Interaction Between the Development of Posture Control and Executive Function of Attention (Reilly et al. 2008)


Objectives_ Series II

- Gain an understanding of the attentional requirements of postural control and how that changes throughout development.
- Gain an understanding of the attentional requirements of postural control in children with cerebral palsy.
- To use this knowledge in assessing the etiology of behaviors observed in the classroom and school environment.

Is Posture Control Automatic or does it require Attentional Resources?
Limited Capacity Theory of Executive Function of Attention

- For each individual, there is finite attentional resources for processing information and;
- Performing any task requiring attentional resources is given a portion of this capacity.
- Therefore, if two tasks are performed together and they require more than the capacity, the performance on either or both deteriorates.
- Practice of a task leads to reduction in the need for attentional resources.

Dual Task Paradigm

- The experimental design that researchers use to assess the attentional demands of a task based on limited capacity theory.
- Postural Control Studies: Two tasks are performed simultaneously. If there is interference in the performance of the primary task (postural control), with the performance of an attentionally demanding secondary task (cognitive task), then the primary task is not automatic, but requires attention.
- Deterioration in performance of cognitive task measured by reaction time and accuracy.
- Deterioration in postural task measured by velocity and range of postural sway.

Demonstration

- Handout: Single vs. Dual Task
Single Task (Baseline): Posture Only

- Wide Stance
- Rhomberg Stance

Which stance position appeared to have the most instability (more postural sway)?

Dual Task: Posture and Stroop (Test 1 and Test 2)

- Pull up the stroop task

Questions/Dual Task: Posture and Easy Stroop Task

Single vs. Dual Task: Did postural sway increase when performing the easy stroop task (test 2) compared to standing without a task (posture only)?
- Wide stance?
- Rhomberg stance?

Wide Stance vs. Rhomberg: Which stance position had the greater increase in sway from baseline to dual task condition?

Cognitive Task: Did the reaction time or accuracy change when performing the easy stroop task?
- Wide Stance?
- Rhomberg stance?
Questions/Dual Task: Posture and Difficult Stroop Task

**Single vs. Dual Task**: Did postural sway increase when performing the difficult stroop task (test 2) compared to standing without a task (posture only)?
- Wide stance?
- Rhomberg stance?

**Wide Stance vs. Rhomberg**: Which stance position had the greater increase in sway from baseline to dual task condition?

**Cognitive Task**: Did the reaction time or accuracy change when performing the difficult stroop task?
- Wide Stance?
- Rhomberg stance?

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Questions/Dual Task: Posture and Difficult Stroop Task

How many experienced interference in both the performance of the stroop task (increase in reaction time compared to baseline) AND postural control (an increase in postural sway compared to baseline)?

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Single vs. Dual Task

Based on your observations and the theory of limited capacity...which of the two stance positions required the most attentional resources?
- Which test (1 or 2) of the Stroop test caused the most interference in postural control?
Global Workspace Model

Posture Only Task: Maintenance of posture in Wide stance or Rhomberg Stance (more difficult)

Evaluation
Perception
Memory
Motor Programs
Allocation of Attention

Sway
Sensory Input
Active muscle synergy

Global Workspace Model

Posture Only Task: Maintenance of posture in Wide stance or Rhomberg stance (more difficult)

Evaluation
Perception
Memory
Motor Programs
Allocation of Attention

Sway
Sensory Input
Attention Needed
Activating muscle synergy

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Easy Stroop Task (test 1)

Secondary task: Stroop task
Motor response

Evaluation
Perception
Memory
Motor Programs
Allocation of Attention

Primary task
Sensory Input
No change in sway
Activating muscle synergy
Global Workspace Model

Primary: Posture Task: Maintenance of posture in Rhomberg Stance/Easy Stroop Task

Secondary task
Stroop task
Motor response

Primary task
Evaluation
Perception
Memory
Motor Programs
Allocation of Attention
No change in sway

Sway
Sensory Input/color
Activate muscle synergy

More Attentional Resources required to control the Rhomberg Stance
Global Workspace Model

Addition of the more Difficult Stroop Task

Secondary task
Stroop task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Program
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input

Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task
Cognitive task

Motor response

Primary task
Evaluation
Perception
Memory
Motor Response
Allocation of Attention

Sway
Sensory Input

Motor response

Primary task
Sway
Sensory Input
Global Workspace Model

Primary: Posture Task: Maintenance of posture in Wide Stance/Difficult Stroop Task

Secondary task

Cognitive task

Evaluation

Perception

Memory

Motor Response

Allocation of Attention

Motor response

Primary task

Sway

Sensory input color

No change in sway

Allocate muscle synergy

Primary task: Posture Task: Maintenance of posture in Rhomberg stance/Difficult Stroop Task

Secondary task

Cognitive task

Evaluation

Perception

Memory

Motor Response

Allocation of Attention

Motor response

Primary task

Sway

Sensory input color

Decrease base of support

Allocate muscle synergy
Primary: Posture Task: Maintenance of posture in Rhomberg stance/Difficult Stroop Task

Secondary task

Cognitive task

Motor Programs

Allocation of Attention

Evaluation

Perception

Memory

Primary task

Motor response

Sway

Decrease base of support

Sensory input

Color

Activate muscle synergy

No change

RT
Research on Attention in Posture Control

- **Adults:**
  - Hierarchy of postural control tasks on the basis of attentional requirements.
  - Sitting to Wide stance to Narrow stance or Romberg stance to Walking to Balance perturbation to changes in sensory environment.
  - Attentional load of the cognitive task affects the degree of postural control interference. The greater the attentional load of the cognitive task, the greater the postural control interference.

- **Older Children:**
  - In children 8-9 years of age, interference in postural control with both easy and difficult cognitive task.

Inquiry

- From a developmental standpoint, is there a difference in the attentional requirement of postural control in young children compared to older children and adults?
- When the demands of the postural control task increase, do the young children have a greater interference in postural control compared to older children and adults?
- Is this interference seen in posture control or in the cognitive task or both?

Developmental Trend in Postural Control in Stance

- **Postural Control: Stance**
  - **4-6 years:**
    - Greatest sway range and velocity compared to older children and adults, therefore more unstable.
    - Greatest variability in the ability to adapt to the differing sensory conditions.
  - **7-10 years:**
    - Less sway compared to younger children (4-6).
    - Greater sway compared to adults
    - Not completely matured in weighting somatosensation for controlling sway.
Developmental Trend in Executive Attention

- **5-10 years**: Executive function of attention to resolve conflict between two stimuli improves.
- **6-8 years**: Greatest interval of time for improvement in resolving conflict between two stimuli.
- **7-10 years**: Capacity is approaching adult levels but not matured.

Hypotheses based on Development of Two Systems

- **Single task**: 4-6 year olds would have larger and faster body sway in wide and modified tandem Romberg compared to older children (7-10 years) and adults.
- **Dual Task**: 4-6 year olds would have greater postural control interference in wide and modified tandem Romberg compared to older children (7-10 years) and adults.
- **Increase demands of postural control**: 4-6 year olds would require greater attentional resources for postural control in modified tandem Romberg stance vs. wide stance compared to older children (7-10 years) and adults and thus experience the greatest interference.
Methodology

- Subjects: 16 children
  - Ages: 6 (YC): 4-6 years, 7 (OC): 7-12 years, 6 (A) adults (20-26 yrs.)
- Posture Task:
  - Easy: Wide stance (lower attentional demand)
  - Difficult: Modified tandem Romberg
- Cognitive Task:
  - Difficult (high attentional demand: Visual Short Term Memory. Equal level for all ages.
  - Measure of attentional capacity
Measurements

- Postural sway: Forces recorded from two force plates from which COP was calculated.
  - A-P maximum excursion and velocity
  - M-L maximum excursion and velocity
- Cognitive: Accuracy
- Attentional Capacity: Number of colored shapes remembered at 70% accuracy.
Developmental Trends

- **Postural Sway:**
  - 4-6 yrs: Greatest and fastest body sway in wide and modified tandem Romberg compared to 7-12 year olds and adults.
  - 7-12 year olds: Greater and faster sway in both stance positions compared to adults.

- **Attentional Resources:**
  - 4-6 yrs: Attentional Resources: The least attentional capacity compared to 7-12 year olds and adults.

- **Dual Task:**
  - 4-6 year olds were the only group who experienced interference in postural control in both stance positions.
  - 4-6 yrs: Greater interference in forward sway in Rhomberg vs. wide stance, therefore, the attentional demand in the Rhomberg was greater than in the wide stance.
  - No group experienced interference in the cognitive task.
Observed Behaviors

- Cognitive task appears to take priority for attentional resources in dual-task conditions.
- Frequent change of postures in sitting
- Compensation to stabilize posture:
  - Wrapping feet around the chair
  - Laying head on desk to write
  - Supporting weight on arms
  - Kneeling in chair
- ‘Falling out of chair’ when focused on reading
- Falling on playground, the clumsy child
- Increased falls in busy hallways
- Reverting to lower level, automatic postures or motor patterns in order to perform the cognitive task.

Questions?

The Interaction Between Executive Attention and Postural Control in Dual-Task Conditions: Children with Cerebral Palsy (Reilly et al., 2008)

Archives of Physical Medicine and Rehabilitation, 89; 834-842
Cerebral Palsy

- Definition
  - Neuro-developmental impairment caused by a non-progressive defect or lesion to the brain resulting in:
    - Deficits in motor, sensory, and cognitive systems
- Etiology
  - Hemorrhage: Physical damage to brain tissue from blood.
  - Anoxia: Reduced blood supply of O₂ to brain tissue
  - Can occur before, during, or immediate after birth

Cerebral Palsy: Classification

- Specific brain regions with associated muscle tone
  - Spastic: Motor cortex lesions, spasticity
  - Ataxic: Cerebellar lesions, jerky movements, poor balance, lack of adaptation of movement with changing environments and task.
  - Dystonia: Basal ganglia: inaccurate or involuntary movements (athetoid)
  - Hypotonic: Decreased muscular tension, exact location unknown.
- Area of Body involved
  - Monoplegia: One limb
  - Diplegia: Two limbs (lower extremities)
  - Quadriplegia: All four limbs
  - Hemiplegia: One sided involvement

Postural Control System

- Musculo-skeletal
- Body Schema
- Neuromuscular Strategies
- Cognitive (Attention)
Musculoskeletal Limitations Affect Alignment

- Change of muscle architecture contributing to muscle weakness
- Limited joint motion at hip, knee, and/or ankle due to abnormal movement patterns or lack of moving joints through full range.
- Crouch Stance: Line of gravity falls behind the knee.

Body Schema: ‘Rules’ for Posture Control

- **Head Control:**
  - Delay in head control by 4 months, indication of CP (Ellenberg, 1981)
  - Abnormal head orientation in whole body movements may affect the development of an efficient body schema (Bernard 2000).
- **Experienced Sitting:**
  - Top-down muscle activation pattern
  - Co-activation of muscles in hip and neck to increase ‘stiffness’ of trunk
  - Spatial-temporal organization of muscle responses to loss of stability is not present.

Alignment at axis of rotation

Line of Gravity

Increase muscle effort (flexors)
Neuromuscular Deficits in Control of Stance

- **Posture strategies:**
  - Children with Spastic CP:
    - Recruitment is proximal to distal (hip to ankle).
    - Co-activation of muscles to ‘stiffen’ the leg and prevent movement at a joint.
  - Children with Ataxic CP:
    - Typical spatial-temporal organization seen in ankle strategy but
    - Deficit in scaling or adjustment of force to perturbations or sway. Oscillating movements to regain balance.

Sensory Strategies

- Children with CP (7-12 years): Deficits in adapting posture control in changing sensory conditions (Nashner et al. 1983)
  - Hemiplegic Spastic CP: Weight somatosensory cues when vision is present or completely absent, but are destabilized with inaccurate vision.
  - Ataxic CP: Difficulty reweighting to an appropriate sensory system with any changing conditions.

Sensory Strategies:

- **Age:** 4 years
- **Dx:** Right Hemiplegia cerebral palsy
- **Range of Motion:** No contractures but distal spasticity limits motion in ankle dorsiflexion and knee extension with hips flexed.
- **AFO:** On the right to prevent plantar flexion and inversion. Also has a lift due to leg length discrepancy.
- **Attention deficit:** Poor inhibition of stimuli and response. Distracted by visual stimuli.
Video 1_Series II

Executive Attention and Cerebral Palsy

- Children with Diplegic Spastic CP (Christ et al 2003):
  - Periventricular leukomalacia
  - Lesions to neural pathways connecting prefrontal lobe (executive attention) to other brain regions
  - Deficits in inhibitory control and resolving conflict between 2 stimuli.

- Children with Ataxic CP (Courchesne et al.1994):
  - Damage to superior posterior cerebellum
  - Deficits in shifting attention (scanning or shifting between two stimuli).

Inquiry

- What is the attentional requirement for postural control in normal stance for children with cerebral palsy with deficits in both postural control and attentional systems?
- Does the attentional requirement increase when postural control is more demanding in narrow stance?
Hypothesis

- Like the typically developing young children, children with CP would undergo postural control interference in both wide and narrow stance positions with the greatest interference occurring in narrow stance.

Methodology

- **Subjects:**
  - 8 Children with cerebral palsy (10-14 years)
  - 4 with Ataxic CP
  - 4 with Spastic Diplegia
  - 6 typically developing older children (7-12 years)
  - 5 typically developing young children (4-6 years)

- **Posture Task:**
  - Easy: Wide stance
  - Difficult: Narrow stance

- **Cognitive Task:** Same as previous study

Visual Short Term Memory Task

- 7-12 years
- 4-6 years
- Children with CP (10-14 years)
Summary of Findings

- **Postural Sway:**
  - 4-6 year olds had greatest postural sway in wide stance compared to children with CP and older children.
  - Children with CP, especially the children with ataxia had greater sway in narrow stance.
- **Dual Task:** Children with CP, like 4-6 year olds had postural control interference in both stance positions.
- Children with ataxia CP also had cognitive task interference in narrow stance. They were 2.4 times more likely to have correct answer in wide vs. narrow stance.

Observed Behaviors

- Children with mild to moderate CP may appear to be similar in postural control as peers until in a dual-task condition.
- Priority for attentional resources in dual-task conditions appears to be the cognitive task unless the condition causes posture instability, then both tasks may have interference in performance.
- Compensations:
  - More dependent upon external supports in busy environments.
  - Revert to lower level or automatic postures in order to perform a cognitive task.
- Decrease performance in cognitive task:
  - Delayed response
  - Decreased accuracy
- Risk of falls increases in busy environments.
Learning Postural Control in Stance

- **Age:** 5 years
- **Dx:** Lack of normal physiology (undetermined)
- **Assistive Devices:** Forearm crutches for ambulation and SMAFOs bilaterally.
- **Postural Muscle Tone:** Hypotonic
- **ROM:** No contractures but motion is limited in knee extension when hip is flexed (due to tight hamstrings). Limited dorsiflexion due to tight gastrocs.
- **Attention:** Distracted by visual and auditory stimuli. Difficulty inhibiting irrelevant visual and auditory stimuli.

Video 2_Series II

*BioA and Dual Task Conditions*

- In Various Sensory Conditions (Shumway-Cook and Woollacott, 2000)
  - Subjects: Young adults, older adults, BioA
  - BioA: Lost balance in all sensory conditions with the addition of a secondary task a simple auditory reaction time task.
- Recovery of Balance (Bauer et al., 1997)
  - Recovery of balance was more attentionally demanding for BioA compared to healthy older adults.
  - Took longer to stabilize
  - Delayed reaction time in Cognitive task
- Stop Walking when Talking (Lundin-Olsson et al. 1997)
  - Test to predict falls in elderly
  - 58 residents
  - 12 stopped walking and 6 fell

*Balanced Impaired Older Adults*
**Stops Walking when Talking**

- **Age:** 7 year old male
- **Dx:** Spastic cerebral palsy
- **Range of Motion:** Limited end range knee extension bilaterally.
- **Attention:** Can sustain focus to task completion.

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**Video 3_Series II**

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**Respiratory and Postural Muscles: Dual Task**

- Hodges, P: Research
- Every muscle of trunk is both respiratory and postural muscle, especially diaphragm.
- If breathing is compromised, postural muscle activation is reduced to focus on immediate needs of respiration and thus posture is de-stabilized.
- Leads to postural adaptation that may not be affective for optimal growth and maturation.
Attention in Balance Recovery

- **Age:** 5 years
- **Dx:** Lack of normal physiology (undetermined)
- **Postural Muscle Tone:** Hypotonic
- **ROM:** Motion is limited in knee extension when hip is flexed (due to tight hamstrings). Limited dorsiflexion due to tight gastrocs.
- **Attention:** Distracted by visual and auditory stimuli. Difficulty inhibiting irrelevant visual and auditory stimuli.

Video 4_Series II

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