Ecological Task Analysis: Translating Movement Behavior Theory Into Practice

Walter E. Davis
Kent State University

Allen W. Burton
University of Minnesota

A new approach to task analysis is presented based upon an ecological theory of perception and current motor development and control theories. The ecological task analysis (ETA) approach stands in sharp contrast to more traditional approaches and offers procedures equally applicable to instruction and assessment of movement performance as well as to applied research. The strengths of the ETA approach lie in (a) its grounding in current motor development and control theories, (b) its linking of the task requirements, environmental conditions, and performer characteristics, (c) its application of a functional and dynamic approach to instruction and assessment, and (d) its integration of instruction and assessment procedures. Following a discussion of the traditional approach and ecological theory, four concepts are presented that emanate from Gibson's theory of affordances. From these concepts ETA procedures are derived. Applied research questions relating to task analysis are also implied from the ecological approach and are presented in the final section.

It is paramount for scholars in adapted physical education to build a body of knowledge that may be readily used by practitioners to improve the effectiveness and efficiency of their instruction. Basic or theoretical research in the broad discipline of human movement study or kinesiology (including the subareas of exercise physiology, motor control, motor development, and motor learning) should provide the foundation for this body of knowledge from which ideas for applied research may be generated and perhaps even direct applications may be made. Indeed, as noted by Lewin, there is "nothing more practical than a good theory" (cited in Marrow, 1969). Unfortunately, applied research in adapted physical education often has lacked a sound theoretical basis and scientific rigor and has not been carried out in any systematic manner. On the other hand, it might be argued in general that abstract theories and concepts often do not relate well to situations faced by practitioners, and specifically that current theories of motor behavior are not well suited for application. In response to these problems, this paper describes how a new approach to task analysis may be used to forge a better link between theory and practice (Resnick & Ford, 1978; Roberton, 1988).

Request reprints from Walter E. Davis, 162 Memorial Gym Annex, Kent State University, Kent, OH 44242.
This new approach, referred to as ecological task analysis, is proposed to facilitate the linking between basic and applied research and application. It is based upon concepts from Gibson's ecological psychology (Gibson, 1977, 1979) and recent motor control theory (Kugler, Kelso, & Turvey, 1980, 1982; Kugler & Turvey, 1987; Reed, 1982; Saltzman & Kelso, 1987; Turvey, 1977; Turvey, Shaw, & Mace, 1978), and extends the work on task analysis by Herkowitz (1978) and Morris (1980). In the first section of this paper, a cursory review of traditional definitions and practices in task analysis is presented with the focus upon developmental task analysis (Herkowitz, 1978; Morris, 1980), the most recent approach in physical education. This is followed by a description of and theoretical support for the ecological approach. Then the specific procedures involved in ecological task analysis are described, concluding with a discussion of the relationship of ecological task analysis to theoretical and applied research.

**Traditional Task Analysis**

Task analysis has traditionally been defined as the process of identifying the components of a skill or movement and then ordering them into a sequence from easy to difficult (Dunn & Fait, 1989; Sherrill, 1986; Wehrman & Schleien, 1981). The purpose of task analysis is to assist the instructor in assessing skills, writing goals and objectives, and individualizing instruction for children with varying needs and levels of function. There are various broad categories of traditional task analyses, each emphasizing different types of tasks and levels of analyses. These categories of task analyses include information processing, rational, prerequisite, anatomical, and developmental.

**Information-Processing Task Analysis**

In the context of human skill in general, it has been stated that task analysis can be used to "translate subject-matter descriptions into psychological descriptions of behavior and suggest underlying organizations of skills and knowledge capable of leading to or producing skilled performance" (Resnick & Ford, 1978, p. 378). This type of information-processing task analysis may be traced back to similar sets of analyses carried out by Thorndike, Wertheimer, and Piaget (Resnick & Ford, 1978). Thorndike attempted to translate the associationist "laws of effect" into a set of prescriptions for teaching arithmetic by analyzing arithmetic tasks in terms of specific connections, or bonds, between sets of stimuli and responses. Wertheimer's analyses of these tasks consisted of displaying the structure on which solutions are based rather than analyzing actual performance. And finally, Piaget emphasized the differences in the ways children and adults approach certain tasks and the knowledge and logical structures they have available to apply to these tasks.

**Rational, Prerequisite, and Anatomical Task Analysis**

In a similar manner, a rational task analysis can be defined as an attempt to specify processes or procedures that are used in the efficient performance of some task. The result is a detailed description of an idealized performance. Typically it is derived from the structure of the subject matter and does not take into account the limitations of the performer (Resnick & Ford, 1978).
From a top-down perspective, Auxter and Pyfer (1989) suggest how attributes of the performer relative to a specific task may be taken into account by prerequisite and anatomical task analyses. In a prerequisite task analysis, general abilities (such as dynamic balance, extensor strength, or visual acuity) required to perform each component of a particular movement task are identified. Moving a step further down the motor hierarchy, an anatomical task analysis involves a detailed evaluation of the level of functioning of specific joints (e.g., range of motion) and muscles (e.g., strength) necessary to perform the movement pattern. Auxter and Pyfer assert that a deficiency in the identified prerequisite abilities or anatomical parameters clearly defines the needs of a given performer.

Developmental Task Analysis

Perhaps the most extensive and advanced work in task analysis within the motor domain is that of Herkowitz (1978) and Morris (1980). Herkowitz proposes that developmental task analysis involves either (a) the assessment of the motor development status of children or (b) instruction based upon sequentially ordered movement activities and the manipulation of critical variables that may limit movement-skill acquisition. In her scheme, two levels of task analysis are identified. First, a general task analysis (GTA) refers to the task and environmental factors that may affect the general movement skill to be performed. In the GTA example provided in Table 1, seven factors influencing catching behavior are presented.

Second, a specific task analysis (STA) refers to a spectrum of particular activities, from simple to complex, that incorporate combinations of identified factors. For example, the first level of an STA derived from the GTA in Table 1 might specify catching a 12-inch beach ball (size-of-ball factor) rolled along the ground (trajectory-predictability factor) with a hand (implement-length factor). In 1978 Herkowitz acknowledged that persons using her developmental task analysis must rely on intuition to choose task and environmental factors, due to a lack of research on these variables. Presently the same uncertainty still remains regarding the complex relationships between performer, task, and environmental factors.

Morris (1980) suggests a developmental task analysis procedure with the following steps: (a) identify the movement skill to be analyzed; (b) identify the physical principles, environmental factors, and/or elements of movement that may influence movement performance; (c) establish a task-complexity sequence from simple to complex for each identified factor; (d) develop a series of tasks for each factor; and (e) choose an appropriate activity for a particular individual. Steps a, b, and c are quite similar to Herkowitz's (1978) GTA, while Step d is similar to her STA. Morris' (1980) procedure for reception skills is illustrated in Table 2. Both Morris and Herkowitz utilize factors rather than parts, which is a deviation from early task analysis methods. A task analysis approach that breaks tasks down into component parts in effect creates new tasks, each with a different task goal, while this developmental approach allows a task to be modified without changing the goal of the task.

Problems in Traditional Task Analysis

Lack of Clear Definitions and Procedures. Current descriptions, procedures, and uses of task analysis in the motor domain are fraught with a myriad of unresolved questions and problems. First there is some confusion about what
### Table 1

Herkowitz's General Task Analysis for Catching Behavior

<table>
<thead>
<tr>
<th>Levels</th>
<th>Weight of object to be caught</th>
<th>Speed of catcher's mvmt. prior to catch</th>
<th>Direct. in which object being caught</th>
<th>Size of object to be caught</th>
<th>Speed of object to be caught</th>
<th>Level object is traveling re. catcher</th>
<th>Length of exten. used to catch with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>Moderate</td>
<td>No mvmt.</td>
<td>Forward</td>
<td>Moderate</td>
<td>No mvmt.</td>
<td>Chest level</td>
<td>None</td>
</tr>
<tr>
<td>to</td>
<td>Slow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>Moderate</td>
<td>Slow</td>
<td>Sideward</td>
<td>Large</td>
<td>Slow</td>
<td>Above head slightly</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Moderate</td>
<td>Backward</td>
<td>Small</td>
<td>Fast</td>
<td>Fast</td>
<td>Waist level</td>
<td>Moderate</td>
</tr>
<tr>
<td>Complex</td>
<td>Heavy</td>
<td>Fast</td>
<td>Backward</td>
<td>Small</td>
<td>Fast</td>
<td>Knee level</td>
<td>Long</td>
</tr>
</tbody>
</table>

Table 2

Morris’ Task Analysis for Reception

<table>
<thead>
<tr>
<th>Preference</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simple to Complex</td>
</tr>
<tr>
<td>Object speed</td>
<td>Slow to Fast</td>
</tr>
<tr>
<td>Angle of trajectory</td>
<td>Horizontal to Arc</td>
</tr>
<tr>
<td>Object/background color</td>
<td>Blue on white to White on white</td>
</tr>
<tr>
<td>Object size</td>
<td>Small to Large</td>
</tr>
<tr>
<td>Location of thrower</td>
<td>Near to Far</td>
</tr>
<tr>
<td>Location of ball</td>
<td>Midline to Preferred</td>
</tr>
<tr>
<td>Object texture</td>
<td>Soft to Hard</td>
</tr>
</tbody>
</table>


term to use for task analysis procedures, which can be attributed partially to inherent differences in approaches (e.g., part-whole vs. levels of complexity of critical factors). Some procedures are referred to as task analyses while other terms such as developmental sequences or skill progressions are also commonly used. Further, most associated terms such as task complexity, component parts, sequence, or progression are rarely given a clear operational definition.

This lack of clear terminology and definitions is perpetuated by descriptions of task analysis in adapted physical education textbooks that provide few useful guidelines for actually carrying out analyses. For example, Kalakian and Eichstaedt’s (1982) complete discourse on task analysis reads,

> Task analysis is the process by which individual motor skills are broken down into component parts. Through this process, the specific developmental stages through which the learner passes can be identified. Having identified the student’s stage of development in a skill, the teacher can help the student achieve the next stage. (p. 456)

In other texts, instructors are directed to consider environmental factors in developing task analyses (Dunn & Fait, 1989; Sherrill, 1986) but, due to lack of empirical support, they still must guess which factors should be included in a task analysis and the levels of difficulty for each factor (Roberton, 1988).

Lack of Research Support. The lack of research on the effect of environmental and task variables on the performance of basic movement skills has made the development of valid task analyses difficult, but equivocal results of research that has been carried out pose another problem (see Payne, 1982). For example, is it easier to catch a small ball or a large one? Herkowitz (1978) suggests that it is easier to catch a medium and a large ball than a small ball (Table 1), and she is supported by the research of DuRandt (1985), Meadley (1941), Payne (1985), and Payne and Koslow (1981). However, results of studies by Gutteridge (1939) and Isaacs (1980) indicate that smaller balls are easier to catch, as indicated by Morris in Table 2.
To further complicate the issue, Haywood (1986) notes that while children may be more successful in catching a larger ball, they also are likely to exhibit more mature catching form with smaller balls (which is contrary to the observations of Wellman, 1937). These apparent contradictions appear to be related to a general disregard for (a) differences in the goals of the various catching tasks (Payne, 1982) and, more important, (b) the size of the ball relative to the size of the performer (e.g., in terms of a ball size/body size ratio).

Absence of the Person in the Task Analysis Equation. The weak grounding of the traditional task analysis methods for movement skills in current motor development, learning, and control theory and research limits the utility and potential of task analysis for practitioners. One of the most significant problems in current task analysis methods is the failure to account for performer capabilities relative to the requirements of the task. Traditionally, task analysis has been directed away from the characteristics of the performer, instead elaborating only on the characteristics of the task (Smead, 1977).

This conceptualization is consistent with the stimulus-response theory from which task analysis originated; however, this approach is contrary to the recently advanced theories of motor development and control (Kugler, 1986; Kugler et al., 1980, 1982; Thelen, Kelson, & Fogel, 1987; Turvey et al., 1978). Also, the validity of the part-to-whole method of teaching that is at the core of most traditional task analyses (Sherrill, 1986; see Wehman & Schleien, 1981, for an extensive set of part-whole task analyses) has been questioned by motor learning and control researchers and theorists. Goodman and Kelso (1980) and Reed (1982) assert that a complex skill does not consist of a concatenation of simpler parts and, as mentioned earlier, the breaking down of a complex skill results in simpler tasks with goals that are not necessarily the same.

In light of the usefulness of task analysis in facilitating skill acquisition in persons with disabilities in virtually all curricular areas (Renzaglia & Bates, 1983), it is surprising to find very little research or scholarly writing directed toward improving ways of performing task analysis of movement skills (Robertson, 1988). The remainder of this paper is devoted to the description of a new, more functional approach to task analysis of movement skills.

An Alternative Approach to Task Analysis

The need for an alternative approach to task analysis is supported by the current problems in traditional task analysis, some of which are described above. A conceptual basis for a new approach that has the potential to resolve at least some of the cited problems can be found in Gibson's (1977, 1979) ecological approach to perception, Kugler and Turvey's (1987; Kugler et al., 1980, 1982) dynamical systems approach to movement control, and Reed's (1982) theory of action. The application of concepts from these ecologically oriented approaches to perception and movement provide rational solutions to at least three of the above-cited problems.

Perhaps the most crucial problem in the traditional approaches is the failure to include the person in the task analysis equation. This is a strength of the ecological perspective, in which Gibson and his followers advocate the study of movement behavior of persons in their natural environment (i.e., in ecologically valid contexts) and emphasize the critical role of the relationship between task
requirements and the constraints of person and environment in defining perception and motor control (see also Newell, 1986). These views stand in sharp contrast to the traditional stimulus-response theories and the popular information-processing perspective.

Another area of contention is the questionable validity of equating a ‘whole’ skill to the linking together of the individual parts comprising it (Goodman & Kelso, 1980; Reed, 1982). There are scholars in the area of motor learning who endorse the use of ‘part’ or ‘progressive-part’ methods of teaching some types of motor skills (e.g., Magill, 1989); however, from an ecological perspective the modification of the task goal that is often a consequence of the part approach disrupts one of the key factors that define the character of the movement behavior.

The ecological view dictates that the goal for a given task must be expressed in terms of an invariant intended outcome (i.e., in functional terms) and not in terms of specific body parts, which may provide a variety of means to achieve a particular outcome. It should be noted that motor commands are nonspecific at the muscle level (Hebb, 1949; Lashley, 1938); that is, the same movement outcome may be achieved through the use of several different muscle combinations (Stelmach & Diggles, 1982).

And finally, a clearly described approach to task analysis must be based upon current elaborated theories and should stimulate the necessary research to validate both the predictions of the theories and the actual task analysis procedures. In other words, such a task analysis should inspire and provide direction for theoretical and applied researchers alike. Moreover, the focus of attention on a clearly defined, theory based task analysis method also should serve to standardize the meanings and usage of related terminology.

The proposed alternative to traditional task analysis, referred to as ecological task analysis, is defined as the process of changing relevant dimensions of a functional movement task to gain insight into the dynamics of the movement behavior of students, to provide teachers with clues for developing instructional strategies, and ultimately to promote the success of students in performing the task. In regard to instruction, ecological task analysis provides a way to make the movement task easier to assure student success or to make it more difficult in order to challenge the student. Ecological task analysis is guided by the theory of affordance and four related concepts, which are presented and elaborated in the next subsection. These concepts are derived from the ideas spawned by Gibson, Turvey, Kugler, Kelso, and Reed and the work of others who have advanced these ecologically oriented ideas (Newell, 1986; Warren, 1984). For other adapted physical education applications of the theory of affordance, see Burton (1987, 1990), Davis (1984, 1989), and Davis and Rizzo (in press).

Important Concepts in Task Analysis

A cornerstone of Gibson’s (1966, 1979) ecological approach to perception, which provides the foundation for the views espoused by Reed (1982), Turvey (1977), and Kugler (Kugler & Turvey, 1987), is the concept of affordances. An affordance is the opportunity or potential for action that a specific environment offers or “affords” a particular person (Gibson, 1977, 1979). Gibson asserts that people perceive their environment in terms of its functional utility for them and that their actions are guided by this function based information. Four con-
cepts of relevance to task analysis emanate from this theory: (a) actions are relations, not parts; (b) tasks should be categorized by function and intention, not mechanism; (c) invariant features of a task and variations within a task may be defined in terms of essential and nonessential variables, respectively; and (d) direct links should be established between the constraints of the task goal, the performer, and the environment.

*Actions are relations, not parts.* The theory of affordance implies that movements or actions are composed of relations and not parts. Reed (1982) explains:

The differences between the components in an airplane and the components of flying are due to the fact that an airplane is a *thing* and flying is a *relation* (in fact, a disposition instantiated by relations). The units of things can be analyzed into hierarchical levels (e.g., a body and its parts, and their parts, etc.) whereas the units of relations are only analyzable as interlocking properties (e.g., the forces and their vectors operating on a body). (p. 117)

Given this perspective, movement is a relation, not a person or parts of a person, and it emerges from the complex relationships between the task goal, performer attributes, and environmental constraints (Newell, 1986). Therefore the components of movement are relations and not parts. What is needed are concepts and terms that capture this understanding and guide us in analyzing tasks as relationships, not parts or components. Such thinking stands in sharp contrast to the part-whole approach of many adapted physical education programs (Shed, 1986) as well as the neurophysiological approach taken by most physical and occupational therapy programs (e.g., Bobath, 1978; but see Carr, Shepherd, Gordon, Gentile, & Held, 1987, for a contrasting therapy approach).

The necessity of maintaining the same task goal during the application of the task analysis is an important and unique feature of the ecological task analysis approach. As noted previously, traditional task analysis which divides the task into smaller components (part-whole method) violates this principle. On the other hand, backward chaining, which is a variant of traditional task analysis (Hsu & Dunn, 1984), does maintain the same goal. The outcome of the task is first practiced and then the parts of the task leading up to the outcome are added.

*Tasks should be categorized by function and intention, not mechanism.* If actions are relationships and not parts, how then from a performer’s perspective might a task be defined? Reed (1982), in his paper on action theory, states,

What makes an action what it is is not the hierarchical integration of responses into some movement pattern, but rather, it is the nesting of control processes that organize postures and movements to serve some function.

Actions are functionally, not anatomically or mechanically, specific. (p. 121)

Reed mentions control processes but emphasizes the function of a task (i.e., the task goal, what is to be accomplished), which should be the primary interest and focus of the performer and instructor. The same function may be achieved through different anatomical or neurological mechanisms, as illustrated by comparing the mechanisms used to perform the task of catching by a person who is missing one arm and a person who has both arms. This notion is particularly important in adapted physical education, in which achievement should be empha-
sized instead of the missing limb or impaired body part (see Davis & Rizzo, in press).

An initial attempt at categorizing movement tasks by function is presented in Table 3 (see also Davis & Rizzo, in press). The five categories depicted are based on five of the eight systems included in Reed’s (1982) taxonomy of action (basic orienting, investigatory, locomotor, performatory, and play systems). His appetitive, expressive, and semantic systems are not included in the present classification system because they do not relate as directly to movement as the others do. Examples of specific movement skills, which traditionally are placed into locomotor and object-control categories (Ulrich, 1985; Wessel, 1976), are provided for each proposed category.

Note that some common movement skills are not included either because they are combinations of other skills (such as the skip or gallop), or are functionally neutral (such as sitting or standing), or are subsumed under another skill heading (kicking is a specific type of striking). This system is similar to Fine’s (1974) functional job analysis, in which he reduced 4,000 job descriptions into 30 functional task categories under three headings: what workers do in relation to data, people, and things (see also Davis & Rizzo, in press; Fleishman & Quaintance, 1984).

### Table 3

**Functional Movement Task Categories and Related Movement Skills**

<table>
<thead>
<tr>
<th>Functional task categories</th>
<th>Related movement skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Locomotion:</strong> to move from one place to another</td>
<td>Roll; crawl/creep; walk/run; jump/hop/leap;</td>
</tr>
<tr>
<td>Criteria: to move with efficiency, precision, accuracy, speed, and/or distance</td>
<td>slide/glide; climb; swim</td>
</tr>
<tr>
<td><strong>Locomotion on object:</strong> to move on a self-propelled object from one place to another</td>
<td>Propel bicycle; propel boat/canoe; propel</td>
</tr>
<tr>
<td>Criteria: to move with efficiency, precision, accuracy, speed, and/or distance</td>
<td>skateboard/scooter; propel skates/skis;</td>
</tr>
<tr>
<td></td>
<td>propel wheelchair</td>
</tr>
<tr>
<td><strong>Propulsion:</strong> to propel a stationary or moving object or person</td>
<td>Carry; drop; lift; pull-push (bounce,</td>
</tr>
<tr>
<td>Criteria: to propel with efficiency, precision, accuracy, speed, and/or distance</td>
<td>dribble); strike (bat, kick, hit); throw</td>
</tr>
<tr>
<td></td>
<td>(a) Grasp; (b) catch; (b) block</td>
</tr>
<tr>
<td><strong>Reception:</strong> to take or receive a (a) stationary, or (b) moving object or person</td>
<td>(a) Bend (lean);</td>
</tr>
<tr>
<td>Criteria: to secure in hands, feet, or other body part or in an implement (e.g., glove,</td>
<td>(a) reach; (a) turn;</td>
</tr>
<tr>
<td>net); bring to a halt at a close proximity to self</td>
<td>(a) twist; (b) manipulate; (b) write/color/</td>
</tr>
<tr>
<td></td>
<td>draw</td>
</tr>
<tr>
<td><strong>Orientation:</strong> (a) to change position of body or body part relative to an object, person,</td>
<td></td>
</tr>
<tr>
<td>terrain, or event, or (b) to change position of an object or person relative to body or</td>
<td></td>
</tr>
<tr>
<td>body part or object</td>
<td></td>
</tr>
<tr>
<td>Criteria: to move with efficiency, speed, accuracy, and/or precision</td>
<td></td>
</tr>
</tbody>
</table>
Only two categories—functional tasks and related skills—are specified in this classification system; however, there are two other aspects—movement pattern and performance outcome—that may be added to provide a more complete perspective of the action process (see Figure 1). The functional task (what is to be accomplished), along with the constraining features of the performer and environment, specifies the actual skills that can be used to carry out the task. The particular skill is chosen on the basis of the performer’s perception of these relationships; moreover, the exact movement pattern or form of that skill also is determined by the performer’s perception of the task, the environment, and his or her personal attributes as well as the actual task, environment, and person constraints.

![Diagram](image)

**Figure 1** — The action process, from selecting a functional task to actual functional outcome (adapted from Newell, 1986).

Finally, the movement leads to a product or outcome, which should be evaluated in terms of the original task function. For example, the specific skills a lifeguard uses to go from a position on one side of a pool with a wet deck to a gate on the other side (functional task) might include swimming or walking (skill), but probably not running, depending on the guard’s personal attributes. A slippery deck, a megaphone in one hand, and a towel around the waist might modify the guard’s gait pattern (perhaps walking more flat-footed) (movement form) such that he or she reaches the gate later than usual (i.e., the functional outcome).

Invariant features of a task and variations within a task may be defined in terms of essential and nonessential variables, respectively. In ecological task analysis, it is imperative that the goal of a movement task remain constant across instructional variations of the task. Essential variables relate to the invariant features that define a particular class of movements, in essence, specifying the underlying dynamics (Kugler et al., 1980, 1982; Thelen et al., 1987). Shapiro
and Schmidt (1982) cite evidence suggesting that relative timing and relative force are two essential variables that appear to be invariant features within a given class of movements, again emphasizing the point that relations define the nature of a particular movement, not parts. An essential variable can be thought of as a constraint or function that "coordinates" or automatically enforces a relationship among several variables (Kugler et al., 1980). In Thelen et al.'s (1987) words,

a dynamical approach [related to essential variables] is low dimensional, and by abstracting the form of the movement, would reveal regularities inherent in the task despite great differences in scale that are not observable with a more microscopic analysis [high dimensional or related to particular parts or components]. (p. 42)

Nonessential variables, on the other hand, pertain to the changes in scale over which essential variables remain constant; that is, to the "control" or parameterization of the coordinating function (Davis, 1986; Kugler et al., 1980, 1982; Newell, 1986). In ecological task analysis, the term "dimension" is used synonymously with "nonessential variables" in the sense of its definition in both physics and mathematics. Physical dimensions are classified as fundamental or derived, with fundamental dimensions being length, mass, and time; derived dimensions are seen as involving a combination of fundamental dimensions, such as velocity or force. Mathematical dimensions, on the other hand, include any of the independent coordinates required to uniquely specify a point in space. The developmental task analyses put forth by Herkowitz (1978) and Morris (1980) primarily focus on physical dimensions or factors (such as ball diameter or velocity), but also include other dimensions that they suppose may be necessary to uniquely define a performer's behavior on the specified task (such as direction) (see Tables 1 and 2).

The scaling up or down of values on these dimensions, or nonessential variables, may not always linearly relate to a continuum from easy to difficult (Bingham, Schmidt, & Rosenblum, 1989; Kugler et al., 1980, 1982; Warren, 1984), contrary to an implicit assumption of developmental task analysis. For example, Bingham et al. (1989) found that when selecting objects for throwing to a maximum distance, preferred weights increased with an increase in size for the adult subjects but leveled off at about .23 kilograms.

Similarly, Burton and Welch (1990) found that as ball size increases, dribbling may become easier because larger balls (a) allow for a greater range of hand placement error and (b) bounce at slower speeds, which give the performer more time to make temporal and spatial adjustments. But, as Burton and Welch point out, "larger balls also require the application of greater downward force to maintain a dribble at a constant height than smaller balls and, at some critical size, may begin to interfere with the position of the hand relative to the body (i.e., the arm may need to be extended to dribble)" (p. 49). Thus, if there is an optimal ball size for dribbling and throwing for individual performers that is not the maximum or minimum size (Bingham et al., 1989; Burton & Welch, 1990), then the scaling of the ball size dimension must be portrayed as nonlinear.

Further evidence of dimensional nonlinearity is provided by the observation that there may be a critical point—for example either very large or very
small ball sizes—at which a particular task such as dribbling or catching will no longer be possible at all (for a discussion and examples of critical point, see Kugler & Turvey, 1987; Warren, 1984). In locomotion, as movement velocity is scaled up, a critical velocity will be reached at which the specified behavior (walking) will spontaneously transform into a qualitatively different behavior (running) (Shapiro, Zernicke, Gregor, & Diestel, 1981). In children with progressive muscle hypotonia, as in Duchenne muscular dystrophy, one often may observe "Gowers' sign," that is, the children moving to a prone position before attempting to stand and "walking up their legs" to get into a standing position (Gowers, 1879).

Some elderly adults also use a similar pattern of movement when rising to stand (VanSant, 1990). In other words, as strength is gradually scaled down, a critical point is reached at which the children and elderly adopt a qualitatively different movement pattern to stand up (Wallace & Newton, 1989). Critical transition points set the boundaries within which the essential variables of particular tasks remain invariant; that is, they provide the task analyst with a specific range of values across which a dimension may be varied without changing the skill or skill form used to perform the task. Unfortunately, there has been virtually no research related to determining the boundary conditions for any movement skills.

The scaling of a dimension value, besides providing information about critical point, also may be used to identify an optimal point. An optimal point may be defined as the dimension value at which the performance is most efficient (Warren, 1984) and/or most successful. Both critical and optimal points, when expressed as a proportion relative to critical performer attributes, should be the same for all performers with similar physical proportions.

Direct links should be established between the task goal and the constraints of the performer and the environment. In ecological theory, the goal or intentionality of the task is important because it "determines the relevant information" involved in planning and controlling the movement (Saltzman & Kelso, 1987). We may define a goal as the intended outcome of the task (Davis, 1989). Thus, in ecological task analysis it is necessary to identify the task goal in functional terms and to link it to the relevant properties of the performer and the relevant task constraints. The use of "performer-scaled" or "intrinsic" dimension units (Kugler, 1986; Kugler & Turvey, 1987; Warren, 1984) link the environmental and task dimension to relevant properties of the performer, while the use of performer-scaled dimensions to establish the boundary conditions of a task effectively link all three factors (task, performer, and environment) that specify the nature of the movement behavior.

Examples of absolute or extrinsic units of measure traditionally used for nonessential variables or dimensions such as diameter or height are centimeters, meters, inches, or feet. These can be transformed into performer-scaled units by selecting a dimension of interest (e.g., ball diameter) for a particular task (dribbling with one hand), identifying a relevant performer metric (hand width) expressed in the same absolute units (inches) as the dimension of interest, and dividing the dimension value by the performer value. This yields a performer-scaled ratio in which the absolute units cancel, expressing an invariant person-environment or person-task relationship across persons of different body sizes.
For example, the basketball-goal-height/standing-height ratio would be the same for a 6-ft person facing a 9-ft basket as for a 5-ft person facing a 7.5-ft basket (9 ft/6 ft = 7.5 ft/5 ft = 1.5 performer-scaled ratio).

As implied above, ratios involving units of length work out very easily and cleanly; however, dimensions involving other units of measure such as mass (or weight), velocity, time, or frequency may pose a problem. In the case of weight, a performer metric expressed in terms of weight (most likely total body weight) could be used. In the case of velocity or other derived dimensions with length included as a factor, a relative unit such as leg length could be substituted for an absolute unit such as yards, to express velocity in terms of leg lengths per seconds rather than yards per seconds.

In a study examining road-crossing behaviors in children and adults (Lee, Young, & McLaughlin, 1984), the time gap between vehicles on a street was made relevant to the performers by dividing the time gap by the actual time the performer needed to cross the street. This created an intrinsic or performer-scaled dimension in which a value above 1.0 should afford crossing the street. There also may be other cases like shape or direction, which may not be sensitive to scalar changes in any physical measure and simply may be left unchanged.

However, the dimensions that are easily observed and measured by the task analyst or researcher may not be the most relevant variables for a given task-performer-environment interaction. For example, the force of a moving ball as well as friction may significantly affect a performer’s ability to catch the ball (Davis, Clark, & DiRocco, 1990). A set of objectives for researchers should be to identify relevant environmental dimensions (scaled relative to the performer) and to determine the critical and optimal dimension values for different population groups and different task conditions. Even without this group based research, practitioners can find the relevant dimensions and the corresponding critical and optimal points on an individual basis by manipulating various dimensions and observing the change or lack of change in the movement pattern and outcome.

**Ecological Task Analysis**

Ecological task analysis is designed for both instruction and assessment of movement performance. In this section the procedures necessary to carry out an ecological task analysis (ETA) are described in detail, with the steps being based on the concepts elaborated. The advantages of this approach over other instructional and assessment methods also are presented.

**ETA Procedures**

The four major steps in setting up an ETA, which are based on the concepts derived from the ecological and dynamical movement theory, are listed in Figure 2. The first step is to identify the task in terms of its function or what needs to be accomplished (see Table 3 for five broad categories of function). This can be stated in the format of a traditional behavioral objective—including specification of conditions and criterion—except that the behavior should not be a skill, like a throw or jump, but a function. The task must be presented in a way that will allow the student to clearly understand the task goal, conditions, and criteria. Explanation and demonstration could be used, but structuring the immediate environment is essential (see Davis, 1989, for a discussion on this topic). Once
Steps:

1. Select and present the task goal—one of the functional movement categories. Structure the environment and provide verbal and other cues to the student that allow for an understanding of the task goal.

2. Provide choices—have the student practice the task, allowing him/her to choose the skill and the movement form. Observe and/or record the skill choice and movement form in qualitative measures and the performance outcome in quantitative or qualitative measures.

3. Identify the relevant task dimensions and performer variables. Manipulate one or two task dimensions to find the optimal performance level. Observe and/or record the skill choice, movement form, and performance outcomes in qualitative and/or quantitative measures, and compare results with previous measures.

4. Provide direct instruction in skill selection and movement form. Manipulate task variable to challenge the student. Observe and/or record the skill choice, movement form, and performance outcomes in qualitative and/or quantitative measures, and compare results with previous measures.

Figure 2 — Ecological task analysis model for assessment and instruction of movement tasks.

The functional behavioral objective is established, then the specific skills that may be used to carry out the task (there will usually be more than one) can be identified.

Step 2 is to allow the student choices. The student chooses the skill, the movement pattern and, where appropriate, the implement. For example, if the task is to propel an object (functional task), such as a soft ball, from third to first base (conditions) before the runner crosses the base (criterion), the possible skills could include throwing, striking, pushing, or carrying. In this case throwing appears to be the best skill choice, but the actual skill choice of the student needs to be identified. The functional criterion is somewhat variable, depending on the runner’s speed and the size and skill of the person playing first base, but it involves both ball speed (force-velocity) and accuracy limits.

The criterion must be a functional measure of the outcome (qualitative and/or quantitative) and is uniquely specified by each instance. For example, each runner moving at different speeds will give the thrower a different amount of time to make the throw to first base. The measure could be qualitative (the throw did or did not arrive accurately and/or in time to beat the runner) or quantitative
(actual throwing time relative to running time and accuracy as measured by distance from the target center).

Practice time is given, during which the instructor observes and evaluates the students’ initial skill and movement pattern choice and initial performance outcomes. What choices are made and how successful are the students in meeting the task criterion? This evaluation leads to the third step, identifying and manipulating the relevant task dimensions and performer variables (see Table 4). These task dimensions and performer variables may be derived directly from the conditions explicitly stated in the functional behavioral objective or from the implicit conditions. Dimensions that occur in natural performance contexts, such as throwing distance by baseball infielders or outfielders and ball speed and trajectory in catching situations, should be given top priority. Each task dimension must be considered relative to the relevant performer variables, such as the throwing distance relative to body size and strength (maximum throwing distance) or ball size relative to hand size in catching.

Table 4
Task Dimensions by Performer Variables by Category

<table>
<thead>
<tr>
<th>Categories</th>
<th>Task dimensions</th>
<th>Performer variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support surface</td>
<td>Height from ground; obstacles; regularity; slope; stability; texture; viscosity; friction; type of footwear; width</td>
<td>Base-of-support width; foot-length/CG ratio; height; region of reversibility</td>
</tr>
<tr>
<td>Object to be acted on</td>
<td>Static; color; shape; size; texture; weight; dynamic; direction relative to body; trajectory; velocity</td>
<td>Body-part surface area; height; limb length; weight; movement/reaction time; static limb strength</td>
</tr>
<tr>
<td>Equipment used to act upon object or environment</td>
<td>Flexibility; length; material/composition; shape/proportion; weight</td>
<td>Body-part surface area; height; limb length; weight; body-part dynamic strength</td>
</tr>
<tr>
<td>Response requirements</td>
<td>Accuracy (temporal, spatial); amount of time; consistency; distance; extent of joint motion; number of body parts; velocity</td>
<td>Flexibility/range-of-motion; height; limb length; weight; movement/response time; body-part dynamic strength</td>
</tr>
<tr>
<td>Information (prior, during, &amp; after)</td>
<td>Duration/delays (timing); quality/precision; quantity; relevancy; abstractness</td>
<td>Perceptual systems function</td>
</tr>
</tbody>
</table>

The heart of the ETA is assessing the student’s performance on the functional task across a set of one or more dimension values. Usually the dimensions are varied one at a time but combinations are possible (see Ulrich, 1988). The immediate objective for varying the dimensions is to first provide the student with success or, in ecological task analysis terminology, to assist in discovering the optimal point. For example, if the student is not being successful during the initial performance of catching, the ball size and/or trajectory may be changed. If catching is still not successful, another dimension may be varied.
If all possible dimensions are used without the student achieving success, then either the task goal and criteria or the task itself must be changed. However, the five task categories listed in Table 3 are achievable by nearly everyone given the appropriate conditions and criteria. Although a person with lower limb paralysis may not run, he or she can locomote given the appropriate assistive device. A person without vision can successfully receive an object if the relevant task dimensions are scaled to some critical value.

In Step 3, the instructor must guide the student in several ways. First, the task goal must be emphasized and the student must be encouraged to attend to the environmental information specifying that goal. Thus, for catching, the student should focus on the flight of the ball. Second, when the student is successful in achieving the goal, the instructor should acknowledge this. Success and its acknowledgment are important for motivation and learning (Sherrill, 1986). Third, after achieving success, the task must be made progressively more difficult to challenge the student. Whiting (1980) asserts that “to acquire skill does not mean to repeat and consolidate but, to invent, to progress . . . and the progressive refinement of solutions to motor problems posed by the environment” (p. 545).

Manipulating the relevant task dimensions relative to performer variables is the method of making the task more difficult without changing the task goal. By continuing to increase or decrease the value of the dimension, the boundary conditions or critical points of the task-performer relations may be determined. How far can the throwing distance ratio be changed before the student can no longer reach the target with the same movement pattern? Periodic practice at or near the critical points should extend these points or boundary conditions and make the skill performance more stable. Or, perhaps more important, the student may alter his or her throwing pattern to a more effective and efficient one, which may be what occurs as children advance in the developmental sequences (Kugler et al., 1982; Roberton, 1988).

As the dimensions are varied, the following assessment information should be recorded: (a) the function category and specific skill used to carry out the task; (b) the absolute dimension value; (c) when appropriate, the performer-scaled ratio; (d) the process or movement pattern used (a qualitative description such as overhand throw is often sufficient); and (e) the performance criterion in terms of a functional outcome.

The general instruction or assessment procedure may be modified in several ways. First, it may be possible to alternate between Steps 2 and 3 by allowing the choices to be made sometimes by the student and sometimes by the instructor. The choice may be made by the student initially and then the instructor may change the skill from throwing to kicking, for example, while maintaining the same functional category (object propulsion) and task criterion (accuracy). The student may then be allowed to choose the ball size. Second, more than one dimension may be varied either simultaneously, creating many different combinations, or one at a time (see Ulrich, 1988). And third, after the regular procedure has been completed, the student may be asked to perform again at the same dimension values, but with a particular skill form (movement pattern) that would allow for a comparison of what was spontaneously chosen with what actually could be done.

Although manipulating dimensions should result in positive changes in
movement pattern as well as performance outcomes, it may be helpful to subsequently assist the student in changing his or her movement pattern by direct instruction. Direct instruction on the movement pattern, the fourth step in the ETA procedures, includes the traditional demonstrations and passive positioning used to illustrate a desired movement pattern. However, it must be stressed that this step should follow the dimension manipulation procedures. Evaluating the movement form and performance outcomes and then comparing them to previous results are important procedures in this final step.

Advantages of ETA

The consequence of these procedures provide many important clues for use in planning future instructional strategies for the student. These clues include the following: (a) under what set of conditions the student is able to achieve the task; (b) the set of conditions that elicit the most efficient and effective (optimal) performance; (c) the dimension values at which the student chooses to use a different skill or to perform a skill in a qualitatively different way or fails in the task (critical point or boundary conditions); (d) the student's relative flexibility or rigidity in applying various movement solutions (skills and movement patterns) to a range of movement problems (i.e., sets of task conditions); and (e) the student's consistency in applying the same movement solution to the same movement problems.

In addition, the ETA provides a means of directly comparing a student's optimal and critical points for a particular skill with the mean optimal and critical points for other populations (such as those with or without disabilities) through the use of performer-scaled ratios, as allowed by existing research. When the student's optimal and critical points significantly differ from the standard values—as when he or she chooses to use a different skill or skill form than is usually seen at a particular set of conditions—there is also information regarding whether the student can actually perform the standard skill or skill form.

Tables 3 and 4 provide a first approximation of some of the task categories, corresponding skills and dimensions, and performer variables relevant to physical education. The lists are not complete and research is required to test the validity of the current items. However, this work represents an important step toward a more flexible, dynamic, function based program that accounts for individual differences and a step away from the traditional categorical labeling and neurophysiological approaches.

The ecological task analysis approach is equally applicable to instruction and assessment. In regard to the latter, it addresses some of the problems in assessment in physical education that were pointed out by Davis (1984). First, most standardized motor assessment tools are designed to include the least number of tasks necessary to gain an accurate sample of the defined domain of functioning and to minimize the range of environmental conditions under which each task is performed. This may be necessary and sufficient for standardized tests, which primarily are used when comparing groups or when comparing an individual to an age norm, but this type of test yields little useful information regarding instructional programming. The ETA (and Ulrich's [1988] "comprehensive systems approach to assessment") includes the measurement and manipulation of environmental conditions, which Davis (1984) considers to be an essential ingredient of the assessment procedure.
Second, most motor assessment instruments are designed to be used with children across a wide age range, but the obvious differences in physical size across age and the effect of these differences on performance are rarely considered. Davis (1984) notes that some physical measures may be recorded but they usually are not directly linked to the performance variables. Many tests partially account for physical differences by standardizing scores relative to the means and standard deviations for each age group (i.e., transforming raw scores into standard scores), but they fail to account for different size children who are the same age. In the ETA, environmental dimensions and performance criteria are expressed in performer scaled units whenever appropriate to control for differences both within and across age groups. Using performer scaled units allows behavior objectives to be written for a group of students and yet can be applied fairly to each individual.

And third, most assessment tools used in adapted physical education focus either on abilities (e.g., the Bruininks-Oseretsky Test of Motor Proficiency, Bruininks, 1978) or skills (e.g., the Test of Gross Motor Development, Ulrich, 1985), with no regard for the actual function of these abilities or skills. Further, some tests evaluate qualitative differences in the process used to perform a particular skill (e.g., the Test of Gross Motor Development, Ulrich, 1985; the Ohio State University Intra Gross Motor Assessment, Loovis & Ersing, 1979). However, few if any tests allow the student to choose which skill to use to accomplish a particular functional task. In contrast, Davis (1984) suggests that abilities and skills are meaningless when they are placed outside of a functional context. Similarly, Ulrich (1988) defines movement competence, the construct of interest in most motor assessment tools, as “displaying correct target behaviors in appropriate settings” (Hogg & Sebba, 1987) (p. 43). The ETA includes assessment of choices at both skill and skill-form levels (see Figure 1), emphasizing the functional context of the student’s performance.

Theoretical and Applied Research

Ecological task analysis offers practitioners a functional alternative to traditional task analysis methods, providing essential information regarding the factors that influence a student’s movement behavior and subsequent clues for designing instructional programs. However, the most important aspect of ETA may be its foundation on theory and basic research. Christina (1988) strongly recommends that research in motor behavior follow both tracks, basic research and applied research, in order to build a specialized body of practical knowledge that parallels the body of fundamental knowledge of basic research (p. 420).

The benefits of this approach to research is that it (a) provides an empirical basis for practical endeavors, such as teaching; (b) offers the opportunity to validate theories in terms of practical applications; (c) indicates how theories may be modified or whether they need to be discarded completely, pushing forward the pursuit of basic knowledge; and (d) as new or modified theories are generated, suggests how practices may be improved even further. There has been little of this type of parallel research in the past 15 years (Christina, 1988), but the ETA provides a model of how this process may be actualized. The first step is the translation of theory into practical applications, which was described in the preceding subsections on ETA; the next step is the clear statement of theoretical
assumptions or hypotheses which may be subjected to empirical scrutiny, providing the focus of this section.

The key assumption of the ETA is that for each skill or skill form used to achieve a particular functional goal, there are optimal and critical points, expressed whenever appropriate in performer-scaled units, which are invariant across persons of different physical sizes. This assumption or set of assumptions, then, leads to several research questions. The three related questions to be elaborated here address (a) identifying and ordering relevant task dimensions, (b) identifying optimal and critical points and testing the invariance of these points across persons of different ages, physical sizes, and/or developmental status, and (c) comparing subjects on their perceptual judgment or sensitivity to the environmental and task constraints relative to their own capabilities.

In addition the ETA model itself must be tested, for example by comparing it against contrasting approaches such as the part-whole method with respect to movement skill acquisition. While studies comparing teaching methods are often plagued with methodological difficulties, such comparison may be somewhat easier here because it could be limited to one movement function such as object propulsion.

Implicit in the assumption of invariant optimal and critical points is the identification of relevant dimensions or factors and, when appropriate, related performer variables, in terms of which of these points are expressed. Thus one possible research question concerns the identification of the dimensions that significantly influence the performance of different movement skills and the ordering of these dimensions in terms of which ones account for the most performance variance. Differences across age and handicapping conditions also should be considered in addressing this issue. It may not be possible to obtain a true dimensionless number (ratio in the same units) for some dimensions. For example, as stated previously, variables of length and size (geometric) are considerably easier to measure than kinetic variables such as force and strength (energy expenditure). However, an approximation is possible and will yield useful information. Thus, using limb length and size in place of strength is possible.

Another example is to use stride lengths per second instead of feet per second, which can be a measure of a performer characteristic to compare with the speed requirement of the task. Then groups that vary in absolute stride length could be compared on jumping form and distance or accuracy in hitting the takeoff board, for example, by manipulating the task speed to the length/speed ratio. Thus, whether running speed was an important relevant dimension for the accuracy of hitting the takeoff board and for jumping distance and form could be determined. Other dimensions could then be identified and compared on their relative contribution to jumping. Both Herkowitz (1978) and Roberton (1988) have expressed the need for research on this question.

More than one skill and more than one form of a skill may be used to achieve a particular functional goal; accordingly, the second possible research question relates to the critical points at which the skills or skill forms change and the invariance of these critical points across persons of different ages, physical size, and/or developmental status. A recent study directed at some of the issues embodied in this second question was carried out by Burton (1990).

In Burton's study, developmentally disabled (DD) preschoolers, nonhandi-
capped (NH) kindergartners, and NH fourth-graders were asked to locomote through a sequence of four high-jump type barriers of variable heights as quickly as possible. The particular modes of locomotion that the subject used in negotiating each barrier height (e.g., jump over, step over, crawl under) was recorded and the critical transition points (expressed in terms of relative height or the barrier height/leg length ratio) for two separate transitions to qualitatively different movement behaviors as height was scaled up were calculated. For example, the transition from going over to going under the barrier occurred at 0.96 of the NH fourth-graders’ leg length, at 0.88 of the NH kindergartners’ leg length, and at 0.68 of the DD preschoolers’ leg length. Thus, at least for this one critical transition point, there were significant differences between the DD and NH children who were the same age but not between the younger and older NH children.

The same research question may be asked pertaining to the invariance of optimal points as well as critical points for various skills or skill forms across persons of different ages, size, and/or developmental status. Along these lines, two experiments reported by Warren (1984) were devoted to comparing the differences between short and tall men in the relative stair height (expressed in terms of a riser height/leg length ratio) determined to be energetically optimal to a biomechanical model. In the first experiment, Warren had measured subjects’ perceptions of the optimal (most comfortable) stair height, which he also compared to the relative stair height which actually was energetically optimal. Consistent with the stated assumptions, Warren found that the perceived optimum relative stair height was 0.25 for both short and tall men, which closely matched the actual optimum relative stair height of 0.26 for both groups.

As indicated, both studies posed a third research question regarding the awareness of subjects to the environmental and task constraints relative to their own capabilities in achieving task goals (knowing their optimal and critical points). This question is referred to as perceptual judgment or perceptual sensitivity and it has been answered in two ways. One approach is to present various task conditions visually and ask subjects to verbalize their capabilities. Subjects’ answers are then compared to their actual performance of the task under each condition as in Warren’s (1984) study.

The other approach is to present the conditions to subject groups who vary in their general motor skills and observe their movement behavior and success in completing the task, as in the study by Burton and Welch (1990) which was described earlier. Forsstrom and von Hofsten (1982) used a similar approach and found that subjects with motor impairments were able to compensate for their slow movements by changing the angle of reach to catch a moving object. This suggests that the subjects correctly perceived the movement task relative to their own limitations, contrary to the results of the Burton and Welch (1990) study.

Using the first approach, Warren (1984; Warren & Whang, 1987) and Mark and Vogele (1987) found subjects to be very accurate in judging geometric constraints posed by stair heights, passageways, and chair heights. On the other hand, Davis et al. (1991) found both nondisabled and mentally disabled subjects (including Down syndrome) to be relatively less accurate in judging their ability to pick up a large ball with one hand. This was especially true in attempts to catch a maximum size ball that was moving. The subjects with disabilities were significantly less capable than those without disabilities.
Summary

A confluence of theory and application has been achieved through a new approach to task analysis. Ecological task analysis is equally applicable to assessment and instruction as well as to applied research, and it offers several advantages over the traditional approaches. Although considerable work remains in order to validate the model, refine its use, and expand its application, it is a step toward a more flexible, dynamic, and functional instruction and assessment program and a step away from the traditional approaches to teaching and therapy used for populations with disabilities. The three basic research questions derived from the key assumption of the ETA define a broad systematic program of research which has the potential to unify the efforts of basic and applied researchers in building a body of fundamental knowledge useful to theorists and practitioners alike. Currently the literature related to both motor development and adapted physical education consists of many isolated studies that do little to build theory or push forward our basic knowledge in these areas (Roberton, 1988).

References


**Acknowledgment**

A special thanks to the graduate students whose comments and questions have been very valuable in formulating and clarifying the ideas expressed here.