THE EFFECT OF VISUAL ENVIRONMENTAL DISTRACTION ON GAIT PERFORMANCE IN CHILDREN

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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BY

FABIAN BIZAMA, MPT

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DENTON, TEXAS

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To the Dean of the Graduate School:

I am submitting herewith a dissertation written by Fabian Bizama entitled: "The Effect of Visual Environmental Distraction on Gait Performance in Children." I have examined this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements of the degree of PhD with a major in Physical Therapy.

Ann Medley, PT, PhD, CEEAA, Major Professor

We have read this dissertation and recommend its acceptance:

Elaine Trudelle-Jackson, PT, PhD

Linda Csiza, PT, DSc, NCS

Director

Accepted:

Dean of Graduate School

DEDICATION

For my grandparents, Daniel and Lina Bizama, and Luis and Ada Rigacci, thank you for everything you have done to lead me here and for your never ending love.

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ABSTRACT

FABIAN BIZAMA

THE EFFECT OF VISUAL ENVIRONMENTAL DISTRACTION ON GAIT PERFORMANCE IN CHILDREN

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Purposes of this study were to identify the effect of visual distraction on gait parameters in children, describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking. Gait parameters as measured by the GAITRite system included: velocity, step length, step width, and double limb support percentage (DLS%) of gait cycle. The standardized test used was the mobility domain of the functional scale of the Pediatric Evaluation of Disability Inventory (PEDI).

Forty-two participants completed data collection; 24 males and 18 females, age range 16 to 90 months (mean=43.2 months, standard deviation=22.9 months) combined normative standard score mean for the mobility domain of the functional scale of the PEDI was=46.77, standard deviation=9.85; mean score confirms that participants were typically developing children. Participants were divided into three groups for data analysis according to their WE: early walkers (6-11 months of WE), pre-school walkers (12-37 months of WE), and experienced walkers (38-79 months of WE).

A 3x2 multivariate analysis of variance (MANOVA) assessed differences between groups (effect of WE) and within groups (effect of condition) on gait. The interaction between group

(effect of WE) and condition (effect of visual distraction) was not significant, $F(74)=0.612$, $p=0.765$. However, significant main effects of WE group $F(74)=5.300$, $p \leq 0.001$ and visual distraction condition $F(36)=2.586$, $p=0.053$ were found. A MANOVA was followed with univariate F-tests (ANOVAs) to further assess differences in main effect of group and WE.

The results of this study show that visual environmental distraction significantly affected gait performance in children. Visual distraction decreased velocity from 110.04 cm/sec to 97.73 cm/sec ($p=0.003$), and increased DLS% of gait cycle from 18.29% to 20.39% ($p=0.025$) in all children.

Results suggest physical therapists need to consider attentional requirements when assessing gait; even in children with more WE. If attention to task is a limiting factor for performance or learning of a motor task, physical therapists may need to address the limitations in attention to task more directly.

Future studies should include children with special needs and with a variety diagnoses. Special consideration may be needed for children whose diagnosis includes specific attention to task limitations, such as attention deficit disorder and autism.

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CHAPTER I

INTRODUCTION

Achieving independent functional mobility, especially walking, is often identified as a focus in physical therapy. Furthermore, the desired outcome of physical therapy intervention frequently includes achieving functional independent walking, or gait. This outcome is particularly important in pediatric practice, where independent walking is frequently a main goal desired by the family. In order to better serve physical therapy clients, it is important to fully comprehend all aspects of how typically developing children achieve desired developmental milestones such as walking. The intent of this project was to expand the knowledge of the role of attentional demands and its influence on postural control in the development of complex motor skills such as walking in children.

The development of postural control is critical to the acquisition of complex motor skills as well as for the production of coordinated motor behavior. The control of posture is an essential requirement for daily activities, including the development of gait (Lajoie, Teasdale, Bard, & Fleury, 1993; Shumway-Cook & Woollacott, 1985; Sveistrup & Woollacott, 1996).

Postural control is a complex process that requires the interaction of musculoskeletal and neurological systems (Bradley, 2000; Shumway-Cook & Woollacott, 2006).This process has traditionally been considered automatic or reflex controlled, suggesting that postural control systems use minimal attentional resources. However, recent research has provided evidence against this assumption (Shumway-Cook & Woollacott, 2006). Numerous studies suggest that a significant attentional demand exists and that attentional requirements for postural control vary depending on the postural task, the age of the individual, and their balance abilities (Cherng, Liang, Hwang, & Chen, 2007; Woollacott & Shumway-Cook, 2002). Moreover, as the demand for stability increases, an associated increase in attentional resources used by the postural control system occurs (Lajoie et al., 1993; Shumway-Cook & Woollacott, 2006; Woollacott & Shumway-Cook, 2002).

Often, research for studying the interaction of attention and postural control uses a dual task design in which postural control (considered the primary task), and a secondary task are performed together. In general, dual task design studies exhibit three basic assumptions:(1) a limited processing capacity exists within the central nervous system, (2) performance of any task requires a part of the individual's central processing capacity to attend to the task at hand, and (3) two tasks sharing the processing capacity of the system may result in disturbances in the performance of one or both tasks if the processing capacity of the individual is exceeded (Lajoie et al., 1993). Unfortunately, dual task design studies are limited in clarifying the exact attentional cost of postural tasks because of the interacting effects between the two tasks. Nevertheless, many dual task design studies have been helpful in documenting that the sensorimotor processing essential to postural control requires attentional resources (Brown, Shumway-Cook, & Woollacott, 1999; Lajoie, Teasdale, Bard, & Fleury, 1996; Lajoie et al., 1993; McIlroy et al., 1999; Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997; Woollacott & Shumway-Cook, 2002).

In the pediatric field, the results of motor learning research guide intervention strategies to assist a client in achieving appropriate developmental skills. In order to identify the underlying process that determines skill acquisition during development, a clinician must know variables that are important at a given age, how each variable changes during development, and the impact of change on all the other variables (Bradley, 2000).

Statement of the Problem

Physical therapists are trained to identify and to understand the postural demands of a variety of tasks including gait. They are able to account for the level of balance abilities depending on the age of the individual. However, limited information exists in terms of assessing and understanding the attentional requirements of developmental skills. Even less research is available documenting how children manage the attentional demands of a given task or how a child's performance of a given task is affected by the child's ability to manage different attentional requirements (Reilly, van Donkelaar, Saavedra, & Woollacott, 2008; Stoffregen et al., 1997).

Understanding of a child's attentional abilities, the level of sensory processing and organization, and the influence of the environmental factors on the performance of motor tasks, including postural control and gait, is crucial in enabling and guiding the therapist to modify and adapt the task environment appropriately and individually for each child in order to facilitate the desired performance of the motor task (Larin, 2000; Shumway-Cook & Horak, 1986). Reilly et al (2008) emphasized the importance of understanding factors competing for attentional resources during a child's performance of different tasks so that educators can create an age appropriate academic environment that is most conductive to learning (Reilly et al., 2008). In comparison, physical therapists must be able to monitor and address all aspects of a task that may be competing for the child's attentional resources to be successful with assessing the child's limitations and with implementing intervention activities (Larin, 2000; Shumway-Cook & Horak, 1986). In order to better serve physical therapy clients, it is important to fully comprehend all aspects of how typically developing children achieve desired developmental milestones such as walking.

Normative gait parameter values have been documented in typically developing children by using the GAITRite system (CIR Systems, Inc. 60 Garlor Drive Havertown, PA 19083), but attentional demands were not considered as variables in previous research methods while measuring gait in those children (Dusing & Thorpe, 2007). Therefore, the intent of this project was to expand the knowledge of the role of attentional demands and its influence in postural control in the development of complex motor skills such as walking in children.

Purpose of Study

The purpose of this study was to identify the effect of visual distraction on gait parameters in children. A secondary purpose was to describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking. The gait parameters of interest included: velocity, step length, step width, and double limb support percentage of gait cycle. The standardized test used was the Pediatric Evaluation of Disability Inventory (PEDI).

Research Questions

1. Does a visual environmental distraction have a significant effect on gait performance in children?
2. Does walking experience have a significant effect on gait performance in the presentence of a visual environmental distraction in children?

Hypotheses

Research Hypotheses

1. Visual environmental distraction will have a significant effect on gait performance in children.
2. Walking experience will have a significant effect on gait performance in children in the presence of a visual distraction.

Null Hypotheses

1. Gait parameters, as measured by the GAITRite system, will be equal under the two testing conditions: no visual distraction vs. with visual distraction.
2. Walking experience will not have an effect on gait parameters, as measured by the GAITRite system, under the two testing conditions: no visual distraction vs. with visual distraction, in children.

Variables

The following dependent variables were measured by the GAITRite system: velocity, step length, step width, and double limb support percentage of gait cycle.

The following independent variables were used as grouping variables: walking experience and condition: no visual distraction vs. with visual distraction.

Operational Definitions

Study-related terms were defined as follows for the purpose of this study:

1. Postural control: the control of the body's position in space for the purposes of balance and orientation. Postural control or balance requires that the center of body mass (COM), or center of gravity, is maintained over the base of support (BOS). Equilibrium reaction: the body's response to shifting or tilting of the support surface and are hypothesized to be controlled by the highest level of the central nervous system, the cortex (Shumway-Cook & Woollacott, 2006; Woollacott & Shumway-Cook, 2002; Woollacott & Shumway-Cook, 1990).
2. Visual distraction: television screen set playing children's programming such as cartoons: Veggie Tales® (Big Idea Entertainment, LLC. Big Idea, Inc. 320 Billingsly Court #30, Franklin, TN 37067). The sound will be muted so that the distraction is only visual in nature.
3. Manage a distraction: participant is able to maintain postural control and exhibit no change in gait parameters while distraction is present.

4. Attention: the information processing capacity of the participant (M. Woollacott & Shumway-Cook, 2002).
5. Typically developing children: no delays confirmed by a normative standard score of 30 (or higher) on the mobility domain of the Pediatric Evaluation of Disability Inventory (PEDI) (Haley, Coster, Ludlow, Haltiwanger, & Andrellos, 1992).
6. Independent walking: walking without upper extremity support or assistive device for at least 10 feet (ft) without loss of balance on level surfaces.
7. Walking experience: independent walking consistently for a determined period of time.
8. Gait speed (velocity): division of the distance traveled by the ambulation time. It is expressed in centimeters per second (cm/sec) (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.).
9. Step length: distance from heel center of the current footprint to the heel center of the previous footprint. It is measured along the line of progression which is the line connecting the heel centers of two consecutive footfalls of the same foot. The unit of measure is centimeters (cm) (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.).
10. Step width: distance from the midline midpoint of the current footprint to the midline midpoint of the previous footprint on the opposite foot. The unit of measure is centimeters (cm) (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.).

11. Double limb support percentage of gait cycle: double limb support time expressed as a percentage of the gait cycle time of the same foot (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.).

Assumptions

The following assumptions will be accepted for the purpose of this study:

1. The sample of individuals participating in this study was representative of the population of typical developing children.
2. The children participating in this study were motivated to complete all data collection requirements.
3. Only a limited central processing capacity exists within the central nervous system and performing any task requires a part of the individual's central processing capacity to attend to the task at hand. If two tasks share the processing capacity of the system, the performance in one or both tasks can be disturbed when the processing capacity of the individual is exceeded. In this case, it was assumed that the performance of gait parameters would be affected.

Limitations

The following limitations were present in this study:

1. A relatively small sample size may have resulted in smaller effects.
2. This study was not able to clarify the exact attentional cost of postural control needed for gait and the visual distraction because of the interacting effects between the two factors.

3. This study did not account for possible unexpected environmental sounds that may have been considered distractions for the participants.

Significance of the Study

Postural control is essential for performing activities of daily living and requires significant attentional demands. Visual distractions may affect postural control during functional activities such as gait. The effect of attentional demands on the performance of motor skills such as gait has not been extensively studied in children. The results of this study expand the knowledge of the role of attentional demands and the influence of a visual distraction on postural control in the development of complex motor skills such as walking in children. With this knowledge, physical therapists can better plan and modify interventions for children.

CHAPTER II

LITERATURE REVIEW

The purpose of this study was to identify the effect of visual distraction on gait parameters in children. A secondary purpose was to describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking. The gait parameters of interest included: velocity, step length, step width, and double limb support percentage of gait cycle. The standardized test used was the mobility domain of the Pediatric Evaluation of Disability Inventory (PEDI).

This chapter begins with a review of theoretical background of motor learning followed by a review of the neuroscience behind motor control. Then, the development of postural control and the development of gait are discussed. After that, attentional demands and the role of vision on postural control are reviewed. Finally, information about instruments and assessments used in this study is presented.

Theoretical Background of Motor Learning and Motor Control

Motor learning is a complex process resulting in the performance or the execution of a movement task. It includes practice and experience for the acquisition and modification of movement resulting in a relatively permanent change in the ability for purposeful movement of a person. It also includes learning new strategies for the execution of a motor task, and emerges from a cooperative process of perception, cognition, and action (Schmidt, 1975; Shumway-Cook & Woollacott, 2006).

Motor control is the study of the nature and control of movement and it focuses on understanding the control of movement already acquired (Shumway-Cook & Woollacott, 2006). Historically, several theoretic perspectives in motor learning and motor control have been presented, and three distinctly different theoretic perspectives are currently encountered in motor control literature: maturational, learning, and dynamic based views (Bradley, 2000).

One dynamic based view, the dynamic systems theory, is one of the more recent theories of motor learning. A fundamental hypothesis of the dynamic systems theory is that multiple identifiable variables exist and establish a context for movement initiation and execution. Such variables interact among each other at different levels depending on the child's development and depending on the task. These variables include: sensorimotor variables, mechanical variables, cognitive variables, and task requirements. The environmental factors fall within the specific task requirements (Bradley, 2000).

Kamm et al (1990) described how the dynamic systems theory better explains the influence of contributing factors such as: arousal, the neuromuscular system, gravity, and others, in performance of a given task or behavior. The authors expanded the concept of self-organization of the system; they stated "biological organisms are complex, multidimensional, cooperative systems, and no one subsystem has logical priority for organizing the behavior of the system". This means that performance of a task results from the coordination of all the system's components. The authors explained that "each of these components may initially be free to vary, resulting in many degrees of freedom to be controlled”. Furthermore, the authors stated that “behavior represents a compression of the degrees of freedom as the system assembles into a functional pattern. Most functional tasks can be achieved with a variety of movement patterns, but we tend to use the one that requires the least amount of energy and that is the most efficient melding of the many parts involved” (Kamm, Thelen, & Jensen, 1990).

A second fundamental hypothesis is that the relationship or interaction between these variables is in constant flux and therefore shapes the features of a movement as it unfolds (Larin, 2000; Scholz, 1990). According to the dynamic systems theory, motor performance is said to emerge from the dynamic cooperation of all subsystems within the context of a specific task. Both the general context (postural, gravitational, and social) and the particular aspects of a given task have equally important organizing influences. Each system and each component is necessary but insufficient to explain movement changes on its own (Bradley, 2000; Kamm et al., 1990; Woollacott & Shumway-Cook, 1990).

The neuromuscular system is composed of many interacting components. The neuronal networks are assumed to provide the supporting framework for pattern generation and the stability of a pattern of motion depends on the balance of cooperation and competition within all the neurophysiological components. Patterns of movement are portrayed not as rigidly fixed or programmed in the central nervous system but as flexible and adaptable. The patterns of movement are said to have “preferred paths”. In addition to established “preferred paths”, motor skills emerge from an interaction between development-related changes in movement dynamics and brain structure function (Bradley, 2000; Larin, 2000; Scholz, 1990).

The dynamic systems theory is in agreement with one of the most widely embraced motor learning theories: the schema theory (Bradley, 2000). The schema theory proposes that motor development is a function of learning rules to evaluate, correct, and update memory traces that compose a “schema” or a concept for a given class or pattern of movement. The schema theory assumes the presence of three constructs: general motor programs, recollection, and recognition. According to the schema theory, general motor programs are loosely defined as sets of instructions, which are stored in the central nervous system as schemas or concepts, which are responsible for organizing the fundamental components of a movement (Schmidt, 1975).

In this context, motor control can be described as the process of scaling the different neuromuscular components up or down in order to appropriately perform the desired movement. From this perspective, coordination is defined as the process by which movement components are sequenced and organized within a temporal parameter; and their relative magnitudes determined in order to produce a functional movement pattern, or synergy. Coordinated movement often involves multiple joints and several muscles that are activated at the appropriate time and with the correct amount of force so that a smooth, efficient, and accurate pattern of movement occurs. A major problem faced by the nervous system in the coordination of functional movement has been referred to as the “degrees-of-freedom” problem. The central nervous system (CNS) is able to affect the different variables of a movement (body position, stiffness of body segments, force produced by muscle tissue, and speed) in order to appropriately perform the desired movement (Shumway-Cook & Woollacott, 2006).

A well-known model of motor learning is the model proposed by Gentile. The Gentile model for acquisition of motor skills is based on the proposition that skill learning takes place in two stages: initial and late. In the initial stage of learning a motor skill, the learner discovers a reasonably effective approach to desired movement patterns. In the later stage, the learner concentrates on achieving skilled performance. The latter processes are said to be task dependent, changing according to the environmental context and the function of the action (Larin, 2000).

These theories and models are consistent in suggesting that development of motor control involves much more than the maturation of reflexes within the central nervous system. Development of motor control is a complex process, with new behaviors and skills emerging from an interaction between the child's maturing nervous and musculoskeletal system, and with the environment. In concurrence with this framework, the emergence of postural control is likewise based on complex interactions between neural and musculoskeletal systems; these include:

1. Changes in the musculoskeletal system, including development of muscle strength and changes in relative mass of the different body segments.
2. Development or construction of the coordinative structures or neuromuscular response synergies used in maintaining balance.

3. Development of individual sensory systems, including somatosensory, visual, or vestibular systems.
4. Development of sensory strategies for organizing these multiple inputs.
5. Development of internal representations important in the mapping of perception to action.
6. Development of adaptive and anticipatory mechanisms that allow children to modify the way they sense and move for postural control (Shumway-Cook & Woollacott, 2006).

Neuroscience of Motor Control

Two models of central nervous system (CNS) control have been used to describe the neural basis for developing posture and movement control: the reflex-hierarchical model and the systems model. In the reflex-hierarchical model, motor development is viewed as moving from reflexive to voluntary control as the child's nervous system matures. The emergence of independent balance and locomotion is seen as dependent on the maturation of sequentially higher levels of the CNS hierarchy. Higher levels of behavior, such as the equilibrium reactions, modify immature behaviors, such as tonic reflexes, which are controlled by lower levels within the CNS (Woollacott & Shumway-Cook, 1990). However, newer theories and models of motor control are consistent in suggesting that the development of motor control involves much more than the maturation of reflexes within the central nervous system (Shumway-Cook & Woollacott, 2006).

According to the systems model, motor control is achieved by the proper CNS organization of the information arriving from multiple sensory systems throughout the body.

Normally, peripheral inputs from visual, somatosensory (proprioceptive, cutaneous, and joint receptors), and vestibular systems are available to detect the body's position and movement in space with respect to gravity and the surrounding environment. The CNS components then organize this information in a purposeful manner (Shumway-Cook & Woollacott, 2006).

Another component of nervous system control of posture and motor performance is the presence of central pattern generators (CPGs). Central pattern generators are proposed to account for the basic neural organization and function required to execute coordinated, rhythmic movements, such as locomotion, chewing, grooming, and respiration. CPGs are commonly defined as interneural networks, located in either the spinal cord or brainstem. CPGs can order the selection and sequencing of motorneurons independent of descending or peripheral afferent neural input (Bradley, 2000).

In addition, according to the equilibrium-point hypothesis, the CNS strives to control body and particularly joint position in space. Every position can be defined by a unique combination of external and internal forces: primarily agonist and antagonist muscle forces and the net result of the mathematical calculation of all forces involved is an appropriate pattern or position. Once a motor program is sufficiently established, the CNS activates the appropriate muscles to contract and move a limb segment until the segment reaches the point in space where all active and passive muscle forces are in equilibrium (Bradley, 2000; Feldman, 1986).

Development of Postural Control

The development of postural control is critical to the acquisition of complex motor skills as well as for the production of coordinated motor behavior. The control of posture is an essential requirement for daily activities, including the development of gait. This developmental process requires the maturation of two interactive components within the postural control system. The first component is responsible for coordinating muscles and joints into appropriately organized response patterns, and the second component is responsible for ensuring that the body's responses remain consistently context dependent (Lajoie et al., 1993; Shumway-Cook & Woollacott, 1985; Sveistrup & Woollacott, 1996).

Postural control or balance requires that the center of body mass (COM), or center of gravity (COG), is maintained over the base of support (BOS). Equilibrium reactions are described as the body's response to shifting or tilting of the support surface, and are hypothesized to be controlled by the highest level of the CNS, the cortex (Shumway-Cook & Woollacott, 2006; Woollacott & Shumway-Cook, 2002; Woollacott & Shumway-Cook, 1990). Maintaining balance or postural control involves a continuous dynamic process of multiple compensatory adjustments, a process of feedback organization and control (Horak, Shupert, & Mirka, 1989; Lee & Aronson, 1974; Shumway-Cook & Horak, 1986; Woollacott & Shumway-Cook, 1990).

Postural control involves controlling the body's position in space for the dual purpose of stability and orientation and it requires continuous active control, coordination, and effort (Shumway-Cook & Woollacott, 2006). Postural control is a sensorimotor process and is dependent on the task itself, the individual, and the environment. Efficient postural control is dependent on the appropriate detection and processing of information from the somatosensory (proprioceptive, cutaneous, and joint receptors), visual, and vestibular systems. It requires the integration of these systems, as well as the subsequent activation of appropriately organized muscular responses that serve to produce an accurate representation of the movement of the center of gravity and, in turn, produce the appropriately proportional body sway or correction to remain within the desired orientation (Foster & Sveistrup, 1996; Horak et al., 1989; Rankin, Woollacott, Shumway-Cook, & Brown, 2000; Shumway-Cook & Woollacott, 1985; Shumway-Cook & Horak, 1986; Shumway-Cook & Woollacott, 2000; Stoffregen et al., 1997; Sveistrup & Woollacott, 1996; Woollacott, Debu, & Mowatt, 1987).

The essential neural components to postural control include: motor processes, sensory-perceptual processes, and higher level processes. The motor processes include organizing muscles throughout the body into neuromuscular synergies. The sensory/perceptual processes involve the organization and integration of visual, vestibular, and somatosensory systems. The higher level processes are essential for mapping sensation to action, and ensuring anticipatory and adaptive aspects of postural control. Importantly, several authors hypothesize that the three sensory systems contributing to postural control (visual, vestibular, and somatosensory) activate the same coordinative structures or postural synergies in response to postural perturbations (Bradley, 2000; Rankin et al., 2000; Shumway-Cook & Woollacott, 2006; Sveistrup & Woollacott, 1996). Postural synergies are defined as multiple muscles that are constrained to act together as a functional unit, with fixed temporal and spatial parameters reflecting the interaction of the musculoskeletal and motor systems. The term muscle coordination describes the processes which determine the temporal sequencing and the distribution of contractile activity among the muscles of the trunk and the extremities (Nashner, 1982; Sveistrup & Woollacott, 1996).

As mentioned earlier, sensory systems activate these synergies. Each system provides unique information that is processed and integrated for postural control. The somatosensory system provides information about the motion of the body with respect to the support surface and motion of body segments with respect to each other. The visual system provides information about motion of the body with respect to extra personal space, the environment. Finally, the vestibular system provides information about linear and angular acceleration of the head (Horak et al., 1989). Because postural control is dependent on the appropriate integration of somatosensory input, this input must be properly understood within the CNS. The term sensory organization describes the processes of “making sense” of sensory input which determine the timing, direction, and amplitude of corrective postural action based on the processing of the body’s orientation information from visual, somatosensory, and vestibular inputs. Although each of the three sensory systems is considered essential to optimal control of posture, each system can compensate to some extent for the other two, and the relative importance of each system appears to vary with contextual demands (Bradley, 2000; Horak et al., 1989; Nashner, 1982).

Typically, as we become experts in a movement task, we learn to recognize those sensory cues most reliable to predicting how the environment may change during movement execution, and we can learn to ignore less useful cues. Simultaneously, we learn to predict how our movements will change our relationship with respect to a more or less predictable environment and determine the postural requirements for the task. Complex neuromuscular responses are available early in development, but the child's ability to select the most favorable strategy and the immediate context in question are critical determinants in this process (Bradley, 2000). Horak et al. suggest that either abnormal sensory input or an abnormal central selection and weighting process may result in an inability to identify, organize, and select an appropriate sensory reference for postural control, even in young persons with normal sensory function (Horak et al., 1989).

Certain critical components limit the rate of the development of postural control required for daily activity. Rate-limiting components are those aspects of the system that limit the rate at which the independent behavior emerges. One factor that may be critical for development is the speed with which postural reactions must be executed (Stoffregen et al., 1997; Woollacott & Shumway-Cook, 1990).

In general, infants show a cephalocaudal gradient in the development of postural responses. Control appears first in the muscles of the neck, as early as 4 months; then the trunk musculature, at 5 to 8 months; and finally the lower extremities musculature, in stance, at 10 to 14 months (Woollacott et al., 1987; Woollacott & Shumway-Cook, 1990). This same sequence of development is seen in the development of synergies. Woollacott et al. (1987) reported a cephalocaudal development of postural response synergies in infants following perturbations of the support surface, with initial responses recorded in the muscles of the neck as early as 4 month of age. As infants matured and gained experience in sitting and standing, the postural response expanded to include the trunk and finally the lower extremities. In addition, even though sway response was higher in children when compared to adults, the children's sway response decreased with increased age and development, but was not equal to the adults' lower levels of sway even in the 7 to 10 years old group (Woollacott et al., 1987).

Sundermier et al (2001) documented balance responses on a moving force platform in 9 months to 10 years old children. Children were grouped in four different developmental skills levels. Postural responses were documented by measuring muscle activity using surface EMG in key postural muscles including: gastrocnemius, tibialis anterior, hamstrings, quadriceps, paraspinals, and abdominals. The results of this study showed that children at lower developmental levels, the new walkers group with a mean age of 12.6 months, have smaller magnitude muscle activity in proximal muscles, and they also exhibit slower muscle activation onsets and shorter burst durations than children in higher developmental levels (Sundermier, Woollacott, Roncesvalles, & Jensen, 2001).

Sveistrup and Woollacott studied a small group of infants who were unable to stand independently until they were able to maintain standing independently. The purpose of their study was to document the development of automatic postural responses by measuring the child's muscle activation patterns in response to postural perturbations in a standing position. The participants were asked to stand on a platform that moved forward and backward. Surface EMG was used to measure the muscle activation of key postural muscles including: gastrocnemius, tibialis anterior, hamstrings, quadriceps, trunk extensors, and abdominals. Measurements were obtained at five key stages of the child's development: early pull-to-stand (mean age of 33 weeks), pull-to-stand (mean age of 40 weeks), independent stance (mean age of 48 weeks), independent walking (mean age of 56 weeks), and late independent walking (mean age of 65 weeks). The results of this study showed that in the early pull-to-stand stage, infants exhibit a pronounced level of background muscle activity with postural muscles in the legs and trunk, and not a well-defined tonic response modulated in response to movement perturbation. However, by the late independent walking stage, the muscle activity recorded had a distinct muscle activity response to the perturbation introduced by the platform movement. The authors proposed a calibration process that occurs during the period of development of postural control in which the infant learns to map the sensory information onto increasingly larger and more appropriate sets of muscle patterns as the learning to control the body in balancing tasks progresses. The authors also suggested that in this process of learning to generate the appropriate muscle response synergy, infants are constantly influenced both by the physical components of the task and by their own neurological and biomechanical components (Sveistrup & Woollacott, 1996).

As previously described, the process of development of postural stability requires the maturation of interactive components within the postural control system; including the coordination of muscles and joints into appropriately organized response patterns. Children begin to either consciously or subconsciously select a postural strategy from an array of possibilities based on context as early as 13 to 14 months of age. Stoffregen et al. showed that 14-month-old typically developing children exhibit very adaptive postural control actions to variations in surface properties. This study showed that children are capable of controlling a wide variety of patterns of motion, including hip and ankle strategies, in order to maintain stance (Stoffregen et al., 1997).

Shumway-Cook and Woollacott (1985) demonstrated that children produce postural synergies which are appropriately specific to the direction of body sway. The results of their study showed that children exhibit a greater variability in the organization of postural response synergies than adults. Moreover, children show even more variability between 4 to 6 years of age suggesting that the structural organization of postural synergies underlying standing balance is not fully developed in the 4 to 6 year-olds (Shumway-Cook & Woollacott, 1985).

Development of Gait

Physical therapists must fully comprehend all aspects of how typically developing children achieve desired developmental milestones such as walking. Then, knowledge of typical development can be applied to assessment and intervention of children with special needs. Sutherland completed a review of the key components describing the process of gait maturation and in an effort to identify what are the factors controlling the maturation of gait. Sutherland grouped the data from studies reviewed into the following categories: time-distance parameters, kinematics, electromyography, kinetics, and energetics. The author concluded that in addition to growth, there is a maturation process controlling the gait changes up until 3.5 to 4 years of age. After this age, growth alone can explain the majority of the changes after that time. The changes that take place after this maturation period are primarily found in the time-distance parameters, which correlate well with limb length and body height. For example, that cadence decreases, while stride length and velocity increase as children approach 7 years of age (Sutherland, 1997).

Hausdorff et al (1999) studied the maturation of gait parameters by measuring stride time variability in 50 typically developing children from 3 to 14 years of age. Children walked at their normal pace for 8 min around a 400 m track. A force-sensitive switch placed inside the child's right shoe measured heel strike of each stride, and stride time of each step during the 8 min walk. Children were divided into three age groups for data analysis: 3 to 4 years old, 6 to 7 years old, and 11 to 14 years old.

Age significantly affected stride time variability. In addition, there was an inverse relationship between variability and age. Both the standard deviation and the coefficient of variation were significantly larger in the 3 to 4 years old group in comparison to the 6 to 7 years old group. In addition, these same measures were significantly larger in the 6-7 years old group in comparison to the 11 to 14 years old group (Hausdorff, Zemany, Peng, & Goldberger, 1999).

Beck et al (1981) also studied the gait patterns of 51 typically developing children ranging from 11 months to 14 years old. The gait parameters measured were: velocity, stride length, cadence, support time, swing time, and dual limb support time. Participants walked at a slow pace, normal pace, and fast pace on a 10 m walkway that included a variety of pressure sensitive sensors along the way. Results of this study showed that the slowest and fastest speeds common to all gait observations was 0.81 and 1.25 m/s respectively, while the mid-range walking speed was 1.04 m/s. Stride length and cadence were observed to increase while swing and support times were found to decrease with increasing walking speed. All parameters depend on age at each of the walking speeds. At mid-range walking speed, stride length increased from 0.72 m in the youngest group (1-2 years old) to 1.14 m in the oldest group (13-15 years old). At mid-range walking speed, cadence decreased from 184 steps per minute in the youngest group to 110 steps per minute in the oldest group while time of swing stage increased from 0.26 s in the youngest group to 0.49 s in the oldest group while time of support increased from 0.41 s in the youngest group to 0.60 s in the oldest group.

Beck et al (1981) showed that gait patterns of typically developing children are both velocity and age dependent. Moreover, these changes were shown to correlate well with changes in height. The authors concluded that in order to properly assess the gait of typically developing children, differences in age, height, and walking speed need to be considered (Beck, Andriacchi, Kuo, Fermier, & Galante, 1981).

Yaguramaki and Kimura studied gait changes during development of walking by comparing gait in children and adults. The authors studied 35 typically developing infants (age range 7-70 months); 20 participants were examined longitudinally every few months, and a group of adults (11 male adults) was used as a control group. Participants walked barefoot on a 7 m walkway and medio-lateral motion and angular displacement were measured by a three-dimensional gait analysis system. Results of this study showed increased variability of most measurements during the first 4-6 month of independent walking. There was a significantly greater medio-lateral motion in infants than in adults. However, medio-lateral motion decreased considerably within a few months of the onset of independent walking. The authors concluded that the large medio-lateral motion in infants may be due to larger step width. Step width was not measured directly but estimated step width parameters were obtained looking at the relationship between shoulders and ankles position during gait. The authors reported the "ankles of younger infants lay outside the boundary of the shoulder whereas the ankles of older infants and adults were always inside their shoulders". Angular displacement analysis showed several differences in gait pattern of young infants in comparison to adults. For example, infants walked in a forward-bend posture and did not exhibit hip hyperextension until 6 months of walking experience. The authors concluded that the walking pattern of infants of the same chronological age was more developed in those infants with more walking experience (Yaguramaki & Kimura, 2002).

Hallemans et al (2005) compared the walking pattern of toddlers and adults and to investigate the effect of walking experience on gait parameters in children. The gait pattern of 10 healthy children (age range 13.5 to 18.5 months) was analyzed using inverse dynamic analysis (IDA); 10 adults (age range 20-30 years) comprised the control group. The walking experience in the children group ranged from 2 weeks to 5 months. Participants were videotaped with an automated infrared retro-reflective camera system as they walked on a designated walkway. Several spatio-temporal gait parameters were calculated for data analysis. Participants in the children group were divided in 4 subgroups according to walking experience: 1 month, 2 months, 3 months, and 4 months respectively. Results showed generally smaller net joint moments in toddlers when compared to adults. In addition, larger stride length in the 4 month walking experience group in comparison to the other three groups, and single support time was higher in comparison to group 1 (1 month walking experience). No significant differences were identified between groups 1-3 (Hallemans, De Clercq, Otten, & Aerts, 2005).

All of the studies reviewed suggest that gait parameters change as children mature.

Postural Control and Attentional Demands

Postural control is a complex process that requires the interaction of musculoskeletal and neurological systems (Bradley, 2000; Shumway-Cook & Woollacott, 2006). This process has traditionally been considered an automatic or reflex controlled one, suggesting that postural control systems use minimal attentional resources. However, recent research has provided evidence against this assumption (Shumway-Cook & Woollacott, 2006). Numerous studies suggest that a significant attentional demand exists and that attentional requirements for postural control vary depending on the postural task, the age of the individual, and their balance abilities (Cherng et al., 2007; Woollacott & Shumway-Cook, 2002).

Often, research for studying the interaction of attention and postural control uses a dual task design in which postural control (considered the primary task), and a secondary task are performed together. In general, dual task design studies exhibit three basic assumptions: (1) a limited processing capacity exists within the central nervous system, (2) performance of any task requires a part of the individual's central processing capacity to attend to the task at hand, and (3) two tasks sharing the processing capacity of the system may result in disturbances in the performance of one or both tasks if the processing capacity of the individual is exceeded (Lajoie et al., 1993). Unfortunately, dual task design studies are limited in clarifying the exact attentional cost of postural tasks because of the interacting effects between the two tasks.

Nevertheless, many dual task design studies have been helpful in documenting that the sensorimotor processing essential to postural control requires attentional resources (Brown et al., 1999; Lajoie Y et al., 1996; Lajoie et al., 1993; McIlroy et al., 1999; Shumway-Cook et al., 1997; Woollacott & Shumway-Cook, 2002).

Interaction of variables varies depending on the child's development and on the task. These variables include: sensorimotor variables, mechanical variables, cognitive variables, and task requirements. The environmental factors fall within the specific task requirements. The amount of attention dedicated to monitoring a movement is viewed as a variable that can affect the performance of a motor skill. Typically developing children initially execute new movements in a ballistic manner, ignoring feedback. Then they swing to the opposite extreme attempting to process excessive amounts of feedback, before finally learning to selectively attend to feedback. Once the child learns to selectively attend to feedback, more attention, or mental processing, can be assigned to reading the environment and predicting the environmental changes and movement outcome as the movement is executed (Bradley, 2000).

The majority of research that describes the relationship between attention and postural control has been done with adult participants. However, some of the results observed in adults can be useful to understand the role of attentional demands in postural control in children.

For example, Kerr et al (1985) studied the interaction between postural control and the performance of two types of memory tasks, spatial and non-spatial memory task, in young adults. The results showed no significant difference in postural sway or balance steadiness, as measured by a force platform that calculated the center of pressure, during the performance of either of the memory tasks tested. However, decreased spatial memory task recall scores (a secondary task) were documented during the performance of the postural task (maintaining the tandem Romberg position on a force platform for 12 seconds). The authors concluded that concurrent balance requirements lead to a decrement in the recall ability for the spatial memory task. The authors also proposed that, although postural control is attentionally demanding in young adults, not all cognitive tasks affect postural control in the same way. They suggest that cognitive spatial processing and postural regulation may require common mechanisms, based on experimental results where maintaining a standing position interfered with a memory task. Moreover, the authors proposed a link between postural control and spatial cognition because both of these functions are related to vision (Kerr, Condon, & McDonald, 1985). It is possible that children would exhibit a deficit in postural control under similar conditions where attention to a visual task detracts from the central nervous system ability to appropriately allocate the attentional resources needed to maintain balance.

Rankin et al (2000) compared muscle response characteristics in young adults (mean age of 25.3 years) and older adults (mean age of 78.7 years) in response to platform perturbations while standing under two conditions: control versus performing a math task. The platform moved either forward or backward, at specific velocity intervals. For the math task condition, the participants were required to subtract by three from a randomly given number. The study measured the activity of postural muscles with surface EMG while the participants were standing on the moving platform. Surface EMG electrodes measured muscle activity in the following muscles: gastrocnemius, tibialis anterior, biceps femoris, rectus femoris, erector spinae, and rectus abdominus. The results of this study showed a decreased magnitude of muscle activity in response to platform movement in both agonists and antagonist muscles (gastrocnemius and tibialis anterior) during performance of the subtraction task in comparison to the control measurements. When looking at the effect of age in postural response, the results of this study showed that older adults have a lower muscle response at faster speeds of platform movement. They suggested loss of balance results from a failure of the system's ability to integrate and organize the sensorimotor information and produce the appropriate musculoskeletal response. The authors suggested that a possible cause for this failure is a deficit in the higher brain center's ability to appropriately allocate the attentional resources needed to maintain balance (Rankin et al., 2000). It is possible that children would also exhibit a deficit in postural control under similar conditions where attention to a cognitive task detracts from the central nervous system ability to appropriately allocate the attentional resources needed to maintain balance.

Shumway-Cook et al. (1997) studied the effect of cognitive demands on postural control in young adults (mean age of 31 years), older adults without history of falls (mean age of 74 years) and older adults with history of falls (mean age of 78 years). The participants were tested under two standing conditions: firm vs. compliant foam surface. The participants were asked to perform two secondary cognitive tasks: a visual perceptual task and a language task. The results were compared to the participants' performance of the two cognitive tasks while sitting as the control condition. The participants' postural control or postural sway in standing was measured by calculating the displacement of the center of pressure (COP) as measured by a force platform. The authors hypothesized that as adults' age, increased attention is needed to compensate for deterioration within a sensory system (Shumway-Cook et al., 1997).

In the study by Shumway-Cook et al. (1997), postural stability in older adults with a history of falls was negatively affected by performance of both a visual perceptual task ($p < .03$) and a language task ($p < .0001$) compared to young adults. The results suggest that during the simultaneous performance of a cognitive and postural task, postural stability suffers rather than the performance of the cognitive task. In addition, when postural demands are high, due to the stability requirements inherent in the task being performed or because the individual has a limited capacity to maintain postural stability due to aging or disease, even relatively non-demanding cognitive tasks may have a negative effect on postural stability. The authors concluded that the allocation of attention during the performance of concurrent tasks is complex, depending on many factors including the nature of both the cognitive and the postural task (Shumway-Cook et al., 1997). In comparison, it is possible that children would also exhibit a deficit in postural control under similar conditions influenced by developing nervous and somatosensory systems instead of aging or disease.

Lajoie et al. (1993) studied whether attentional demands vary as a function of the type of postural task being performed in young adults, mean age of 26 years. The authors examined four postural tasks: sitting, standing with wide BOS, standing with narrow BOS, and walking conditions as the primary tasks, and an auditory reaction time as the secondary task. As expected, the more stable sitting task yielded faster reaction times than the standing and walking tasks. However, the subjects' reaction time decreased while performing a more demanding postural task. The authors concluded that postural control is attentionally demanding and the attentional demands increase with the complexity of the postural task being performed. The authors stated that an upright standing position requires more attention than sitting, and walking requires more attention than either of these first two tasks. The authors suggested that the attentional demands of a postural task increase with an increase in the balance requirements. In addition, attentional demands may vary within the walking cycle because decreased reaction time was documented during the single leg support phase suggesting an increased attentionally demanding period within the walking cycle (Lajoie et al., 1993). It is unknown whether the same pattern would be seen in children.

In a later publication, Lajoie et al. (1996) addressed whether normal aging has an effect on the attentional demands of the different postural tasks being performed. In this study, the authors report additional data obtained from eight elderly participants with a mean age of 71 years. The authors again examined four postural tasks: sitting, standing with wide BOS, standing with narrow BOS, and walking conditions as the primary tasks, and an auditory reaction time as the secondary task. The results for the older adults were similar to the results seen in the younger adults group: the more stable sitting task yielded faster reaction times than the standing and walking tasks. In addition, the authors documented a greater negative effect, decreased reaction time, in older adults when the standing base of support was narrower suggesting that older adults are more affected by the reduction of the BOS than young adults. Again, the authors concluded that postural control is attentionally demanding, and the attentional demands increase with the complexity of the postural task being performed.

However, no significant difference was observed when comparing reaction times of the older adults during the single leg support phase versus the double leg support phase of their gait cycle (Lajoie Y et al., 1996).

McIlroy et al (1999) studied the postural responses of young adults, ages 21-27 years, under three conditions: seated balancing task, visual-motor tracking task, and dual task condition which involved performance of the visual-motor tracking task and the balancing task at the same time. Surface EMG was used to measure activity of the soleus and the tibialis anterior muscles of the dominant leg. As the authors expected, the first evidence of attentional demand directed to the control of balance did not occur until after the initiation of the earliest compensatory balance reaction, which was marked by a complete pause in the visual tracking behavior in the dual task condition. The authors suggested that the pause in visual tracking appears to mark the start of a second control phase which includes a sustained redirection of attentional resources to the control of the balance reaction. This phase suggests that the attentional demands associated with recovery of stability vary as the processing requirements of postural control vary during the time course of recovery of stability. In this study, the authors concluded that in the dual task condition, attention was substantially diverted from the visual motor task when balance was perturbed, approximately 200-300ms after the initiation of the earliest compensatory balance reaction. The attention needed was presumably redirected to control the compensatory response required to regain balance. The findings suggest that balance control involves three distinct phases, each with distinct attentional requirements. The initial phase is automatic with minimal attentional demands. In the second phase, attention shifts completely away from the secondary task, reflecting attentionally demanding balance control. Finally, in the third stage, attention control is divided between both the balance and the secondary task, and this division persists until equilibrium is restored (McIlroy et al., 1999).

Teasdale et al (1993) examined the extent to which reduction in available sensory inputs increased the attentional demands of standing postural control in adults. This study measured postural control by accounting for the amount of sway measured by displacement of the center of pressure (COP) of the individual while standing on a force platform. Participants completed an auditory reaction time task under the following conditions: vision/normal surface, no vision/normal surface, vision/altered surface, and no vision/altered surface. The results of this study showed that both groups: young adults (mean age of 24.6 years) and older adults (mean age of 71.1 years), exhibit delays in reaction time as the postural task complexity increases. The results also showed that attentional demands increased in both young and older adults when sensory inputs were reduced. In addition, the reaction time of the older adults was more delayed by the absence of vision during quiet stance than that of the younger adults, indicating that postural control under the no vision conditions required more attentional resources for the older than for the young adults. The authors concluded that central processes are an important determinant of postural control, and as the sensory information is reduced, the postural task becomes more difficult for older adults and therefore requires more attentional capacity (Teasdale, Bard, LaRue, & Fleury, 1993). It is possible that children would also exhibit a deficit in postural control under similar conditions due to increased reliance on visual input.

Brown et al (1999) explored the attentional demands of the different strategies used for the recovery of postural control while standing in adults. In this study, young adults (mean age of 25.34 years) and older adults (mean age of 78.74 years) were asked to perform a backward digit recall task prior to, and while recovering from, a disturbance to their standing balance. The backward displacement of the forceplate platform standing surface was done in specific intervals of velocity of displacement. The results of this study showed that taking a step as a strategy to recover postural stability occurs even when the center of mass (COM) is within the base of support (BOS). In addition, the results of this study showed that a step occurred when the COM was located in a more central location within the BOS when the secondary task was added, and this effect was greatest in the older adults group. The authors suggested that motor strategies used for the recovery of postural control are associated with a hierarchy of attentional demands and they concluded that attentional demands associated with recovery of stability are greater in older adults than in young adults (Brown et al., 1999). In comparison, it is possible that children would also exhibit a deficit in postural control under similar conditions influenced by developing nervous and somatosensory systems instead of aging.

Shumway-Cook and Woollacott (2000) studied the effect of cognitive demands on postural control in young adults (mean age of 34.6 years), older adults without history of falls (mean age of 74.6 years), and older adults with history of falls (mean age of 85.3 years). In this study, the participants were asked to perform a reaction time auditory task under the following conditions: firm surface/eyes open, firm surface/eyes closed, firm surface/optokinetic stimulation, sway referenced surface/eyes open, sway referenced surface /eyes closed, and sway referenced surface /optokinetic stimulation. The optokinetic stimulation was used to assess the effect of visual motion within the environment on postural sway. The optokinetic stimulation was accomplished by a moving visual pattern projected on a screen system that surrounded the participant (front and sides). Postural sway was measured by calculating the displacement of the center of pressure (COP) as measured by a force platform. The results of this study showed that, for young adults, the addition of a secondary task did not significantly affect postural sway in standing in any of the sensory conditions tested. On the other hand, for older adults with a history of imbalance and recent falls, the addition of a secondary task produced a significant increase in sway in all of the sensory conditions tested. Moreover, in the more difficult sensory conditions, the addition of a secondary task resulted in loss of balance in some of the older adults. The authors concluded that for young adults, changing the availability of visual or proprioceptive inputs did not increase the attentional demands associated with stance postural control. However, in older adults, as sensory information decreased, attentional demands associated with maintaining standing postural control increased (Shumway-Cook & Woollacott, 2000). It is possible that children would also exhibit a deficit in postural control under similar conditions due to increased reliance on visual input, and influences of developing nervous and somatosensory systems instead of aging.

Although many studies have been conducted on adults, very few studies have been conducted with children. For example, Huang and Mercer completed a review of various studies using dual task methodology for children and adults. The authors explained some key concepts of dual task methodology. Performance of the primary task is assumed to require a proportion of the limited processing capacity of the individual. Therefore, performance of the secondary task is considered a direct reflection of the remaining processing capacity. In this review, the authors conclude that studies of motor performance in children show interference effects when children are asked to perform a secondary task. Older children tend to show less interference than younger children but it is not clear why. The authors suggest that this is possibly due to increased automation of motor performance or improved time-sharing skills with maturation, practice, and experience. The authors concluded that dual task studies provide insight into the changes in performance that may be expected when children are asked to do two things at the same time. Moreover, understanding of the effects of divided attention on motor performance may assist physical therapists in incorporating attentional factors into their examination and intervention techniques (Huang & Mercer, 2001).

Huang et al (2003) studied the influence of concurrent cognitive tasks on gait parameters in 5-7 years old typically developing children. Twenty seven (16 boys and 11 girls) typically developing children participated in this study; the mean age was 6.4 years. Children were asked to walk as fast as possible on a 30 ft long 5 ft wide walkway under 4 conditions: walking alone and walking in combination with three different cognitive tasks. The three cognitive tasks were: visual identification, auditory identification, and memorization.

Results of this study showed that gait speed and cadence were significantly lower under all dual-task conditions in comparison to walking alone, but step length was significantly shorter for walk and visual identification, and walk and auditory identification only. The magnitude of the decrease in walking speeds ranged from 0.18 m/s for the memorization task to 0.43 m/s for the auditory identification task.

The authors concluded that children in the age range of 5-7 years old decrease their gait speed when performing concurrent cognitive tasks. The amount of interference varied with the different cognitive tasks performed. Visual and auditory identification tasks affected both cadence and step length, but memorization task affected only cadence. The authors suggested that further research is needed to determine the effects of concurrent cognitive tasks on performance of various motor tasks in children of various ages who are typically developing and in children with special needs (Huang, Mercer, & Thorpe, 2003).

The Role of Vision in Postural Control

Normally, three classes of sensory inputs are available for balance control: somatosensory, visual, and vestibular. Even though all three sensory inputs are available, the central nervous system mostly relies on only one sense at a time for orientation information (Woollacott & Shumway-Cook, 1990). The challenge of maintaining postural control increases when information from one (or more) of the perceptual systems is in conflict with information coming from the other perceptual systems. This has been demonstrated in experiments in which movement of the visual field is perceived as self-motion, thus conflicting with concurrent somatosensory and vestibular input specifying stability. In order to maintain postural control under these conditions, the individual must be able to integrate and effectively compare the information from the various sensory systems and shift attention from the sensory system providing incorrect information to the sensory system that is providing correct information (Foster & Sveistrup, 1996).

Kerr et al (1985) studied the interaction of memory and standing balance in young adults, and they proposed a link between postural control and spatial cognition because both of these functions are related to vision. The participants were asked to complete a memory task alone (sitting position), a standing balance task alone (tandem stance), and then both the memory task and the balance task at the same time. The results of this study showed that the concurrent performance of balance and memory task resulted in significantly poor recall scores ($p<.001$) for spatial memory component of the memory task. The authors suggested that cognitive spatial processing and postural regulation may require common mechanisms, and proposed a link between postural control and spatial cognition because both of these functions are related to vision (Kerr et al., 1985).

Shumway-Cook and Woollacott (2000) studied the effect of cognitive demands on postural control in young adults, older adults without history of falls, and older adults with history of falls, under different sensory conditions. The results of this study showed that for many individuals, standing in an environment where visual motion cues are unrelated to postural control may be more demanding than maintaining stability without visual cues (Shumway-Cook & Woollacott, 2000).

Lee and Aronson (1974) studied the ability of infants, ranging from 13-16 months old, to maintain standing postural control when visual input provided conflicting information. The participants were instructed to stand in the middle of the room; the child's parents were allowed to be sitting in front of the child. The participants were inside a room constructed with the ability to swing from the ceiling. At the start of the experiment, the room was stationary and the child was allowed to play and become familiar with the environment; then the room was swung to provide the incorrect sense of movement. The results showed that younger children can rarely ignore visual information, even when this information is grossly incorrect, as underscored by the tendency of all the participants to sway and fall when confronted by the conflicting visual stimulus. When abrupt room movements were made, young children compensated with motor responses designed to restore the vertical position. However, since no actual body sway occurred, only the illusion of sway introduced via the visual system elicited a motor response with a destabilizing effect, causing the infants to stagger or fall in the direction of the room movement. The authors suggested that infants learning to stand initially are more influenced by visual cues. The authors also suggested that infants rely on visual information more than mechanical proprioceptive information probably due to increased exposure and development of visual feedback and less exposure to mechanical proprioception feedback from mechanoreceptors from the ankle joints. They suggested that infants have more visual feedback experience, through previous activities such as sitting and crawling, prior to standing control (Lee & Aronson, 1974).

Foster and Sveistrup studied the ability of infants as young as 5 months old and young adults up to 28 years old to interpret the visual flow from movement of the room while maintaining standing postural control. The infants who were not able to maintain independent standing were supported in a standing position by their parent during the experiment. Surface

EMG was used to measure the activity of key postural muscles which included: gastrocnemius, tibialis anterior, lateral hamstring, rectus femoris, trunk extensors, and abdominal muscles. The amplitude of sway was also recorded by a video camera and a computer system that analyzed the digital images to measure the degrees of sway. The results of this study showed that infants as young as 5 months old are able to detect visual flow and will interpret the flow produced by the movement of the room as body sway. Moreover, the motor system is able to produce the directionally appropriate postural responses, as measured by EMG, which serve to correct for the perceived loss of stability. Finally, the probability of recording a response and the magnitude of the responses recorded decreased as subjects gain experience with independent stance and locomotion. The authors found a clear developmental trend in the magnitude of the response elicited, with increased sway seen in younger participants (Foster & Sveistrup, 1996).

Foster and Sveistrup hypothesized that vision plays a different role in postural control for different postural skills. Possibly, a 5-month-old infant who has mastered the postural control required to maintain independent sitting is less dependent on vision than on other sensory information. The increase in the magnitude of the effect of visual perturbation suggests an increased reliance on visual input on children that are just beginning to walk (children from 11-14 months old). Placing the child in a new position, with new postural demands, like independent standing, may require the child to increase the dependence on vision. The authors suggested that, at this young age, the calibration process mapping and continuously updating visual information is ongoing as infants explore new relationships between their bodies and space. They hypothesized that vision mapping precedes mapping by somatosensory inputs.

Infants appear to exhibit vision mapping for muscles controlling stance posture by at least 5 to 6 months, prior to somatosensory system mapping, and long before the infant has much experience in the standing position. The preceding of vision mapping suggests that the infant has to reassemble the synergies when somatosensory inputs are mapped for stance postural control (Foster & Sveistrup, 1996).

According to Foster and Sveistrup, the new walkers were most influenced by the movement of the room, as evidenced by both their emotional and postural responses. The increase in the magnitude of the response recorded in the new walkers group (11 to 14 month old) may in part have been a function of a generally immature postural system that had yet to establish the control parameters for independent stance. The authors concluded infants may start learning to reduce dependence on unreliable visual information shortly after they begin walking. In general, the developmental progression indicates that the visual perturbation becomes increasingly destabilizing as infants begin to stand and walk independently. As the infant gains experience with the walking task, the effect of the perturbation decreases until, finally, in the adult, minimal responses are observed (Foster & Sveistrup, 1996).

Woollacott et al. (1987) studied the control of posture in infants as young as 3 months old and in children up to 9 years of age, and they compared their results to the results obtained in a previously established adult sample. Children were grouped according to age parameters and they were tested on a moving platform as they were instructed to maintain a standing position. The infants who were not able to maintain independent standing were tested in the sitting position, and the infants who were not able to maintain independent sitting were tested in an infant seat. The authors also tested the role of vision in three of the age groups: 2-3 years, 4-6 years, and 7-10 years. The three groups were tested under two vision conditions: eyes open and no vision (participants wearing opaque goggles). The platform was displaced in an anterior or posterior direction. Surface EMG was used to measure the activation of key postural muscles including: gastrocnemious, tibialis anterior, hamstrings, quadriceps, trunk extensor (lumbar paraspinal), abdominal, neck extensor, and neck flexor muscles. The young infants group (3-5 month old) showed a high level of variability among the subjects. In contrast, the children in the 8-14 months group who could sit independently, showed directionally specific neck and trunk muscle activation with a low variability in onset latency (Woollacott et al., 1987).

Under the eyes open condition, the children in the 2-3 year old age group exhibited clearly organized leg muscle responses to the postural perturbation while standing. In addition, their postural responses were larger in amplitude and longer in duration that those see in the adults. Moreover, the trunk musculature activity appears to develop later as it was not consistently present in this group. The children in the 4-6 years old age group also showed leg muscle responses that were clearly organized to respond to the postural perturbation while standing. Their postural responses were larger in amplitude and longer in duration that those see in the adults but not as large as the 2-3 years old group. When slower platform movements were used, the 7-10 years old group showed postural responses that were very similar to the adult group. However, with faster platform movement, the 7-10 year old group showed temporal characteristics that were slightly different from the adult group (Woollacott et al., 1987).

Under the no vision condition, various effects were seen in the activation of postural musculature; but the overall results under this condition, drove the authors to conclude that vision is not required for the activation of postural responses to maintain independent standing in young children. The children were able to maintain standing balance even in the absence of visual input. However, the authors concluded that vision is normally dominant in the 2-3 year-old children during quiet stance. The authors suggested that the strong influence of visual cues on postural control between the ages of 2 and 5 years represents a period of fine tuning of the visual system and an integration of visual cues with vestibular and somatosensory inputs (Woollacott et al., 1987). The strong influence of visual cues in children indicates that visual distractions could affect gait in children.

Berthnthal and Bai also studied the ability of infants, mean age of 13.9 months, to interpret the visual flow from movement of the room while maintaining standing postural control. They also studied the ability of younger infants, divided in three groups: 5, 7, and 9 months old, to interpret the visual flow from movement of the room while maintaining sitting balance. In this study, the moving room was such that the side and front walls could be moved independently, as well as together, so the researchers were able to systematically manipulate the location of the optical flowing the visual field. The authors described optical flow as the global flow of optical texture that is perceived when a person moves in space; it specifies information about objects and spatial layout, and it provides information about the movement of the individuals. They stated that individuals acquire a sense of orientation by using visual input from the environment (Berthal & Bai, 1989).

The results showed that older infants exhibited a directionally appropriate postural response in standing during movement of the whole room or during movement of only the side walls. No measurable response was present on a majority of trials in the front-wall movement condition. The older infants showed greater postural compensations during whole-room movement than during movement of only the side walls. In addition, movement of the room toward the infant produced a larger effect than movement away from the infant while standing. Only the infants in the 9 month old group exhibited postural responses that were significantly directionally appropriate to movements of the whole room. The postural responses seen in the 5 months and 7 months old groups were not statistically significant in terms of appropriate direction of postural adjustment. Infants appeared to use optical flow for maintaining a balanced position and that the information used for perceiving self-movement is often spatially distributed in the visual field. This study showed that infants exhibit a directionally appropriate postural response to visual field movement and that their response may vary when a global or a partial visual movement flow is introduced. The authors concluded that sensitivity to visual flow for controlling posture emerges gradually during the latter half of the first year of life in normal developing infants. They also suggested an ongoing calibration process mapping and continuously updating visual information as infants explore new relationships between their bodies and space (Berthal & Bai, 1989).

GAITRIte

The GAITRite system is an emerging tool for the assessment of gait and is becoming more common in the clinical setting and as a research tool. The GAITRite system is composed of an electronic walkway that collects the spatial and temporal parameters of an individual's gait, and its supportive computer software. As the patient ambulates across the walkway, the system captures the geometry and relative arrangement of each footfall as a function of time. The application software controls the functionality of the walkway, processes the raw data into footfall patterns, and computes the temporal (timing) and spatial (distance) parameters. The software's relational database stores tests individually under each patient and supports a variety of reports and analyses (The GAITRite electronic walkway. GAITRite page.).

Wondra et al (2007) stated that the use of an instrument such as the GAITRite to measure gait parameters is becoming more common in the clinical setting because this system is not labor intensive and can provide the clinician with quick and objective measurement of temporal-spatial gait parameters. Additionally, the level of computer expertise required to operate the GAITRite is minimal (Wondra, Pitetti, & Beets, 2007).

The standard GIATRite walkway contains six sensor pads encapsulated in a roll-up carpet, resulting in an active area of 61 cm wide and 366 cm long; that is approximately 25 in wide and 12 ft long. The active area is a grid with dimensions of 48 sensors by 288 sensors, placed on 1.27 cm centers, resulting in a total of 13,824 sensors (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.).

As the subject ambulates across the walkway, the sensors provide the GAITRite system with information about the relative geometrical arrangement and the amount of the applied mechanical pressure of each footfall as a function of time. The system automatically forms groups of sensors which identified each footfall as a quadrilateral that encloses the footprint. This quadrilateral is subdivided into 12 sections to further identify the foot print, which is then divided in three areas: heel, mid-foot, and fore-foot. The application software processes the raw data into footfall patterns and computes temporal and spatial parameters. The system is able to calculate 9 different spatial parameters and 20 temporal parameters (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.).

Thorpe et al (2005) documented repeatability measures of temporal and spatial gait parameters in typical developing children; a group of 57 children, ages 1.3 to 10.9 years old, participated in this study. The test-retest reliability of the GAITRite was documented in this study by calculating intraclass correlation coefficients (ICCs) for ten spatial and temporal parameters for three age groups: 1 to less than 4 years old, 4 to less than 8 years old, and 8 to less than 11 years old. The following spatial and temporal parameters were compared: velocity, cadence, step length, stride length, heel-to-heel base of support, single support percentage of gait cycle left leg, single support percentage of gait cycle right leg, double support percentage of gait cycle, toe in/out angle left leg, and toe in/out angle right leg. The results of this study show ICCs that range from poor to excellent. In the 1 to less than 4 years old group the ICCs were: 0.70 for velocity, 0.89 for step length, and 0.57 for double leg percentage of gait cycle. In the 4 to less than 8 years old group the ICCs were: 0.74 for velocity, 0.82 for step length, and 0.66 for double leg support (DLS) percentage of gait cycle. In addition, the authors concluded that their repeatability measures are comparable to results obtained with adult subjects (Thorpe, Dusing, & Moore, 2005).

Wondra et al (2007) examined the same day test-retest reliability of the GAITRite in 19 children with motor disabilities, mean age of 6.8 years, under two walking conditions: without orthoses or barefoot, and while wearing orthoses and shoes. In this study, six temporal-spatial gait measurements were evaluated for test-retest reliability: gait velocity (cm/sec), cadence (steps/min), stance time (% gait cycle), stride length (cm), base width (cm), and cycle time (sec). The results of this study show that the majority of the intraclass correlation coefficients (ICCs) calculated, for each condition, exceeded the minimum reliability coefficient criteria of 0.80. In addition, the results demonstrated stability of the majority of the parameters measured when a single trial was administered. The authors concluded that an observed score from a single administration of a test is reflective of the participants' gait performance (Wondra et al., 2007).

The validity and reliability of the GAITRite system has been notably documented with adults subjects. Webster et al. documented the concurrent validity of the GAITRite system by comparing gait parameter measurements obtained with the GAITRite to the values obtained by a three-dimensional motion analysis system in a small group of adult patients who had undergone knee replacement surgery, mean age of 66.5 years. The following gait parameters were compared: velocity, cadence, step length, and step time. The authors concluded that the results of this study showed excellent level of agreement between the two systems with ICCs ranging from 0.92 to 0.99 (Webster, Wittwer, & Feller, 2005).

Van Uden and Besser documented the test-retest reliability of the GAITRite by measuring spatial and temporal parameters in a small group of normal adults, mean age of 34 years. The following parameters were measured: walking speed (cm/sec), step length (cm)stride length (cm), base of support (cm), step time (sec) stride time (sec) swing time (sec) stance time (sec), single support time (sec), double support time (sec) and toe in toe out angle (deg). The measurements were obtained under two conditions: preferred walking speed and fast walking speed. The authors concluded that all spatial and temporal parameters exhibit good to excellent test-retest reliability for the adult population without pathology in both conditions: preferred walking speed and fast walking speed. In the first condition, preferred walking speed, the results of this study showed ICCs of 0.92 or higher, for all parameters measured, with exception of base of support (ICC of 0.80). In the second condition, fast walking speed, the results of this study showed ICCs of 0.91 or higher, for all parameters measured, with exception of: swing time and single support time (ICC of 0.89), and base of support (ICC of 0.79) (van Uden & Besser, 2004).

Bilney et al (2003) documented the concurrent validity of the GAITRite system by comparing gait parameter measurements obtained with the GAITRite to the values obtained by the Clinical Stride Analyser® (CSA) system in a small group of normal adults, mean age of 40.5 years. The CSA system is comprised of a pair of innersoles, with four compression closing switches, which are fitted inside the subject's shoes. In this study, the measurements were obtained under three conditions: preferred walking speed, slow walking speed, and fast walking speed. The following parameters were measured: speed (m/s), cadence (steps/min), stride length (m), single leg support time (SLS) (s) and double limb support as a percentage of the gait cycle (DS%GC). The results of this study showed excellent level of agreement between the two systems for the first three parameters measured: speed, cadence, and stride length, with ICCs of 0.99 for all three walking speed conditions. However, for SLS time the level of agreement between the two systems varied according to the walking speed and from right to left leg; for SLS time the ICCs ranged from 0.52-0.91. Moreover, for DS%GC, the level of agreement between the two systems was poor; for DS%GC, the ICCs ranged from 0.44-0.57 (Bilney, Morris, & Webster, 2003).

In the same study, the authors documented the inter trial repeatability of the GAITRite system by calculating ICCs values from measurements obtained by the GAITRite for all parameters and under all three walking speed conditions. The ICCs calculated for inter trial repeatability purposes, ranged from 0.76 to 0.97 in all parameters documented. The authors concluded that the GAITRite's measures of speed, cadence, and stride length demonstrate good concurrent validity and the GAITRite system exhibits a high level of inter trial repeatability in normal adults, for all the parameters measured in this study (Bilney et al., 2003).

In a similar research study, Cutlip et al (2000) documented the concurrent validity of the GAITRite system by comparing gait parameter measurements obtained with the GAITRite to the values obtained by an instrumented walkway system and video-based three-dimensional motion analysis system (peak performance technologies motus 3.1) in a small group of normal adults. In this study, the measurements also were obtained under three conditions: slow walking speed, neutral walking speed, and fast walking speed. The following parameters were measured: step length (cm), step period (sec), stride velocity (cm/sec), stance duration (sec), swing duration (sec). Pearson product moment correlations were used to compare the values obtained by the two systems; the correlation values ranged from 0.936 to 0.988 for all the parameters measured. The authors concluded that the GAITRite and the video-based system were closely matched for the majority of kinematic variables measured, but the differences between the two systems increased with increasing gait speed (Cutlip, Mancinelli, Huber, & DiPasquale, 2000).

Dusing and Thorpe established normative values for temporal and spatial gait parameters in 438 typically developing children, ages from 1-10 years old; all gait parameters were measured at self-selected speed. The children who participated in this study were recruited from elementary schools, preschools, daycares, and the community in the Chapel Hill, North Carolina area. All children were able to walk at least 100 ft independently and showed no evidence of muscle, bone, joint, brain or nerve dysfunction. Results were reported for several gait parameters on 10 age groups, 1-10 years old respectively. Authors observed more variability in younger children and discussed the possibility that it may be due to the fact that younger children were more distractible during their participation (Dusing & Thorpe, 2007).

Pediatric Evaluation of Disability Inventory

The purpose of this study was to identify the effect of visual distraction on gait parameters in children. A secondary purpose was to describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking. The gait parameters of interest included: velocity, step length, step width, and double limb support percentage of gait cycle. The standardized test used was the Pediatric Evaluation of Disability Inventory (PEDI).

The PEDI is a comprehensive instrument that measures the performance of functional activities in children. The creators identified three applications of the PEDI: to detect functional deficits or developmental delays, to monitor progress of an individual or a group, and to evaluate program outcomes. The PEDI is separated into two main sections: functional scales domains and caregiver assistance scales. The functional scales and the caregiver assistance scales include three domains: self-care, mobility, and social function (Haley et al., 1992). Furthermore, Reid et al (1993) described the items in the mobility domain as falling into two categories: items that measure simple transfer skills and items that measure body transport activities (Reid, Boschen, & Wright, 1993).

The PEDI has been standardized on a normative sample of typically developing children between ages 6 months and 7 years-6 months; a total of 412 children (209 female and 203 male) were included in the normative sample. In addition, a clinical sample of 102 children consisting of three separate groups completed the standardization process. After completing the test, raw scores can be used to obtain normative standard scores and scale scores. The normative standard scores are based on the chronological age of the child and have a mean of 50 and a standard deviation of 10. The scale scores are distributed along a total scale of 100 and describe the child's performance relative to the maximum possible score on the PEDI (Haley et al., 1992).

Feldman et al (1990) documented the concurrent validity of the PEDI by comparing scores of the PEDI to the Battelle Developmental Inventory Screening Test (BDIST). The participants included 40 children between ages of 2 and 8 years; 20 children were typically developing and 20 children were considered to have special needs. The special needs group included 10 children diagnosed with spina bifida and 10 children with arthritic conditions. The results of the study showed moderate ($r = 0.70 – 0.80$) Pearson product moment correlations between the PEDI and the BDIST. The authors concluded that concurrent validity of the PEDI was supported by the results obtain in the study. The authors concluded that construct validity was supported by the significant differences in the PEDI scores of the two groups of children and by subsequent analysis identifying the PEDI scores as a better group discriminator than the BDIST scores (Feldman, Haley, & Coryell, 1990).

Nichols and Case-Smith provided additional support for the intrarater and the interrespondent reliability, and for the concurrent validity of the PEDI in a three part study. Physical therapy students trained in the administration of the PEDI completed interviews for both intrarater and interrespondent reliability components of this study. In this study, the intrarater reliability or test-retest reliability was assessed by completing two separate interviews with the same parents separated by a time period of one week. The participants included 23 children, age range from 26-82 months. The interrespondent reliability was assessed by completing separate interviews with a parent and with either the child's occupational or physical therapist who had been providing therapy services to the child for at least 2 months.

These two interviews were completed in a period of 48 hours from each other. The participants included 17 children, age range from 13-67 months (Nichols & Case-Smith, 1996).

Furthermore, in this study concurrent reliability was established by comparing PEDI scores to Peabody Developmental Motor Scales (PDMS) scores. The child's occupational or physical therapist completed the PDMS assessment prior to completing any of the PEDI interviews. Twenty five children age range from 12-76 months participated in this part of the study. The authors concluded that the general results of this study support the PEDI as a reliable and valid test for the evaluation of children. The reliability coefficients (ICC) reported for intrarater reliability ranged from 0.70 to 0.98 when comparing normative standard scores, and from 0.74 to 0.98 when comparing scaled scores in all domains. The reliability coefficients (ICC) reported for interrespondent reliability ranged from 0.12 to 0.75 when comparing normative standard scores, and from 0.31 to 0.88 when comparing scaled scores in all domains. The results of the concurrent validity analysis consisted of comparison of the raw scores of the PEDI and the PDMS to obtain Pearson correlation coefficients. The total PDMS fine motor and gross motor scores showed coefficients ranging from 0.74 to 0.95 when compared to each of the domains in the PEDI (Nichols & Case-Smith, 1996).

Summary

According to the systems model, motor control is achieved by the proper CNS organization of the information arriving from multiple sensory systems throughout the body. Normally, peripheral inputs from visual, somatosensory (proprioceptive, cutaneous, and joint receptors), and vestibular systems are available to detect the body's position and movement in space with respect to gravity and the surrounding environment. The CNS components then organize this information in a purposeful manner (Shumway-Cook & Woollacott, 2006).

Postural control has traditionally been considered an automatic or reflex controlled process, suggesting that postural control systems use minimal attentional resources. However, recent research has provided evidence against this assumption (Shumway-Cook & Woollacott, 2006). Numerous studies suggest that a significant attentional demand exists and that attentional requirements for postural control vary depending on the postural task, the age of the individual, and their balance abilities (Cherng et al., 2007; Woollacott & Shumway-Cook, 2002). Moreover, in general, as the demand for stability increases, an associated increase in attentional resources used by the postural control system occurs (Lajoie et al., 1993; Shumway-Cook & Woollacott, 2006; Woollacott & Shumway-Cook, 2002).

The amount of attention dedicated to monitoring a movement is viewed as a variable that can affect the performance of a motor skill. The majority of research that describes the relationship between attention and postural control has been done with adult participants. Nevertheless, some of the results observed in adults can be useful to understand the role of attentional demands in postural control in children. For example, Kerr et al (1985) discussed the suggestion that cognitive spatial processing and postural regulation may require common mechanisms, based on experimental results where maintaining a standing position interfered with a memory task in young adults. Moreover, the authors proposed a link between postural control and spatial cognition because both of these functions are related to vision (Kerr et al., 1985).

Understanding of the child's attentional abilities, the level of sensory processing and organization, and the influence of the environmental factors on the performance of motor tasks, including postural control and gait, are crucial in enabling and guiding the therapist to modify and adapt the task environment appropriately and individually for each child in order to facilitate the desired performance of the motor task (Larin, 2000; Shumway-Cook & Horak, 1986).

Reilly et al (2008) emphasized the importance of understanding the factors competing for attentional resources during children's performance of the different tasks so that educators can create an age appropriate academic environment that is most conductive to learning (Reilly et al., 2008). In comparison, physical therapists must be able to monitor and address all aspects of a task that may be competing for the child's attentional resources to be successful with assessing the child's limitations and with implementing intervention activities (Larin, 2000; Shumway-Cook & Horak, 1986).

CHAPTER III

METHODS

Postural control is essential for performing activities of daily living and requires significant attentional demands. Visual distractions may affect postural control during functional activities such as gait. The effect of attentional demands on the performance of motor skills such as gait has not been extensively studied in children.

The purpose of this study was to identify the effect of visual distraction on gait parameters in children. A secondary purpose was to describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking.

The results of this study expand the knowledge of the role of attentional demands and the influence of a visual distraction on postural control in the development of complex motor skills such as walking in children. With this knowledge, physical therapists can better plan and modify interventions for children with impaired postural control.

This chapter outlines the methods including design, participant characteristics, data collection, and data analysis.

Design

This study was descriptive research using a sample of convenience. Independent variables used as grouping variables were walking experience groups (early walkers, pre-school walkers, and experienced walkers) and condition (no visual distraction versus visual distraction). Dependent variables were measured by the GAITRite system and included: velocity, step length, step width, and double limb support percentage of gait cycle.

Participants

The target number of participants was 45 (15 in each group) in order for data analysis to achieve a moderate effect size (0.40) with α-level set at 0.05 and the power set at 0.70 (Portney & Watkins, 2009). Gait speed was used as the primary dependent variable for these calculations. Research documenting the effect size for gait parameters in children is limited. However, Johnston et al., showed a moderate effect size on gait speed in two groups of children with cerebral palsy, 12 and 14 participants respectively, with a mean age of 9 years, 6 months (Johnston et al., 2011).

To recruit participants, the primary investigator (PI) contacted colleagues, friends, and family members with information about this project. The PI also distributed the same information, including a recruitment flyer, to physical therapy students at Texas Woman's University. Interested parents or legal guardians of potential participants were asked to contact the PI, using the phone number or the e-mail address in the recruitment flyer. The PI explained the study and inquired about inclusion and exclusion criteria listed on the recruitment flyer to confirm whether a potential participant qualified for inclusion in the study.

Inclusion Criteria

The following inclusion criteria were used:

1. Boys and girls 1 to 7 years of age
2. Walking ability: children who were able to walk without upper extremity support or assistive device for at least 10 ft without loss of balance on level surfaces.
3. Walking experience: children who had been walking independently (10 ft without loss of balance on level surfaces) for at least 6 months prior to the date of data collection.

Exclusion Criteria

The following children were excluded:

1. Children with a diagnosis of: spinal cord injury or spina bifida because of the unique effects of these conditions on motor performance, including gait.
2. Children who were not able to follow the instructions to complete the data collection process.

The PI discussed inclusion and exclusion criteria when communicating with the parent or legal guardian of potential participants and verified the criteria again at the time of signing a consent form prior to data collection. The PI relied on information provided by parent or legal guardian to decide if a potential participant met inclusion and exclusion criteria to participate in the study.

Instrumentation

GAITRite

The GAITRite system is composed of an electronic walkway that collects the spatial and temporal parameters of an individual's gait, and its supportive computer software. As a participant ambulates across the walkway, the system captures the geometry and relative arrangement of each footfall as a function of time. The application software controls the functionality of the walkway, processes the raw data into footfall patterns, and computes the temporal (timing) and spatial (distance) parameters. The software's relational database stores tests individually in each participant's folder and supports a variety of reports and analyses (The GAITRite electronic walkway. GAITRite page.).

The standard GAITRite walkway contains six sensor pads encapsulated in a rolled-up carpet, resulting in an active area of 61 cm. wide and 366 cm. long; that is approximately 25 in. wide and 12 ft. long. The active area is a grid with dimensions of 48 sensors by 288 sensors, placed on 1.27 cm. centers, resulting in a total of 13,824 sensors (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.; Dusing & Thorpe, 2007).

As the subject ambulates across the walkway, the sensors provide the GAITRite system with information about the relative geometrical arrangement and the amount of the applied mechanical pressure of each footfall as a function of time. The system automatically forms groups of sensors which identify each footfall as a quadrilateral that encloses the footprint. This quadrilateral is subdivided into 12 sections to further identify the foot print, which is then divided in three areas: heel, mid-foot, and fore-foot. The application software processes the raw data into footfall patterns and computes temporal and spatial parameters. The system is able to calculate 9 different spatial parameters and 20 temporal parameters (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.).

Thorpe et al (2005) investigated test-retest reliability of the GAITRite in a group of 57 typically developing children, ages 1.3 to 10.9 years old. The authors calculated intraclass correlation coefficients (ICCs) for ten spatial and temporal parameters: velocity, cadence, step length, stride length, heel-to-heel base of support, single support percentage of gait cycle left leg, single support percentage of gait cycle right leg, double limb support percentage of gait cycle, toe in/out angle left leg, and toe in/out angle right leg. ICCs ranged from poor to excellent; specifically in the 1 to less than 4 years old group. ICCs were 0.70 for velocity, 0.89 for step length, and 0.57 for double limb percentage of gait cycle. In the 4 to less than 8 years old group, ICCs were 0.74 for velocity, 0.82 for step length, and 0.66 for double limb support (DLS) percentage of gait cycle. In addition, the authors concluded that their repeatability measures were comparable to results obtained with adult subjects (Thorpe et al., 2005).

Pediatric Evaluation of Disability Inventory

The Pediatric Evaluation of Disability Inventory (PEDI) is a comprehensive instrument that measures the performance of functional activities in children. The creators identified three applications of the PEDI: to detect functional deficits or developmental delays, to monitor progress of an individual or a group, and to evaluate program outcomes. The PEDI is separated into two main sections: functional scales domains and caregiver assistance scales. The functional scales and the caregiver assistance scales include three domains: self-care, mobility, and social function (Haley et al., 1992). Furthermore, Reid et al (1993) described the items in the mobility domain as falling into two categories: items that measure simple transfer skills and items that measure body transport activities (Reid et al., 1993).

The PEDI has been standardized on a normative sample of typically developing children between ages 6 months and 7 years-6 months; a total of 412 children (209 female and 203 male) were included in the normative sample. In addition, a clinical sample of 102 children consisting of three separate groups completed the standardization process. After completing the test, raw scores can be used to obtain normative standard scores and scale scores. The normative standard scores are based on the chronological age of the child and have a mean of 50 and a standard deviation of 10. The scale scores are distributed along a total scale of 100 and describe the child's performance relative to the maximum possible score on the PEDI (Haley et al., 1992).

Feldman et al (1990) documented the concurrent validity of the PEDI by comparing scores of the PEDI and the Battelle Developmental Inventory Screening Test (BDIST) in typically developing children and children with special needs who were 2 to 8 years. The results of the study showed moderate (r = 0.70 – 0.80) Pearson product moment correlations between the PEDI and the BDIST. The authors concluded that concurrent validity of the PEDI was supported. They also concluded that construct validity was supported by the significant differences in the PEDI scores of the two groups of children and by subsequent analysis identifying the PEDI scores as a better group discriminator than the BDIST scores (Feldman et al., 1990).

Nichols and Case-Smith assessed intrarater and interrespondent reliability, as well as concurrent validity of the PEDI in children ages 12 to 76 months. Reliability coefficients (ICC) reported for intrarater reliability ranged from 0.70 to 0.98 when comparing normative standard scores, and from 0.74 to 0.98 when comparing scaled scores in all domains. The reliability coefficients (ICC) reported for interrespondent reliability ranged from 0.12 to 0.75 when comparing normative standard scores, and from 0.31 to 0.88 when comparing scaled scores in all domains. Concurrent validity was also established with Pearson correlation coefficients ranging from 0.74 to 0.95 for caparison of total PDMS fine motor and gross motor scores with each domain of the PEDI (Nichols & Case-Smith, 1996).

Procedures

If the parent or legal guardian wished for the child to participate in the study, then the PI scheduled a time for data collection. The PI instructed the parent or legal guardian to dress the participant in regularly worn clothing and shoes.

At the scheduled time, the PI explained the study design, and the parent or legal guardian was asked to read and sign an informed consent form prior to any data collection. The PI inquired about inclusion and exclusion criteria to confirm whether a potential participant qualified for the study and answered any further questions about the study. After the parent or legal guardian signed the consent form, the PI completed the mobility domain of the functional scale of the Pediatric Evaluation of Disability Inventory (PEDI) and then proceeded with gait data collection. Data was collected at the School of Physical Therapy at Texas Woman's University, at the T. Boone Pickens Institute of Health Sciences, Dallas Center.

The data collection room was prepared with the GAITRite system in such a way that the visual field of the participant could be adjusted to both sides of the walkway. The GAITRite walkway was placed in between one wall and a system of panels allowing for approximately 5 ft of open space on each side for safety. The walkway area was restricted to only individuals directly associated with the study in order to maintain privacy as well as to prevent distractions to the participants.

At the time of data collection, the PI entered the participant's information into the GAITRite computer to create the participant's profile. This information included participant's name, age, and date of data collection. In addition, participants had a personal identification number (PIN) that was used when exporting data from GAITRite computer for data analysis. The participant's profile and data was saved in the GAITRite computer which uses the password protected GAITRite software.

The PI explained that if at any point the child appeared distressed or if the child became upset, the data collection would be stopped and the parent or legal guardian would be allowed to hold the child and take a break before attempting further data collection. Then, the PI explained the gait data collection procedures to the parent or legal guardian and to the participants as follows: the participants were instructed to walk towards their parent or legal guardian at the end of the GAITRite walkway. The starting point was marked with a line on the floor 4 ft away from the start of the GAITRite walkway so that the child achieved desired gait speed prior to walking on the GAITRite walkway. The parent or legal guardian was instructed to call the child to walk towards them. If additional motivation was needed, the parent or legal guardian was allowed to tell the child that he/she would be allowed to play with a toy, or an item of interest, after walking.

Gait parameter measures were obtained using the GAITRite system and recorded in the system's computer. The gait parameters of interest included: velocity, step length, step width, and double limb percentage of gait cycle.

The participants completed the walkway measurements under the following two conditions:

1. No visual distraction: side panels were placed along the GAITRite walkway to block all visual distractions.
2. With visual distraction: side panels were removed and participant was able to see the visual distraction. The visual distraction was composed of a television screen set playing children's programming such as cartoons: Veggie Tales® (Big Idea Entertainment, LLC. Big Idea, Inc. 320 Billingsly Court #30, Franklin, TN 37067). The sound was muted so that the distraction was only visual in nature. The television screen was placed in the mid-section and approximately 5 ft away from the GAITRite walkway, on the right side as the child walked towards the parent or caregiver.

Each participant completed 2 successful trials under each condition for a total of 4 successful trials, two without distraction and two with distraction. The order of the conditions was systematically randomized so that participants alternated the order of trials, with and without distraction, according to when their data collection appointment was scheduled.

Data Analysis

Participants were divided into three groups for data analysis according to their walking experience: early walkers (6-11 months of walking experience), pre-school walkers (12-37 months of walking experience), and experienced walkers (38-79 months of walking experience). Each participant completed 2 successful trials under each condition for a total of 4 successful trials, two without distraction and two with visual distraction.

Data were analyzed using the 19.0 version of IBM SPSS for windows. Descriptive statistics, including means and standard deviations, are reported to describe the participants overall and for each group.

A 3x2 multivariate analysis of variance (MANOVA) was used to assess differences between groups (effect of walking experience) and within groups (condition: no visual distraction versus visual distraction) with regard to gait parameters: velocity, step length, step width, and double limb support percentage of gait cycle.

A MANOVA was followed with univariate F-tests (ANOVAs) to further assess differences in main effect of group and walking experience. The α-level was set at 0.05. Significant effects were explored with post hoc comparison testing.

In addition, Pearson's correlation coefficients were calculated to describe the role of walking experience in the management of a visual distraction while walking and explore the relationship of management of visual distraction while walking with performance in standardized testing.

CHAPTER IV

RESULTS

The intent of this descriptive study was to expand the knowledge of the role of attentional demands and its influence in postural control in the development of complex motor skills such as walking in children. The purpose of this study was to identify the effect of visual distraction on gait parameters in children. A secondary purpose was to describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking. The gait parameters of interest included: velocity, step length, step width, and double limb support percentage of gait cycle. The standardized test used was the mobility domain of the Pediatric Evaluation of Disability Inventory (PEDI). The research hypotheses were that a visual environmental distraction would have a significant effect on gait performance in children, and that walking experience would have a significant effect on gait performance in children in the presence of a visual distraction. This chapter reports the results of the study including descriptive statistics and data analysis completed.

A total of 42 participants completed data collection for this study; 24 males and 18 females, age range 16 to 90 months (mean=43.2 months, standard deviation=22.9 months). All participants completed the mobility section of the functional scale of the PEDI. The combined normative standard score mean was=46.77, standard deviation=9.85. This mean score is consistent with age appropriate performance of motor skills and confirms that participants were typically developing children.

Participants were divided in three groups for data analysis according to their walking experience: early walkers (6-11 months of walking experience), pre-school walkers (12-37 months of walking experience), and experienced walkers (38-79 months of walking experience). Table 1 shows walking experience and age for each group.

Table 1

Mean, Standard Deviations, and Range for Walking Experience and Age by Group

Group	**Walking experience (months)**		**Age (months)**	
	Mean (SD)	Range	Mean (SD)	Range
Early walkers (n=13)	7.9 (2.1)	6-11	20.1 (2.1)	16-24
Pre-school walkers (n=14)	23.6 (8.2)	12-37	36.4 (7.1)	24-49
Experienced walkers (n=15)	57.3 (13.4)	38-79	69.7 (14.0)	49-90
All (n=42)	30.7 (22.9)	6-79	43.2 (22.9)	16-90

Notes: SD=standard deviation

Data was analyzed for normal distribution and homogeneity of variance assumptions. Shaphiro-Wilk test was used to test normal distribution assumption on each dependent variable and each group. Only velocity for early walkers, W(13) = 0.868, p = 0.049, and velocity with TV distraction for pre-school walkers W(14) = 0.865, p = 0.036, were found to deviate significantly from normality. All other dependent variables met the assumption of normality for each group ($p > 0.05$). Lavene's statistic was used to test the assumption of homogeneity of variance for between group comparisons and adjustments made when violated.

Descriptive statistics, including means and standard deviations, are reported to describe performance on each of the dependent variables for the participants overall and for each group. Table 2 depicts mean and standard deviation values for each gait parameter by group and under each condition: no distraction (control) versus visual distraction (TV). All gait parameters increased with age under both conditions.

Table 2

Mean and Standard Deviations for Gait Parameters by Group and Condition

Dependent variables	**Early walkers** (n=13) Mean (SD)	**Pre-school walkers** (n=14) Mean (SD)	**Experienced walkers** (n=15) Mean (SD)
Velocity (cm/sec)	101.25 (26.30)	109.72 (22.86)	117.97 (27.73)
Velocity TV (cm/sec)	88.75 (19.81)	94.01 (12.84)	108.98 (24.15)
Step length (cm)	32.14 (4.78)	38.83 (8.36)	49.32 (7.99)
Step length TV (cm)	32.21 (6.12)	36.55 (6.97)	48.02 (8.70)
Step width (cm)	33.60 (4.26)	41.16 (4.99)	50.03 (8.14)
Step width TV (cm)	32.61 (4.91)	39.25 (3.80)	49.19 (8.22)
DLS % of gait cycle	16.04 (5.60)	18.15 (2.67)	20.36 (3.66)
DLS % of gait cycle TV	18.95 (8.03)	20.57 (2.95)	21.47 (3.15)

Notes: DLS= double limb support, TV=visual distraction

A 3x2 multivariate analysis of variance (MANOVA) was be used to assess differences between groups (effect of walking experience) and within groups (effect of visual distraction or condition) on measures of gait parameters (velocity, step length, step width, and double limb percentage of gait cycle). The interaction between group (effect of walking experience) and condition (effect of visual distraction) was not significant, F(74)= 0.612, *p*=0.765 (Pillai's Trace). However, significant main effects of walking experience group F(74)= 5.300, *p*≤0.000 and visual distraction condition F(36)= 2.586, *p*=0.053 were found.

Post Hoc Comparison Testing

A MANOVA was followed with univariate F-tests (ANOVAs) to determine which dependent variables had significant main effects. The α-level was set at 0.05.

Table 3 shows F-values and *p*-values for within group comparisons for each dependent variable, and table 4 shows *p*-values for between group post hoc test comparisons for each dependent variable.

In exploring the main effects of visual distraction (condition), there were no significant differences in step length and step width when comparing values obtained with a visual distraction to those with no visual distraction. However, there was a significant reduction in velocity (*p*=0.003) and a significant increase in DLS percentage of gait cycle (*p*=0.025) when comparing the two visual distraction conditions. That is, there was a significant difference in velocity and DLS percentage of gait cycle when comparing measures taken with a visual distraction when compared to those taken without a visual distraction, regardless of walking experience group.

Table 3

Gait Parameters Interactions by Condition Only

Dependent variables	**Condition only**	
	F-value	*p*-value
Velocity (cm/sec)	10.304	0.003
Step length (cm)	3.023	0.090
Step width (cm)	4.072	0.051
DLS % of gait cycle	5.467	0.025

Notes: DLS= double limb support

In exploring the main effects of walking experience group, significant effects were found for all four dependent variables. These significant main effects were followed with post hoc pairwise comparisons to determine which of the three groups differed significantly. Gabriel's pairwise test comparisons were chosen due to small differences in group sizes and assumption of homogeneity of variance being met for the majority of dependent variables.

Results of pairwise comparison testing show that there were significant differences ($p \leq 0.05$) when comparing early walkers to experienced walkers in all dependent variables. In addition, there was a significant difference ($p \leq 0.05$) in step width when comparing early walkers to pre-school walkers group, and a significant difference ($p \leq 0.05$) in step length and step width when comparing pre-school walkers to experienced walkers. Table 4 shows *p*-values for post hoc test group comparisons for each dependent variable.

Table 4

Post Hoc Pairwise Comparison Testing for Each Dependent Variable

Variables	Group	Group	Sig
Velocity (cm/sec)	Early walkers	Pre-school walkers	.731
		Experienced walkers	.044
	Pre-school walkers	Experienced walkers	.294
Step length (cm)	Early walkers	Pre-school walkers	.136
		Experienced walkers	≤.001
	Pre-school walkers	Experienced walkers	≤.001
Step width (cm)	Early walkers	Pre-school walkers	.008
		Experienced walkers	≤.001
	Pre-school walkers	Experienced walkers	≤.001
DLS % of gait cycle	Early walkers	Pre-school walkers	.452
		Experienced walkers	.046
	Pre-school walkers	Experienced walkers	.569

Notes: DLS= double limb support

Relationship between Standardized Test Performance and Management of Visual Distraction

A secondary purpose of this study was to describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking. The gait parameters of interest included: velocity, step length, step width, and double limb support percentage of gait cycle. The standardized test used was the mobility domain of the Pediatric Evaluation of Disability Inventory (PEDI).

The PEDI provides normative standard scores and scale scores. The normative standard scores are based on the chronological age of the child and have a mean of 50 and a standard deviation of 10. The scale scores are distributed along a total scale of 100 and describe the child's performance relative to the maximum possible score on the PEDI (Haley et al., 1992). Standardized scores and scale scores were calculated for each group. Table 5 shows the mean standard and scale scores on the PEDI for each age group. The combined normative standard score mean was=46.77, standard deviation=9.85. This mean score is consistent with age appropriate performance of motor skills and confirms that participants were typically developing children. The mean scale score increased with walking experience for all groups: early walkers=64.29, pre-school walkers=74.06, and experienced walkers=94.08. These scale scores are considered age appropriate performance of motors skills for typically developing children for all group.

Table 5

Mean and Standard Deviation for PEDI Standard and Scale Scores by Group

Group	**PEDI Standard score** Mean (SD)	**PEDI Scale score** Mean (SD)
Early walkers (n=13)	52.28 (5.09)	64.29 (4.29)
Pre-school walkers (n=14)	41.69 (9.52)	74.06 (8.41)
Experienced walkers (n=15)	46.75 (11.12)	94.08 (8.65)
All (n=42)	46.77 (9.85)	78.19 (14.59)

Notes: PEDI= mobility domain of the functional scale of the Pediatric Evaluation of Disability Inventory; SD=standard deviation

In order to explore any possible relationship between management of visual distraction while walking with performance in standardized testing, Pearson's correlation coefficients were calculated between PEDI scales scores, walking experience, and each gait parameter measured under both conditions: no distraction and with visual distraction. Pearson's correlation coefficients are described below according to the guideline suggested by Portney and Watkins (Portney & Watkins, 2009).

Results showed an excellent relationship between PEDI scale scores and walking experience r=.916 ($p \leq 0.01$) independent from condition. Table 6 shows Pearson's correlation coefficients under no visual distraction condition. Under no visual distraction condition, there was a good to excellent relationship between PEDI scale scores and step length r=.808 ($p \leq 0.01$), and step width r=.848 ($p \leq 0.01$), and a fair relationship between PEDI scale scores and velocity r=.361 ($p \leq 0.05$), and DLS percentage of gait cycle r=.364 ($p \leq 0.05$).

Moreover, there was a moderate to good relationship between velocity and step length r=.667 (p≤0.01), step width r=.625 (p≤0.01), and DLS percentage of gait cycle r=-.513 (p≤0.01). It is important to notice that there was an inverse relationship between velocity and DLS percentage of gait cycle. In addition, there was a good to excellent relationship between step length and step width r=.965 (p≤0.01).

Table 6

Pearson's Correlation Coefficients for no Visual Distraction Condition

Variables	**PEDI scale score**	**Velocity (cm/sec)**	**Step length (cm)**	**Step width (cm)**	**DLS % of gait cycle**
PEDI scale score	1	.361*	.808**	.848**	.364*
Velocity (cm/sec)		1	.667**	.625**	-.513**
Step length (cm)			1	.965**	.123
Step width (cm)				1	.175
DLS % of gait cycle					1

Notes: *p≤0.05; **p≤0.01; *PEDI= mobility domain of the functional scale of the Pediatric Evaluation of Disability Inventory; DLS= double limb support*

Table 7 shows Pearson's correlation coefficients under a visual distraction condition. Under visual distraction condition, there was a good to excellent relationship between PEDI scale scores and step length r=.788 (p≤0.01), and step width r=.833 (p≤0.01), and a moderate to good relationship between PEDI scale scores and velocity r=.520 (p≤0.01).

Moreover, there was a moderate to good relationship between velocity and step length r=.722 (p≤0.01), step width r=.757 (p≤0.01). There was a fair relationship between velocity and

DLS percentage of gait cycle *r*=-.443 (*p*≤0.01). It is important to notice that there was an inverse relationship between velocity and DLS percentage of gait cycle. In addition, there was a good to excellent relationship between step length and step width *r*=.916 (*p*≤0.01).

Table 7

Pearson's Correlation Coefficients with Visual Distraction Condition

Variables	**PEDI scale score**	**Velocity TV (cm/sec)**	**Step length TV (cm)**	**Step width TV (cm)**	**DLS % of gait cycle TV**
PEDI scale score	1	.520**	.788**	.833**	.126
Velocity TV (cm/sec)		1	.722**	.757**	-.443**
Step length TV (cm)			1	.916**	-.024
Step width TV (cm)				1	.056
DLS % of gait cycle TV					1

*Notes: *p≤0.05; **p≤0.001; TV=visual distraction; PEDI= mobility domain of the functional scale of the Pediatric Evaluation of Disability Inventory; DLS= double limb support*

CHAPTER V

DISCUSSION

This descriptive study expands the knowledge of the role of attentional demands and its influence in postural control in the development of complex motor skills such as walking in children. The purpose of this study was to identify the effect of visual distraction on gait parameters in children. A secondary purpose was to describe the role of walking experience in the management of a visual distraction while walking, and explore the relationship between performance in standardized testing and management of visual distraction while walking. The gait parameters of interest included: velocity, step length, step width, and double limb support percentage of gait cycle. The standardized test used was the Pediatric Evaluation of Disability Inventory (PEDI).

This chapter starts by providing an overview of the study followed by results of hypothesis testing. Then, conclusions and clinical implications are discussed. Subsequently, the study's strengths and limitations are presented, and finally recommendations for future studies are discussed.

Overview

This study was descriptive research using a sample of convenience. Independent variables used as grouping variables were walking experience groups (early walkers, pre-school walkers, and experienced walkers) and condition (no visual distraction versus visual distraction).

Dependent variables were measured by the GAITRite system and included: velocity, step length, step width, and double limb support percentage of gait cycle.

Each participant completed 2 successful trials under each condition for a total of 4 successful trials, two without distraction and two with distraction. The order of the conditions was systematically randomized so that participants alternated the order of trials, with and without distraction, according to when their data collection appointment was scheduled.

Participants were divided into three groups for data analysis according to their walking experience: early walkers (6-11 months of walking experience), pre-school walkers (12-37 months of walking experience), and experienced walkers (38-79 months of walking experience). A total of 42 participants completed data collection for this study; 24 males and 18 females, age range 16 to 90 months (mean=43.2 months, standard deviation=22.9 months).

Results of Hypothesis Testing

Hypothesis One

Visual environmental distraction will have a significant effect on gait performance in children. Results of this study showed that a visual distraction had a significant effect on gait parameters in children.

Hypothesis Two

Walking experience will have a significant effect on gait performance in children in the presence of a visual distraction. Results of this study showed that a walking experience did not have a significant effect on gait performance in children in the presence of a visual distraction.

Discussion of Hypothesis Testing Results

In this section, results of hypothesis testing are discussed for both research hypotheses combined. The results obtained answer both research questions of this study. The hypothesis that a visual environmental distraction would have a significant effect on gait performance in children is confirmed by the results of the main effects of distraction testing. That is, there was a significant difference in velocity and DLS percentage of gait cycle when comparing measures taken with a visual distraction when compared to those taken without a visual distraction, regardless of walking experience.

However, the results obtained do not confirm the second hypothesis that walking experience would have a significant effect on gait performance in children in the presence of a visual distraction. Significant interaction effects were needed to confirm this hypothesis and these were not found for the multivariate analysis or univariate analyses for any of the gait variables.

The results of this study show that a visual environmental distraction had a significant effect on gait performance in children independently of the level of walking experience. Surprisingly, gait performance was affected by a visual distraction even in children with more walking experience. The expectation was that gait parameters of children with more walking experience would not be affected by a visual distraction.

The results of this study show that a visual environmental distraction had a significant effect on gait performance in children independently of the level of walking experience. Gait performance was affected by a visual distraction even in children with more walking experience.

Moreover, results showed that a visual distraction had a significant effect on several gait parameters in children. Under a visual distraction condition, children in all groups, age range 16-90 months (mean=43.2 months, standard deviation=22.9 months), exhibited a significant decrease in velocity (p=0.003), and a significant increase in DLS percentage of gait cycle (p=0.025). Overall, the mean velocity decreased from 110.04 cm/sec with no visual distraction to 97.73 cm/sec with visual distraction. In addition, the mean DLS percentage of gait cycle increased from 18.29% with no visual distraction to 20.39% with visual distraction.

Results of the current study for velocity and DLS percentage of gait cycle under no visual distraction condition are comparable to results reported by Dusing and Thorpe (2007) who established normative values for temporal and spatial gait parameters at self-selected speed in typically developing children, ages from 1 to 10 years old. For 1 to 7 years old children, velocity parameters reported by Dusing and Thorpe ranged from 82.05 to 127.29 cm/sec, and DLS percentage of gait cycle parameters ranged from 16.56 to 18.89 percent. Step length and step width parameters were not reported by the authors. As part of their study, the authors discussed the observed increased variability in younger children and discussed the possibility that it may be due to the fact that younger children were more distractible during their participation (Dusing & Thorpe, 2007).

Comparisons of the results of the current study to those of Dusing and Thorpe (2007) indicate some differences in findings when visual distractions are present. For example, with visual distraction, DLS percentage of gait cycle was considerably higher for all age groups to the results reported by Dusing and Thorpe.

For the early walkers group (mean age=1.7 years) the mean DLS percentage of gait cycle was 18.95 compared to 16.56% for the 1 year old group and 16.87% for the 2 year old group reported by Dusing and Thorpe. For the pre-school walkers group (mean age=3.0 years) the mean DLS percentage of gait cycle was 20.57% compared to 16.87% for the 2 year old group and 18.89% for the 3 year old group. Finally, for the experienced walkers group (mean age=5.8 years) the mean DLS percentage of gait cycle was 21.47% compared to 16.45% for the 5 year old group and 16.23% for the 6 year old group (Dusing & Thorpe, 2007).

Mean velocity was also different from values reported by Dusing and Thorpe. In the current study, the mean velocity under visual distraction condition was 108.98 cm/sec for the experienced walkers group compared to 123.51 cm/sec for the 5 year old group and 127.29 cm/sec for the 6 year old group (Dusing & Thorpe, 2007). These comparisons suggest that a visual environmental distraction can have a significant effect on gait performance in children, even children with more walking experience.

Participants in the current study walked slower under visual distraction condition, considered a dual task condition. These results are similar to results reported by Huang et al (2003). Huang et al. explored the influence of concurrent cognitive tasks on gait parameters in 5 to 7 year old typically developing children. Children walked as fast as possible under 4 conditions: walking alone and walking in combination with three different cognitive tasks. The three cognitive tasks were: visual identification, auditory identification, and memorization. Gait speed was significantly lower under all dual-task conditions in comparison to walking alone. The magnitude of the decrease in walking speeds ranged from 18 cm/sec for the memorization task to 43 cm/sec for the auditory identification task. Huang et al. concluded that children in the age range of 5 to 7 years old decrease their gait speed when performing concurrent cognitive tasks. The amount of interference varied with the different cognitive tasks performed (Huang et al., 2003).

In the current study, the decrease in velocity from no distraction to visual distraction condition, for the experienced walkers group (mean age=5.8 years) was only 8.99 cm/sec. Perhaps, the presence of a visual distraction does not affect velocity to the same degree as performing concurrent cognitive tasks while walking. Nevertheless, visual environmental distraction does impact gait performance in children of all experience level.

Relationship between Standardized Test Performance and Management of Visual Distraction

In order to explore any possible relationship between management of visual distraction while walking with performance in standardized testing, Pearson's correlation coefficients were calculated between PEDI scales scores, walking experience, and each gait parameter measured under both conditions: no distraction and with visual distraction.

Independent of condition, results showed a good to excellent relationship between PEDI scale scores and walking experience r=.916 ($p \leq 0.01$). This is most likely due to the mobility domain content of the PEDI which includes several items related to locomotion or independent walking. Several items assess the child's ability for walking indoors and outdoors for different distances. Moreover, several additional items assess the child's ability to ascend/descend inclines and negotiate walking on different surfaces, like lawn or gravel.

Under both conditions, results showed a good to excellent relationship between step length and step width (no visual distraction condition *r*=.965, $p \leq 0.01$; visual distraction condition *r*=.916, $p \leq 0.01$). Caution should be exercised when interpreting the relationship between step length and step width due to the way that the GAITRite system measures each of these parameters. Step length is measured along the line of progression on the sagittal plane and step width is measured along a diagonal line between midpoint of one footprint to the midpoint of the contralateral footprint (CIR systems inc. the GAITRite electronic walkway measurements and definitions 2006.). This may have resulted in a higher correlation value than if step width was measured strictly along the lateral plane.

As expected correlations between velocity and step length, between velocity and step width, and between velocity and DLS percentage of gait cycle were moderate to good regardless of environmental condition. These results suggest that condition did not affect the relationships among these variables.

Clinical Implications

The implied assumption of motor control and motor learning research is that the results obtained will advance clinical interventions to improve or restore motor function limited as a consequence of disease or injury. In the pediatric field, the results of motor learning research will guide the intervention strategies to assist a client in achieving their age appropriate developmental skills. In order to identify the underlying process that determines skill acquisition during development, a clinician must know not only which variables are important at a given age but also how each variable changes during development and the impact of that change on all the other variables (Bradley, 2000).

Hypothetically, typically developing children have the physical ability to properly respond to postural perturbations during gait. However, because of limited ability to maintain attention on one task, in the presence of a visual distraction, they are not able to adequately integrate and properly process the sensory information. This inability to process sensory information limits their ability to create and perform appropriate physical responses to the postural perturbations present during gait.

Shumway-Cook and Woollacott (2006) suggested that the postural demands of younger children use more of their attentional resources than compared to older children, and this need may affect both their postural and cognitive performance in dual-task situations. Therefore, since many activities that children perform have both postural and cognitive components, clinicians can expect that performance on the postural task, on the cognitive task, or on both tasks will suffer if the attentional capacity of the child is exceeded while performing the two tasks simultaneously (Shumway-Cook & Woollacott, 2006).

Valvano (2004) proposed a model of intervention to assist clinical reasoning that can be applied when physical therapists need to assess a child's ability to manage attentional demands of a complex motor task such as gait. The model allows for intervention if attention to task is identified as a limiting factor for performance and for learning a motor task. The model emphasizes the importance of learning functional motor activity but also addresses the impairments associated with neurological conditions. In this model, the environment is one of the three key components of functional activity focused intervention. The other two components are the child, and the task itself. The clinician is considered a “change agent who facilitates the child’s search for a coordination solution that will enable a task to be performed or refined.”

In addition, Valvano discussed the concept of constraints, which are described as factors that limit a child’s ability to perform a given motor task. These constraints can be factors related to the individual, the task, or the environment. Valvano proposed that the poor quality of movement seen in children with neurological conditions may be accounted for by information processing deficits in addition to limitations in the production of movement. Valvano explained that many task and the environment related guidelines for motor learning are based on principles from the information processing perspective. These principles are:

1. stages of information processing that occur prior to movement execution
2. memory
3. attention

Valvano argues that to successfully perform a task the performer must attend specifically to relevant environmental cues (Valvano, 2004).

Valvano’s argument is consistent with previous literature emphasizing the need to understand a child’s attentional abilities in order to understand a child’s overall performance of complex motor tasks. Moreover, understanding the level of sensory processing and organization, and the influence of the environmental factors on the performance of complex motor tasks is crucial to facilitate the desired performance for a given motor task. This understanding will guide physical therapists in appropriate modification of environmental conditions necessary for motor learning (Larin, 2000; Shumway-Cook & Horak, 1986). Furthermore, understanding of the effects of divided attention on motor performance may assist physical therapists in incorporating attentional factors into their examination and intervention techniques (Huang & Mercer, 2001).

The results of the current study suggest that physical therapists need to consider attentional requirements when assessing gait; even in older children with more walking experience. If attention to task is identified as a limiting factor for performance and for learning of a motor task, physical therapists may need to address the limitations in attention to task more directly as part of the treatment plan.

Limitations

This study had several limitations. First, the relatively small sample size may have resulted in smaller effects and may limit the generalizability of the study. The sample included a wide age range (16 to 90 months) which may improve the ability to generalize results to other groups of children. Second, we were not able to clarify the exact attentional cost of postural control needed for gait and the visual distraction because of the interacting effects between the two factors. Third, other possible unexpected environmental sounds may have been considered distractions for the participants, but every effort was made to control the environmental conditions so only visual distractions were provided. Lastly, only typically developing children were included in the study; this may limit the application of the study results to children with special needs, including children with a diagnosis that includes attention to task deficits.

Recommendations for Future Studies

Levac et al completed a review of the literature to identify and describe the application of selected elements of three motor learning strategies. The authors explained how dynamic systems theory guides contemporary functionally based intervention approaches in which learning outcomes are considered to emerge through a process of self-organized interaction between the characteristics of the child, the features of the task, and the learning environment (Levac, Wishart, Missiuna, & Wright, 2009). Since all participants had at least 6 months of walking experience, future studies should include children who are just starting to walk to further explore the role of managing distractions during earlier stages of learning a complex motor skill such as walking.

In addition, since all participants were typically developing children, future studies should include children with special needs and with a variety diagnoses that result in need for physical therapy intervention. Valvano argued there is a need for additional research to determine optimal guidelines for motor learning functional activities, and for the adaptations of these guidelines for children with neurological conditions (Valvano, 2004). Moreover, special consideration may be needed for children whose diagnosis includes specific attention to task limitations, such as attention deficit disorder and autism.

Since gait performance for children in all three age groups was affected by visual distraction, further study is needed to determine at what age or at what level of walking experience a visual environmental distraction has no significant effect on gait performance.

Moreover, the current study should be replicated using different types of distractions including auditory stimuli and multisensory distractions to better mimic the clinical environment.

Conclusion

The results of this study show that a visual environmental distraction had a significant effect on gait performance in children independently of the level of walking experience. Gait performance was affected by a visual distraction even in children with more walking experience.

Physical therapists may need to consider attentional requirements when assessing gait; even in older children with more walking experience. If attention to task is identified as a limiting factor for performance and for learning of a motor task, physical therapists may need to address the limitations in attention to task more directly as part of the treatment plan.

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APPENDIX A

IRB Approval Letters

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378
email: IRB@twu.edu
http://www.twu.edu/irb.html

DATE: November 14, 2014

TO: Mr. Luis Fabian Bizama
School of Physical Therapy - Dallas

FROM: Institutional Review Board - Dallas

Re: *Extension for The Effect of Visual Environmental Distraction on Gait Performance in Children (Protocol #: 16864)*

The request for an extension of your IRB approval for the above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. If subject recruitment is on-going, a copy of the approved consent form with the IRB approval stamp is enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. A copy of the signed consent forms must be submitted with the request to close the study file at the completion of the study.

This extension is valid one year from November 28, 2014. Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. All forms are located on the IRB website. If you have any questions, please contact the TWU IRB.

cc. Dr. Ann Medley, School of Physical Therapy - Dallas
Graduate School

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 FAX 940-898-4416
e-mail: IRB@twu.edu

November 26, 2013

Mr. Luis Fabian Bizama

Dear Mr. Bizama:

Re: The Effect of Visual Environmental Distraction on Gait Performance in Children (Protocol #: 16864)

The request for an extension of your IRB approval for the above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. A copy of any signed consent forms must be filed with the request to close the study at the completion of the project.

This extension is valid one year from November 28, 2013. Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. If you have any questions, please contact the TWU IRB.

Sincerely,

Catherine Bailey

Dr. Catherine Bailey, Chair
Institutional Review Board - Dallas

cc. Dr. Ann Medley, School of Physical Therapy - Dallas
Graduate School

TWU TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 FAX 940-898-4416
e-mail: IRB@twu.edu

November 14, 2012

Mr. Luis Fabian Bizama

Dear Mr. Bizama:

Re: The Effect of Visual Environmental Distraction on Gait Performance in Children (Protocol #: 16864)

The request for an extension of your IRB approval for the above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. A copy of any signed consent forms must be filed with the request to close the study at the completion of the project.

This extension is valid one year from November 28, 2012. Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. If you have any questions, please contact the TWU IRB.

Sincerely,

Catherine Bailey

Dr. Catherine Bailey, Chair
Institutional Review Board - Dallas

cc. Dr. Ann Medley, School of Physical Therapy - Dallas
Graduate School

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 FAX 940-898-4416
e-mail: IRB@twu.edu

February 10, 2012

Mr. Luis Fabian Bizama

Dear Mr. Bizama:

Re: The Effect of Visual Environmental Distraction on Gait Performance in Children (Protocol #: 16864)

Your application to the IRB was reviewed and approved on 11/28/2011. This approval is valid for one (1) year. The study may not continue after the approval period without additional IRB review and approval for continuation. It is your responsibility to assure that this study is not conducted beyond the expiration date.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. If you have any questions, please contact the TWU IRB.

A final report must be submitted to the IRB at the conclusion of the study. If using a consent form, copies of the signed informed consent are to be submitted with the final report before the study file can be closed.

The Institutional Review Board is pleased to acknowledge your sense of responsibility for ethical research. If you have any questions concerning this review, please contact me at (214) 706-2461 or email SLin@twu.edu.

Sincerely,

Suh-Jen Lin

Dr. Suh-Jen Lin, Chair
Institutional Review Board - Dallas

cc. Dr. Vertira Lovelace-Chandler, School of Physical Therapy - Dallas
Graduate School

APPENDIX B

Consent Form

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title: The effect of visual environmental distraction on gait performance in children

Primary Investigator: Fabian Bizama, PT, MPT	214-689-7700	LBizama@twu.edu
Advisor: Ann Medley, PT, PhD	214-689-7701	SMedley@twu.edu

Explanation and Purpose of this study

Children who have been walking for 6-12 months may have a harder time walking when they are distracted by things that they see going on around them in comparison to children who have been walking for more than 12 months.

The purpose of this will be to see if a distraction, such as a cartoon playing on the television, affects the way that children walk. We would also like to see if the same distraction affects walking in children with less walking experience any differently than children who have more walking experience.

Research Procedures

If you agree to have your child take part in this study, you will be asked a series of questions by the primary investigator in order to complete a test that measures how well your child is developing. These questions are to complete the mobility section of a standardized test called Pediatric Evaluation of Disability Inventory (PEDI). The results of this test will describe the level of performance of mobility skills for each child in comparison to other children their age.

Then, your child's walking pattern will be measured using an electronic walkway with sensors that provide information on each step as your child walks across the walkway. The walkway with sensor pads is connected to a computer and is called GAITRite system.

Your child's walking pattern will be measured under two conditions: first condition without visual distraction, and second condition with visual distraction. Each participant will complete at least 2 trials under each condition for a total of 4 trials; two without distraction and two with distraction.

The investigator will explain the data collection procedures to you and to your child as follows: your child will be instructed to walk towards you from one end of the walkway to the other end. You will be instructed to call your child to walk towards you. If additional motivation is needed, you will be allowed to tell your child that he/she will be allowed to play with a toy, or an item of interest, after walking.

The children will be divided into groups according to their walking experience. The walking patterns of each group will be analyzed and compared.

Approved by the Texas Woman's University Institutional Review Board
Date: 11-28-14
Revised: 11-13-14

Participant or Parent/guardian initials

Potential Risks

Potential risks related to your child's participation in this study include emotional discomfort or embarrassment. We will try to minimize these risks by keeping the testing area free of people who are not directly related to the study, and if at any point your child becomes upset, the testing will be discontinued and you will be allowed to comfort your child as needed.

Another possible risk is the release of confidential information. Confidentiality will be protected to the extent that is allowed by law. All the identifiable information will be kept in a locked file cabinet. Only the primary investigator and his advisor will have access to any confidential information. All the identifiable information will be destroyed within 5 years; identifiable data in paper form will be shredded and identifiable data in computer of the GAITRite system will be permanently deleted. It is anticipated that the results of this study will be published in the primary investigator's thesis as well as in other research publications. However, no names or other identifying information will be included in any publication.

The researchers will try to prevent any problem that could happen because of this project. You should let the researchers know at once if there is a problem and they will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

Participation and benefits

Your child's involvement in this research study is completely voluntary, and you may discontinue your child's participation in the study at any time without penalty. The only direct benefit of this study to you is that at the completion of the study a summary of the results will be mailed to you upon request.*

Questions regarding this study

If you have any questions about the research study you may ask the researchers; their phone numbers are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conducted, you may contact the Texas Woman's University of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu. You will be given a copy of this signed and dated consent form to keep.

Signature of participant Date

Signature of parent/guardian Date

*If you would like to receive a summary of the results of this study, please provide an address to which this summary should be mailed:

Approved by the Texas Woman's University Institutional Review Board Date: 11-26-14

Revised: 11-13-14

2

APPENDIX C

Pediatric Evaluation of Disability Inventory Scoring Form

Pediatric Evaluation of Disability Inventory

VERSION 1.0

Stephen M. Haley, Ph.D., P.T., Wendy J. Coster, Ph.D., OTR/L, Larry H. Ludlow, Ph.D., Jane T. Haltiwanger, M.A., Ed.M., Peter J. Andrellos, Ph.D.

SCORE FORM

ABOUT THE CHILD ID# ______

Name ______

Sex M ☐ F ☐ Ethnic group or race ______

Age	Year	Month	Day
Interview Date	______	______	______
Birth Date	______	______	______
Chronological age	______	______	______

Diagnosis (if any) ______

ICD-9 code(s) ______ primary ______ ______ additional

CURRENT STATUS OF CHILD

☐ hospital inpatient
 ☐ acute care
 ☐ rehabilitation

☐ lives at home
☐ lives in residential facility

other (specify) ______

School or other facility ______

Grade placement ______

ABOUT THE RESPONDENT (Parent or Guardian)

Name ______

Sex M ☐ F ☐

Relationship to child ______

Type of work (be specific) ______

Years of education ______

ABOUT THE INTERVIEWER

Name ______

Position ______

Facility ______

ABOUT THE ASSESSMENT

Referred by ______

Reason for the assessment ______

______

______

Notes ______

______

GENERAL DIRECTIONS

Below are the general guidelines for scoring. All the items have specific descriptions. Consult the Manual for individual item scoring criteria.

PART I Functional Skills: 197 discrete items of functional skills

Self-care, Mobility, Social Function
- 0 = unable, or limited in capability, to perform item in most situations
- 1 = capable of performing item in most situations, or item has been previously mastered and functional skills have progressed beyond this level

PART II Caregiver Assistance: 20 complex functional activities

Self-care, Mobility, Social Function
- 5 = Independent
- 4 = Supervise/Prompt/Monitor
- 3 = Minimal Assistance
- 2 = Moderate Assistance
- 1 = Maximal Assistance
- 0 = Total Assistance

PART III Modifications: 20 complex functional activities.

Self-care, Mobility, Social Function
- N = No Modifications
- C = Child-oriented (non-specialized) Modifications
- R = Rehabilitation Equipment
- E = Extensive Modifications

PLEASE BE SURE YOU HAVE ANSWERED ALL ITEMS.

PEDI Research Group, Health and Disability Research Institute, Boston University, 53 Bay State Road, Boston, MA 02215 2101
Email: hdr@bu.edu • Phone (617) 353-3277, Fax (617) 358-1355 • URL: http://www.bu.edu/hdr/products/pedi/index.html

Part I: Functional Skills

SELF-CARE DOMAIN Place a check corresponding to each item: Item scores: 0 = unable; 1 = capable

A. Food Textures	0 (unable)	1 (capable)
1. Eats pureed/blended/strained foods		
2. Eats ground/lumpy foods		
3. Eats cut up/chunky/diced foods		
4. Eats all textures of table food		

B. Use of Utensils	0	1
5. Finger feeds		
6. Scoops with a spoon and brings to mouth		
7. Uses a spoon well		
8. Uses a fork well		
9. Uses a knife to butter bread, cut soft foods		

C. Use of Drinking Containers	0	1
10. Holds bottle or spout cup		
11. Lifts cup to drink, but cup may tip		
12. Lifts open cup securely with two hands		
13. Lifts open cup securely with one hand		
14. Pours liquid from carton or pitcher		

D. Toothbrushing	0	1
15. Opens mouth for teeth to be brushed		
16. Holds toothbrush		
17. Brushes teeth; but not a thorough job		
18. Thoroughly brushes teeth		
19. Prepares toothbrush with toothpaste		

E. Hairbrushing	0	1
20. Holds head in position while hair is combed		
21. Brings brush or comb to hair		
22. Brushes or combs hair		
23. Manages tangles and parts hair		

F. Nose Care	0	1
24. Allows nose to be wiped		
25. Blows nose into held tissue		
26. Wipes nose using tissue on request		
27. Wipes nose using tissue without request		
28. Blows and wipes nose without request		

G. Handwashing	0	1
29. Holds hands out to be washed		
30. Rubs hands together to clean		
31. Turns water on and off, obtains soap		
32. Washes hands thoroughly		
33. Dries hands thoroughly		

H. Washing Body & Face	0	1
34. Tries to wash parts of body		
35. Washes body thoroughly, not including face		
36. Obtains soap (and soaps washcloth, if used)		
37. Dries body thoroughly		
38. Washes and dries face thoroughly		

I. Pullover/Front-Opening Garments	0	1
39. Assists, such as pushing arms through shirt		
40. Removes T-shirt, dress or sweater (pullover garment without fasteners)		
41. Puts on T-shirt, dress or sweater		
42. Puts on and removes front-opening shirt, not including fasteners		
43. Puts on and removes front-opening shirt, including fasteners		

J. Fasteners	0 (unable)	1 (capable)
44. Tries to assist with fasteners		
45. Zips and unzips, doesn't separate or hook zipper		
46. Snaps and unsnaps		
47. Buttons and unbuttons		
48. Zips and unzips, separates and hooks zipper		

K. Pants	0	1
49. Assists, such as pushing legs through pants		
50. Removes pants with elastic waist		
51. Puts on pants with elastic waist		
52. Removes pants, including unfastening		
53. Puts on pants, including fastening		

L. Shoes/Socks	0	1
54. Removes socks and unfastened shoes		
55. Puts on unfastened shoes		
56. Puts on socks		
57. Puts shoes on correct feet; manages velcro fasteners		
58. Ties shoelaces		

M. Toileting Tasks (clothes, toilet management, and wiping only)	0	1
59. Assists with clothing management		
60. Tries to wipe self after toileting		
61. Manages toilet seat, gets toilet paper and flushes toilet		
62. Manages clothes before and after toileting		
63. Wipes self thoroughly after bowel movements		

N. Management of Bladder (Score = 1 if child has previously mastered skill)	0	1
64. Indicates when wet in diapers or training pants		
65. Occasionally indicates need to urinate (daytime)		
66. Consistently indicates need to urinate with time to get to toilet (daytime)		
67. Takes self into bathroom to urinate (daytime)		
68. Consistently stays dry day and night		

O. Management of Bowel (Score = 1 if child has previously mastered skill)	0	1
69. Indicates need to be changed		
70. Occasionally indicates need to use toilet (daytime)		
71. Consistently indicates need to use toilet with time to get to toilet (daytime)		
72. Distinguishes between need for urination and bowel movements		
73. Takes self into bathroom for bowel movements, has no bowel accidents		

SELF-CARE DOMAIN SUM	

PLEASE BE SURE YOU HAVE ANSWERED ALL ITEMS

Comments

PEDI — 2

MOBILITY DOMAIN

Place a check corresponding to each item: Item scores: 0 = unable; 1 = capable

UNABLE 0 | CAPABLE 1

A. Toilet Transfers

1. Sits if supported by equipment or caregiver
2. Sits unsupported on toilet or potty chair
3. Gets on and off low toilet or potty
4. Gets on and off adult-sized toilet
5. Gets on and off toilet, not needing own arms

B. Chair/Wheelchair Transfers

6. Sits if supported by equipment or caregiver
7. Sits unsupported on chair or bench
8. Gets on and off low chair or furniture
9. Gets in and out of adult-sized chair/wheelchair
10. Gets in and out of chair, not needing own arms

C. Car Transfers

11. Moves in car; scoots on seat or gets in and out of car seat
12. Gets in and out of car with little assistance or instruction
13. Gets in and out of car with no assistance or instruction
14. Manages seat belt or chair restraint
15. Gets in and out of car and opens and closes car door

D. Bed Mobility/Transfers

16. Raises to sitting position in bed or crib
17. Comes to sit at edge of bed; lies down from sitting at edge of bed
18. Gets in and out of own bed
19. Gets in and out of own bed, not needing own arms

E. Tub Transfers

20. Sits if supported by equipment or caregiver in a tub or sink
21. Sits unsupported and moves in tub
22. Climbs or scoots in and out of tub
23. Sits down and stands up from inside tub
24. Steps/transfers into and out of an adult-sized tub

F. Indoor Locomotion Methods (Score = 1 if mastered)

25. Rolls, scoots, crawls, or creeps on floor
26. Walks, but holds onto furniture, walls, caregivers or uses devices for support
27. Walks without support

G. Indoor Locomotion: Distance/Speed (Score = 1 if mastered)

28. Moves within a room but with difficulty (falls; slow for age)
29. Moves within a room with no difficulty
30. Moves between rooms but with difficulty (falls; slow for age)
31. Moves between rooms with no difficulty
32. Moves indoors 50 feet; opens and closes inside and outside doors

H. Indoor Locomotion: Pulls/Carries Objects

33. Changes physical location purposefully
34. Moves objects along floor
35. Carries objects small enough to be held in one hand
36. Carries objects large enough to require two hands
37. Carries fragile or spillable objects

PEDI — 3

I. Outdoor Locomotion: Methods

38. Walks, but holds onto objects, caregiver, or devices for support
39. Walks without support

J. Outdoor Locomotion: Distance/Speed (Score = 1 if mastered)

40. Moves 10-50 feet (1-5 car lengths)
41. Moves 50-100 feet (5-10 car lengths)
42. Moves 100-150 feet (35-50 yards)
43. Moves 150 feet and longer, but with difficulty (stumbles, slow for age)
44. Moves 150 feet and longer with no difficulty

K. Outdoor Locomotion: Surfaces

45. Level surfaces (smooth sidewalks, driveways)
46. Slightly uneven surfaces (cracked pavement)
47. Rough, uneven surfaces (lawns, gravel driveway)
48. Up and down incline or ramps
49. Up and down curbs

L. Upstairs (Score = 1 if child has previously mastered skill)

50. Scoots or crawls up partial flight (1-11 steps)
51. Scoots or crawls up full flight (12-15 steps)
52. Walks up partial flight
53. Walks up full flight, but with difficulty (slow for age)
54. Walks up entire flight with no difficulty

M. Downstairs (Score = 1 if child has previously mastered skill)

55. Scoots or crawls down partial flight (1-11 steps)
56. Scoots or crawls down full flight (12-15 steps)
57. Walks down partial flight
58. Walks down full flight, but with difficulty (slow for age)
59. Walks down full flight with no difficulty

MOBILITY DOMAIN SUM

PLEASE BE SURE YOU HAVE ANSWERED ALL ITEMS.

SOCIAL FUNCTION DOMAIN

Place a check corresponding to each item: Item scores: 0 = unable; 1 = capable

A. Comprehension Word Meanings

1. Orients to sound
2. Responds to "no"; recognizes own name or that of familiar people
3. Understands 10 words
4. Understands when you talk about relationships among people and/or things that are visible
5. Understands when you talk about time and sequence of events

B. Comprehension of Sentence Complexity

6. Understands short sentences about familiar objects and people
7. Understands 1-step commands with words that describe people or things
8. Understands directions that describe where something is
9. Understands 2-step commands, using if/then, before/after, first/second, etc.
10. Understands two sentences that are about the same subject but have a different form

C. Functional Use of Communication	0 (Unable)	1 (Capable)
11. Names things		
12. Uses specific words or gestures to direct or request action by another person		
13. Seeks information by asking questions		
14. Describes an object or action		
15. Tells about own feelings or thoughts		

D. Complexity of Expressive Communication	0	1
16. Uses gestures with clear meaning		
17. Uses single word with meaning		
18. Uses two words together with meaning		
19. Uses 4-5 word sentences		
20. Connects two or more thoughts to tell a simple story		

E. Problem-resolution	0	1
21. Tries to show you the problem or communicate what is needed to help the problem		
22. If upset because of a problem, child must be helped immediately or behavior deteriorates		
23. If upset because of a problem, child can seek help and wait if it is delayed a short time		
24. In ordinary situations, child can describe the problem and his/her feelings with some detail (usually does not act out)		
25. Faced with an ordinary problem, child can join adult in working out a solution		

F. Social Interactive Play (Adults)	0	1
26. Shows awareness and interest in others		
27. Initiates a familiar play routine		
28. Takes turn in simple play when cued for turn		
29. Attempts to imitate adult's previous action during a play activity		
30. During play child may suggest new or different steps, or respond to adult suggestion with another idea		

G. Peer Interactions: (Child of similar age)	0	1
31. Notices presence of other children, may vocalize and gesture toward peers		
32. Interacts with other children in simple and brief episodes		
33. Tries to work out simple plans for a play activity with another child		
34. Plans and carries out cooperative activity with other children; play is sustained and complex		
35. Plays activities or games that have rules		

H. Play with Objects	0	1
36. Manipulates toys, objects or body with intent		
37. Uses real or substituted objects in simple pretend sequences		
38. Puts together materials to make something		
39. Makes up extended pretend play routines involving things the child knows about		
40. Makes up elaborate pretend sequences from imagination		

Comments

I. Self-Information	0 (Unable)	1 (Capable)
41. Can state first name		
42. Can state first and last name		
43. Provides names and descriptive information about family members		
44. Can state full home address; if in hospital, name of hospital and room number		
45. Can direct an adult to help child return home or back to the hospital room		

J. Time Orientation	0	1
46. Has a general awareness of time of mealtimes and routines during the day		
47. Has some awareness of sequence of familiar events in a week		
48. Has very simple time concepts		
49. Associates a specific time with actions/events		
50. Regularly checks clock or asks for the time in order to keep track of schedule		

K. Household Chores	0	1
51. Beginning to help care for own belongings if given constant direction and guidance		
52. Beginning to help with simple household chores if given constant direction and guidance		
53. Occasionally initiates simple routines to care for own belongings; may require physical help or reminders to complete		
54. Occasionally initiates simple household chores; may require physical help or reminders to complete		
55. Consistently initiates and carries out at least one household task involving several steps and decisions; may require physical help		

L. Self-Protection	0	1
56. Shows appropriate caution around stairs		
57. Shows appropriate caution around hot or sharp objects		
58. When crossing the street with an adult present, child does not need prompting about safety rules		
59. Knows not to accept rides, food or money from strangers		
60. Crosses busy street safely without an adult		

M. Community Function	0	1
61. Child may play safely at home without being watched constantly		
62. Goes about familiar environment outside of home with only periodic monitoring for safety		
63. Follows guidelines/expectations of school and community setting		
64. Explores and functions in familiar community settings without supervision		
65. Makes transaction in neighborhood store without assistance		

SOCIAL FUNCTION DOMAIN SUM

PLEASE BE SURE YOU HAVE ANSWERED ALL ITEMS.

Parts II and III: Caregiver Assistance and Modification

Circle the appropriate score for Caregiver Assistance and Modification for each item.

	Caregiver Assistance Scale						Modification Scale				
	Independent	Supervision	Minimal	Moderate	Maximal	Total	None	Child	Rehab	Extensive	
SELF-CARE DOMAIN	5	4	3	2	1	0	N	C	R	E	
A. **Eating:** eating and drinking regular meal, do not include cutting steak, opening containers or serving food from serving dishes	5	4	3	2	1	0	N	C	R	E	
B. **Grooming:** brushing teeth, brushing or combing hair and caring for nose	5	4	3	2	1	0	N	C	R	E	
C. **Bathing:** washing and drying face and hands, taking a bath or shower; do not include getting in and out of a tub or shower, water preparation, or washing back or hair	5	4	3	2	1	0	N	C	R	E	
D. **Dressing Upper Body:** all indoor clothes, not including back fasteners; include help putting on or taking off splint or artificial limb; do not include getting clothes from closet or drawers	5	4	3	2	1	0	N	C	R	E	
E. **Dressing Lower Body:** all indoor clothes; include putting on or taking off brace or artificial limb; do not include getting clothes from closet or drawers	5	4	3	2	1	0	N	C	R	E	
F. **Toileting:** clothes, toilet management or external device use, and hygiene; do not include toilet transfers, monitoring schedule, or cleaning up after accidents	5	4	3	2	1	0	N	C	R	E	
G. **Bladder Management:** control of bladder day and night, clean-up after accidents, monitoring schedule	5	4	3	2	1	0	N	C	R	E	
H. **Bowel Management:** control of bowel day and night, clean-up after accidents, monitoring schedule	5	4	3	2	1	0	N	C	R	E	Self-Care Modification Frequencies
Self-Care Totals	SELF-CARE SUM										
MOBILITY DOMAIN											
A. **Chair/Toilet Transfers:** child's wheelchair, adult sized chair, adult-sized toilet	5	4	3	2	1	0	N	C	R	E	
B. **Car Transfers:** mobility within car/van, seat belt use, transfers, and opening and closing doors	5	4	3	2	1	0	N	C	R	E	
C. **Bed Mobility/Transfers:** getting in and out and changing positions in child's own bed	5	4	3	2	1	0	N	C	R	E	
D. **Tub Transfers:** getting in and out of adult-sized tub	5	4	3	2	1	0	N	C	R	E	
E. **Indoor Locomotion:** 50 feet (3-4 rooms); do not include opening doors or carrying objects	5	4	3	2	1	0	N	C	R	E	
F. **Outdoor Locomotion:** 150 feet (15 car lengths) on level surfaces; focus on physical ability to move outdoors (do not consider compliance or safety issues such as crossing streets)	5	4	3	2	1	0	N	C	R	E	
G. **Stairs:** climb and descend a full flight of stairs (12-15 steps)	5	4	3	2	1	0	N	C	R	E	Mobility Modification Frequencies
Mobility Totals	MOBILITY SUM										
SOCIAL FUNCTION DOMAIN											
A. **Functional Comprehension:** understanding of requests and instructions	5	4	3	2	1	0	N	C	R	E	
B. **Functional Expression:** ability to provide information about own activities and make own needs known; include clarity of articulation	5	4	3	2	1	0	N	C	R	E	
C. **Joint Problem Solving:** include communication of problem and working with caregiver or other adult to find a solution; include only ordinary problems occurring during daily activities (for example, lost toy; conflict over clothing choices)	5	4	3	2	1	0	N	C	R	E	
D. **Peer Play:** ability to plan and carry out joint activities with a familiar peer	5	4	3	2	1	0	N	C	R	E	
E. **Safety:** caution in routine daily safety situations, including stairs, sharp or hot objects and traffic	5	4	3	2	1	0	N	C	R	E	Social Function Modification Frequencies
Social Function Totals	SOCIAL FUNCTION SUM										

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Pediatric Evaluation of Disability Inventory

VERSION 1.0

Name ______________________ Test Date ______________ Age ________

ID# ______________ Respondent/Interviewer ______________________

SCORE SUMMARY

Composite Scores

DOMAIN		RAW SCORE	NORMATIVE STANDARD SCORE	STANDARD ERROR	SCALED SCORE	STANDARD ERROR	FIT SCORE*
Self-Care	Functional Skills						
Mobility	Functional Skills						
Social Function	Functional Skills						
Self-Care	Caregiver Assistance						
Mobility	Caregiver Assistance						
Social Function	Caregiver Assistance						

*Obtainable only through use of software program

MODIFICATION FREQUENCIES											
SELF-CARE (8 ITEMS)				MOBILITY (7 ITEMS)				SOCIAL FUNCTION (5 ITEMS)			
None	Child	Rehab	Extensive	None	Child	Rehab	Extensive	None	Child	Rehab	Extensive

Score Profile

DOMAIN		NORMATIVE STANDARD SCORES	SCALED SCORES
Self-Care	Functional Skills	10 30 50 70 90	0 50 100
Mobility	Functional Skills	10 30 50 70 90	0 50 100
Social Function	Functional Skills	10 30 50 70 90	0 50 100
Self-Care	Caregiver Assistance	10 30 50 70 90	0 50 100
Mobility	Caregiver Assistance	10 30 50 70 90	0 50 100
Social Function	Caregiver Assistance	10 30 50 70 90	0 50 100

± 2 standard errors

PEDI Research Group: Stephen M. Haley, Ph.D., P.T., Wendy J. Coster, Ph.D., OTR/L, Larry H. Ludlow, Ph.D., Jane T. Haltiwanger, M.A., Ed.M., Peter J. Andrellos, Ph.D.