Applying Motor-Control Theory to Physical Therapy Practice: A Case Report

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ABSTRACT

Purpose: This case report describes the application of an integrated, systems-based theory of motor control to physical therapy practice.

Client Description: The patient was a 5-year-old boy with spastic hemiplegic cerebral palsy who was entering kindergarten. Parent concerns related to the child's safety in playground activities such as playing on the slide.

Interventions: Motor-control theory, including factors related to the task, the environment, and the individual, was used to guide and direct physical therapy management related to the patient goal of safely and effectively climbing the ladder to the playground slide.

Patient Outcomes: When the child entered kindergarten, he was able to safely ascend the ladder to the playground slide, using a modified movement pattern, when distractions were minimized. However, attentional issues continued to affect task execution when other children were present.

Implications: This case report demonstrates a means by which current knowledge and theory can be integrated into clinical practice.

Future Directions: Applying motor-control theory to this case led to the development of clinical questions for future research.

Key Words: application of theory, case report, cerebral palsy, motor control, physical therapy, systems

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RÉSUMÉ

Objectif : Ce rapport de cas décrit l'application à la pratique de la physiothérapie d'une théorie intégrée, fondée sur des systèmes pour le contrôle moteur.

Description du client : Le patient était un garçon de 5 ans souffrant de paralysie cérébrale avec hémiplégie spasmodique qui s'apprêtait à entrer à la maternelle. Les parents étaient inquiets pour la sécurité de l'enfant lors d'activités dans le parc de jeux, notamment s'il utilisait la glissière.

Interventions : Une théorie du contrôle moteur, dont des facteurs liés à la tâche, à l'environnement et à l'individu, a été utilisée pour orienter et diriger la gestion de la physiothérapie liée à l'objectif du patient de parvenir à monter en toute sécurité l'échelle de la glissière du parc de jeux.

Résultat pour le patient : Lorsque l'enfant est entré à la maternelle, il était capable de monter dans l'échelle de la glissière de façon sécuritaire en faisant un mouvement modifié, par lequel les risques de distraction étaient minimisés. Toutefois, des problèmes d'attention continuent d'affecter l'exécution de cette tâche par l'enfant en présence d'autres enfants.

Conséquences : Ce rapport de cas démontre un moyen par lequel les connaissances et les théories actuelles peuvent être intégrées à la pratique clinique.

Orientations futures : L'application d'une théorie du contrôle moteur à ce cas a permis l'élaboration de questions cliniques pour des recherches futures.

Mots clés : application d'une théorie, contrôle moteur, paralysie cérébrale, physiothérapie, rapport de cas, systèmes

INTRODUCTION

Motor control is defined as the ability to regulate the mechanisms essential to movement.¹ A variety of theories exist that attempt to explain the process of motor control; these theories create a conceptual basis upon which therapists examine and treat patients with movement dysfunction.^{1,2} Traditional theories of motor control, including the hierarchical theory, describe movement

regulation as a rigid top-down process in which the central nervous system (CNS) functions as the command centre for all movement tasks. Higher centres within the CNS, such as the motor cortex, are considered to inhibit lower centres, including the midbrain and the spinal cord, and thus regulate movement. According to these top-down theories, movement dysfunction in individuals with CNS damage occurs as a result of the loss of this

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inhibition from the higher centres within the CNS. Without this inhibition, reflexes are thought to emerge and dominate abnormal movement patterns. Similarly, these theories view motor development as occurring based on the maturation of the brain.¹

In contrast to these top-down theories, systems theory, dynamic systems theory, and ecological theory conceptualize movement regulation as a distributed process that results from the interaction of the multiple factors and systems working together to generate and control movement.¹ Bernstein,³ considered by many to be the father of *systems theory*, described the body as a mechanical system with a huge number of joints and muscles, which he called “degrees of freedom” that need to be controlled in any movement task. Bernstein³ maintained that the role of the CNS is to control, organize, and coordinate the many degrees of freedom and the effects of gravity in movement synergies.^{1–3} *Dynamic action theory* also describes motor control as a self-organizing system, meaning that rather than being controlled by higher centres, movement emerges based on the demands of the system.¹ Specific to this theory is the concept of control parameters, described as variables that, when changed, result in changes within the movement system. In contrast, *ecological theory* emphasizes the organization of movement as a result of interactions of the environment and goal-directed actions. Ecological theories also emphasize that perception plays a greater role in action than does sensation.¹

In *Motor Control: Integrating Research into Clinical Practice*,¹ Shumway-Cook and Woollacott describe an integrated motor-control theory that reflects key elements of hierarchical, systems, dynamic action, and ecological theories. This integrated systems-based theory conceptualizes movement as a product of the interaction among the individual, the task, and the environment. Shumway-Cook and Woollacott’s theory reflects many of the concepts of other systems-based theories, in which movement is thought to be generated by an individual to meet the demands of a specific task performed within a specific environment.¹

Overview of the Integrated Systems-Based Theory

According to Shumway-Cook and Woollacott,¹ *task attributes* define and constrain the execution of a movement task. Task attributes are classified based on whether the activity is a discrete task with a discernable beginning and ending point, such as moving from sit to stand, or a continuous task with a variable ending point, such as walking or biking. An additional task attribute relates to whether the base of support is stationary or changing; for example, in quiet standing the base of support is still, but in ascending stairs, the base of support changes with each step. Other considerations include upper-extremity manipulation requirements,

the amount of attention demanded by a task, and the variability of the movement itself.¹ When analyzing movement tasks, physical therapists must also consider biomechanical factors such as the specific muscle groups and muscle actions involved in an activity; the range of motion (ROM) required for the movement; and the coordination, power, and speed demands of the task.^{1,4}

Environmental attributes also contribute to the execution of movement tasks.¹ *Environmental constraints* can be divided into regulatory and non-regulatory conditions. Regulatory conditions are factors that mould or shape the movement, such as the angle of the walking surface or the shape of a ball. Non-regulatory conditions are those factors that may affect performance but do not directly shape the movement, such as background noise or air temperature. When analyzing the environment in which movement tasks occur, physical therapists must also consider whether the task takes place in a stationary or in a moving environment.⁵ In a stationary environment, the regulatory conditions involve a fixed terrain and non-moving objects, and the environment influences only the spatial parameters of the movement. When activities occur in a moving environment, where objects, other people, or the supporting surface are in motion, movements must conform to both spatial and temporal parameters of the environment.^{1,5}

According to Shumway-Cook and Woollacott,¹ individual constraints to movement may be divided into three categories: action, perception, and cognition. Constraints related to *action* involve the motor system and include primary impairments, such as muscle tone and muscle strength, and secondary impairments, such as ROM deficits. Constraints related to *perception* involve factors that affect or limit the internal registration or integration of sensory information. Examples of potential perceptual constraints include difficulties interpreting key environmental stimuli and decreased awareness of body position in space. Constraints in the *cognitive* realm relate to attention, emotions, and motivation and include factors such as fear of falling and the ability to attend to environmental stimuli during the execution of functional activities.

When examining individual constraints on motor control, physical therapists must also consider the postural control requirements related to a task and the environment.^{1,6} Postural control is defined by Shumway-Cook and Woollacott¹ as the ability to control the body’s position in space for the combined purposes of stability and orientation; postural control requirements relate to demands for both postural orientation and postural stability. The *postural orientation* for most functional tasks requires a vertical point of reference between the body and the environment. *Postural stability* requirements relate to the need to control the centre of mass within the base of support and are heavily influenced by environmental factors such as the size and firmness of

the base of support; stability demands increase with a narrowed base of support and on a more compliant surface. Postural stability demands also vary based on whether the task demands a stationary centre of mass with a constant base of support, as in quiet standing, or a moving centre of mass with a changing base of support, as when ascending stairs.

Taxonomy of Tasks

Although not unique to the motor-control theory outlined by Shumway-Cook and Woollacott,¹ Gentile's Taxonomy of Tasks provides a classification for movement activities based on environmental and task demands.⁵ This taxonomy identifies as least challenging those stability tasks that do not require upper-extremity manipulation and that are performed in a stationary, non-variable environment. Tasks in the taxonomy steadily increase in difficulty with the addition of mobility requirements, the addition of a manipulation component, or increased variability in the environment. For example, standing in a quiet room is a stability task without manipulation requirements performed in a closed environment with little variability. Standing at a bus stop with traffic moving by is a stability task without manipulation requirements performed in an open or variable environment. Standing at the bus stop and getting money out of a wallet adds manipulation to the task, and running to the bus stop while getting money out of a wallet makes the task even more challenging by adding a mobility component with manipulation. Therapists can use the taxonomy to identify the degree of difficulty associated with a movement task and to progress the complexity of a task by altering its taxonomy.

Purpose

Physical therapists' practice is often focused on the specific body impairments and activity restrictions that influence an individual's ability to execute movement tasks.^{1,7} According to Shumway-Cook and Woollacott,¹ a clinical approach that also recognizes the influence of the task and the environment on an individual's execution of a specific functional movement activity may help therapists to better address motor-control deficits. The purpose of this case report is to describe the application of Shumway-Cook and Woollacott's¹ integrated systems-based theory of motor control to physical therapy (PT) practice focused on addressing a specific functional goal of a child with cerebral palsy.

CASE DESCRIPTION

Informed consent and permission to publish this case report were obtained from the patient's legal guardian; assent was obtained from the patient. The patient in this case was a 5-year-old boy with left hemiplegic cere-

bral palsy who demonstrated gross motor function at Gross Motor Function Classification System—Expanded and Revised (GMFCS-ER) Level I.⁸ The history was obtained from the patient's family and from medical records. The patient was born at 34 weeks' gestation following a pregnancy complicated by maternal pre-eclampsia. Delivery was via caesarean section; birth weight was 6 lb 1 oz. The patient was hospitalized in the neonatal intensive care unit (NICU) for 8 days after birth, during which time he was intubated for 1 day and experienced neonatal jaundice. Beginning in infancy, the patient had seizures, which at the time of the case report were well controlled with medication (levetiracetam). Computed tomography (CT) reports in the medical records indicated right hemispheric schizencephaly and an absence of the corpus callosum. The patient wore a left dynamic ankle-foot orthosis (DAFO) and a right minimal-control foot orthotic. He wore glasses and exhibited strabismus. At the time of this case report, the patient was receiving weekly direct physical, occupational, and speech therapy in a private outpatient community therapy clinic.

During the child's annual PT examination, his mother stated that he would be starting kindergarten in approximately 4 months and that she was concerned about his ability to participate safely in playground activities such as climbing the ladder to the slide. The patient expressed his desire to be able to play with his classmates on the playground slide. Safely and effectively ascending the ladder to the kindergarten slide was added as a goal to his PT plan of care. Other goals, such as transitioning up from the floor without upper-extremity use, jumping, hopping on one foot, and executing sudden stops and turns while running, were also included in the plan of care. This case report focuses on the goal related to ascending the playground slide.

EXAMINATION

In this case report, PT examination is described based on the three elements of motor control outlined by Shumway-Cook and Woollacott¹: the task, the environment, and the individual. Specifics related to the task and the environment are based on the actual kindergarten playground slide, located at a public school approximately 15 to 20 minutes' drive from the clinic where the patient received PT services.

Analysis of the Task

The task analysis of ascending a playground slide ladder is provided in Table 1. The task was a mobility task requiring upper-extremity manipulation. While this task had a discernible beginning and ending point based on the number of rungs on the ladder, climbing a ladder to a slide could, like walking, be considered a continuous

Table 1 Task Analysis: Ascending a Ladder to a Playground Slide

<i>Component of the Task</i>	<i>Specific Task Requirements</i>
Mobility task with upper-extremity manipulation	<ul style="list-style-type: none"> • Bilateral, reciprocal upper- and lower-extremity movements up each rung • Movement alternating between an open- and closed-chain activity • Bilateral coordination
Lower-extremity range of motion	<ul style="list-style-type: none"> • Active hip and knee flexion to >90 degrees and ankle dorsiflexion beyond neutral during the open-chain portion of the task • Active movement into hip and knee extension and ankle plantarflexion during the closed-chain portion of the task
Lower-extremity muscle activity	<ul style="list-style-type: none"> • Concentric muscle activity with strength minimally at 3/5 to move the extremity against gravity during the open-chain portion of the task • Sufficient muscle power of the hip and knee extensors and ankle plantarflexors to propel the body up the ladder during the closed-chain portion of the task
Upper-extremity function	<ul style="list-style-type: none"> • Alternating grasp and release of the ladder with each hand while the body is moving forward in space • Moulding of the hands around the ladder • Sufficient strength to stabilize and support the body during movement • Scapulohumeral rhythm to allow for appropriate hand placement and maximal efficiency in the upper extremities
Trunk demands	<ul style="list-style-type: none"> • Trunk maintained upright throughout the task • Lateral trunk flexion on the same side as the moving extremity during the open-chain portion of the task • Trunk elongation on the same side as the weight-bearing extremity during the closed-chain portion of the task • Slight rotation with flexion at the lower trunk during the open chain-component of the task
Sensory demands	<ul style="list-style-type: none"> • Visual and perceptual skills to scan the environment for other children and obstacles • Awareness of body and extremity position in space (body schema / body awareness) • Touch and temperature awareness
Attentional demands	<ul style="list-style-type: none"> • Potential safety concerns, such as other children on the slide, demanding a high level of attention • Divided attention (equal attention must be given to multiple factors simultaneously)²⁵ • Dual-task conditions created by the demand to attend both to postural control issues and to cognitive factors such as making safety judgements related to other children on the slide and social interactions with other children on the playground^{25,27,29}

task. Biomechanical considerations included concentric muscle activity at the lower extremities, muscle power to propel the body forward up the ladder, ROM needs at the upper and lower extremities, and the coordination needed to use both sides of the body. Postural control demands within the task were high, given the relatively narrow ladder rungs and the constantly changing base of support required by the task.

Analysis of the Environment

The specific environment in which this movement task was to be performed played a major role in the functional execution of the task: performing this task on a quiet playground without other children present would be very different from doing so with many other children on the playground during a busy recess period. Since the objective was for this child to participate in typical playground activities, he had to be able to perform the task in a very active environment in which noise and visual distractions could potentially affect task execution. The demands of monitoring and adjusting to other children on the slide made this an open task in which movement must be modified to accommodate a changing environment.

Regulatory factors in the environment included the distance between the rungs of the ladder, the speed of the movement, and the steepness of the ladder. Other children moving about on the playground created a moving environment. Non-regulatory factors that may have affected performance but did not directly result in changes to the movement included the amount of noise on the playground, the presence of distractions (such as other children), and the possibility that other children might pester him to hurry and go down the slide.

Analysis of Individual Factors and Constraints

The patient's annual PT examination included tests and measures traditionally associated with paediatric PT practice, such as the Gross Motor Function Measure (GMFM-88),⁹ the Pediatric Evaluation of Disability Inventory (PEDI),¹⁰ goniometric measurements, functional strength assessment, functional mobility assessment, and clinical observations of movement quality.⁷ Results of the GMFM-88 are provided in Table 2. Normative standard scores for each domain on the PEDI were >2 standard deviations below the mean, indicating that the patient's functional skills in the areas of self-care, mobil-

Table 2 Results of the Gross Motor Function Measure (GMFM-88)

<i>Domain</i>	<i>Raw Score</i>	<i>Percentage Score</i>
Lying and rolling	51/51	100
Sitting	59/60	98.3
Crawling and kneeling	41/42	97.6
Standing	33/39	84.6
Walking, running, and jumping	55/72	76.3

ity, and social function were significantly different from those of his age-matched peers in the normative sample.

Consistent with the patient's GMFCS-ER level,⁸ clinical observations performed during the examination revealed that he was able to sit without upper-extremity support; ambulate independently indoors and outdoors; run; jump; and hop two to three times consecutively on his right lower extremity. He was also able to ascend and descend curbs and stairs using a pattern of marking time on the stairs. Asymmetries were noted, in that the patient primarily used his right upper extremity for all tasks. He was also observed to frequently maintain his left upper extremity in a position of shoulder adduction and internal rotation, elbow flexion, forearm pronation, and wrist flexion. When asked, the patient was able to attempt activities with his left upper extremity, but he did so with visible effort and limited success, especially in grasping and releasing objects.

Observation also revealed that the patient primarily initiated movements toward his right side. The patient was observed to position his body such that activities were always performed toward his right; when activities were introduced from the left, he was observed to reposition himself to bring the activity into his right body space. Modified sensory testing techniques were performed with vision occluded;^{1,7,11} the patient was able to discern the precise location of a sticker placed on his right extremities but was unable to consistently locate stickers placed on his left extremities. He could accurately discern and locate sharp versus dull inputs on his right extremities but could only vaguely convey the location of such inputs on his left extremities. The patient was also consistently able to describe the position of his right extremities but not that of his left extremities. These findings, combined with the observation that the patient preferentially performed activities in right body space, suggested that although the patient was aware of his left extremities, he did not fully integrate the left side of his body into his body schema.^{1,11}

Consultation with the patient's occupational therapist confirmed that the patient had significant difficulties with upper-extremity function. His hand use was reportedly classified at Level IV on the Manual Ability Classification System for Children with Cerebral Palsy (MACS),¹² indicating that he was able to handle a limited

selection of easily managed objects in adapted situations. The occupational therapist also noted that the patient exhibited delays in his play and peer-interaction skills. Consultation with the patient's speech therapist revealed that the patient had delays in both expressive and receptive language skills. Attentional issues were noted by both occupational and speech therapists, who reported that the patient was easily distracted and required multiple cues to remain on task. These attentional issues were also noted during the PT examination. Difficulties with safety were reported by both occupational and speech therapists, especially with respect to the patient's awareness of other people and of objects in his environment, and safety was identified as an issue during the PT examination as well. Both the occupational therapist and the speech therapist reported that the patient easily became frustrated when activities were even slightly challenging for him or when he was unable to perform an activity without assistance.

As part of the examination process, the first author (LKK) observed the patient performing the specific task outlined in the specific goal. At that time, the patient attempted to climb the ladder leading with his right extremities, such that his body was rotated, with the right side close to the ladder and the left side rotated away from it. He did not use his left upper extremity at all during the activity, but instead held his left arm in shoulder adduction and internal rotation, elbow flexion, forearm pronation, and wrist flexion. He had difficulties propelling his body up the ladder and was unable to coordinate the reciprocal nature of the task. Instead he used a step-to pattern in which he grasped the ladder with his right hand, stepped up a rung with his right foot, then stepped up with his left foot, placing only his forefoot in contact with the rung. He then leaned the right side of his body into the ladder for support while releasing the ladder with his right hand to grasp the next rung. Throughout the activity, the patient appeared to monitor his left lower extremity visually, especially when placing his left foot on the rung. Although he required physical assistance to propel himself up the ladder and to prevent him from falling, he was able to perform between 50% and 75% of the activity (i.e., he required moderate assistance).¹³ The patient appeared to become frustrated when he could not complete the activity independently; with encouragement, however, he was able to continue to attempt the task.

EVALUATION, DIAGNOSIS, AND PROGNOSIS BASED ON MOTOR-CONTROL PRINCIPLES

Based on the patient/client management model outlined in the *Guide to Physical Therapist Practice*,⁷ examination findings related to the task, the environment, and the individual were synthesized and assessed. Evaluating the findings of the task and environmental analyses

Table 3 Individual Constraints Influencing the Patient's Ability to Ascend the Ladder to the Playground Slide

Category	Individual Constraints
Action	<p>Constraints within the Neuromuscular System:</p> <ul style="list-style-type: none"> • Velocity-dependent increased resistance to passive movements at the left extremities • Marked asymmetries in posture and movement (patient demonstrated greater functional use of his right extremities) • Poor isolation and control of left-extremity movements • Decreased functional left grasp and release • Poor bilateral coordination skills • Difficulties controlling weight shifts over a fixed distal extremity <p>Constraints within the Musculoskeletal System:</p> <ul style="list-style-type: none"> • Decreased active ROM in the left extremities, with left ankle plantarflexion further limited by the DAFO • Decreased pelvic stability • Altered left scapulohumeral rhythm • Lower-extremity muscle weakness in the quadriceps, hip flexors, hamstrings, hip extensors, ankle dorsiflexors, and ankle plantarflexors, with greater weakness noted on the left <p>Constraints within the Cardiopulmonary System:</p> <ul style="list-style-type: none"> • The patient fatigued easily and often had difficulty keeping up with the activity level of his typically developing peers.
Perception	<ul style="list-style-type: none"> • Decreased tactile discrimination abilities at the left extremities • Altered body schema and decreased awareness of body position in space. Although the patient appeared to be aware of his left extremities, his cone of stability did not fully integrate his left extremities, particularly when the demands and challenges of an activity were high. • Patient was observed to rely on visual tracking of his lower extremities during movement activities, which resulted in his bringing his body away from the ladder to visually monitor his lower extremities. • Visual impairments, including ocular muscle imbalances, created difficulties in accurately scanning the environment. • Potential concerns related to the patient's strabismus included double vision and possible visual field neglect.³²
Cognition	<ul style="list-style-type: none"> • The patient was easily distracted by others in the environment. • Frustration appeared to be an issue when the patient was not able to perform activities independently. Other children pestering him to move quickly added to his frustration and further affected his execution of the movement task.

revealed that this functional activity was a mobility task with manipulation requirements that was to be carried out in a variable, open, and moving environment. These specifications placed the task high on Gentile's Taxonomy of Tasks,⁵ indicating that it was an extremely challenging activity.

In recognition of the theoretical principle that movement is the product of interaction among the individual, the task, and the environment, specific individual constraints that influenced the patient's ability to ascend the ladder to the playground slide were determined; these are listed in Table 3. Further evaluation of the environmental and task demands with respect to the patient's individual constraints revealed potential safety issues, including the patient's use of visual monitoring of his lower-extremity movements to compensate for difficulties with body schema, decreased awareness of body position in space, and potential visual problems associated with his strabismus. These safety issues were thought to be compounded by the patient's frustration, which appeared to limit his ability to use problem-solving skills.

The degree of task difficulty as indicated by Gentile's Taxonomy, the patient's individual constraints and functional abilities, and potential safety issues were considered when establishing the patient's prognosis for achieving the goal. Given that the patient's gross-motor

repertoire included stair climbing and other higher-level skills, it was determined that the goal was reasonable and appropriate for inclusion in the plan of care. It was also determined, however, that achieving the goal would require intense practice of task components and of the task itself, as well as interventions to address the patient's individual constraints. A review of the literature related to motor learning further revealed that children, especially those with neuromotor conditions, may take longer than adults to learn new motor skills and may require a higher practice intensity to achieve motor learning.^{14–16} Based on these factors, as well as the scheduling preferences of the family and the anticipated start date of the patient's kindergarten program, the frequency of intervention was set at two 60-minute sessions per week over approximately 10–14 weeks.

INTERVENTION

When beginning to work with a child on a new or challenging goal, the therapist should set the task and environmental demands so as to allow the child to be as successful as possible.¹ A child who is frustrated and/or feeling unsuccessful may not be motivated to participate in intervention strategies, which may further complicate existing motor-control issues. In this case, to allow the patient initial success, environmental distractions were

Table 4 Intervention Activities Based on Motor-Control Theory

<i>Activity</i>	<i>Environmental Set-Up</i>	<i>Opportunities to Progress the Activity</i>
Mobility task with no manipulation requirement: Closed environment → The child stood and tapped his foot in an alternating pattern on a small bench.	<ul style="list-style-type: none"> Environmental distractions were minimized by conducting the sessions in a more private area within the clinic, where the environment could be maximally controlled. 	<ul style="list-style-type: none"> The bench height was increased toward the height needed for the slide (9"). The depth of the step was steadily decreased to mimic the rungs of the slide. Speed was increased. Environmental distractions were increased by having other patients and their therapists in the same treatment area.
Stability task with manipulation requirement: Closed environment → The child stood in front of bilateral, stationary upright poles and maintained a static grasp on the poles with both hands.	<ul style="list-style-type: none"> Environmental distractions were minimized as above. Modifications such as wrapping dycem around the pole on the left could have been used to facilitate grasp. 	<ul style="list-style-type: none"> Controlled grasp and release of the poles with both hands simultaneously Controlled grasp and release of the poles with one hand and then the other Increased speed Environmental distractions increased as above
Mobility task with manipulation requirement: Closed environment → The child stood holding bilateral, stationary upright poles and tapped his feet in an alternating pattern on a small bench.	<ul style="list-style-type: none"> Environmental distractions were minimized as above. 	<ul style="list-style-type: none"> Increased height and decreased step depth as above Increased speed Step up on the bench while moving hands upward along the upright poles
Mobility task with manipulation requirement: Closed environment → The child stood at the ladder to a small slide in the therapy gym and tapped the first rung of the ladder. Manipulation requirements were added by having the patient grasp the ladder with both hands.	<ul style="list-style-type: none"> Using a ladder to a smaller slide in a protected environment allowed progression of the task while controlling the environmental distractions and the demands of a taller slide. Environmental distractions were minimized as above. 	<ul style="list-style-type: none"> Step up on the first rung on the ladder while moving the hands upward along the ladder Incrementally increase the number of rungs ascended until the child reached the top of the slide Increased speed Distractions increased, a more open environment created by having another child playing on the slide at the same time
Mobility task with manipulation requirement: Open environment → The child stood at the ladder to the kindergarten slide and tapped the first rung of the ladder. Manipulation requirements were added by having the patient grasp the ladder with both hands.	<ul style="list-style-type: none"> Distractions were initially minimized by attempting to schedule sessions at the playground during times when other children were less likely to be on the playground. 	<ul style="list-style-type: none"> Step up on the first rung on the ladder while moving the hands upward along the ladder Incrementally increase the number of rungs ascended until the child reached the top of the slide Increased speed Increase distractions by having the patient's sibling playing on the slide at the same time Distractions further increased by scheduling sessions at times when other children were more likely to be on the playground

minimized by controlling the setting and the number of people in the treatment area; task demands were modified, using Gentile's Taxonomy as a guide. A summary of the intervention activities based on the motor-control theory is provided in Table 4.

To further ensure the patient's success when task or environmental demands were changed, activities were consistently modified to reflect the lower levels of Gentile's Taxonomy. For example, as outlined in Table 4, intervention was initiated using a small bench, and the patient progressed from standing at the bench and tapping to with his feet, to grasping stationary poles and tapping his feet on the bench, to stepping up onto the bench while moving his hands up the stationary poles. When interventions progressed to using the ladder

to a small slide, activities moved through this same sequence, such that the patient once again started by tapping his feet on the first rung of the ladder and steadily progressed to stepping up the rungs of the small ladder. Using Gentile's Taxonomy to structure and progress activity demands in this manner helped to ensure the patient's success at each stage of progression and may have helped to prevent frustration during the sessions. Throughout all activities, the first author provided assistance to perform tasks if needed, but this assistance was withdrawn as soon as possible.

As is typical in physical therapy intervention for children,¹¹ all activities were made into games and play, to help motivate the patient to participate actively in the intervention session. Examples of play included using a

modified red light–green light (stop-and-go) game when changing the speed at which activities were performed and involving the patient in pretend-play scenarios such as climbing the ladder “to search for pirates.” In addition to motivating the patient, these components of play appeared to encourage him to complete multiple repetitions of each intervention activity and helped to increase the practice intensity achieved during each session.^{15,16}

During treatment sessions, traditional non-task-specific interventions were also provided to address identified individual constraints. These included strength training, endurance activities, ROM activities, and activities to help increase the patient’s awareness and function of his left extremities. These interventions were selected based on a review of the current literature.^{1,11,17–20} A total of 19 visits were dedicated to working toward this particular goal; interventions based on motor-control theory accounted for approximately 50% of each session held in the clinic setting. Two of the 19 sessions were conducted at the kindergarten playground, where a majority of the session was devoted to interventions based on motor-control theory. Attempts were made to conduct additional sessions at the playground, but weather and scheduling issues made it necessary to conduct sessions at the clinic instead. During sessions at the playground, other children were present in the environment, but because the sessions took place during the summer holidays, the playground was not nearly as busy as during the school year.

PATIENT OUTCOMES

When the child entered kindergarten, he was able to ascend the ladder to the playground slide using a functional and safe movement pattern when environmental distractions were minimized and there were only a few other children on the playground. As anticipated, the quality of his movements continued to demonstrate asymmetries, in that his grasp was not as strong on the left and he did not reach very far up the ladder with his left upper extremity. During actual recess periods, however, when the playground was at its busiest, he continued to have difficulties with attention, and his movement pattern deteriorated, becoming markedly asymmetrical. Under these busy environmental conditions, safety once again became an issue.

DISCUSSION

This case report describes the application of an integrated, systems-based theory of motor control to physical therapy practice. Although a case report lacks the control of a research study, the importance of using theory to guide and enhance contemporary physical therapy practice has been well documented by other sources.^{21,22} By systematically applying Shumway-Cook

and Woollacott’s¹ theory to a specific patient case, we were able to integrate current knowledge and theory into clinical practice. By considering factors related to the interaction of the environment, the task, and the individual, we were able to identify potential constraints to function that affected the patient’s execution of the specific play skill in the context of a busy kindergarten playground. Using Gentile’s Taxonomy, we were able to modify the level of difficulty within the intervention activities and progress the motor control demands of the activities by manipulating both task and environmental demands. The outcomes in this case could have been strengthened through the use of goal-setting instruments such as the Canadian Occupational Performance Measure²³ or the Perceived Efficacy and Goal Setting System (PEGS)²⁴ to gain greater insight into the patient’s and family’s perception of progress toward the goal.

As noted by several authors,^{1,25} physical therapists may not fully recognize the impact of attentional issues on a patient’s motor control and function. This lack of recognition was a factor in this case. Only by applying the motor-control theory to each aspect of the PT management process, including gathering the outcomes in the environmental context of the specific goal, were we able to fully recognize the patient’s attentional deficits as a major limitation to his execution of a high-level motor task in a busy environment. Although children of various ages have been found to have difficulties with postural control and increased postural sway under dual-task conditions,^{26,27} individual constraints in the cognitive realm appear to have affected the patient’s execution of movement tasks to a greater extent than could have been accounted for by his age alone. Although tools such as the TUG_{cognitive}²⁸ have not yet been validated or normed for use in children with cerebral palsy, use of such tools might have provided a more thorough examination of cognition and attention and thus allowed us to identify the full impact of attentional issues on motor control earlier on.

These observations support research findings that children with cerebral palsy experience more difficulties with dual-task interference than typically developing children do.²⁹ In this specific case, the attentional demands of the activities were increased at each level of the taxonomy only after the patient had achieved a level of success with the activity. To adequately address these attentional issues in intervention, further research is needed to investigate the impact of increasing attentional demands at various points in the intervention process to determine whether the timing of increased attentional demands influences patient outcomes.

Several authors have suggested that the dual-task conditions inherent in community settings such as playgrounds may explain why patient improvements observed in the clinic setting do not necessarily translate into

improved performance in other environments.^{26,30} Although attempts were made in this case to tailor the intervention conditions to the dual-task demands of a busy playground environment, these endeavours met with limited success and raised clinical questions that could not be answered based on a search of the current literature. Perhaps additional sessions conducted at the actual playground setting would have been more beneficial, or perhaps environmental distractions in the clinic should have been introduced earlier or with greater frequency. Again, further research is needed to assist therapists in determining optimal intervention strategies.

IMPLICATIONS

Although therapists may not always be aware of the theories they use to guide patient care, clinical practice is a reflection of a therapist's philosophies concerning the characteristics and causes of movement dysfunction.^{1,31} The application of motor-control theory to this case directed and shaped PT management of the patient and led to development of clinical questions for future research. The case also allowed us to recognize more completely the impact of the patient's attentional issues on his motor control and motor function.

KEY MESSAGES

What Is Already Known on This Topic

According to Shumway-Cook and Woollacott, a clinical approach that recognizes the influence of the task, the environment, and the individual on the execution of a specific functional movement activity may assist therapists in addressing the motor-control deficits of specific patients.

What This Study Adds

This case report demonstrates a means by which current knowledge and theory can be integrated into clinical practice. By systematically applying an integrated systems-based theory of motor control, we were able to base clinical decisions within the physical therapist management of a child with cerebral palsy on contemporary theory and practice.

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