Why Aren’t You Paying Attention?

Interaction Between the Development of Postural Control and the Executive Function of Attention

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**Introduction**

- Acknowledgement
- Perspective
- Handouts
Objectives of the Series

From a dynamical systems perspective, course participants will:

- Gain an understanding of the child in a multitasking context based on the knowledge of development of posture control and executive attention.
- Gain an understanding of the child with cerebral palsy in a multitasking context based on the knowledge of abnormal development of posture control and executive attention.
- Gain an understanding in the application of this knowledge as a tool for modifying the task or the environment for the child’s success in learning and performance.
Objectives of Series I

- Gain an understanding in the theory of dynamical systems as a framework for understanding the emergence of behaviors throughout early development.
- Gain knowledge in the various functions of both the postural control and attentional systems.
- Gain an understanding in the development of postural control and attention from a dynamical systems framework.

Dynamical Systems Framework

Principles of Dynamical Systems Theory
**Self-organizing:** Behaviors emerge from the interactions of the individual's systems within his/her context of development (environment and task).

![Diagram showing Developing Systems, Environment, Behavior, and Task]

**Dynamical System Principles**

- **Non-linear:** A change in the development of a system, or the nature of the environment may be the determining factor as to the emergence of a more mature behavior. A small change can facilitate large changes in behaviors.

- **Variability:** Occurs when there is a transition between **stable** states of a behavior.

![Graph showing 1:1 correspondence (linear) and Stair step pattern (non-linear)]
Posture Control

Function and Development

Foundation for Movement

- Provides Stability for the Upright Posture
  - Static: Maintenance of posture stability
    - Sit
    - Stand
  - Dynamic: Regaining stability when lost.

- Prepares body for movement: Aligning body or body segments according to the demands of the task including preparing the body for a loss of balance due to voluntary movement.
Orientation to task

Stability

Anticipatory

Postural Control in Stance
Terminology: Postural Control in Stance

- **Posture Stability (Balance):** Ability to maintain center of gravity (COG) within the base of support (BOS). In stance, base of support is defined by the borders of the feet.

- **Postural Sway:** Movement of the whole body over the base of support. A measure of posture stability.
  - The faster the whole body moves, the less stable the individual in stance.
  - The greater the distance of sway towards the outside borders of the base of support, the less stable the individual in stance.
  - The greater the frequency of sway, the less stable the individual in stance.

Task: Testing stability limits

- Stand-up next to a wall or table in case you need your arms to regain balance.
- Stand with feet shoulder width apart
  - Sway forward and back (anterior-posterior) over your feet. Then, side to side (medial-lateral).
- Test how far you can sway forward before you take a step. This is your limit of stability in the forward position (anterior).
- Test how far you can sway backwards.
- Which direction (forward or backwards) do you lose your stability the quickest?
- How far can you move side to side. Is the point of control from the hip or ankle?
Postural Sway and Stability

Limits Anterior- Posterior

- Inverted pendulum with rotation about the ankle
- The larger the area of the BOS, the larger the limits of stability.
- A-P limits are about 55-80% of foot length in young adults

Postural Sway and Stability

Limits Medial-Lateral

Movement from side to side is controlled by the hip in wide stance.
A narrower base of support increases the need to control movement at the ankle.
Task

- Now narrow your base of support by bringing your feet together.
- Sway side to side.
- Do you feel the control of movement more in hip or ankle?
- Which stance configuration has the least limits of stability in the side to side direction: narrow or wide stance?

Measurements of Postural Sway

**Force Platforms:** Measures vertical and horizontal forces during postural sway.

- **Center of Pressure (COP):** A central point of pressure calculated from these forces.

**Outcomes:**
- velocity of sway
- maximum range of sway
- total distance in a set amount of time
- frequency of sway
Developmental Changes in Postural Sway

- Postural sway decreases in range and velocity as the child matures.
  - Therefore, children are less stable in standing compared to adults.
  - Younger children less stable compared to older children.
  - Sway does not reach adult-like movement until 7 years of age.
  - Due to changes in postural control systems
Postural Control System: Biological Systems

Neuromuscular System
Neuromuscular: Postural Muscle Tone

- Postural Tone = specific set of muscles tonically active during stance to keep body aligned with line of gravity


Neuromuscular: Control postural sway

- **Sway synergy**: A set of muscles working together to reduce postural sway.
  - Activated through stretch to muscles, tendon, and joint receptors of the ankle.
  - Direction specific (forward-backward, side-to-side).
  - Muscles activated in a specific order in time (ankle, thigh, hip, trunk).
Spatial-Temporal Organization of Sway Synergy


Development of Neuromuscular System for Stance

- Prior to pull to standing (3-6 months)
  - Tonic muscle activity only
  - No organization or pattern
- Pull to stand (7-9 months)
  - Ankle muscles only of sway synergy are activated in direction specific burst
- Independent standing (12-15 months)
  - Sway synergy complete
  - Timing, amplitude of muscle activation improved with walking experience.
  - By age 7, pattern of muscle activation is like that of an adult, but not fully mature.
Musculoskeletal System

Musculoskeletal: Postural Alignment

- Amount of body sway affected by body alignment.
- When body is aligned along the line of gravity, energy requirements are minimized and stability is maximized.

Musculoskeletal Changes

Skeletal Growth: Changes in location of COG
- Located higher in children compared to adults
  - Due to body proportions
  - Head and trunk of child are proportionately heavier than pelvis and legs compared to adult.
- A sway of 10 degrees will have a larger arc of movement when COG is located above the waistline.

Musculoskeletal Changes

Early Alignment in standing (Cusick, B, MS, PT):
- Hip Abducted and Externally Rotated
- Forward Trunk Lean
  - Limited lumbar extension
  - Hip flexion and anterior tilt of pelvis
- Extension accomplished by upper back extensors and scapular retractors.
Musculoskeletal Changes

- Until arches of foot develop (6-7 years), COP in the anterior-posterior direction is located more towards the heel than the mid-foot (Usui et al. 1995)

Cusick, 1990

Central Nervous System

Control of posture in stance is based on a body schema
Body Schema: Stance

- Body Schema: Internal ‘rules’ for postural control hypothesized to be partly:
  - Genetically determined (DNA)
  - Learned from sensory-motor experiences

- Dependent upon feedback from sensory systems:
  - Representation of body geometry (proprioception)
  - Representation of forces acting on body mainly related to condition of the support surfaces (tactile, proprioception).
  - Representation of body orientation to vertical and horizontal space (vision, vestibular, neck proprioceptors)

Sensory Systems
Sensory Contributions

- **Somatosensory:** Stimulation from receptors of the skin (tactile); joints, tendons, and muscles (proprioception) provides central nervous system feedback as to position of head, trunk, and limb in relation to each other; and to the support surface.

- **Vestibular:** Sensory stimuli from the receptors of the vestibular mechanism located in the inner ear with information as to the position and movement of head in space and within the gravitational field.

- **Visual:** Stimulation from the receptors of the retina indicating position and movement of head in space; distance and location of objects in relation to the body.

Body schema for postural control develops according to the changes in the other systems and is dependent on the experiences of the child.
Development of Body Schema for Upright Postural Stability

- Develops in Cephalo-caudal (Head to Lower Extremities) direction.

- Head Control:
  - Tonic neck flexor activity prior to head control
  - **10 weeks**: organized muscle responses emerges.
  - Mapping of vision to head position (somatosensory and vestibular).
    - Optical righting
    - Stronger response of head righting with vision present.

Development of Body Schema for Upright Postural Stability

- Postural control in Sitting:
  - **Learning to sit**: Neuromuscular activation pattern is proximal to distal and **vision** is the dominant sensory system.
    - 2 months: No organized neuromuscular responses.
    - 3-5 months: Organized neuromuscular responses of head and trunk only.
  - **Experienced sitters**: Neuromuscular activation pattern is distal (hips) to proximal (head) and dominant sensory system becomes the **somatosensory** system.
    - 8 months
Sitting

Pyramid of Motor Skill Development

- Skill
- Perceptual-Motor
- Postural Control
- Body Schema
- Early Sensory-Motor Experiences
- Pre and Post-natal

Piek, 2006
Sensory Strategies

Mapping of Sensation to Motor Responses

Test for Sensory Strategies

<table>
<thead>
<tr>
<th>Sensory Condition</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory Information</td>
<td>Vest Vision</td>
<td>Vest Somato</td>
<td>Vest Somato</td>
<td>Vest Vision</td>
<td>Vest</td>
<td>Vest</td>
</tr>
<tr>
<td>Accurate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inaccurate</td>
<td>None</td>
<td>None</td>
<td>Vision</td>
<td>Somato</td>
<td>Somato</td>
<td>Vision Somato</td>
</tr>
</tbody>
</table>
Development of Sensory Strategies for Stance

- Before age of 4 years, vision is the dominant sense for controlling posture in stance.

- 4-6 years is a time of transition. The child begins to depend less on vision and more on somatosensation at the ankle and foot for posture control in stance.

- 7 yrs-early adult: Continual development of weighting somatosensation for postural control. 7-10 years of age, sensory strategies resemble that of an adult.

4 year old in 4 sensory conditions

- Wide stance
- Support surface
  - Hard
  - Foam (reduce somatosensation..weighting vestibular and vision)
- Vision
  - Eyes opened
  - Eyes closed (Oclude vision...weighting somatosensation and vestibular).
**Self-organizing:** Behaviors emerge from the interactions of the individual's systems within his/her context of development (environment and task).
Questions?

Attention

Functions and Early Development
What is Attention?

“It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or thoughts… Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others

William James (1890)…..

Attention Neural-Networks

Functions

Arousal/Alert
(State of Attention)

Orienting

Executive
Systems of Attention

- Sensory-Motor Systems
- Orientation/Investigating network
- Arousal/Alert network
- Executive Function network
- Language
- Cognition and past experiences

Measurement of Attention

- **Duration and Frequency of Looking**: Infants
- **ERP (Event Related Potential)**: EEG measures brain waves and changes in brain waves during an activity
- **fMRI**: Magnetic Resonance Imaging reveals activated areas of brain during a stimulus or activity
- **Single cell neurons** (animal)
- **Marker task**: A specific task used to examine the efficiency of the attentional networks.
  - Stroop
  - ANT and ChANT
Alert State of Attention
Global and Selective States of Attention

Autonomic Nervous System

- sympathetic
- parasympathetic

- Anxious, fight or flight
- Attentive/alert
- Awake but drowsy
- sleep

ignore
attend

Functions of the Alerting Network

- Increases state of attentiveness in preparation for a signal to be processed.
- Maintains a state of preparedness for effortful processing of information (Vigilance).
- Present by 3 months of age.
- Not fully developed until adolescence.
State of Selective Attention

Physiology of the selective state
- Lower heart rate when focused on external events
- Higher heart rate when problem solving
- Reduced motor activity
- Relaxation at mouth and chin
- Reduced fidgety movements

Orienting/Investigative Network

*Cognitive Neuroscience, 2002*
Orienting/Investigative System

- Ability to direct attention to a specific location or feature of an object and involves:
  - Disengaging focus from one stimulus in the environment
  - Shift attention to another object or location in space.
  - Re-engage focus to that stimulus.

- Proceeds from involuntary (0-2 mos.) to voluntary (6-9 months).

- The ability to shift attention from internal stimuli to another (i.e., thoughts, memories) proceeds into adolescence, consistent with the development of control over goal-directed behaviors, i.e., scanning and searching.

Orientation: Scanning Environment

Early Development in Attention, 1996
Developmental Changes in the Selection of Attention

- **Newborns** select by high contrast, larger images.

- **Infants 2-3 months** select by novelty of location or novelty of the object.

- **3-9 months**: The ability to touch and manipulate drives selection of attention; choosing objects by their tactile and manipulative characteristics.

- **9-12 months**: Whole body movement through space is the driving force in what is attentionally selected. Attention to distant events and objects. Joint Attention begins to develop.

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Video2_selective attention
Developmental Changes in the Selection of Attention

- **18-24 months: Dramatic changes in selectivity at this age due to:**
  - Increase in executive function of attention
    - Longer looking at toys
    - Inhibiting distractions and selecting one toy over others
  - **Development of language:**
    - Naming objects
    - Symbolic Play
    - External direction of attention through language
  - **Self-awareness**
    - Recognition of self in mirror
    - Greater awareness of behavior in relation to social standards.
  - **Improvement in comprehension of events**
Executive Function Network

Independent Control of Attention

Executive Function of Attention

- Function: Goal-Directed Behaviors
  - Inhibition/Facilitation of a sensory stimuli dependent upon its relevancy.
  - Maintains focus and vigilance (level of alertness).
  - Storing, Maintaining, and Retrieval of information from working memory
  - Self-regulation (emotions, arousal, thoughts).
  - Cognitive Flexibility:
    - Resolving conflict between two stimuli
    - Switching from one stimuli to another
    - Stroop Task (marker task).
- Capacity Limited
Modulation of a Sensory Signal

Stroop Task

- You will need a watch with a second hand or stop watch.
- In a seated position:
  - In TEST 1: Say each word. It doesn't matter whether you go up and down or from left to right. Record your time in seconds (reaction time)
  - In TEST 2: Say the print colour of each word - NOT the word itself. Read in the same direction as Test 1. Record your time in seconds (reaction time)
- Which of the tests takes the longest time to complete?
- Were you more alert taking Test 2 compared to taking Test 1?
- Difference in the time to process a response?
Development of Executive Function

- Toddler: 18 – 24 months: Related to increase in cognitive, language development, and social interactions.
  - Sustained visual attention increases
  - Inhibiting distractions improves
  - Attention can be directed with words, i.e. naming objects
  - Cognitive flexibility: Able to play with more than one toy, change play according to change in rules.
  - Self-regulation: A greater awareness of their behavior in accordance with social standards.

Development of Executive Attention

- Preschool years (3-5) yrs.
  - Shift between external control for self regulation of attention to more independent control.
    - Will remove themselves from noisy environments in order to focus attention
  - Focus continues to develop.
  - A larger increase in the ability to inhibit irrelevant stimuli and an impulsive response, i.e., playing Simon Says.
  - Performance to social standards becomes a motivating factor for this shift.
- School Age (5-10 years)
  - Increase in the development in the resolution of conflict between two stimuli (cognitive flexibility and inhibition) but
  - Larger leap in development around 6-8 years
Age related changes in Focused Attention in two situations

<table>
<thead>
<tr>
<th></th>
<th>2.5 yrs</th>
<th>3.5 yrs</th>
<th>4.5 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Puppet Show</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking</td>
<td>442 /600 (73%)</td>
<td>522 /600 (87%)</td>
<td>553 /600 (92%)</td>
</tr>
<tr>
<td>Focused Attention</td>
<td>64.2</td>
<td>141.0</td>
<td>173.0</td>
</tr>
<tr>
<td>Time away from task</td>
<td>71.9</td>
<td>5.8</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Free Play</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking</td>
<td>503/600</td>
<td>537/600</td>
<td>533/600</td>
</tr>
<tr>
<td>Focused Attention</td>
<td>78</td>
<td>155</td>
<td>174</td>
</tr>
<tr>
<td>Time away from task</td>
<td>51</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

Duration in seconds  
*Early Development in Attention, 1996*

**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
Global Neuronal Workspace

Vigilance (Alert)

Stroop Task: Read the word "blue"

Evaluation
Motor Responses
Perception
Short Term Memory
Allocation of Attention

congruent

word

color

Motor response "blue"

Global Workspace

Global Neuronal Workspace

Vigilance (Alert)

Stroop Task: Name color of ink "red"

Error
Motor Responses
Perception
Short Term Memory
Allocation of Attention

suppress

facilitate

word

incongruent

color

Motor response "blue"

Global Workspace
**Self-organizing:** Behaviors emerge from the interactions of the individual's systems within his/her context of development (environment and task).