COGNITIVE CONTROL OF BALANCE AND GAIT IN PD

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Agenda

• **Attentional demands of gait**
  – Dual tasking in PD
  – Role of complexity of motor task

• **Set switching in balance and gait**

• **Inhibition in balance and gait**
Are gait and balance problems expressions of cognitive deficits?
Compensation through cognitive control

Impaired cognition worsens motor impairments

- Brain pathology
- Intact cognition
- Motor impairments
- Dual task performance
- Cognitive impairments
- Executive dysfunction
- Motor impairments
How does cognition play a role?

• Cognitive resources needed to walk
  – Sharing attention
  – Specific cognitive functions: response inhibition, set switching, ...

• Compensatory cognitive strategies
  – Priority of tasks
  – Goal-directed actions ("take large steps")
Paying attention to walking
Design dual-task performance

- ST cognitive task
- ST walk
- DT walk & cognitive task
Dual-tasking in PD

- 121 early PD
- 189 controls

Rochester et al., Neurosci 2014

Dual-task interference

(dual task - single task) ÷ single task
Dual-tasking strategies

- Prioritize cognition: stop walking while talking
- Both tasks deteriorate in DT: lower gait speed, lower cognitive performance
- Prioritize gait: higher gait speed, higher cognitive performance

Stop talking while walking
Stop walking while talking
Dual-tasking and falls

Large cohort (N=262) of idiopathic PD

ST Stroop

“low”

“high”

ST Walk

DT Walk & Stroop

Falls Telephone

Computerised system
gait speed DT < ST

Prioritize cognition

Both tasks deteriorate in DT

Prioritize gait

Smulders et al., J Neurol 2012
IS STRAIGHT-AHEAD GAIT TOO EASY?
Higher cognitive control tasks

Cognitive control

- Straight walking
- Gait initiation
- Turning
- Gait adaptability
Attentional demands of turning: FoG episodes

<table>
<thead>
<tr>
<th></th>
<th>Straight</th>
<th>180°</th>
<th>360°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single task</td>
<td>0%</td>
<td>37.5% [21.4–53.6]</td>
<td>31.6% [16.1–47.1]</td>
</tr>
<tr>
<td>Dual task</td>
<td>5% [0–12.3]</td>
<td>37.5% [21.4–53.6]</td>
<td>61.1% [44.9–77.4]</td>
</tr>
</tbody>
</table>

Percentage of trials calculated from the total amount of trials for each separate condition in which freezing occurred (from the seven freezers who froze during the protocol) and 95% confidence intervals in brackets [ ].

Spildooren et al., Mov Disord 2010
Obstacle avoidance: activation of frontal cortex

Maidan et al., NNR 2016
Obstacle Avoidance in Stroke

Short side step...
Dual task does not worsen obstacle avoidance
Dual task worsens cognitive task
Interim conclusion

- Attention is needed for gait
- Evidence for extra DT deficit in PD during straight-ahead gait not overwhelming
- Look at individual performances
- Look at performance on both tasks
- Consider more complex motor tasks
SPECIFIC COGNITIVE FUNCTIONS
Compensation through cognitive control

Impaired cognition worsens motor impairments
Executive function

<table>
<thead>
<tr>
<th>Attention</th>
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<tbody>
<tr>
<td>Set Shifting</td>
</tr>
<tr>
<td>Updating</td>
</tr>
<tr>
<td>Inhibition</td>
</tr>
</tbody>
</table>
Attention

signal-to-noise ratio

(a) (b)
Inhibition

Updating

Inhibition

Flexible shifting from one set or task to another.

Cognitive flexibility

Antonym:
Cognitive stability (maintenance, perseverance)

Tasks:
Wisconsin Card Sorting Task
Trail making test B
Specific Set Switching paradigms

Courtesy of Roshan Cools
Set Shifting

Inhibition

Update information in working memory

Tasks:
N-back tasks
Letter working memory tasks

Set Shifting

Updating

Inhibition

Ability to stop ongoing process or task.

Poor inhibition: Impulsivity

Tasks:
Go-NoGo Tasks
Stop Signal Tasks
Stroop Tasks
Simon-like Tasks

Amanzio et al. Brain 2011
COGNITIVE DEFICITS IN PD
Cognitive impairments are common in newly diagnosed PD

<table>
<thead>
<tr>
<th>No. of tests impaired</th>
<th>Patients with Parkinson disease, %</th>
<th>Healthy controls, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>37.4</td>
<td>68.6</td>
</tr>
<tr>
<td>1</td>
<td>24.3</td>
<td>20.0</td>
</tr>
<tr>
<td>2</td>
<td>14.8</td>
<td>7.1</td>
</tr>
<tr>
<td>3</td>
<td>8.7</td>
<td>2.9</td>
</tr>
<tr>
<td>4</td>
<td>3.5</td>
<td>1.4</td>
</tr>
<tr>
<td>≥5</td>
<td>11.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Number of impaired tests and percentages of Parkinson disease patients and healthy controls demonstrating impairments

Muslimovic et al., Neurology 2005
**VISUOSPATIAL / EXECUTIVE**

- **Copy Cube**
  - Draw CLOCK (Ten past eleven) (3 points)

**MEMORY**

<table>
<thead>
<tr>
<th></th>
<th>FACE</th>
<th>VELVET</th>
<th>CHURCH</th>
<th>DAISY</th>
<th>RED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st trial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd trial</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**ATTENTION**

- **Read list of digits (1 digit/ sec.).**
  - Subject has to repeat them in the forward order
  - Subject has to repeat them in the backward order


- **Read list of letters.** The subject must tap with his hand at each letter A. No points if \( \geq 2 \) errors

- **Serial 7 subtraction starting at 100**
  - \( [\ ] 93 \) \( [\ ] 86 \) \( [\ ] 79 \) \( [\ ] 72 \) \( [\ ] 65 \)
  - 4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**

**ABSTRACTION**

- **Similarity between e.g. banana - orange = fruit**
  - \( [\ ] \) train - bicycle \( [\ ] \) watch - ruler
Freezing of gait: a particular group?

The Specific Contributions of Set-Shifting to Freezing of Gait in Parkinson’s Disease

Sharon L. Naismith, DPsych (Neuro), MAPS, CCN, James M. Shine, MBBS, and Simon J.G. Lewis, MBBCh, BSc, MRCP, FRACP, MD*

Naismith et al. Mov Disord 2010

CONFLICT AND FREEZEING OF GAIT IN PARKINSON’S DISEASE: SUPPORT FOR A RESPONSE CONTROL DEFICIT

J. VANDENBOSSCHE, A.D.D., N. DEROOST, A.D.
E. SOETENS, A.D. P. ZEISCHKA, A.D. SPIELDOOREN.
E. VERCRUYSSE, A.D. A. NIEUWBOER, A.D. AND
E. KERKHOF, A.D.

Vandenbossche et al. 2012

Freezing of Gait in Parkinson’s Disease Is Related to Impaired Motor Switching During Stepping

Katrijn Smulders, PhD,1,2* Rianne A. Esselink, MD, PhD,1 Bastiaan R. Bloem, MD, PhD,1 and Roshan Cools, PhD3,4

Smulders et al. Mov Disord 2015
SET SWITCHING
Postural inflexibility in PD

Chong et al. J Neurol Sci 2000
Compensatory stepping
Flexibility in compensatory stepping

Diagram showing steps and switch conditions for different groups:
- Healthy: 8 steps, 8 FiPs, switch
- PD: 1 step, 4 FiPs, switch
- PD no FOG: 1 step, 8 FiPs, switch
- PD FOG: 1 step, 3 FiPs, 1 step, 8 FiPs, switch

Graphs showing step length (cm) for T1, non-switch, and switch conditions:
- Healthy: 15 cm
- PD: 10 cm

Comparing PD no FOG and PD FOG:
- PD no FOG: 20 cm
- PD FOG: 10 cm

Significance level: **
Voluntary stepping

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Smulders et al Mov Disord 2015

Motor shift effects

- ▲ PD–freezer
- ■ PD–no freezer
- □ HC

no shift  |  motor shift
INHIBITION
Simon task

COMPATIBLE

INCOMPATIBLE

Van den Weerdenberg et al. Front Hum Neurosci 2010
How does this relate to movement?

Simon task in PD:
gait & balance deficits ↔ impulsive errors

Wylie et al. JNNP 2012
gait deficits and postural instability (PIGD) 

impulsivity 

falls
Barratt: Trait impulsivity

- Motor impulsivity
  - Acting without thinking
  - “I act on the spur of the moment.”

- Attentional impulsivity
  - Lack of focusing on the task at hand
  - Thought insertions, racing thoughts
  - “I say things without thinking.”

- Non-planning impulsivity
  - Lack of futuring or forethought
  - “I plan trips well ahead of time.”

Stanford et al. Pers Ind Diff 2009
Impulsive patients fall more often

Smulders et al., PLoS One 2014
“...some of the worst fallers are those who impulsively jump from their chair or turn without thinking”

Ahlskog, Neurology 2010 p. 1227
General summary

- **Attentional demands of walking**
  - Reveal subtle gait impairments
  - Monitor prioritization of tasks

- **Switching - gait initiation difficulty**
  - In-place vs. step recovery strategies
  - Freezing of gait

- **Inhibition**
  - Impulsivity predisposes to falls
The solution?
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