Motor Skill Acquisition
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The purpose of this article is to provide a framework for understanding motor skill and the process by which it is acquired. A selective historical overview is presented to demonstrate how the study of movement is a necessary preliminary to the study of motor skill learning. The phenomenon of skill is explored as an inherent feature of goal-directed organisms whose effective functioning depends on achieving a degree of competence in solving problems that are encountered in the everyday world. The relationship between problems and solutions is discussed. Movement is examined as a problem-solving tool and as the means by which the individual expresses skill. Factors that influence the individual's level of skill are fully explored, along with the implications for functional behavior. The creative use of resources in problem solving is thoroughly examined, and tasks are discussed in terms of the demands imposed on the individual. [Higgins S. Motor skill acquisition. Phys Ther. 1991;71:123-139.]

Key Words: Learning, Motor skills, Problem solving.

Historical Overview

It would be safe to say that the issue of learning has not been addressed by movement scientists in any systematic way since the early 1970s. At that time, a seminal article by Gentile appeared that addressed learning from an interactional point of view, that is, one that examined learning as a function of the interaction of the individual and the environment in the pursuit of goal attainment. (Gentile was influenced by the earlier works of such psychologists of skill as Bartlett, Welford, Poulton, Connolly, Whiting, Bilodeau, Kay, Cratty, Fits, Henry and Rogers, Henry, and Adams. Gentile's article offered a framework for studying not only learning, but movement in relationship to context-dependent, goal-directed behavior. Prior to this time, the analysis of movement was considered the province of kinesiologists and biomechanists. The study of learning was largely restricted to the study of the outcomes of movement (i.e., speed, accuracy, movement time, reaction time) rather than on the process by which these outcomes were produced. The focus of Gentile's article was on understanding movement as it becomes organized and differentiated in varying environmental contexts (which she called "open" and "closed" environments after Poulton). Motor skill acquisition was viewed as a stage-related process directed toward the understanding of the goal and the subsequent development of an information-based motor plan and motor response that suited the attainment of the goal.

Gentile's article was shortly followed by an influential article by Schmidt. Schmidt, influenced by Adams, proposed a schema theory of motor learning that was, in part, to take the field in the direction of examining the underlying processes supporting the production of movement that was considered a derivative of a centrally represented and generalizable motor program. (The work of Keele, Stelmach, and Marteniuk was also considered influential in this regard.) The work of this period marked the entry of the field of motor learning into an intense focus on understanding movement itself and on understanding issues of control.

Considered polemical at the time, because of its departure from the entrenched, strictly anatomical-biomechanical approach to the study of movement, was a book by Higgins. Higgins viewed an individual's movement as a window into the underlying neural pro-
cesses supporting it. Distinctly different from the perspective of kinesiologists and biomechanists, movement was considered an external manifestation of the resolution of interacting internal and external constraints surrounding its production. Higgins sought to specify the factors, or “constraints” as he called them, influencing the organization and control of movement, again from an interational point of view, and proposed a model for the multidimensional analysis of movement (also see article by Arend and Higgins²¹).

The study of movement, both as a process and as a product, became the essential focus of the field. Movement was examined as the means by which the individual interacts within the environment and as a product of the processes underlying movement. Attempts were made to examine processes that were viewed to deal with the environmental, morphological, and biomechanical constraints surrounding a particular goal-directed performance. The study of learning was temporarily abandoned for want of a better understanding of the relationships that would have a direct bearing on how learning could be viewed: for example, relationships of the individual to the world; of movement to functional behavior; and of neuromotor, musculoskeletal, biomechanical, and environmental phenomena.

Perhaps the most important realization of this period was the importance of context and task in the organization of skillful movement. A systems perspective of human behavior was replacing an associationist point of view, and paradigms were being developed that could be applied to the study of behavior (see, for example, such classical papers as those presented at the Alpbach Symposium in 1968²³). Skill and movement, from this perspective, were viewed as dynamic, relative, and adaptive. In order to better define the relationship of the individual as problem solver to the external world, a systematic study of tasks ensued (see, for example, articles by Arend and Higgins²² and Gentile and colleagues²³).

As a result of this work, a theoretically derived taxonomy of skill developed that allowed the co-analysis of context and movement. Movement differentiation was analyzed as a function of task, environmental condition, and nature of the postural, limb manipulatory, and perceptual demands, given any number of variables (see articles by Higgins²⁴ and Higgins and Spaeth²⁵).

It took nearly 20 years to develop a viable integrative framework for the study of motor skill (which, of course, is still evolving). During that time, many movement scientists were attracted to the ecological perspective offered by Gibson²⁶ for the study of perceptual processes. There was an interest in developing parallels for viewing goal-directed adaptive movement in a similar and inclusive vein. That viewpoint allowed the study of movement as an emergent property of the organism, based on the extraction of information from pertinent sources rather than an internally built model of the world and responses to its conditions. Work in this direction was spearheaded by Turvey²⁷ and further developed by movement scientists and developmental psychologists such as Kelso,²⁸ Kugler et al,²⁹ Thelen et al,³⁰ Thelen,³¹ von Hofsten,³² and Goldfield.³³ (See the special issue of Human Movement Science³⁴ for a selection of articles examining and further extending the emergent viewpoint and the special issue of Developmental Psychology³⁵ for a selection of articles applying a dynamical systems approach to the study of motor development.)

With the recent development of models for the study of self-organizing systems (see especially works by Kelso and Schoner²⁸ and Haken²⁵) and the consideration of the role of mental processes in the genesis of movement,³⁷ the explanatory power of the emergent viewpoint regarding movement became a viable alternative to the more entrenched representational point of view. With a fuller understanding of the individual as actor in the environment, and of movement as a means for goals to be achieved, the field is again ready to address issues about learning. (See recent articles by Gentile³⁸ and Jeka and Kelso³⁹ addressing issues of learning from differing, although overlapping, perspectives.)

Purpose and Perspective

This article offers a framework, along with exemplary references, for viewing movement as the means by which problems are solved, for viewing skill as the degree of effectiveness in the deployment of movement, and for viewing learning as context-dependent problem solving. The view presented, although essentially a dynamical system's approach, is often an amalgam of ideas and findings of many researchers and theoreticians who have contributed to our understanding of movement and learning over the past 20 years. Reference to their work does not imply agreement with their perspective, but rather is intended to encourage the reader to seek out these important works as rich sources of ideas for practice.

The initial focus of the article will be to examine the relationship between problems and solutions—between action, movement, and skill. The concept of skillfulness will be fully explored and then used to discuss the phenomenon of learning as the acquisition of skill.

Ultimately, as therapists, we are interested in the development of competence, that is, how individuals become effective problem-solvers at any point (or condition) in their lives, and on how their degree of competence is reflected in their behavior and affects their function. Skill is viewed as a form of competence (ie, as a degree of effectiveness), and skillful behavior is viewed as an application of the resources available to the individual for achieving goals. Learning is viewed as the process by which the individual organizes available resources, with reference to a specific problem, and gains control over that organization.
In order to understand learning in this context, one must view the individual as, by nature, a problem-solving organism engaged in meaningful interaction with the environment and possessing the capacity to marshal his or her resources in service of adaptive behavior to varying degrees of effectiveness. Understanding learning becomes a function of understanding the interaction between problems and the available resources of the individual and environment. Importantly, the individual's degree of effectiveness in the learning process (and thus in problem solving in general) will be limited by his or her ability for critical self-analysis and environmental analysis in light of the problems encountered and by his or her ability to generate and control the solutions to these problems.

**What Is Skill?**

Skill may be viewed as an aspect of the ongoing function of an individual in his or her daily encounters with the world. A person's skill is his or her degree of competence in handling those encounters. That is, skill is an individual’s ability to consistently achieve a goal(s) under a wide variety of conditions. Specific to the study of motor skill, the goals are considered motor problems (ie, to lift a cup) that are to be achieved by the execution of an appropriately organized movement. A person’s motor skill is thus expressed by some level of control over goal-directed movement. The greater the ability to analyze problems and to marshal the resources to use movement as a problem-solving tool, the greater the degree of skill.

We must study problems in order to understand skill. Problems are goals that arise as a function of an encounter between the individual and the surround, occurring under an infinite variety of conditions across a life-span. Skill is the ability to solve problems with a degree of consistency and economy. To understand skill, we seek to understand the kinds of problems that are encountered and the resources that are available to solve them at any point in time. We seek to understand what the problem or task demands of the individual solving it and how the individual’s resources are pertinent to the specific problem.

**Actions, Movement, and Skill**

**Problems and actions.** The problems we engage in may be viewed as a goal to be achieved by the individual. These problems present a task(s), having an inherent set of demands, to the individual. The demands of the problem specify the nature of the activity that the individual will be involved in (a more specific analysis of task demands is provided later in this article).

Attaining goals may involve many actions on the part of the individual, each subserving the demands of the task. For example, the goal of crossing the street poses demands that specify the actions of orienting (eg, looking, listening, or touching) and locomoting. The task demands matching one’s solution to the movement or position of vehicles, pedestrians, and traffic signals, and it demands an excursion of the individual over the surface. Our actions describe an operation on the environment (or on the self in the environment) by the individual. Actions are realized, to varying degrees of effectiveness, through movement. In this example, orienting might be realized through an eye/head movement and locomoting through a walking movement.

The particular action and the particular movement(s) that evolve during problem solving are context dependent and thus are indeterminate. For example, the action of pushing serves many goals; however, the movement(s) used to enact the push depend on the unique problem, the state of the individual, and the state of the environment at that time. Similarly, the action of walking subserves many goals or tasks. However, the kinematic details of the walking movements emerge as conditions unfold.

Actions may also be viewed as modes of available interaction between the individual and the environment. In this sense, they can be considered as resources to the individual. At the same time, they may serve to constrain our problem-solving behavior. Our pool of available actions is subject to change as the individual or the environment changes. For example, with a particular trauma, “looking” may no longer be an available mode of interaction. If the individual wishes to achieve the goals that demanded looking, an alternative (presumably equivalent) action would have to be marshalled in order for the goal to remain viable. Similarly, the movement capabilities of the individual may change, influencing the way in which an action may be realized. For example, a neck injury might alter the movement(s) used to enact the action of looking; however, the individual can still accomplish the goal through the act of looking. With a particular environmental condition, a particular mode of interaction or movement may be more or less appropriate. These indeterminacies must be dealt with for us to be competent in our problem solving. That is, we learn to be consistent and reliable problem solvers under indeterminant conditions—as a fact of life.

Therapists (and teachers) often define goals and actions as motor skills that the individual needs to acquire: dressing, walking, driving a car. The attainment of the goal in these activities or skills requires an appropriately organized behavioral product. For motor skills, this behavioral product is a movement.

**Movement and skill.** Movements are the means by which motor problems or motor skills are solved. A movement is viewed as a kinematic chain of motion having spatial and temporal coherence relevant to the task at hand. The structure of the movement is emergent, dynamic, and responsive to the task, the individual, and the environment (see article by Higgins for a full discussion of this issue). As the context of the task changes, so does the kinematic structure of the movement change.
The structure of the movement may be relatively stereotypical (ie, kinematically consistent) or nonstereotypical (kinematically variable), depending on the problem and its context. Context refers to the momentarily effective environmental conditions surrounding the problem and the state of the individual at the time of performance (ie, the constraints surrounding performance). The narrower the context, the narrower the solution and the more consistent the movement. The broader the context, the broader the range of solutions and the less consistent the movement. In both cases, the skill of the individual lies in his or her ability to consistently achieve the goal. In the narrow case, the goal may indeed be a kinematically consistent movement (ie, a cartwheel). In the broad case, the goal is anathema to a kinematically consistent movement; rather, the movement solutions are as varied as the contexts (eg, crossing a city street). (See Chapter by Gentile 38 for a full discussion of this issue.)

In the clinic, we are largely exposed to narrowly defined tasks in controlled environmental conditions with relatively stereotypical movements emerging as solutions. This is perhaps a necessary first step in the therapeutic process, or a final step if the conditions are severe. The study of skill, however, necessitates the examination and genesis of movement solutions in all contexts. As facilitators of skill, we must be prepared to develop intervention techniques that ensure success in as many contexts as possible.

In the real world, we encounter contexts that exist on a continuum of narrow to broad, and we must be effective in all of these contexts. An individual's overall skillfulness is evaluated by the ability to embrace all contexts and all solutions. The skillfulness of the individual will be reflected in his or her degree of effectiveness in using movement as a problem-solving tool for any number of tasks or in actions that are inherent in those tasks.

If individuals are not capable of movement as the organized behavioral product, they cannot reflect or exercise their skill. This is an unlikely and extreme case. Even quadriplegic individuals can reflect their skill by organizing a movement response to solve problems—even if their problem-solving tool is limited to an eye movement. Skill is the effective use of any behavioral product capable of externally manifested action.

If movements, be they kinematically consistent or variable, are the means by which motor problems are solved, the individual's capacity to produce and control a wide range of movements bears a direct relationship to the scope of his or her problem-solving capacity. That is, a larger field of tasks and solutions is potentially available to the individual. It is assumed that an individual's potential to produce and control movement and the knowledge bases supporting this behavior develop as a function of genetic and experiential history (see the special issue of Quest 4 devoted to the issue of motor development). As facilitators of skill development, it behooves us to enhance the movement capabilities of the individual to the greatest extent possible because that would extend the individual's problem-solving capacity. At the same time, we should facilitate the development of the cognitive and perceptual knowledge bases that are well organized over a wide range of problems and a wide range of conditions.

**Summary**

Skill is one's degree of effectiveness in achieving the goal using any appropriate solution. It is a statement about one's problem-solving capacity. For motor skills, it is a statement about one's degree of effectiveness in using movement as a problem-solving tool. Skillful movements are organized products that are task-specific, well-timed, well-directed, conforming to constraints imposed by the morphological and environmental conditions; in the individual's capacity to produce and control movement and the knowledge bases supporting this behavior develop as a function of genetic and experiential history (see the special issue of Quest 4 devoted to the issue of motor development). As facilitators of skill development, it behooves us to enhance the movement capabilities of the individual to the greatest extent possible because that would extend the individual's problem-solving capacity. At the same time, we should facilitate the development of the cognitive and perceptual knowledge bases that are well organized over a wide range of problems and a wide range of conditions.

**Levels of Skill**

All movements represent a blend of internal and external forces. Skillful movements approach an optimal blend; that is, a blend that is best suited to the task at hand and to the individual and his or her surroundings at that point in time. The progressive incorporation of external forces into the organization of movement occurs as a function of development and learning. Bernstein 20 identified this phenomenon and aptly called it "seizing the moment of least resistance."

Skillful movements, whether they are the movements that subserve perception or those that subserve performance, are well-organized movements. Both the strategy supporting the genesis of the movement and the kinematic details of the movement are well-adapted to the task. Skillful movements achieve the goal with an economy of effort (see articles by Sparrow 45 and Sparrow and Irigary-Lopez 46 for a more in-depth discussion). In order for an economy of effort to occur, it is necessary to minimize muscular effort and maximize the use of external power sources when possible and when appropriate.
ate.43 External power sources include motive forces such as gravity, momentum, friction, wind and water resistance, and ground-reaction forces. With the well-timed incorporation of external power sources into the spatial and temporal organization of the movement (eg, through summation of forces or transfer of momentum), an individual is able to minimize muscular effort. The individual must have some idea (often intuitive knowledge) as to how external forces can be exploited and must have some idea as to how to incorporate them within the movement. The task-specific blend of internal and external forces needs to be learned.

The implication is that skillful movements, in addition to achieving the goal, do not waste energy. There is a differential and well-timed allocation of external forces or transfer of momentum), an individual is able to minimize muscular effort. The individual must have some idea (often intuitive knowledge) as to how external forces can be exploited and must have some idea as to how to incorporate them within the movement. The task-specific blend of internal and external forces needs to be learned.

Skill exists along a continuum of effectiveness that is related to the degree of consistency in the achievement of the goal and thus to the ability to organize and execute a movement that suits the goal. The skillfulness of the individual is dependent on his or her creative utilization of the pool of available resources.

A high level of skill is characterized by a high degree of consistency in achieving the goal. This skill level implies that the individual can achieve the goal under a wide variety of conditions. Because any change in condition precipitates a change in some element(s) of the solution, a high degree of skill implies an ability to diversify or generalize or spontaneously create the means (the movement); it implies using any appropriate variety of means. There is, however, a further restriction: Solving the problem with an economy of effort implies that the highly skilled individual exhibits the biomechanically and physiologically optimal solution. At high levels of skill, the individual is capable of incorporating mechanical-reactive phenomena with the organization of movement so that there is an optimal blend of internal and external forces (this issue is fully explored by Higgins45). (Recent work by Sparrow and Irigary-Lopez46 examines the optimization of physiological phenomena as an aspect of efficiency. I would argue that efficient movement optimizes psychological resources as well. Work is needed in this area.)

A lesser degree of skill could be characterized by total inconsistency in achieving the goal, consistency under a few conditions, control over only a narrow range of means, or using a large degree of effort. Most of us fall into this category. We are pretty good at many things, but must settle, for any number of reasons (be they cognitive, morphological, or sociocultural), for performance that is short of highly skilled. No skill, however, is not a viable alternative for a problem-solving organism.

People are, by nature, skillful—albeit to varying degrees of effectiveness. Their degree of effectiveness may be limited by numerous factors: genetic potential, cognitive ability, structural or neuromotor characteristics, access to a narrow range of movements, developmental or sociocultural history, psychological state, or, quite simply, intent or whim. With a lesser degree of skill, however, our flexibility in problem solving and the range of tasks accessible to us are limited.

The degree of skill we attain on most tasks is generally to the satisfaction of the individual within constraints imposed by cognitive, morphological, or sociocultural factors. That is, although we may wish to be or know we can be more skillful on a particular task, we may not wish to devote the time and energy needed to achieve such a level. We thereby settle for a level that suits our momentary needs. Therapists, parents, or peers can play a critical role in influencing the level of skill that an individual attains (ie, by setting goals and standards of performance). However, externally imposed standards have the potential to cause conflict and a stressful or unsuccessful learning experience unless the individual accepts them as his or her own. Similarly, the therapist must accept the individual's standards or work toward some mutually agreeable and realistic goals. Ultimately, it is the individual who defines the degree of skill that is satisfactory for himself or herself.

If we view skill as a degree of effectiveness in utilizing resources, skill level may, in part, be attributable to the nature of the resources. Although the resources may limit us, we can be quite clever in our solutions, because skill is a product of the interaction of these resources. Thus, we can, within limits, make up for shortcomings by exploiting our strengths. The narrower the task demands, the less flexibility the individual has in creative resource usage and the more stereotypical the solution. For people with severely limited resources, this might be a blessing or a hindrance—a blessing because they can learn a form of participation, or a hindrance because the demands of the task in light of the nature of their condition may preclude their participation.

Resources as Constraints and Affordances

What are these resources and how are they developed? How can they be changed through training, learning, or morphological or environmental alterations? How does the task interact with the selective organization of resources? How are they mutually limiting? Can an individual understand his or her resources? By what means, and to what extent? How can we view resources as a knowledge base, and how might we expand that base?

Resources are the morphological and psychological characteristics of the individual, the structural characteristics of objects and events in the exter-
nal environment, and the characteristics of the field of external forces inherent in the environment. Resources might be viewed as constraints on the individual, or they might be viewed as affordances. As constraints, they are the factors that are uniquely orchestrated in the organization of movement. As affordances, they are the relative functional offerings inherent in the individual's operational characteristics and in a particular environment for a particular individual.

Resources may be relatively stable features of the individual or the environment, or they may change rather slowly or rapidly (e.g., changes attributable to growth, development, learning, or sudden trauma; environmental changes attributable to context; changes in object dimensions; changes in scale). Importantly, resources are tools for problem solving and are recognized as such (albeit often intuitively and to varying degrees of effectiveness) by the individual. (For further discussion, see the works of Goldfield, Gentile, Higgins, Gibson, Newell, and Goldfield and Shaw.)

**Skill as Creative Resource Usage**

The seemingly simple definition of skill as creative resource usage is imbued with subtleties regarding the underlying prerequisites of skillful behavior. For example, to creatively utilize resources toward goal attainment and to be effective implies that the individual has a mastery of control over the processes involved in problem solving. The individual has acquired and can deploy functional synergies to his or her advantage.

Optimally, the individual understands the goal and what is demanded of him or her, can organize a movement that complements—indeed exploits—his or her capabilities and capacities within a particular environmental milieu, and has an intuitive understanding of his or her own states and capacities and an ability to analyze the environment in light of these constraints and the task at hand (cognitive and perceptual skills). The individual is able to develop and control the means to the goal (i.e., to control his or her movement and achieve a complementarity of the afferent and efferent processes that support it), not only under one set of conditions, but under any conditions in which this task arises.

The individual must be selectively attentive and adaptive to both internal and external conditions surrounding the task (and context). To achieve an economy of effort, the individual must be capable of a well-timed incorporation of nonmuscular forces in the organization of the movement or willing to trade off biomechanical efficiency for another purpose. Lastly, the individual must be capable of incorporating or exploiting the operating characteristics of his or her own body (whether psychological, physiological, biomechanical, or neuromotor) that impose limits on the organization of the movement.

Any degree of success in achieving a goal, regardless of the level of skill, demands that the individual be an active participant in the task. The processes and prerequisites underlying the genesis of skillful performance are the same for us all. It is the therapist's/teacher's role to understand these prerequisites and develop intervention strategies that would help to enhance the individual's available resources (see article by Arend for a framework that the therapist might apply). Importantly, an individual's available pool of resources can be altered. It is our role as therapists and teachers to develop techniques to assess an individual's resources, to determine which resources are pertinent to particular problems, and to ensure that the performer matches these requirements. If the individual does not meet these requirements, we must plan to alter his or her resources by developing programs to enhance strength, flexibility, or endurance; by developing basic skills that might subserve the task (e.g., the ability to summate forces, track a moving object, or time the placement of a limb to a moving or stationary object); or by developing a plan to alter the environment and the individual's relationship to the environment.

**Example of Skillful Behavior**

To gain greater insight into the phenomenon of skill, we can examine the problem-solving behavior of the fraternal twins "Jimmy" and "Johnny," as filmed during a developmental study by McGraw in the 1930s. (The original longitudinal films taken by McGraw are permanently housed in the Film Library, Teachers College, Columbia University, New York, NY.) As depicted in Figures 1 and 2, the boys were engaged in a problem-solving task involving the manipulation of a set of pedestals of various heights to attain an object otherwise out of reach. I selected this particular sequence because it demonstrates the many characteristics of skillful behavior discussed in this article. More specifically, it demonstrates how skill is relative to the individual in every sense of the word: his or her size, scale, point in development, cognitive ability, fitness level, and degree of competence and confidence. Figures 1 and 2 demonstrate quite different problem-solving strategies emerging over time, but each eventually resulting in achieving the same goal.

The first pictorial sequence in Figure 1 depicts Johnny at 20 months of age after 3 weeks of exposure to the task. He was trying to get an object placed on top of the tallest of eight pedestals. He moved the smallest pedestal adjacent to the largest pedestal, recognized he could not reach the object, and involved an intermediately higher pedestal . . . but placed it in an inappropriate spatial relationship and failed at the task. (We are not certain whether he was capable of moving or climbing on one of the taller pedestals or whether he even noticed them or viewed them as a tool. Even if he had used a taller pedestal, however, it seems that he might have placed it an inappropriate distance from the object.)
Figure 1. "Johnny" in his attempts to acquire an object placed out of his reach by moving any of a series of eight available pedestals graded in height. Johnny is depicted at 20 months of age, 26 months of age, 5 years of age, and 8 years of age. (Adapted from McGraw M. Growth: A Study of Johnny and Jimmy [filmstrip]. New York, NY: Babies Hospital, 1932-1940.) (Drawn by JGH Moore.)
Figure 2. "Jimmy" ('Johnny's' fraternal twin brother) attempting the same task described in Figure 1 legend at 26 months of age, 28 months of age, 5 years of age, and 8 years of age. (Adapted from McGraw M. Growth: A Study of Johnny and Jimmy [filmstrip]. New York, NY: Babies Hospital; 1932–1940.) (Drawn by JGH Moore.)
At 8 years of age, Johnny selectively approached and swiftly moved only one of the pedestals (rather easily) to a cluster arrangement. Using several, but not all, of the pedestals that he positioned, he climbed to the top and attained the object.

At 5 years of age (after not having performed this task for 3 years), he swiftly moved the pedestals with a spinning action into a cluster arrangement that provided him with various alternatives; however, he used only three to climb on. He attained the object with momentary trepidation in standing at the top, which he quickly overcame.

At 8 years of age, Johnny selectively approached and swiftly moved only two pedestals. He attained the object, mounting the pedestals with ease.

The first pictorial sequence in Figure 2 depicts Jimmy at 26 months of age after 7 weeks of exposure to the task. (Practice began for each boy 2 weeks after he showed he could understand the problem.) Johnny began practice at 19 months (77 weeks) of age, and Jimmy began practice at 23 months (94 weeks) of age. At 26 months of age, Jimmy used a strategy similar to his brother's: he used a number of pedestals (more than Johnny), placed them in an inappropriate spatial relationship to the object, and failed at the task. Cognitive limitations regarding spatial relationships (and perhaps a scale-induced limitation at manipulating and climbing a higher pedestal) initially made success at this task impossible for either boy.

In the next sequence, at 28 months of age, Jimmy used a cluster arrangement, but selected pedestals of inappropriate heights in his attempt to reach the object and eventually withdrew from the task (perhaps indicating limited knowledge of spatial relationships or of self in relation to the task and pedestals). He was frustrated.

At 8 years of age, Jimmy still carefully positioned the pedestals in a staircase arrangement, using his full body to push them, and attained the object by climbing up the stairs. He used all the pedestals and had not achieved the selective manipulation of only the essential pedestals; however, the strategy he chose suited his needs. That is, perhaps all of the pedestals were essential in his regard.

In this sense, we cannot fairly compare Johnny's and Jimmy's respective levels of skill because the strategy should suit the individual and cannot be imposed or unfairly expected. Although Johnny had a higher level of skill (and a different pool of available resources) than Jimmy, it would not be appropriate to use Johnny's strategy and movement solutions as a prototype for the lesser-skilled Jimmy to mimic or aspire to. We can, however, ask how we can alter Jimmy's available pool of resources to enhance his success and skill at the task. The point is that neither skill, nor strategy, nor movement can be imposed—they are derived and evolve as a function of experience by an active participant. This is an important lesson for us as parents, teachers, and therapists that will be dealt with again later in this article.

I believe the most striking aspect of this observational analysis is how it shows that the strategy and the behavior of each child, at any time, complemented his strengths and weaknesses and reflected his current level of understanding and skill. The task demanded an application of resources (i.e., of skill). There was no single solution. The goal was consistently achieved by Johnny (and ultimately Jimmy), using variable solutions (of actions and movements), each a function of the momentary conditions surrounding performance and each revealing useful information about the performer. This was not a study of learning, but rather of how current abilities are reflected in strategy and movement.

The sequences depicted in Figures 1 and 2 show how Johnny and Jimmy applied their current capacities toward the resolution of the goal, and, paradoxically, but very much characteristic of skill, how each child was limited in the degree of goal attainment by his current capacity for goal resolution. There was active participation in the problem and a creative use of resources that were exploited in the attempt to achieve the goal.

Any creative use of resources implies that the individual has self-knowledge, an understanding of the task, and an idea of how the two variables might interact. Indeed, access to this knowledge is critical because it is the very knowledge that forms the basis of the problem-solving strategy. (For example, Riccio and Stoffregen examined shifts in strategy to control stance as a function of available information and...
goal. Interestingly, they view the efficiency of stance not in biomechanical terms, but rather in terms of its consequences for other behaviors. That is, stance is efficient if it can serve the purposes of perception and action. The usefulness of stance, however, is dependent on the individual’s ability to control stability.

Fundamental to the genesis of skillful behavior are the individual’s capacity for self-knowledge and capability for task analysis and environmental analysis. Both types of knowledge are accessible to the individual on the basis of an interaction of proprioceptive, exteroceptive, exproprioceptive, and cognitive processes, and they are dependent on a unique genetic and experiential history. Proprioception refers to the extraction of information regarding the position and movement of the body (ie, on the state of the individual, or the internal environment), exteroception (commonly considered perception) refers to the extraction of information regarding the state of the external world, and exproprioception refers to the extraction of information regarding the movement or position of self in relation to the external world. All three are perceptual processes subserving action. All three processes are information-dependent and influenced by an individual’s unique genetic and experiential history. They may be considered as skills in their own right and are amenable to learning.

Cognitive processes refer to the development and operation of the knowledge underlying decision making and underlying the perceptual processes that support goal-directed behavior.

Typical of problem-solving behavior, both boys in Figures 1 and 2 engaged in problem solving at various levels of skill (as a function of their development and context), and their skill evolved to different degrees—both in the parsimony of their solutions and in the assuredness of their movement. There was, I am sure, a good deal of incidental learning—about pedestals and how to move them, about spatial relationships, about self in relationship to the environment and to the task, and about one’s own strengths and weaknesses (the kinds of knowledge that accrue as a function of experience in any task). What did not occur at any time, however, was a stereotypical pattern of movement to solve the task. Skillful behavior is not simply the execution of a stereotypic movement, and a particular motor skill (eg, moving a pedestal) is not synonymous with a movement. Skillful behavior is the effective use of an available pool of resources such that effective movements emerge in response to the surrounding conditions. What is effective is defined by the current status of the performer, not by some ideal form.

Examples of Skillful Use of Resources

To further illustrate how individual resources can be skillfully applied to a specific task, consider the following two examples of handicapped individuals who have already learned some fairly complex skills.

A young man with a congenital deficit, leaving him with little functional movement in his lower extremities, is swimming. He has learned a swimming technique that complements his morphology, but the task had to be narrowly defined for him—he could not breathe on every stroke, and he could not use his lower body to contribute to balance and propulsion in the water. He totally submerged his body in the prone position during swimming, used a modified breaststroke for a number of strokes, rested at the pool’s edge, and then continued to swim the length of the pool in this fashion.

A young woman with arm structure typical of thalidomide-induced deformities is playing table tennis. She quite competently manipulates the paddle and ball to her advantage. Her serving and stroking techniques are modified to her capabilities. She cannot reach shots that are at extreme positions. Within her range of attainable shots, she is quite skillful.

In both examples, the individuals are clearly comfortable with themselves and their capacities. Both individuals, having congenital deficits that they have come to terms with, are quite knowledgeable about themselves. These individuals are clearly skillful, relative to their pool of resources. As participants in a recreation program for handicapped individuals, they were not taught movements, but rather, as already-skilled individuals, they have learned to analyze tasks in light of their capabilities and to devise problem-solving strategies that work for them, in an environment that supports and guides their learning and celebrates their participation in the process.

Task Analysis

Regardless of skill level, when individuals attempt a new task, they must first analyze the task in relation to their currently available pool of resources. Based on this analysis, many decisions are made. The individual will either engage in the task as defined, alter the task to better suit the available resources (if possible), devise a plan to alter the resources and attempt the task at a later time, or withdraw from the task.

Skill in task analysis is also subject to varying degrees of effectiveness. Ideally, there should be a complementarity between the outcome of the task analysis and the subsequent (or simultaneous) motor behavior of the individual. Individuals who have a lower level of skill in task analysis are less likely to engage in effective motor behavior than individuals who have a higher level of skill in task analysis. For example, they may inappropriately choose to attempt a task that they are ill-prepared for, or they may be unable to determine which aspects of the environment or which personal resources are pertinent to the problem. Similarly, individuals may be highly skilled at task analysis, but have a low degree of motor skill. They may indeed have a good idea about what needs to be done, but know that they cannot do it. Hence, they appropriately redefine the task, or attempt to alter their pool of resources to make the task accessible to them, or withdraw from the task.
I offer a problem for you to resolve as an example of a typical task analysis. The task is to climb the tree depicted in Figure 3. Although the following questions are not meant to be all-inclusive or indicative of exactly what—either in context or in sequence—an individual would ask, I believe they embody the essence of task analysis: What does this problem entail or demand of you (e.g., in terms of actions, movements, cognitive knowledge, information extraction, strength)? What do you need to know about the tree? About yourself? About yourself in relation to the tree? How will you, and how can you, gather this information? How then, if you choose to participate, will you climb the tree? What will your strategy be? How will you evaluate the effectiveness of your strategy? Your movement? On what basis? If the task is presented under a different set of conditions, how might your strategy or movement(s) change (e.g., if you were tired, injured, stronger, younger, or being chased)? If the tree was smaller or a bough breaks, would you still participate? Would you know when to withdraw? Would you be able to?

It should be apparent that your skillfulness in this example is not synonymous with your ability to execute a series of tree-climbing movements that you have automatized. Your skillfulness is dependent on a realistic appraisal of the problem and a matching of the demands of the problem to your resources. Throughout your participation in this task, you must remain responsive to contingencies that may arise. You must remain analytical in a self-referential fashion. In order for this type of participation in the task to occur, the task must have meaning or significance to you and you must have a basis for self-observation and environmental observation. Your strategy and movement will emerge as your analysis and participation proceed.

What if you cannot be adequately responsive or analytical in this task? What if your pool of resources does not match the task? What if the task really does not interest you (an interesting problem to analyze in its own right)? Perhaps you would (rightly) choose not to climb the tree. Are there any problems or characteristics that you already know about yourself that would preclude your involvement? What could you, or a teacher, or a therapist do to make this task accessible to you or to deal with the limiting problems or characteristics that you know of? How would you feel if someone told you what to do, analyzed the problem for you, presupposed your capabilities, or made you dependent on their judgment and analysis of the problem, rather than facilitating your active involvement in the problem?

The initial series of questions posed in this example are typical of the largely intuitive task analysis that an individual would engage in before and during problem solving. The individual's degree of effectiveness in performing the task is based on his or her realistic and useful analysis of the task, ongoing responsiveness to contingencies, and confidence in his or her problem-solving ability. Task analysis is a skill unto itself—a self-referentially based skill that is dependent on existing personal resources.

Role of Task Analysis in Problem Solving

The ultimate result of task analysis specifies for the individual the nature of the forces involved in solving the problem and how these forces might be dealt with in the solution. That is, the individual determines such things as the magnitude of the force needed for this task, where and when these forces are applied on the object(s) or on the body, how external forces are pertinent to the task and how and when they should be incorporated, the role the limb segments and torso play in the allocation and absorption of these forces, and how the body and the environment can be organized to apply these forces. A problem-solving strategy is born, and an orientation (that is, a stance or a cooperative arrangement of the body and the environment) is assumed to initiate the
The organization of the movement that emerges is representative of the individual's analysis and particularization of the force problem.

**Translating a Force Problem Into a Strategy and Movement**

Consider the example of the task of pushing a pedestal. Making the goal more specific, imagine that you are asking someone to move the pedestal, as nearly as possible, in a linear fashion (versus rotating it upon its corners). Looked upon as a force problem, this task demands an application of force through the center of gravity of the object in order for it to move linearly; pushing large, heavy objects is most efficiently achieved by applying those forces simultaneously by the involved body parts. The problem becomes redefined in terms of what it takes to get an object to move a certain way under certain conditions and in terms of what it takes for a person to move an object that way.

Decisions will need to be made regarding the nature of force to be applied and the way it will be applied. In principle, the magnitude of the force is dependent on the mass and inertia of the pedestal and the desired velocity to be imparted to the object; the direction that the force should be applied is dependent on the type of motion desired (ie, linear or angular) and the degree of friction between the object and the ground. The individual analyzes the task to answer these questions. The individual's answers are only as effective as his or her knowledge about how objects move.

In order now to apply a force to get the pedestal to move linearly, the individual must decide how the body and the environment might be organized to effectively apply such a force. Ideally, a force is only as effective as the stability and firmness of its base of support. So, an individual ought to establish a firm base of support between the feet and the ground, widen the stance in the direction of the intended motion, place the hands equidistant from the center of gravity of the object and apply forces of equal magnitude through both hands (lest the object rotate), open the hand in order to establish a larger area of contact, stabilize the shoulder-arm complex and spine so that the force generated by the powerful leg muscles is effectively transmitted to the object without dissipation, and apply the force steadily and slowly. The individual's particularization of the force problem to the movement, however, is as effective as his or her knowledge about how he or she can move objects. The effectiveness of the actual movement that emerges is dependent on the individual's ability to control it along desired parameters.

A series of principles (mechanically, morphologically, and environmentally derived) were applied to the resolution of the force problem and became particularized as a strategy for movement. We can evaluate an individual's effectiveness in solving the problem against this standard. We must, however, have a basis for understanding individuals' deviations. For example, how might the problem-solving strategy or movement be affected if the shoulder, arm, wrist, or hand musculature is weak; if there is insufficient friction between the feet and the ground; if the individual is unsure of himself or herself; if the individual does not understand the goal; if an observer is present; or if the pedestal is tall, short, or too heavy?

**Summary**

It can be stated that tasks pose force problems to be solved by an individual through some cooperative relationship among body segments and the environment. The strategy and movement that emerge to solve the problem are reflective of the individual's skill in task analysis, of the currently available pool of resources, and of the individual's skill in marshaling those resources and controlling the movement. The strategy and movement that emerge are compatible with these skills and resources—they are a derivative of them.

The momentary marshaling of resources is as efficient as it can be for the surrounding set of circumstances (including individual mood state or whim). If we, as therapists, wish to alter an individual's problem-solving strategy or movement, we must alter the resources that underly its organization and thus enhance the problem-solving capacity of the individual.

The genesis of motor skill is dependent on a unique interplay of cognitive and perceptual processes that support task analysis and motor behavior. The quality of an individual's participation in a variety of tasks is considered to be limited by currently available resources. Yet, at the same time, the act of participation is a refiner of those resources. Active participation is our way of applying and accruing knowledge, that is, of learning. Learning is the process of becoming skillful. It is the process of experientially inducing change in those resources amenable to learning and in the behavior they support. It is the study of how experience is retained and applied in our functional interactions with the world.

**Learning**

Traditionally, learning is defined as the process that results in a relatively permanent change in behavior brought about by experience. Let us examine this notion of permanence. What does it mean when we have "learned" something or when we have experienced a relatively permanent change in behavior? It implies a change so profound that we have truly altered our operating knowledge base. It implies that we have access to and have benefited from the information base and analytical processes of the skill we have learned. We not only can perform the skill (ie, solve the problem), but we can also apply the knowledge and control accrued to future behavior. This application of knowledge and control occurs autonomously, on an unconscious and intuitive level. When we have learned something, that knowledge becomes a tool that is available for subsequent interactions, while limiting the scope...
The view that I am presenting here argues that, during learning, we apply currently available analytical skills to acquire information relating the relevant variables of the task in a self-referential fashion. We acquire the ability to analyze tasks and to marshal the resources necessary to successfully participate in those tasks.

What Is Learned?

During learning, the learner is progressively developing a system of principles to constrain the body so that it may ultimately act as a single, harmonious unit, organized with reference to a specific problem. A specific problem-solving strategy and the associated movement emerge as a function of this acquired knowledge and as a function of level of development and skill.

To get an idea of what is being learned during skill acquisition, consider the example of a quadriplegic individual, recently paralyzed in a diving accident, in the process of learning how to control himself in the water. He is relearning to swim by controlling his head-neck position. He is learning to use the positioning of his head and neck to induce passive movements of the shoulder-arm complex. In a sense, the paralyzed parts of his body can be viewed as external objects over which he has some control and that have some control over his nonparalyzed body parts. This new relationship must be understood and then exploited.

In this example, the learner uses his available resources, with verbal and manual assistance from an instructor, in order to define his relationship to the water. The addition of externally provided resources (e.g., a flotation device, a supporting hand) could facilitate this process, but only if the external support would not unrealistically alter the information the performer needs to obtain or the nature of the coordination he needs to develop (as a flotation device might indeed do). In addition, there is always a danger that the performer becomes overly reliant on external support. In this example, the instructor initially supplies manual support and progressively withdraws that support.

Under this structured condition, the performer is relearning how his body behaves in the water and how he can use his body to exploit the buoyant effects of water. He is learning to use his available resources to balance himself in a vertical float position so that he may ultimately manipulate his position in the water. This learner has confidence in his ability to reacquire this skill and has trust in the ability of the instructor to help him. To his advantage, as a previously skilled swimmer, he has considerable knowledge about water and the act of propulsion through water. His main concerns are to reformulate this knowledge in a way that is pertinent to his current condition and to exert the control necessary to apply such knowledge.

The learner in this example must revise his knowledge base about his own body and how it interacts with the environment. This situation is quite different from that of the previous examples of people with congenital limitations who are fully aware of their resources and who, during skill acquisition, need to apply their resources to the task. In this example, the learner first needs to rediscover the relevant features of his self and become familiar with his own limited pool of resources as they relate to the task of maintaining and manipulating a position in water. This rediscovery process necessitates a great deal of exploration on the part of the learner. This process will be enhanced by the support of his teacher/therapist, who will establish a context that allows exploration to occur. The redevelopment of his working knowledge base will form an important substrate for future learning (see article by Arend for a full development of this issue).

As teachers and therapists, we are not imparting movement solutions to a learner, but rather we are providing an opportunity for guided discovery on the part of the learner. We allow the learning process to occur and attempt to facilitate that process. Learning is viewed as an interactive and cyclic process of discovery and mastery over the knowledge bases that support functional behavior.

Summary

What is being discovered? The learner is discovering the relevant relationships and features of the self and the environment in light of the task and principles relating these variables as they apply to the emerging cooperative relationship among body parts and between the body and the environment. The individual is discovering the nature of the force problem to be solved and how to apply the sources of information pertinent to its resolution in structuring the problem-solving strategy and movement.

By what means? The learner discovers these relationships and principles by the application of existing resources, that is, task-driven and self-referential proprioceptive, exproprioceptive, exproprioceptive, and cognitive processes. The individual uses existing observational and analytical tools that support task analysis, self-analysis, and environmental analysis.

What is being mastered? The learner, essentially, is mastering the unconscious and intuitive procedural knowledge that directs the marshaling of resources for this task. In this way, knowledge may be consistently and autonomously applied in the execution of the movement. Additionally, the individual masters the ability to selectively control the blend of forces that underly the body-environment relationship appropriate to the task.

The Process of Learning

Learning is a process demanding insight into the task and selective attention to the pertinent sources of information within the self and within the task environment.
environment that will influence the behavior. Of central concern during the learning process in the acquisition of motor skill is the ability on the part of the learner to ultimately organize a coherent pattern of movement that suits the demands of the task. This product (i.e., the movement), however, will evolve and transform throughout the learning process and will reflect the current status of the learner.

The early phases of skill learning are characterized by a high degree of cognitive-conscious involvement on the part of the learner in analyzing the motor problem or engaging in task analysis. The learner is attempting to understand both what is expected and how the problem-solving strategy and movement can be compatible with the variables involved in the task. It is not possible to engage in any appropriate motor behavior until this insight occurs, that is, until the learner understands the means-ends relationship (or, as indicated earlier, the nature of the force problem to be solved). The learner is developing a totally complementary system for solving the problem. He or she must learn to meaningfully organize all behaviors that support the intricately intertwined information-gathering and performatory aspects of the task. At the same time, the learner's performance is limited by his or her current knowledge and currently available organizational capacities. Learning will result in a relatively permanent change in behavior because this knowledge base is altered. In a sense, the existing and the pending bases of knowledge merge and co-evolve in a nonlinear fashion. At the same time, it is not possible for effective learning to occur if the learner does not meet the minimum prerequisites to engage in the task, that is, if the currently available pool of resources is in some way inadequate for successful goal attainment.

The central problem for the learner then is to understand the nature of the motor problem to be solved so that a coordinated pattern of movement can emerge—one that is maximally compliant with demands imposed by biomechanical, anatomical-physiological, and environmental variables pertinent to the task. The goal of the first phase of learning a motor skill is to discover the relationships between these variables and the movement.

This phase serves the purpose of clarifying for the learner what is important in the task and offers the learner a basis for developing a general strategy to approach the task, along with a general idea of a body-environment relationship that will be likely to achieve the goal. It is only with this insight that the learner will have sufficient clarity of purpose and means to establish a system for self-observation and environmental observation needed in order to extract information, modify behavior, and analyze performance. When such insight occurs, meaningful development of a cooperative relationship can begin. There is a context for the extraction and use of information and a context for the progressive refinement of the movement toward some personally defined biomechanical or functional optimum (perhaps itself evolving). If the learner is confused, the solution is confused. Achieving clarity of purpose and insight into the means-end relationship signifies that the learner is ready to attempt and refine that relationship.

At this point, the learner is through the first phase of learning and has answered the question: What does this task demand of me, and how might I resolve these demands in my movement solution? Now, through practice, the learner can further refine the solution. Continued practice is directed at achieving a degree of technical mastery over this and other viable solutions until the marshaling of resources underlying the movement solutions becomes autonomous, that is, becomes a part of the individual's working knowledge base and a tool for subsequent learning.

Summary

This is the essence of learning—a cyclic process of discovery, mastery, and generalization. Learning does not end with technical mastery; rather, learning refines existing knowledge. Learning makes accessible goals that were not previously attainable, because the individual is truly changed by the knowledge accrued. As Bruner stated, each change associated with learning reflects what is gained, and, with each gain, the task is approached anew.

Engaging in the problem-solving process represents a commitment on the part of the individual to (1) gain insight into the task, which provides the meaning needed to direct perceptual and cognitive problem-solving strategies and to interpret outcomes; (2) gain insight into the force problem to be solved, that is, the cooperative effort or relationship among body parts and external objects and forces required to solve the problem; (3) particularize the force problem to the movement, that is, actually develop a coordinative-compensatory relationship among body parts and external objects and forces; and (4) progressively refine and gain a degree of control or mastery over the knowledge base that supports the skill and the allocation of forces supporting the movement that emerges under this and similar (or quite unique) conditions.

Changes In Motor Behavior as a Function of Learning

A Tendency Toward Efficiency

As skill is acquired during the process of learning, behavior tends to develop efficiency. That is, there is a tendency toward the consistent application of an underlying set of principles that are mechanically, environmentally, and psychologically-morphologically derived and task specific. These principles are ultimately observed as invariant characteristics of the movement (despite differences in the actual pattern of movement between or within performers). The movement is, in essence, structured around these principles. The movement, therefore, changes as knowledge of the principles change. Similarly, the movement...
changes as the individual's ability to control the kinematic chain changes.

Using the example of Johnny and Jimmy, we observed changes in performance over time on a task that demanded suitable manipulation and placement of pedestals and execution of a climbing strategy to attain the goal. In this task, efficiency could be evaluated in terms of the selective utilization of pedestals and the pattern of energy expenditure in moving and climbing them. As mentioned earlier, success in this task is not dependent on the automatization of a particular movement. Yet, if we were to evaluate the evolution of selected elements of the boys' movements over time, we would see a tendency toward efficiency (ie, in terms of hand placement on the pedestal, body position in relation to the pedestal, speed of movement, placement of limbs and torso in the act of climbing). These elements would approximate a more efficient solution over time, despite kinematic variation in the actual movements used. The solutions would be more efficient.

Some tasks, however, do require a kinematically consistent movement as part of the goal. In these tasks, the evolution of the structure of the movement during the learning process is the focus of the observer's attention. The processes underlying the transformation of movement are the same, however, regardless of the task. Problem-solving strategies and movements transform in similar ways, in the direction of efficiency, during the learning process (and during development, as observed and reported by Seefeldt and Haubenstricke64 and pictorially depicted by Wickstrom62).

As efficiency develops, the learner is viewed as optimizing constraining principles and structuring the movement around these principles. Learning may be viewed, in this context, as the gradual refinement of movement (and its supporting processes) toward a biomechanical or functional optimum that is personally derived—one that minimizes work done and maximizes goal accomplishment. It is viewed as the gradual adaptation to the task and to environmental constraints, so that energy expenditure is minimized or so that personal, perhaps functional, goals are met.

Progressive Transformation of the Structure of the Movement

During the learning process, and as the knowledge and control bases develop, a movement form is progressively modified in a way that is personally suited and adaptive. As the learner is discovering relevant constraints to be marshaled in the skill, the knowledge and control (or confusion) so far accrued are reflected in the problem-solving strategy and in the spatial and temporal structure of the movement. Thus, examining shifts in the structure of the movement during the learning process lends insight into the learner's current knowledge and control capabilities.

Typical of many learning experiences, the learner initially restricts degrees of freedom of movement by self-imposing some form of rigidity or freezing of body segments (Connolly63 aptly called this restriction of movement the use of self-tetany). Self-tetanies are seen in the movement as small ranges of motion in participating joints, the use of a limited (and often inappropriate) number of body segments, and the inclusion of unnecessary and inappropriate pauses in the continuity of the movement (what would colloquially be called "jerkiness"). Seefeldt and Haubenstricke64 offer a developmental example of the same phenomenon.

At this point, the learner seems to be attempting to simplify the degree of control needed over the body, while learning the appropriate supporting relationships (ie, among agonist and antagonist muscle groups, among proximal and distal segments, and among internal and external forces). The shortened kinematic chain that emerges allows the learner to test ideas about the task in a limited fashion and to slowly acquire the control over forces involved in the task. Knowing this, it behooves us, as teachers, to suggest ways in which the control problem could be appropriately simplified, rather than leaving the restriction up to the less knowledgeable learner.

The learner redefines the goal for himself or herself. Typically, in the initial phase of learning, from an observer's point of view, movements are riddled with inconsistencies, extraneous movements, and pauses. Additionally, the movement may not be coordinated with external objects that are involved in the skill. That is, the learner may temporarily remove the interaction with external objects as part of his or her goal because it is too complicated to deal with. The learner may redefine the goal as the structure of a kinematic chain that is divorced from selected environmental controls. Knowing that this is likely to happen, the teacher/therapist can be invaluable in more appropriately redefining (or, better yet, progressively building) the task so that it is accessible to the learner, yet does not ultimately detract from the ultimate, more complicated, coordination required. Be forewarned that the result of the learning process could be the automatization of poor or inadequate understandings and thus poor or inadequate solutions (which could be due to the inadequacies of the learner or the teacher/therapist).

The learner's moment-to-moment goal(s) may not be known by an external observer and may not resemble the ultimate goal of the task. A wise teacher/therapist is aware that the learner is clearly working on the establishment and refinement of a movement relationship that is only as effective as his or her currently evolving knowledge. It is unlikely that the learner is matching the movement to an ideal form—this would be an inappropriate mimicry, rather than guided, self-referential discovery.

The mimicking of solutions is a temporary strategy at best. The learner will have learned nothing about the problem or about generating a solution to the problem. Rather, the learner will have learned to be a rep-
tional behavior. Movement remains the ultimate means by which functional interaction with the world occurs. Skillfulness is thus limited by the nature of the resources available to the individual that support the genesis of movement and that underly its control. One's degree of skill is dynamic and evolving.

Motor skill is the ability to use movement as a problem-solving tool. The demands that are inherent within the tasks we encounter must be analyzed, understood, and resolved in a self-referential fashion. Ultimately, these demands are translated into a cooperative relationship among body segments, and between the body and the environment. To construct (coordinate) and effect (control) this relationship, the individual must understand the nature of forces that underly it. Movement is structured around the understanding of the force problem. The effectiveness of the movement is limited by the skill in analyzing the task. Effective movement is dependent on generating an appropriate coordinative relationship between the body and the environment. Effective movement is dependent on the ability to control the spatial and temporal allocation of internal and external forces underlying its production.

Learning is the process by which the individual acquires motor skill. That is, it is the process by which the individual acquires the knowledge to coordinate and control movement in order to consistently and autonomously achieve his or her goals.

Implications for Therapeutic Intervention

Learning is a process. We deny that process if we attempt to provide the solution. We must view learning as a process of coming to terms with a task in a self-referential fashion. It is the understanding of all the elements involved in the task that enables the product (ie, the movement) to emerge.

Our goal, as facilitators of learning, is not to get the learner to perform a movement, but rather to facilitate the understandings that produce that movement. Our goal as therapists is to facilitate the learning process in a way that is suited to the unique characteristics of the learner and to respect the product for all it has to tell us. Too often we view the product as deficient and wrong, rather than as an evolving reflection of the learner's current level of understanding and control. In this sense, it is never wrong.

If a person cannot participate in the learning process, for whatever reason, we may have to impart nongeneralizable solutions. We must understand, however, that this person is being trained. With learning, there is generalizability. With training, there is a memorization of solutions that are nongeneralizable and of limited value. If we teach solutions, rather than encouraging discovery and active generation of strategies, we short-change the learner. In order for the learner to become fully functional, he or she must engage in the learning process autonomously—independent of us.

Our ultimate goal is to help the learner become autonomous as a learner, with the most effective set of resources possible and with the means for self-enhancing those resources. We wish the learner to become a competent problem solver whose movements are effective in achieving his or her goals. Our role then is to assist the learner in understanding, amassing, and refining the resources that serve as the "raw material" for skill expression and learning. We wish to assist the learner in the development of his or her abilities to both analyze tasks and develop effective, personally suited, cooperative relationships between the body and the environment for any task he or she may encounter. In essence, we wish to assist the learner in exerting control over the factors that influence the detailing and progressive refinement of movement—self-understanding, environmental understanding, and self-as-agent in the environment for the task at hand.
References

Motor Skill Acquisition
Susan Higgins
PHYS THER. 1991; 71:123-139.