Clinical Forum

Using Motor Learning Approaches for Treating Swallowing and Feeding Disorders: A Review

Justine J. Sheppard
Teachers College, Columbia University, New York, NY

Milestones are markers of a child's progress toward mature independent skill. They are said to occur when a child engages in a task with sufficient success to achieve the desired functional outcome (Woolacott & Jensen, 1996). However, the milestone is only a moment in a complex and continuous process of skill acquisition (Thelen, 1989).

ABSTRACT: **Purpose:** This article discusses children's development of mature swallowing and feeding as a process of skill acquisition and considers the applicability of motor learning concepts for advancing these capabilities in school-aged children.
Method: The motor learning literature was reviewed, with concentration on (a) concepts that are relevant for the acquisition of skill and (b) structuring practice experiences to optimize learning.
Results: The discussion includes (a) swallowing physiology with a focus on motor task components, (b) normal development of eating skills, (c) factors that may slow or disrupt normal development, (d) motor learning concepts found to influence learning efficiency and performance adequacy, (e) applications to the assessment and treatment of pediatric swallowing and feeding disorders, and (f) an illustrative case history.
Conclusion: Deficiencies in swallowing and feeding may encompass eating, saliva control, swallowing during oral hygiene, and swallowing medications. Motor learning literature provides a rich foundation of evidence-based theory and educational strategies for the development and remediation of motor-based skills such as swallowing and feeding.

KEY WORDS: swallowing and feeding disorders, dysphagia, motor skills

Milestone precursors mark the gradual emergence of the behavior and, during subsequent experience with the behavior, the skill and the underlying competencies that support its performance improve. As the skill improves, efficiency and independence are achieved in a variety of environments with a variety of activity partners. This is the course that can be expected for the acquisition of developmental swallowing and feeding skills from birth to approximately 3 years of age (Arvedson & Brodsky, 2002; Rudolph, 1994; Schwaab, Niman, & Gisel, 1986a).

The typically developing 3-year-old preschool student is, therefore, expected to be ready to participate safely and efficiently in classroom eating activities with only the age-expected level of educational support and supervision. In addition, it is assumed that the child is able to regulate his or her eating and drinking adequately to maintain nutrition and hydration during the school-day. The child with a swallowing and feeding disorder is often unable to meet these expectations.

The acquisition of developmental motor skill, that is, the process by which the developing child assembles movements into functional activities, has been considered from a variety of theoretical perspectives. Piek (2006) provided a comprehensive review of this history. Early research considered developmental motor physiology and cognition as the primary influences for the initiation and acquisition of a skill. More recent research has resulted in models that incorporate environment and task demand as essential for the expression of motor behavior (Thelen, 1995; Thelen & Smith, 1994). That is to say that the educational process is involved in the expression of developmental motor skills, such as eating, as it is involved in the expression of traditional educational domains, such as writing. Furthermore, practice of the task is the primary mechanism for development of the motor skill (Schmidt & Lee, 1999; Schmidt & Wrisberg, 2004). The problems that have interfered with swallowing

and feeding skill development may be seen as issues that are underlying the child's difficulties with other educational domains (see McKirdy, Sheppard, Osborne, & Payne, 2008).

The purpose of this article is to discuss children's development of mature swallowing and feeding as a process of skill acquisition within this motor learning framework and to consider how this perspective may inform the assessment and treatment of pediatric swallowing and feeding disorders in a school setting. (Schmidt & Lee, 1999; Schmidt & Wrisberg, 2004; Sheppard, 2005). The discussion will include (a) a review of swallowing physiology with a focus on motor task components, (b) a summary of normal development of eating skills, (c) factors that may slow or disrupt normal development, (d) principles of motor learning that have been found to influence learning efficiency and performance adequacy in the acquisition of motor skills, (e) application of these principles to the assessment and treatment of pediatric swallowing and feeding disorders, and (f) an illustrative case history. This review is intended to inform the reader of the principles and practices that are generally used in training motor skills as background for selecting and evaluating therapeutic strategies that are specific to pediatric swallowing and feeding disorders. Except as illustrated in the case history, it is beyond the scope of this review to discuss individual treatment activities, but rather to provide the reader with information that will aid in selecting and devising appropriate and effective strategies.

The Motor Components of Swallowing

The reflexive and voluntary motor components of swallowing may be conceptualized as a four-phase process. The oral preparation, oral initiation, pharyngeal, and esophageal phases involve structures and muscles of the nose, mouth, throat, chest, abdomen, and aerodigestive tract. Successful completion of swallowing depends on coordination of the movements of swallowing with body postural control and breathing, and, for independence, with upper limb and upper body movements. The sensory components of swallowing are complex as well. The child is receiving relevant sensory information from contact receptors for touch, pressure, and taste; from distance receptors for smell, vision, and hearing; from proprioceptors for position and movement of the joints and muscles involved in swallowing; and from the organ systems that convey information about respiration, body position in space and alignment, hunger, thirst, and the condition of the gut. This sensory array changes from moment to moment during activities that involve swallowing and thus guide the coordination of structures and systems. The intra- and interpersonal psychology of swallowing and feeding behaviors, although not components of motor function per se, influence the readiness of the child and his or her effectiveness in advancing eating and other swallowing skills (Arvedson & Brodsky, 2002; Rosenthal, Sheppard, & Lotze, 1995).

Each of the four phases of swallowing includes essential motor components of the total task. In the oral preparatory phase, the child regulates bolus size for each swallow and the rate and rhythm of intake for subsequent swallows. The bolus is chewed and/or mixed with saliva for acceptable ease of swallowing, partitioned for preferred size of bolus, and moved into position for controlled delivery into the pharynx. During this phase, a combination of reflexive and voluntary mechanics are recruited to achieve the desired outcome. Airway protection, although influenced by oral preparation, begins with oral initiation. Initiation of swallow is coordinated precisely with the breath cycle. The bolus is controlled as it is propelled into the pharynx, thereby initiating the reflexive movements of swallowing. Airway protection and bolus propulsion continue in the pharyngeal phase, with complex coordinated movements of the structures in the neck and ongoing breath control. Ingestion is completed in the esophageal phase, with relaxation and opening in sequence of the upper and lower esophageal sphincters and peristaltic movements of the esophageal muscles. The forces that open the sphincters and hold them open until the bolus has passed are the elevation and stabilization of the larynx and bolus propulsion. As the bolus passes, the sphincters return to their contracted state and the bolus is retained in the stomach (Arvedson & Brodsky, 2002). Successful completion of swallowing results from ongoing intrinsic feedforward (i.e., anticipation of the demands of that particular bolus and adjustment of swallowing mechanics as the bolus moves from one phase of swallowing to the next) and feedback (i.e., appreciation of the phase-by-phase results of the effort for correction of errors during the swallow and for learning) (Miller, 1999). Table 1 provides a summary of the motor components of swallowing.

Normal Developmental Acquisition of Eating Skills

The infant and young child acquire swallowing and feeding skills for which they have no prior knowledge. This is in contrast to the learning that occurs subsequently to improve their previously learned skill. For example, a nippling infant who reaches an age at which the transition to spoon feeding is expected is positioned appropriately for the new task, is offered semisolid food with a spoon, and is encouraged to accept it. The child is able to tolerate the new conditions, that is, maintain a calm alert state; adjust to the modified postural alignment and the smells, tastes, and consistency of the new food; and demonstrate an emerging ability to remove the food from the spoon and swallow it. Thus, physiological readiness, the environment, and the task requirements are compatible. This task begins the process for acquisition of the oral motor skills and related swallowing competencies needed to ingest the new food consistency with the new utensil. The infant marshals available components that best fit the nature of the task. Once these are assembled, the behavior is modulated through a process of trial, error, and error correction (Piek, 2006; Thelen, 1989). Thus, the child's initial attempts at spoon feeding become more precise and efficient through the trial and error that occurs with practice repetitions within the variable contexts of the feeding sessions (Schmidt & Wrisberg, 2004).

Skills for eating, drinking, and saliva management are acquired earlier in childhood. The ability to take oral medications and control the oral hygiene bolus are more advanced, yet commonly acquired, swallowing skills. Early maturational changes in emerging chewing have been described (Sheppard & Mysak, 1984), as have the developmental changes in control of swallowing and breathing during the acquisition of spoon-feeding skills (Christofarou-Gioules, 2006) and the maturation of chewing skills (Schwaab et al., 1986a; Schwaab, Niman, & Gisel, 1986b).

The parent, the eating environment, and the child's receptiveness are considered to be significant components of this process (Davies et al., 2006; Thelen, 1995). The considerable variability among infants in the age at which they acquire these skills may in part be attributed to the cultural and individual differences among families in the timing for introducing new eating experiences.

The milestone sequences have been described and discussed extensively (Arvedson & Brodsky, 2002; Kedesdy & Budd, 1998;

Table 1. Task analysis of the motor components of swallowing.

Stage of swallowing	*Task component*	*Action*
Postural control preparation	Appropriate postural alignment for eating	Moving toward approaching the bolus; assuming stable head–neck and body alignment for controlling the bolus in the mouth and pharynx and facilitating swallowing
Oral preparation	Pacing eating rate (for self-feeders)	Regulating bolus size and the rate of eating
	Orienting	Lining up the mouth with the approaching bolus, opening the mouth for the size and shape of the bolus, and moving toward the bolus
	Reception	Removing the bolus from whatever it is attached to (e.g., stripping a spoon, licking, biting)
	Containing	Controlling the bolus to prevent it from falling from the mouth at the lips or the back of the tongue
	Bolus processing	Chewing the bolus and/or mixing it with saliva to adjust its viscosity for ease of swallowing
	Oral transport	Moving the food in the mouth in order to form the bolus and move it into place for initiating the reflexive swallow
	Coordinating breathing and transport	Maintaining a nasal–pharyngeal airway during oral preparation; adjusting oral air pressure gradients to control the bolus in the mouth
Oral initiation	Posterior bolus stabilization/control	Positioning the formed bolus between the tongue and palate or in the vallecular spaces
	Bolus propulsion	Stabilizing the jaw and moving the tongue to propel the bolus into the pharynx
	Initiating the swallowing reflex	Activating the sensory and motor pathways that initiate the pharyngeal phase of swallowing
	Coordinating breathing and initiating the swallowing reflex	Regulating breathing so that swallows are initiated and breathing stops at the end of, or during, exhalation (initiates a period of apnea)
Pharyngeal phase	Velopharyngeal closure	Elevating the velum and contracting the superior pharyngeal constrictor to seal off the nose from the mouth
	Protecting the airway	A series of movement coordinations that include the base of tongue, hyoid bone, larynx, vocal folds, and epiglottis that direct the bolus toward the esophagus and prevent the bolus from entering the trachea and direct it toward the esophagus
	Opening the cricopharyngeal sphinter (CPS)	Moving the larynx upward and forward to pull open the CPS and hold it open until the bolus passes into the esophagus
	Coordinating breathing in the pharyngeal phase	Holding breath until the bolus passes into the esophagus
Esophageal phase	Relaxing the CPS	Activating the sensory and motor pathways that relax the CPS
	Transporting the bolus	Activating the sensory and motor pathways that propel the bolus through the esophagus
	Relaxing the lower esophageal sphincter (LES)	Activating the sensory and motor pathways for relaxing the LES
	Resuming tonic contraction in upper and lower esophageal sphincters	Activating the sensory and motor pathways for contracting the CPS and LES

Rudolph, 1994). In general, the milestones are defined by transitions between types of foods (i.e., liquids to soft solids to chewable foods of various levels of difficulty), types of utensils (i.e., bottles to spoons and forks to cups and straws), and independence (i.e., holding bottle, feeding with fingers, and independent use of utensils). The primary eating milestones are generally considered to be nippling, eating from a spoon, drinking from a cup, sipping from a straw, biting, chewing, and self-feeding. In the transition from one motor milestone to the next, the child is seen as acquiring the subskills that culminate in, and support, acquisition of the next milestone function. This period of transition may be viewed as a continuous sequence of motor learning—a period in which the child is consolidating the skills that he or she is using in preparation for advancing to the next skill in the sequence. Although milestones are identified as moments in time when a new skill is seen to emerge, precursors to the emergence of the milestone and gradual improvement in competency and consistency of performance of the new skill following the milestone have been identified in eating as well as in the acquisition of locomotion and manual skills (Christoforou-Gioules, 2006; Piek, 2006; Sheppard & Mysak, 1984; Thelen, 1989). Sensory tolerances and sensory capabilities are seen to emerge in an interwoven sequence with movement capabilities as the new skill emerges. Table 2 provides a model of eating milestones and related subskills that make up the sequence of acquisition.

In eating as in other developmental motor sequences, the process is nurtured through the ongoing assistance, supervision, and support of the caregiver (Satter, 1990). There are developmental progressions of competence that culminate in saliva control, control of the oral hygiene bolus, and the ability to take oral medications that are seen as milestones in normal development.

Table 2. Developmental motor milestones and subskills for eating.

Milestone	*Subskills*	*Food characteristics*
Nippling	Swallowing capability for increasing the bolus size	Thin liquid
Eating from a spoon	Swallowing capability for increasing the bolus viscosity, texture, and size	Semisolid, smooth; levels of texture from grainy to mashed
	Change in swallowing dynamics from suckling swallow to mature swallow	
	Ability to control the bolus in an upright posture (move the bolus against gravity from front to back of the mouth)	
	Coordination of breathing and swallowing	
Chewing	Chewing capability for single texture pieces	Crisp, soft to chew (cracker) Soft, soft to chew (banana) Single pieces Multiple pieces
	Chewing capability for mixed texture foods	Mixed soft foods
	Chewing capability for firm and fibrous foods	Fibrous meats; uncooked, hard vegetables
	Capability for increasing mastication forces and stamina for the task	
	Swallowing capability for increased bolus viscosity	
Drinking from an open cup	Containing small sips of the dispensed liquid	Thin or thicker liquid
	Sipping single sips	
	Coordinating breathing for sipping and swallowing	
	Controlling sips in the mouth and forming a liquid bolus	
	Swallowing with a cup in the mouth	
	Sipping and swallowing multiple sips	
Biting	Ability to adjust jaw alignment to bite for gnawing	Teething biscuits of various hardness
	Ability to exert a crushing force to sever the food	Biscuits for biting and munching; soft/crisp
	Swallowing capability for increased bolus viscosity	
Drinking from a straw	Sipping and swallowing single sips with a straw in the mouth	Thin or thicker liquid
	Coordinating breathing for sipping and swallowing	
	Sipping and swallowing multiple sips	
Self-feeding	Holding the bottle	Formula and other liquids
	Removing and replacing the bottle in the mouth	
	Holding a teething biscuit; removing and replacing the biscuit in the mouth	Hard teething biscuits
	Finger feeding bite-size pieces	Crisp pieces (dry cereal); soft pieces (soft fruit)
	Holding a spoon while being fed	Smooth foods for spooning
	Spooning/forking; maintains grip on utensil while food is in the mouth; familiar foods for which oral management is well established	More viscous and textured foods for spooning; chewable foods for forking
	Covered cup, single and multiple sips	Liquids
	Open cup, single sips advancing to multiple sips	

It appears from the ease with which a typically developing child acquires eating skills that there may be a period of optimum brain plasticity, a critical period, during the first year to 2 years of life, when it is relatively easy for the typically developing child to acquire these skills through experience (Piek, 2006). Brain plasticity may continue to support changes in swallowing and feeding skills in older children. However, in instances in which the skills have not been acquired within the normal age range, specialized training strategies and more practice may be needed for the child to acquire the same skills that are acquired more efficiently, that is, with fewer practice repetitions and less structuring of the learning environment, and at an earlier age (Illingworth & Lister, 1964; Piek, 2006).

Disruption of Normal Development

Normal motor development of swallowing and feeding may be disrupted through a delay in the acquisition of milestone skills, that is, the skills may not appear within the normally expected age range. Or, deficiency in the performance of the skill may result in an inefficient or unsatisfactory swallowing or feeding outcome. Delayed development of eating skills in the school-aged child may result from a number of scenarios. Swallowing and feeding disorders in infancy or early childhood may interfere with the timely acquisition of developmental eating skills. Children who have experienced these disorders in their preschool years may enter school with a limited variety of eating skills and/or inefficient or unsatisfactory skills (Sheppard, 1997). Pediatric onset dysphagia that has resulted from primary neurological, genetic, or anatomic/structural etiologies (e.g., apraxia, cerebral palsy, Down syndrome, cleft palate, autism spectrum disorder) may include delays in the development of eating skills in addition to performance deficiencies (Arvedson & Brodsky, 2002; Gisel, Lange, & Niman, 1984). Furthermore, immature eating skills may be one component of an overall developmental delay in a child with global developmental delay or diagnosed intellectual disability (Kurjan, 2000; Prontnicki,

1995; Sheppard, 1994). Whatever the cause, delayed and deficient development of eating skills may interfere with the child's participation in the school-based activities that involve eating. Furthermore, there may be health and safety ramifications associated with the elevated risk to the child of choking and/or inadequate nourishment and hydration while in school (Homer, Bickerton, Hill, Parham, & Taylor, 2000).

Delays in development may occur when one or more system deficiencies limit the rate at which the skill can emerge (Sheppard, 1994; Thelen & Smith, 1994). In swallowing and feeding, the deficient system may be a motor system such as body postural control, respiratory function, reflex reactivity, or strength and stability of oral or pharyngeal musculature. Problems with attention; behavioral control; and sensory acuity, perception, and integration have been implicated (Morris & Klein, 2000). However, irrespective of system deficiencies, appropriate learning and task environments are considered essential for assembling and expressing the behavior (Thelen, 1989). If practice time, environmental supports, and task repetitions are inappropriate or insufficient, the behavior may be delayed or dysfunctional movement patterns may be established. Once established, these patterns tend to become stable and difficult to change (Piek, 2006; Thelen & Smith, 1994).

Relevant Concepts in Motor Learning

Motor learning approaches are educational strategies for optimizing the learning of motor skills. Following is a selection of motor learning concepts that may aid in devising effective practice routines. For each of these concepts, there is an evidence base for their use in the acquisition of developmental skills, training/acquisition of new motor skills, and/or improvement of existing skills. To date, there has been little study or discussion of the application of these concepts to swallowing and feeding disorders. The references that are provided are primarily reviews of this motor learning research literature and, where available, applications to swallowing and feeding.

Attention and motivation. In learning a new motor skill, the child will be more likely to engage if he or she feels comfortable with (tolerates) and is attentive to the sensory array that will be associated with the task. In advancing swallowing and feeding, the child tolerates sitting in a chair, the smells and tastes of soft-solid and table food, the textures of table foods in the mouth, the sensations associated with the utensils (spoon, fork, cup, straw) required for eating, the social closeness of the guiding/supervising adult, and the complexities of the environment in which the activity is taking place. For self-feeding, the child tolerates a utensil in his or her hand at the same time that the food is being processed in his or her mouth (Schmidt & Wrisberg, 2004; Sheppard, 1994). Task-specific sensory tolerances are associated with the acquisition of tooth brushing and taking oral medications.

Variability in developmental sequences. Although the majority of children follow predictable sequences in maturation of skill sets such as eating, it is important to keep in mind that there are a considerable percentage of exceptions. In a study of progressions leading to walking, Largo, Kunda, and Thun-Hohenstein (1993) found 13% of the children in their study to follow atypical sequences to achieve normal walking. Schwaab et al. (1986b) found tongue posture on swallowing to vary considerably in children at 2, 3, and 4 years of age. It is reasonable to assume that there may be a benefit from learning developmental skills in a typical developmental sequence and with typical developmental patterns. However, it is useful to be mindful that atypical sequences and atypical patterns may be appropriate functional platforms for advancing skills in some children (Schwaab et al., 1986a, 1986b; van der Maas & Hopkins, 1998).

Specificity of learning. The concept of specificity refers to the similarity of the practice task to the target skill at which the training is directed and to the conditions associated with performance of that skill. For example, an easy eating task performed in a typical eating environment for the child will be more effective in terms of performance and retention of skill than one that is modified for "rehearsal" (see explanation of rehearsal strategies below). Practice experiences that result in the fastest learning and best retention of skill are those that most closely approximate the movement coordinations and the environment of the target task as well as the typical conditions in which it will be performed (Henry, 1968; Schmidt & Wrisberg, 2004; Sheppard, 2005). Thelen and colleagues, in their studies of emerging infant locomotion, observed the effects of "specificity of learning." They concluded that it is the task, not any pre-existing practice, that assembles the emerging skill (Thelen, 1989). They considered action and sensory perception as represented in the target task to be inseparable in the learning of developmental motor skills and not replicable in a simulated task (Thelen & Fogel, 1989). Based on clinical and experimental observations of emerging eating skills in children, it is reasonable to hypothesize that these principles may apply to the acquisition of swallowing and eating skills (Christoforou-Gioules, 2006; Sheppard & Mysak, 1984).

Implicit learning. Implicit learning refers to the improvement in performance that results from experiences with the task, without specific attention to or awareness of the change. Implicit training in swallowing behaviors involves manipulation of the natural task conditions, cuing, and reinforcement so as to shape the desired changes. For example, cuing and reinforcement for alternating drinking and spooning may be used to modulate the rate of spooning. Research indicates that learners perform skills more effectively, retain them better, and are able to attend to additional environmental demands when the skills are learned implicitly (Schmidt & Wrisberg, 2004). The benefits of implicit learning have also been demonstrated in children and adults with special needs (Krinsky-McHale, Devenny, Kittler, & Silverman, 2003; Vinter & Detable, 2003).

Rehearsal strategies. Rehearsal refers to practice experience that is not functional or that disrupts the functional integrity of the target task. In examining the concept of rehearsal, it may be useful to consider whether the student is just beginning to have experiences with this task or is at the stage of improving performance on the task. Furthermore, it is useful to consider whether the target skill is a serial task in which the components of the task have minimal motor influence on each other, such as stirring and chopping in a cooking activity, or one in which there is interaction among the task components, such as in the phases of swallowing.

Rehearsal strategies include simulation, fractionalization, segmentation, and simplification. *Simulation* refers to practice that mimics the actual task used without actually performing it. Examples in eating are pretending to self-feed with an empty spoon or cup as a means of training self-feeding and chewing on a rubber "chewy" as a means of developing or improving chewing skills. *Fractionalization* refers to practicing the parts of a complex skill separately; for example, practicing finger feeding of chewable pieces of food that results in swallowing without chewing followed

by separate practice working on chewing in which the bolus may be placed on the molars. *Segmentation* refers to practicing one part of a task until it is functional, then adding the next step and practicing the two parts together; for example, beginning with independently bringing a cup to the mouth and dispensing the bolus, followed by independently bringing the cup to the mouth and sipping from the cup. *Simplification* refers to reducing the level of difficulty of the task. This may be accomplished by slowing the task down or manipulating the stimulus conditions to make the task easier. For example, regulating the rate at which food is placed in the mouth, or the bolus size or viscosity, or using chewable bolus that has been observed to be easier to chew may be seen as simplifications. The integrity of the task is retained, albeit in an easier form.

There are three questions to be asked in using these strategies: Will practicing an altered version of the target skill affect learning of the target skill? How much of the training time should be devoted to this sort of practice? Is there an advantage to using a simplified version of the actual target task? Some benefit has been found at the very early stages of learning for simulation, fractionalization, and segmentation. However, the more interaction between the parts of the task, the less benefit that accrues. Simplification, it appears, is the better strategy for interactive task sequences. However, according to the specificity of learning concept, transition to the normal rhythm and rate for the task performance would have to be made (Schmidt & Lee, 1999; Schmidt & Wrisberg, 2004).

Maximizing opportunity for practice. The more practice opportunities, the better the performance and the better the retention (Schmidt & Lee, 1999). Repetitions are essential for the acquisition of motor skills. The most important variable in a training program has been found to be the amount of practice (Schmidt & Lee, 1999). Early learning is characterized by the child's attempt to get the idea of the movement and understand the basic coordinations involved in the task. It is natural for learners at this stage to lack confidence and be hesitant in their reactions. Maximizing practice at this stage typically requires more assistance and reinforcement. As the learning progresses, the child is more relaxed, the movements are more consistent, there are fewer errors, and less support may be needed. In the later stage of learning, the child is confident, movements are more automatic, and the learner recognizes errors (Schmidt & Wrisberg, 2004). Practice should be maximized at each of these stages for improvement and maintenance of the skill.

Blocked and random practice. The effectiveness of the practice repetitions depends on the practice context. *Blocked practice* refers to practice repetitions of a single task sequence, as is typically seen in drills. *Random practice* refers to practice sequences in which the related tasks in a behavior are performed in no particular order. An example of blocked practice in eating is biting and chewing a cracker until finished, followed by taking repeated drinks from a cup until finished. In contrast, the same lesson structured for random practice would facilitate drinking alternately with bites of a cracker. Although blocked practice may be useful during initial practice of a task in the early learning stage, and fewer errors may occur in performance, random practice has been found to result in better learning as measured by retention, that is, the ability to recall what has been learned and perform it again (Schmidt & Wrisberg, 2004).

Distribution of practice. Research has addressed the relative benefits for motor learning of using available practice time for longer sessions of massed practice (e.g., a mealtime) as compared to distributing practice time interspersed with rest periods (e.g., two daily snacks) or with longer intervals (e.g., practice periods on alternate days). The best way to distribute the available practice time is a key concern for teachers and clinicians. Results of this research demonstrate consistently that practice performance and retention of skill (learning) are better in distributed practice (Schmidt & Lee, 1999). An important advantage for advancing eating skills in the school setting is the multiple, daily practice opportunities that are available. The typically developing child takes 2 to 3 years to fully develop mature eating skills—an indication of the large number of practice opportunities that are required during the period when brain plasticity is optimal (Arvedson & Brodsky, 2002; Piek, 2006; Schmidt & Lee, 1999; Schmidt & Wrisberg, 2004; Sheppard, 1994, 2005).

Extrinsic feedback. Feedback occurs during and following task performance from both intrinsic and extrinsic information. *Intrinsic* information in eating encompasses the sensations associated with the bolus characteristics, the movements and emotions occurring during ingestion, and the child's reaction following the experience. *Extrinsic* feedback encompasses the information that is provided to the child. The guiding adult or peers may provide this information. Extrinsic feedback has been found to support learning in motor tasks through motivation, reinforcement, and correction of error. Specifically, extrinsic feedback consists of information about the adequacy of the child's performance, how long the child will have to persist at the task at hand before the activity ends, and, when appropriate, the adult's pleasure at the child's performance (see McKirdy et al., 2008). Extrinsic feedback is particularly useful to beginners as they often are not able to interpret the adequacy of their own movements. Feedback used as positive reinforcement immediately following an action tends to increase the likelihood that under the same stimulus conditions, the same action will be repeated; negative reinforcement and punishment have less predictable effects. More frequent feedback has been found most useful during early learning of a behavior; intermittent feedback is better during later learning as it reduces the likelihood of dependence effects (Schmidt & Wrisberg, 2004).

Transfer of learning. The learning of a motor skill involves acquiring the ability to perform the task consistently in practice and in the variety of environments in which it is appropriate. This concept is of interest because it directly addresses the question of the relationship of learning that occurs during practice to performance of the target task in its natural context. Transfer of learning, in its broadest consideration, refers to the influence of prior experience on the performance of the target skill in that variety of natural environments (Schmidt & Wrisberg, 2004). In an educational program for improving eating, the fundamental environments are the classroom, lunchroom, on class trips, and, arguably, home. This form of transfer from therapeutic activity to natural environments is often referred to as generalization. Transfer of eating performance for preferred foods to other foods of similar texture and viscosity for which the child is less experienced or to foods of different texture and viscosity are also examples of transfer of learning. In general, research indicates that the best outcomes for learning and retention are to maximize practice in natural routines and natural environments. It is useful to be mindful when selecting practice activities that do not meet this standard that previous training

experiences may have a negative transfer effect on the target (Schmidt & Wrisberg, 2004).

Implications for Assessment and Treatment

How may we use this information in the treatment of pediatric swallowing and feeding disorders? The typical assessment of swallowing and feeding skills includes a comprehensive medical and developmental history, examination of the anatomy and physiology of the structures and systems involved in swallowing activities, and determination of the level and adequacy of development for these skills and the affective behaviors associated with these tasks. Family issues and the broader cultural context may be included. In some instances, a modified barium swallowing study or consultation with a gastroenterologist may be warranted in order to determine if there are oral initiation, pharyngeal, or esophageal phase abnormalities that need to be considered. In other instances, additional evaluations may be warranted to determine if there are other disorders or difficulties that may affect the child's potential to benefit from the training program and to succeed. These evaluations include, but are not limited to, dental, pulmonary, neurological, and psychological evaluations (Arvedson & Brodsky, 2002; Arvedson & Lefton-Greif, 1998; Rosenthal et al., 1995).

The motor learning literature focuses our observations in several respects:

- Thelen (1995) alerts us to determine which elements of motor and affective behavior may be the limiting factors on rate of change and efficiency of performance in these emerging skills. The speech-language pathologist (SLP) is looking for specific components that will hold back or promote development, as limiting factors and strengths must be considered in setting goals and objectives for advancing the skill. The task analysis model in Table 2 may be used as a reference for examination and for describing the motor performance.
- Intrinsic and extrinsic feedback may have interfered with or facilitated development thus far and may be shaping current behavior. It is useful to know what deliberate and inadvertent feedback is being provided and has been provided in the past.
- The child's developmental "level" ought to be considered with respect to the continuum of emergence and refinement of the skill. For any particular eating skill, such as drinking from a cup or chewing, the child may be in an early stage of emergence for skill, a middle stage of motor awareness and consolidation of abilities, or an advanced stage of automaticity.
- There may be related factors that interfere with learning or the performance of skills that the child has demonstrated. In this regard, motivation and attention should be examined.

The motor learning literature alerts us to the subtleties that are involved in training motor skills. Education and therapy involve establishing effective conditions for training so as to maximize benefit.

Attention is an important variable in learning success. The child who has sufficient ability to attend selectively is ready to engage in a motor learning task. The more complex the visual and acoustic environment, the higher the level of demand for selective attention and the harder it will be for the child to attend. The SLP and teacher control the complexity of the task environment and otherwise support the child to compensate for difficulties with attention (Schmidt & Wrisberg, 2004; Sheppard, 1994; Sohlberg & Mateer, 1989).

Motivation is needed for the child to derive maximum benefit from training and to perform skills once they are acquired. For children who like to eat, learning of an eating task is inherently motivating. For children who find learning new eating tasks more difficult and therefore may not enjoy eating, eating per se will not be sufficient reward to be motivating (Kerwin, Ahearn, Eicher, & Burd, 1995). Furthermore, swallowing behaviors involving tooth brushing and taking oral medications do not have the potential for inherent motivation that may be obtained in eating. Appropriate selection of rewards and moderating the difficulty and duration of the training task are effective strategies for maintaining motivation (Schmidt & Wrisberg, 2004).

Outcomes for treatment may be improved by attention to the structure of the practice activity with regard to specificity of tasks, distribution of practice, and early introduction of more varied treatment routines. Transition of training to the classroom and other typical daily environments at the early stage of emergence of skill may yield better outcomes with respect to learning and retention.

Case Example

The motor learning approach to advancing eating skills is illustrated by the case history of Ned, a 3-year-old child who, because of kidney failure and the associated need to balance his nutrient intake carefully, had been nourished primarily by bottle feeding. Typically, Ned fed himself his bottle in a reclining position on his mother's lap. He had experienced the gastrointestinal distress that is characteristic of kidney failure and so was not motivated by eating. His medical condition had improved. He had no history of respiratory or upper airway disorder. His gross and fine motor capabilities, as evaluated by physical and occupational therapists, were within normal limits. He was enrolled in preschool with an individualized educational program for advancing his eating skills, improving speech and language, and special education.

Clinical swallowing and feeding assessment. Ned's developmental level for eating skills was at nippling. His level of skill for sucking was high, in motor learning terminology, automatic. He could feed himself his bottle. His pattern was atypical in that he was able to take the bottle only in a supine position. He enjoyed social intimacy in eating when he was held during nippling. He had none of the higher level skills or subskills (see Table 1) and, other than social intimacy, had none of the sensory tolerances that would support acquisition of more mature eating behaviors. Ned was fed frequently during the day so that the typical, mealtime-snack, hunger-satiation cycles had not been established. There were no clinical signs of oral or pharyngeal neuromotor disorder or difficulties with airway protection that warranted referral for a modified barium swallow study. Ned's failure to develop more mature eating skills appeared to be associated solely with his illness and his limited eating experiences. As for his other swallowing behaviors, Ned's control of saliva was normal, and he cooperated in brushing his teeth as expected for age without any difficulty managing the saliva accumulation during the task. He took his medications by nipple (Arvedson, 2000; Arvedson & Brodsky, 2002; Arvedson & Lefton-Greif, 1998; Sheppard, 1987, 1994).

Treatment. A program was developed in collaboration with Ned's family to advance his eating skills. The objectives were

implemented in sequence as part of the daily classroom routine and speech therapy program. In addition, the same objectives were implemented at home to the extent that they were culturally and personally acceptable to the parents. The program provided daily, distributed practice sessions at meal and snack times and in related services, thus maximizing practice opportunities. The practice tasks were selected in approximation of expected developmental sequences for food texture and viscosity. The tasks and practice environments were as similar to the natural environmental context as could be arranged. At each level of the program, the practice sessions contained increasing variability as tolerated by Ned. Incidental training was the primary training strategy as Ned was encouraged to participate, cued for practice, and reinforced consistently for meeting objectives in the typical classroom and home routines. He was rewarded for cooperating in training for eating skills with permission to engage in preferred activities and other privileges that he valued. Duration of practice was moderated so as not to exceed Ned's tolerance in any given session and for any given task. Ned developed confidence in the knowledge that when he was finished with the task as presented, he would not be asked to do any more and would receive his reward. The program was structured to be consistent with the motor learning concepts discussed above (Piek, 2006; Schmidt & Lee, 1999; Schmidt & Wrisberg, 2004; Thelen & Fogel, 1989).

The objectives were implemented in the sequence described in the following sections for all snacks and meals in the classroom and at home (Morris & Klein, 2000; Sheppard, 1994).

Improving sensory tolerances for learning to eat. The activities in this first phase included sitting up in a well-fitting chair at the table during all snacks and meals with his classmates and his family. Ned was trained to keep his plate, cup, and utensils on the table in front of him. Once these behaviors were established, Ned was trained to leave food and drink on the table in front of him. Initially, this included a cookie, yogurt, and a small amount of milk in a cup.

Precursers to spoon feeding. Ned's eating schedule was adjusted so that he was taking his bottle on a three meal, two snack schedule that conformed to classroom and home routines. He was trained to feed himself his bottle sitting up in his eating chair and to lick tastes of milk from a spoon.

Eating from a spoon. Next, Ned was trained to accept small tastes of yogurt from a spoon. He was fed slowly to allow ample time for swallowing and breathing. The food was selected because of its similarity to his milky nipple feeding. Practice routines emphasized maintaining upright head alignment with chin down during eating yogurt. This strategy was used to encourage a more mature swallow for the spooned food. The next step was to increase the amount of yogurt accepted and the rate of intake. Exercises provided practice with gradually increased bolus size, number of accepted spoons, and promptness in taking the food from the spoon. Once Ned was eating 4 oz of yogurt in 20 min, he was trained to accept a variety of smooth foods. One new food was introduced at a time. When Ned was accepting 2 oz or more of the new food for 3 consecutive days, that food was included in his meal/snack diet and the next new food was introduced. As each new food consistency was added, Ned was trained to accept 10 to 12 foods of similar texture and viscosity before advancing to the next food type. Viscosity was increased gradually to allow time for the acquisition of motor capabilities for swallowing more viscous foods.

Advancing skills for swallowing increased texture and viscosity. Ned's preferred foods were introduced in grainy then mashed consistencies. Initially, the foods were moist. As Ned's ability to swallow thicker foods was established, the added moisture was reduced gradually.

Precursurs to self-feeding, biting and chewing, and drinking from a cup. Early in the program, Ned was encouraged to hold a spoon in his hand as he was fed yogurt. He was trained to hold pieces of apple and cracker, preferred foods for this activity, in his hand and lick them. Next, he was trained to hold and gnaw on harder foods. Bagels and hard biscuits were frozen so that Ned could gnaw on them with less risk of getting larger pieces in his mouth. As part of this precursor phase, Ned was trained to bring a cup to his mouth. A bit of yogurt was smeared on the rim to provide a small taste and elicit a swallow.

Advancing skills for biting and chewing. This phase began with Ned being trained to bite off small pieces of a crisp, soft-to-munch, moist cracker, such as a graham cracker. He was feeding himself these foods. Chewing skills were advanced by first placing foods on his preferred side for chewing. The order for introducing chewable food was single bites or pieces of crisp food, such as graham crackers and cold cereal pieces; next soft pieces, such as banana, soft fish and meat, and cooked carrot; next mixed texture pieces; and finally firm and fibrous foods such as raisins, pretzel rods, and firmer meats. As each chewing type was introduced, the easier foods were given at meals and snacks as part of his diet. Ned experienced difficulty during chewing in moving food out of his cheek. He needed considerable tactile (a tap on his cheek) and verbal cuing to become aware of food that remained in his cheek and to use the muscles in his cheek and tongue to remove, chew, and swallow it.

Drinking from an open cup and straw. Ned was trained to accept single sips of his bottle drink dispensed into his mouth from an open cup. Next, he was taught in sequence to sip from the cup and to swallow with the cup in his mouth. As Ned's skills improved, he was able to sip and swallow sequentially. The next objectives were for drinking from a straw. The straw was cut in half and placed in a cup so that the liquid was close to the top of the straw. Ned was trained to take a single sip and swallow. Initially, Ned would let the straw drop from his mouth after each sip. He advanced to sequential swallows and to holding the container while he drank.

Transition to self-feeding. Initially, Ned's family preferred to continue to feed him, thereby limiting opportunities for self-feeding at home. Goals and objectives for self-feeding were introduced in school. The first objectives were for self-feeding with a cup. This began with small amounts of Ned's preferred bottle drink in the cup. Ned was instructed to pick up the cup and take a drink. As skills for dispensing developed, the amount in the cup was increased. The activity requirement was that Ned finish the amount in a given time interval. If he failed, the cup was refilled to the target amount and he started again. Within a few sessions, Ned was finishing 4 oz in 10 min, and this became part of his school snack and lunch routine. Ned learned first to feed himself his preferred and familiar yogurt with a spoon. At first, the clinician and teacher assisted as needed for sufficient success to maintain Ned's motivation. This assist was faded quickly and Ned was allowed to develop his skill through trial and error. Ned advanced to feeding himself a variety of smooth, grainy, and mashed foods with a spoon and to using a fork. He would master the skill at each food level before advancing to the next level. Finally, Ned was trained to generalize these self-feeding and oral skills for school trips. His family agreed that it was time to generalize the skill to home and community. The

school staff collaborated with the parents in this effort and the transfer was successful.

Ned continued to have episodes of kidney problems. He would tend to backslide in his eating and drinking skills when he was ill and advance when he felt better. He achieved the objectives in his program and progressed to having fully developed functional skills in school and in a variety of community eating environments in 2 years. However, Ned continued to need extra supervision and support in novel settings, such as when traveling. It took another year for Ned's parent to report that Ned was exhibiting mature eating behaviors in all environments. At 5 years of age, Ned transitioned to a regular kindergarten class and continued his education in regular class placements.

CONCLUSION

The motor learning literature is a resource for evidence-based training concepts for the training of developmental motor skills. Although we must be mindful that the concepts and premises in this literature result from studies of the acquisition of skills that are unrelated to swallowing and feeding, the applicability of these findings to populations of children and adults, both with and without disabilities, and to a variety of motor tasks, suggests that they are worth considering for informing training of swallowing and feeding activities. McKirdy et al. 2008 achieved successful outcomes using this motor learning approach in their study of transition from tube to oral feeding. Additional work is needed to explore the applicability and efficacy of specific strategies to the variety of swallowing and feeding problems that are seen in school-aged populations and to the school environment per se.

In setting goals and developing habilitation programs for children with swallowing and feeding disorders, the school-based SLP balances concern for the health and safety of the child with educational aims for advancing skills. The primary consideration is to maintain the child's nutrition, hydration, and swallowing safety as the optimum condition in which swallowing skills may be gradually advanced. The SLP considering use of the concepts and strategies presented in this review should be mindful of the limitations presented by each child's specific impairments in swallowing and by his or her vulnerability for nutritional and respiratory disorder. The appropriate sequence and timing for advancing each child's skills and the selection of strategies is first and foremost selected in light of that knowledge.

REFERENCES

Arvedson, J. C. (2000). Evaluation of children with feeding and swallowing problems. *Language, Speech, and Hearing Services in Schools, 31,* 28–41.

Arvedson, J. C., & Brodsky, L. (2002). *Pediatric swallowing and feeding. Assessment and management.* Albany, NY: Singular Thompson Learning.

Arvedson, J. C., & Lefton-Greif, M. A. (1998). *Pediatric videofluoroscopic swallow studies: A professional manual with caregiver guidelines.* San Antonio, TX: Communication Skill Builders.

Christoforou-Gioules, I. (2006). *The developmental coordination of respiratory movements and swallowing.* Unpublished manuscript.

Davies, W. H., Berlin, K. S., Sato, A. F., Fischer, E. A., Arvedson, J. C., Satter, E., et al. (2006). Reconceptualizing feeding and feeding disorders in interpersonal context: The case for a relational disorder. *Journal of Family Psychology, 20*(3), 409–417.

Gisel, E. G., Lange, L. J., & Niman, C. W. (1984). Tongue movements in 4- and 5-year-old Down's syndrome children during eating: A comparison with normal children. *American Journal of Occupational Therapy, 38*(10), 660–665.

Henry, F. M. (1968). Specificity vs. generality in learning motor skill. In R. C. Brown & G. S. Kenyon (Eds.), *Classical studies on physical activity* (pp. 331–340). Englewood Cliffs, NJ: Prentice-Hall.

Homer, E., Bickerton, C., Hill, S., Parham, L., & Taylor, D. (2000). Development of an interdisciplinary dysphagia team in the public schools. *Language, Speech, and Hearing Services in Schools, 31,* 62–75.

Illingworth, R. S., & Lister, J. (1964). The critical or sensitive period, with special reference to certain feeding problems in infants and children. *Journal of Pediatrics, 65*(2), 839–848.

Kedesdy, J. H., & Budd, K. S. (1998). *Childhood feeding disorders. Biobehavioral assessment and intervention.* Baltimore: Brookes.

Kerwin, M. E., Ahearn, W. H., Eicher, P. S., & Burd, D. M. (1995). The costs of eating. A behavioral analysis of food refusal. *Journal of Applied Behavior Analysis, 28*(3), 245–260.

Krinsky-McHale, S. J., Devenny, D. A., Kittler, P., & Silverman, W. (2003). Implicit memory in aging adults with mental retardation with and without Down syndrome. *American Journal on Mental Retardation, 108*(4), 219–233.

Kurjan, R. M. (2000). The role of the school-based speech-language pathologist serving preschool children with dysphagia: A personal perspective. *Language, Speech, and Hearing Services in Schools, 31,* 42–49.

Largo, R. H., Kunda, S., & Thun-Hohenstein, L. (1993). Early motor development in term and preterm children. In A. F. Kalverboer, B. Hopkins, & R. Geuze (Eds.), *Motor development in early and later childhood: Longitudinal approaches* (pp. 247–265). Cambridge, MA: Cambridge University Press.

McKirdy, L. S., Sheppard, J. J., Osborne, M. L., & Payne, P. (2008). Transition from tube to oral feeding in the school setting. *Language, Speech, and Hearing Services in Schools, 39,* 246–257.

Miller, A. J. (1999). *The neuroscientific principles of swallowing and dysphagia.* San Diego, CA: Singular.

Morris, S. E., & Klein, M. D. (2000). *Pre-feeding skills, A comprehensive resource for mealtime development.* San Antonio, TX: Therapy Skill Builders.

Pick, J. P. (2006). *Infant motor development.* Champaign, IL: Human Kinetics.

Prontnicki, J. (1995). Presentation: Symtomatology and etiology of dysphagia. In S. R. Rosenthal, J. J. Sheppard, & M. Lotze (Eds.), *Dysphagia and the child with developmental disability. Medical, clinical and family interventions* (pp. 1–14). San Diego, CA: Singular.

Rosenthal, S. R., Sheppard, J. J., & Lotze, M. (Eds.). (1995). *Dysphagia and the child with developmental disabilities. Medical, clinical, and family interventions.* San Diego, CA: Singular.

Rudolph, C. (1994). Feeding disorders in infants and children. *Journal of Pediatrics, 125,* S116–S124.

Satter, E. (1990). The feeding relationship: Problems and interventions. *Journal of Pediatrics, 117,* S181–S189.

Schmidt, R. A., & Lee, T. D. (1999). *Motor control and learning, A behavioral emphasis* (3rd ed.). Champaign, IL: Human Kinetics.

Schmidt, R. A., & Wrisberg, C. A. (2004). *Motor learning and performance, A problem-based approach* (3rd ed.). Champaign, IL: Human Kinetics.

Schwaab, L. M., Niman, C. W., & Gisel, E. G. (1986a). Comparison of chewing cycles in 2-, 3-, 4-, and 5-year-old normal children. *American Journal of Occupational Therapy, 40*(1), 40–43.

Schwaab, L. M., Niman, C. W., & Gisel, E. G. (1986b). Tongue movements in normal 2-, 3-, and 4-year-old children: A continuation study. *American Journal of Occupational Therapy, 40*(3), 180–185.

Sheppard, J. J. (1987). Assessment of oral motor behaviors in cerebral palsy. *Seminars in Speech and Language, 8*(1), 57–70.

Sheppard, J. J. (1994). Clinical evaluation and treatment. In S. R. Rosenthal, J. J. Sheppard, & M. Lotze (Eds.), *Dysphagia and the child with developmental disabilities. Medical, clinical and family interventions* (pp. 37–76). San Diego, CA: Singular.

Sheppard, J. J. (1997). Pediatric dysphagia and related medical, behavioral, and developmental issues. In B. C. Sonies (Ed.), *Dysphagia, a continuum of care* (pp. 55–73). Gaithersburg, MD: Aspen.

Sheppard, J. J. (2005). The role of sensorimotor therapy in the treatment of pediatric dysphagia. *Perspectives on Swallowing and Swallowing Disorders (Dysphagia), 14*(2), 6–10.

Sheppard, J. J., & Mysak, E. D. (1984). Ontogeny of infantile oral reflexes and emerging chewing. *Child Development, 55,* 831–843.

Sohlberg, M. M., & Mateer, C. A. (1989). *Introduction to cognitive rehabilitation. Theory and practice.* New York: Guilford.

Thelen, E. (1989). The (re)discovery of motor development: Learning new things from an old field. *Developmental Psychology, 25*(6), 946–949.

Thelen, E. (1995). Motor development: A new synthesis. *American Psychologist, 50*(2), 79–95.

Thelen, E., & Fogel, A. (1989). Toward an action based theory of infant development. In M. Gunnar & N. Hazen (Eds.), *Action in social context* (pp. 23–62). New York: Plenum.

Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action.* Cambridge, MA: MIT Press.

van der Maas, H. L. J., & Hopkins, B. (1998). Developmental transitions. So what's new? *British Journal of Developmental Psychology, 16,* 1–13.

Vinter, A., & Detable, C. (2003). Implicit learning in children and adolescents with mental retardation. *American Journal on Mental Retardation, 108*(2), 94–107.

Woolacott, M. H., & Jensen, J. L. (1996). Posture and locomotion. In H. Heuer & S. W. Keele (Eds.), *Handbook of perception and action: Volume 2. Motor skills* (Vol. 2, pp. 333–403). San Diego, CA: Academic Press.

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Contact author: Justine Joan Sheppard, 111 Chincopee Road, Lake Hopatcong, NJ 07849. E-mail: jjsheppard@worldnet.att.net.