Dual-Task Interference: Definition, Measurement, and Intervention

Tara McIsaac, PhD, PT
Prudence Plummer, PhD, PT
Lisa Muratori, EdD, PT
Nora Fritz, PhD, PT, DPT, NCS
Disclosures

• Dr. McIsaac reports no disclosures
• Dr. Plummer reports no disclosures
• Dr. Muratori reports no disclosures
• Dr. Fritz reports no disclosures
Learning Objectives

• Define dual-task and understand how a dual-task taxonomy may clarify discrepancies in the literature and in clinical findings of dual-task interference effects.

• Discuss the measurement of dual-task interference.

• Understand the importance of task selection and instruction, and the impact on dual-task performance.

• Discuss the interference resulting from simultaneous task performance in healthy individuals and people with neurologic dysfunction, and the implementation of dual-task training in patient populations.
Overview

• Define dual-task and review current evidence on dual task interference effects.
• Measurement and factors influencing dual task performance.
• Discuss the role of a proposed dual task taxonomy to clarify discrepancies in the literature and clinical testing.
• Dual task training considerations. Application through clinical cases and results from clinical research.
• Panel discussion and Q&A with audience members.
Defining dual-task and reviewing current evidence on dual-task interference effects

Tara L. McIsaac, PhD, PT
Arizona School of Health Sciences
A.T. Still University
Mesa, AZ
Paying attention to two or more tasks is costly.
“Stops walking when talking” test predictor of falls in elderly

Lundin-Olssen et al. 1997
Two primary modes of mobility more risky due to inattention

<table>
<thead>
<tr>
<th>Pedestrians admit to dangerous crossing behavior despite knowing risk</th>
<th>Drivers admit to behavior endangering pedestrians despite knowing risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PEDESTRIANS THAT ENGAGE IN ACTIVITY</strong></td>
<td><strong>DRIVERS THAT ENGAGE IN ACTIVITY</strong></td>
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<tr>
<td><strong>PEDESTRIANS THAT FIND THE ACTIVITY DANGEROUS</strong></td>
<td><strong>DRIVERS THAT FIND THE ACTIVITY DANGEROUS</strong></td>
</tr>
<tr>
<td>Talk on the phone while crossing the street 51%</td>
<td>26%</td>
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<tr>
<td>Text or email while crossing the street 26%</td>
<td>55%</td>
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<tr>
<td>Listen to music while crossing the street 34%</td>
<td>25%</td>
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<tr>
<td>60% of pedestrians use smartphones when crossing the street</td>
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For more information, visit www.LibertyMutual.com
Dual Task Defined

the concurrent performance of two tasks that can be performed independently and have distinct and separate goals.

Each task performance can be measured independently as a single task
Healthy adults dampen the vertical motion of the cup when walking.
Complex control of fluid dynamics versus dual task interference?

TUG Total Duration

Second Task

Straight Gait Speed

Turn Velocity
Studies of Dual Task Performance

• Number of Publications by Population
  – Healthy young adults (241)
  – Aging (429)
  – Neurologic Involvement
    • Parkinson Disease (146)
    • Stroke (128)
    • Traumatic Brain Injury (96)
    • Multiple Sclerosis (40)
    • Huntington’s disease (10)
    • Essential Tremor (4)
    • Mild Cognitive Impairment (73), Dementia (173), Alzheimer’s (127)
Dual Tasking Activities Studied

• Number of Publications by Activity
  – Upright stance & locomotion
    • Balancing / Postural control (375)
    • Walking / Gait (569)
  – Seated locomotion
    • Driving (141)
    • Bicycling (2)
    • Wheelchair propulsion (?)
  – Manual tasks
    • Reaching & Grasping (47)
    • Dexterity (4)
Why Use Dual Task Paradigms?

- To assess cognitive and executive function
- To assess gait and fall risk
  - Meta-analysis of 30 studies:
    - Gait speed in Single Task and Dual Task walking equally good for predicting falls and discriminating fallers & non-fallers
- Ecological validity – assess everyday function

McFadyen et al. 2015 *Neuropsych Rehabil*
Menant et al. 2014 *Ageing Res Rev*
Information Processing for Motor Behaviors

• Increased demand for information processing does not alone create a dual task

• Circular Argument:
  – *Defining* a dual task by level of attentional load and allocation, yet *measuring* dual task performance by attentional load and allocation.

• Dissociability of *goals* of concurrently performed tasks – measure each task performance
Factors influencing dual-task performance

Prue Plummer, PhD, PT
Department of Allied Health Sciences
Division of Physical Therapy
University of North Carolina
Chapel Hill, NC
Classic dual-task paradigm

1. Measure performance of each task in isolation (single-task)
   - Gait alone
   - Cognitive task alone (sitting)

2. Measure performance of each task while performed concurrently (dual-task)
Patterns of dual-task performance

- 9 patterns based on performance change (direction) in each task relative to single-task performance.

<table>
<thead>
<tr>
<th>Cognitive performance</th>
<th>No change</th>
<th>Improved</th>
<th>Worsened</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No change</strong></td>
<td>No dual-task interference</td>
<td>Cognitive facilitation</td>
<td>Cognitive interference (motor-related)</td>
</tr>
<tr>
<td><strong>Improved</strong></td>
<td>Motor facilitation</td>
<td>Mutual facilitation</td>
<td>Motor-priority trade-off</td>
</tr>
<tr>
<td><strong>Worsened</strong></td>
<td>Motor interference (cognitive-related)</td>
<td>Cognitive-priority trade-off</td>
<td>Mutual interference</td>
</tr>
</tbody>
</table>

Adapted from Plummer et al, Arch Phys Med Rehabil (2013)
Patterns of cognitive-motor interference

Plot gait DTE against cognition DTE to understand the nature of the interference

Patterns of cognitive-motor interference after stroke

Cognition DTE (clock)
Gait speed DTE

**Stroke** (n=24)
Age:
- 65.2 years (33-86)
Post stroke onset:
- 8.8 months (2.5-24)
Factors influencing attention allocation during dual-task walking

- **Extrinsic factors**
  - Task difficulty (cognitive, motor)
  - Instructions
  - Environmental hazards/distractions
  - Variable being measured

- **Intrinsic factors**
  - Motor impairment (postural reserve)
  - Usual gait speed
  - Balance self-efficacy
  - Cognitive reserve (education)
  - Lesion location?

- **Pattern (magnitude and direction) of dual-task interference**

- **Task prioritization**
Extrinsic factors influencing CMI

• Nature and/or difficulty of cognitive task
  – e.g., 1-back, clock, speech
    (Plummer-D’Amato et al, Gait Posture, 2008)

• Nature and/or difficulty of gait task
  – Unobstructed gait versus obstacle crossing

• Variable being measured
  – Gait speed versus gait variability
  – Reaction time versus accuracy

• Environmental complexity
  – Closed versus open environment
Intrinsic factors influencing CMI

• Motor impairment
  – Lower extremity motor impairment after stroke is correlated with dual-task costs on gait (Plummer-D’Amato et al, Gait Posture, 2012)

• Usual gait speed
  – Slower walkers have greater dual-task costs on gait
    • Stroke (Plummer-D’Amato et al, Gait Posture, 2012)
    • Older adults (Plummer-D’Amato et al, Gait Posture, 2011)

• Balance self-efficacy
  – Individuals who appear to prioritize the non-gait task have greater balance confidence (Plummer-D’Amato et al, Int J Ther Rehabil, 2012)

• Cognitive reserve
  – Education appears to offset dual-task effects on cognition (Plummer-D’Amato et al, J Aging Res, 2012)
Task prioritization effects on CMI

• Instructions can influence performance
  – No instruction about task prioritization
  – Instruct to focus more on one particular task
  – Should be the same each time you assess!

• No specific prioritization
  – Spontaneous/default performance
  – Natural attentional biases

• Priority-specific
  – Flexibility in attention allocation
Measuring dual-task performance
Purpose of measurement

• To quantify limitations
  – Develop treatment goals
• To characterize the pattern of dual-task interference
• To infer attentional prioritization
  – Attentional biases, implications for safety
• To evaluate treatment effects
How to measure

• **Absolute measures**: single-task and dual-task parameters (e.g., gait speed)

• **Relative measures**: dual-task effect (cost/benefit)

\[
DTE (\%) = \frac{\pm (\text{dual task} - \text{single task})}{\text{single task}} \times 100
\]
Implications for assessment

• Use the same dual-task combination for pre and post assessment
• Use consistent instructions
• Consider testing more than one type of cognitive-motor dual-task combination
No prioritization instruction

Limitations:

• Selected strategy may be influenced by numerous factors

• Person may change the way they perform the two tasks together on a different day
  – Reliability of dual-task assessment
Recommendations for assessment

1. Establish a standardized assessment protocol
2. Measure key aspects of both gait and cognitive task performance in single and dual-task conditions
3. Examine changes in absolute and relative measures
4. Evaluate changes in one task in relation to the other; consider attentional strategy/trade offs
5. Assess treatment-related changes in absolute measures against known MCID values or other known clinically significant thresholds
6. Evaluate treatment-related changes in relative measures in terms of pattern(strategy change
The Role of a Proposed Dual Task Taxonomy

Lisa M. Muratori, PT, EdD
School of Health Technology and Management
Stony Brook University
New York, NY
Dual Task Defined

...the concurrent performance of two tasks that can be performed independently and have distinct and separate goals.
Dual task pairings

- Cognitive
- Motor
- Continuous
- Discrete
Why a Taxonomy?

- Taxonomies are organizational systems that allow for the categorization or grouping of a specific topic or concept.
- Taxonomies usually have some inherent degree of order built into them although the method to move from a lower to a higher degree of order may not be linear.
- A taxonomy can provide a common language.
## Building a taxonomy

<table>
<thead>
<tr>
<th>Task Novelty</th>
<th>Task Complexity</th>
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Dual-Task Training Considerations

Nora Fritz, PhD, PT, DPT, NCS
Departments of Physical Therapy & Neurology
Wayne State University
Detroit, MI
Types of Interventions

- Motor-Cognitive
- Motor-Motor
- Cognitive-Cognitive
Diagnoses Targeted

Degenerative Disorders
- Parkinson’s disease
- Alzheimer’s disease
- Dementia
- Multiple Sclerosis

Other Populations
- Traumatic Brain Injury
  - mild, severe
- Stroke
  - chronic
- Older Adults
Categorizing Interventions

**Motor**
- Walking
  - Forward
  - Backward
  - Obstacles
- Balancing
  - SOT
  - Dynamic weight shifting
  - External perturbations
- External Cueing
  - Speed
  - Stride length
  - Timing/metronome

**Cognitive**
- Listening to music
- Listening to talk-radio
- Verbal fluency
- Answer autobiographical questions
- Serial 3-subtraction
- Information processing tasks
- Counting backwards
- Auditory choice reaction time task
- Visuospatial task of pattern matching
Methods of Interventions

**Overground/Treadmill**
- Interventions taking place without external technology

**Exergaming/Virtual Reality**
- Interventions relying on a game (e.g., Wii Fit, Kinect) or Virtual Reality system to provide the secondary task
Limitations of Current Intervention Evidence

• Wide variety of intensity, frequency and duration
  – 30 minutes to 3 hours/wk for 16 weeks
  – Improvements have been shown with short-duration training, but follow-up and retention is rarely discussed

• Wide variety of interventions used
  – 12 different protocols across 14 studies examined

Fritz et al., 2015
Limitations of Current Intervention Evidence

• Wide variety of outcomes used
  – > 35 outcome measures used to assess the effect of Dual-Task Training
  – > 7 for assessing Dual-Task gait alone
  – Often dependent on the primary motivation (improve walking? Cognition? Ability to dual-task?)

• Classification of what constitutes “dual-task” training
  – Overground/treadmill vs. VR/exergaming

Fritz et al., 2015
Generalization of the trained task to novel dual-tasks

• Often, the outcome measure used to assess improvement following DTT is the same task upon which the participant was trained.
  – Limitation when showing true effect

• Yogev-Seligmann et al., (2012)
  – Improvements in gait speed & stride time variability during walking with an untrained cognitive task

• Killane et al., (2015)
  – Improvements on untrained an motor dual-task
  – Suggests transfer of training may be possible
Clinical Case 1


• Subjects:
  – 61 individuals with MS
  – Established balance impairment: recommendation from PT for balance training (assessed with questionnaires, Romberg and 1-leg stance tests)
  – 44 female; 17 male
  – Mean age: 47±9 years
  – EDSS: 3±1
Clinical Case 1

• Intervention

  – Nine 30-minute sessions over 3 weeks of:
    • N=20 -- Conventional balance training (control)
    • N=21 -- Exergame training (playing Wii UE games on an unstable platform)
    • N=20 -- Single task exercises on an unstable platform

  – All participants also underwent rehab program in the clinic consisting of PT, OT, ST and neuropsych according to their needs.

Kramer et al., 2014
Clinical Case 1

• Outcome Measures
  – 6 static balance tests on forceplate
    • EOFT, ECFT, SLS-EO; SLS-EC; SLS-typing
  – 4 balance tests on unstable surface
    • EO, SLS, EO + Wii golf pitch, SLS + Wii golf pitch
  – 2 gait measures
    • 10m walk ST and while answering questions
  – 6 month f/u: weekly prospective questionnaires for the amount of balance training performed + falls
    • N=16 with weekly reports at the end of 6 months; 6 exergame, 6 unstable platform, 4 conventional training)
    • N=42 individuals contacted at the end of training
    • N=3 individuals who could not be contacted

Kramer et al., 2014
Clinical

- Results

- Exergaming + unstable surface may be an effective way to improve balance and gait, especially in dual-task situations
- Exergaming may contribute to improved adherence and therefore long-term effectiveness of rehabilitation programs

Kramer et al., 2014
Clinical Case 2


• Subjects
  – 33 individuals with chronic stroke

• Intervention
  – Twenty-four 30-minute sessions over 8 weeks
    • N=11 -- Motor dual-task training group
    • N=11 -- Cognitive dual-task training group
    • N=11 -- Motor-Cognitive dual-task training group
Clinical Case 2

• Outcome Measures
  – Cognitive: none assessed.
  – Motor:
    • TUG
    • Four Square Step Test
    • 10 meter walk test
    • 6 minute walk test
    • Functional Reach Test
    • Stability Test Index (EO & EC)*
    • Weight Distribution Index (EO & EC)*

*no description of these tasks

An et al., 2014
Clinical Case 2

• Results
  – For all measures except FSST and TUG:
    • All groups improved with Motor-Cog>Motor>Cog
    • FSST: MC > C > M
    • TUG: M > MC > C

• Clinical Relevance
  – Motor improvements with DT training without special technologies
  – Combining Motor-Motor dual-tasks and Motor-Cognitive dual-tasks may be beneficial and should be explored in future studies

An et al., 2014
Clinical Case 3


• Subjects

<table>
<thead>
<tr>
<th>Table 1: Personal Characteristics of each Group</th>
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<tr>
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<tr>
<td>Age</td>
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<tr>
<td>Hoehn &amp; Yahr</td>
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<tr>
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<tr>
<td>Frontal Assessment Battery</td>
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<tr>
<td>New Freezing of Gait Questionnaire</td>
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</tbody>
</table>

UPDRS = Unified Parkinson’s Disease Rating Scale, *p <0.05.
Clinical Case 3

- **Intervention**
  - Eight 20-minute sessions over 2 weeks
  - Remained on regular medication for all sessions
  - Combined cognitive and motor training
  - **MOTOR**: VR maze game running at constant 1 m/s and incorporating turns, narrow corridors and doorways
    - Wii balance board & hand controls
  - **COGNITIVE**: concurrent Stroop test presented at the bottom of the screen requiring button press on hand controls
  - Equal priority to both tasks

*Figure 1. Experimental set-up for assessments and intervention showing intervention task with plan of maze (top left), timer (top right) and first-person view of maze (image on main screen).*

*Killane et al., 2015*
Clinical Case 3

- Outcome Measures
  - Different motor & cognitive assessments than training
- VR:
  - ST: stepping in place on balance board through VR corridor
  - ST: seated performance of a 2-stimulus visual “oddball task”
  - DT: combining the 2 ST.
- Motor:
  - Stepping time
  - Stepping time variability
  - Symmetry for both ST and DT conditions.
- Cognitive:
  - Mean reaction time and accuracy during the oddball task in both ST and DT conditions

Killane et al., 2015
Clinical Case 3

• Results

Figure 3. Intervention Outcomes: Time taken to complete maze (left) Reaction Time (centre) and Accuracy: Correct Answers (right) for Freezers (Green) and Non-Freezers (Blue) in the first and last sessions

• Clinical

- There are few interventions that target FOG
- The VR platform can be customized to target specific triggers of FOG for specific patients
- VR could be employed in the home setting for long-term use

Killane et al., 2015
## Beneficial or Not?

<table>
<thead>
<tr>
<th>Comparison Treatment</th>
<th>Outcome Measure</th>
<th>Mean Difference</th>
<th>Effect Size (SMD) and 95% CI</th>
<th>Forest Plots</th>
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<tbody>
<tr>
<td><strong>General Exercise</strong></td>
<td>Gait (DTC velocity) $^{20}$</td>
<td>19.01</td>
<td>1.14 (0.59 to 1.68)</td>
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<td></td>
<td>Gait (DTC stride length) $^{20}$</td>
<td>14.2</td>
<td>1.07 (0.53 to 1.62)</td>
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<td><strong>Null Control</strong></td>
<td>Gait (ST velocity) $^{23}$</td>
<td>0.15</td>
<td>0.56 (-0.60 to 1.71)</td>
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<td>Gait (ST velocity) $^{24}$</td>
<td>0.09</td>
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<td>Gait (ST stride length) $^{26}$</td>
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<td>Gait (DT velocity) $^{22}$</td>
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<td>1.52 (0.50 to 2.54)</td>
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<td>Gait (DT velocity) $^{23}$</td>
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<td>1.11 (-0.10 to 2.33)</td>
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<td>Gait (DT velocity) $^{24}$</td>
<td>0.14</td>
<td>0.55 (-0.60 to 1.70)</td>
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<td>Gait (DT stride length) $^{23}$</td>
<td>0.34</td>
<td>0.35 (-0.79 to 1.49)</td>
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<td></td>
<td>Gait (DT stride length) $^{24}$</td>
<td>0.16</td>
<td>0.90 (-0.29 to 2.08)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gait (DT stride length) $^{26}$</td>
<td>6.00</td>
<td>1.62 (0.71 to 2.43)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Balance (BBS) $^{25}$</td>
<td>4.90</td>
<td>1.67 (0.8 to 2.45)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cognition (FAB) $^{25}$</td>
<td>3.90</td>
<td>1.96 (1.09 to 2.83)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cognition (FAB) $^{26}$</td>
<td>6.00</td>
<td>3.07 (1.88 to 4.08)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cognition (Memory Span &amp; Tracking Task) $^{22}$</td>
<td>-4.75</td>
<td>-0.59 (-1.51 to 0.33)</td>
<td></td>
</tr>
</tbody>
</table>

Fritz et al., 2015

*Favors Comparison*  *Favors DT Training*
Applying DTT to Clinical Practice

• Is my patient appropriate for dual-task training?
• What intervention is best for a specific diagnosis?
• What outcome measures are best for a specific diagnosis?
References


References


References


