F</td>
<td>6M/3F</td>
</tr>
<tr>
<td>Hoehn &amp; Yahr Stage</td>
<td>2.33 ± 0.5</td>
<td>N/A</td>
</tr>
<tr>
<td>UPDRS hand function (48)</td>
<td>7.22 ± 3.06</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Sequence Task

- 3 sequences — alternating hands equally
- Index and middle fingers of both hands
- Contexts: color and location on computer screen
- Sequence-context associations were not told to the participants
- 3 sequences pseudo-randomly presented

Retention Tests

- SAME condition
- SWITCH condition

Switch cost (%) = \(100 \times (\text{SWITCH} - \text{SAME})/\text{SAME}\)

- An indicator of context-dependent learning

Practice

SAME condition

SWITCH condition

<table>
<thead>
<tr>
<th>TT</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD</td>
<td>Control</td>
</tr>
</tbody>
</table>

Under the SWITCH condition, individuals with PD demonstrated a greater decrement in total time accuracy cost (TTAC).

Individuals with PD showed a greater switch cost than the control participants.

Individuals with PD are more context dependent.

Summary

- Individuals with PD are more context dependent than the control participants during motor learning
- Post experimental questionnaire reveals that the greater context-dependency in PD is not due to explicit awareness of the sequence-context associations
- What is the potential neural mechanism leading to this context-dependent behavior?

What Is the Neural Mechanism Associated with Context-Dependent Learning in PD?

- Is excessive context dependency associated with set-shifting ability?
- Does this result from impaired frontostriatal circuitry?
Set-Shifting Ability

- The ability to alter or reorganize behavior where appropriate, either in response to a change in environmental circumstances or with a change in goal
- Set-shifting ability is disrupted even in the early stage of the disease
- Common ways to test set-shifting ability
  - Wisconsin card sorting task
  - Trail making test

Set-shifting ability:

Part A

Part B

Sample of Trail Making Test (TMT)\(^9,10\)

Set-shifting ability:

TMT-B/TMT-A

Set-Shifting Ability Is Mediated by the Frontostriatal Circuit

Relationship between Set-Shifting Ability and Context-Dependent Learning

PD

Control

\( r = 0.89 \)

\( r = -0.29 \)

Summary

- Context-dependency in PD is positively associated with the set-shifting ability
- Set-shifting ability is mediated by the integrity of the frontostriatal circuit
- Will disruption of the frontostriatal circuit lead to the context-dependent behavior observed in PD?
  - To be determined...

Clinical Implications

- Training environment plays a crucial role during treatment
  - Individuals with PD subconsciously utilize external environmental information excessively
  - Individuals with PD may over-rely on contextual cues available in the training environment, which may limit the ability to generalize learned motor tasks to various environmental conditions
- Context-dependency could occur early in the disease stage
  - Especially for those who demonstrate set-shifting deficits
Clinical Implications

• What will be the optimal training strategy?
  ➢ For individuals doing fine in their own environment: challenge their ability to generalize → exposure to various contexts
  ➢ For individuals in the later stages of the disease: train them in the environment where they perform their daily activities, and progress them to novel environmental conditions

• Visual and auditory cueing strategies for individuals with PD
  ➢ Advantages
    - Effective to improve walking ability
    - Decrease freezing of gait
    - Improve dual-task walking
  ➢ Disadvantages
    - Limited carry-over effect
    - Limited transfer capability

How could we optimize the use of cueing training?

Are Individuals with MS Context Dependent?

• Cognitive deficits in MS
  ➢ Slowed mental processing speed
  ➢ Impaired episodic memory
  ➢ Implicit learning may remain intact (limited studies with inconsistent results)
  ➢ 17% of patients with MS have executive dysfunction
    - Associated with greater lesion primary in frontal and parietal regions
    - May have context-dependent behavior?

Are Individuals with TBI Context Dependent?

• Depend on the lesion sites
  ➢ Frontal lobe lesions – executive dysfunction
  ➢ Reasoning
  ➢ Planning
  ➢ Concept formation

Possibly will have context-dependent behavior

Clinical Implications

• No evidence of this context-dependent learning deficit in individuals with MS or TBI
  ➢ Depends on the disease severity and/or the lesion site, context-dependency may be an issue

• Cognitive dysfunctions interact with motor impairments
  ➢ Physical therapy training should consider both impairments at the same time in order to reach the most optimal training effect

Concluding Remarks
### Dual-Task Deficit vs. Context-Dependent Deficit

<table>
<thead>
<tr>
<th></th>
<th>Dual-Task Deficit</th>
<th>Context-Dependent Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptoms</td>
<td>Have difficulty performing two tasks at the same time</td>
<td>Have difficulty generalizing learned motor task from one context to another</td>
</tr>
<tr>
<td>Patient population</td>
<td>PD, MS, TBI</td>
<td>PD, MS(?), maybe TBI</td>
</tr>
<tr>
<td>Associated cognitive impairments</td>
<td>Sat-shifting deficit, limited attentional resources</td>
<td>Sat-shifting deficit, limited ability to transfer learned motor skills</td>
</tr>
<tr>
<td>Associated neural substrates</td>
<td>Premotor, SMA, basal ganglia, inferior frontal areas, parietal areas, precuneus</td>
<td>Possibly the frontostriatal circuit</td>
</tr>
<tr>
<td>Induced risks</td>
<td>Gait impairment, postural instability, falls</td>
<td>Pacing, falls, postural instability</td>
</tr>
<tr>
<td>Training Strategy</td>
<td>Cueing and attentional strategies, dual-task (or multi-task) training</td>
<td>Exposure to various contexts with the same motor task</td>
</tr>
</tbody>
</table>

### An Emerging Field of Study

- Dual-Task Deficit
- Context-Dependent Deficit
- PD, MS, TBI

**Acknowledgements**

- Beth Fisher, PhD, PT
- Carolee Winston, PhD, PT, FAPTA
- James Gordon, EdD, PT, FAPTA
- Giselle Petzinger, MD
- Elizabeth Zelinski, PhD

**References**

Kelly - References


Wagner - References


Lee- References: