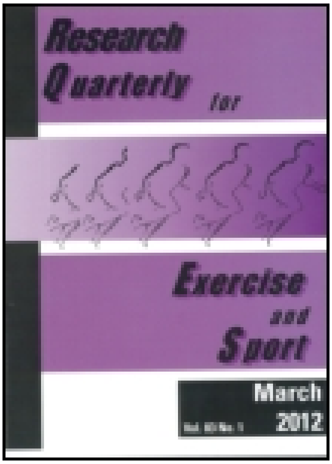

Research Quarterly for Exercise and Sport
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/urqe20

Developmental Characteristics of a Forward Roll

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Published online: 22 Feb 2013.

To cite this article: Kathleen Williams (1980) Developmental Characteristics of a Forward Roll, Research Quarterly for Exercise and Sport, 51:4, 703-713, DOI: 10.1080/02701367.1980.10609331

To link to this article: http://dx.doi.org/10.1080/02701367.1980.10609331

RESEARCH QUARTERLY
FOR EXERCISE AND SPORT
1980, Vol. 51, No. 4, pp. 703-713

Developmental Characteristics of a Forward Roll

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A category checklist of developmental characteristics for the forward roll, modeled after Roberton's "component" approach, was hypothesized for this study. The categories were used to examine the usefulness of a component approach for describing actions occurring during the forward roll. Age-relatedness of category sequences was also explored. Three components were defined: hand/arm, head/neck, hip/leg. Each component was divided into phases which described the temporal course of actions occurring throughout the forward roll, from initial hand placement to heel strike. Within each component phase were hierarchically arranged steps, ordered from primitive to advanced. The potential usefulness of the components as a developmental checklist was examined using three criteria: (1) the comprehensiveness of the category system for describing observed movement behaviors; (2) the observed ordering of each component sequence in relation to the hypothesized ordering; and (3) the sign of the slopes of the age-related functions generated from the data. Results were based on cinematographic analysis of 243 filmed trials of the forward roll performed by 5-, 7-, and 9-year-old children ($N = 49$). The results indicated that the hypothesized category system for the forward roll was an objective and comprehensive descriptor of the observed movement configurations in the children tested. Additionally, five of the seven component phases met the criteria suggested for the screening of potential developmental sequences: (1) proper sequence order and (2) correct sign of the slope of the developmental functions. That is, younger children were categorized at lower component steps more often than older children; older children were more likely to be categorized at higher levels of behavior. Further testing using longitudinal data would be appropriate for these five phases, to examine whether they are indeed valid developmental sequences. Steps within the remaining two component phases were apparently misordered, or ill-defined. Further cross-sectional study of the phases would be needed before longitudinal validation.

Kathleen Williams is at the University of Wisconsin-Madison, Madison, WI 53706. This study was completed in partial fulfillment of the M.S. degree in the motor development and child study laboratory, Department of Physical Education and Dance, at the University of Wisconsin-Madison, under the direction of Lolas E. Halverson. The author would also like to acknowledge the guidance of Mary Ann Roberton and Margaret J. Safrit, Committee persons, and Stephen Langendorfer for his comments on earlier drafts of this manuscript.

Researchers have used several approaches for formulating descriptions of developmental categories of motor skill. Shirley (1931) developed a loose hierarchy of motor patterns that she called "stages" of locomotion. This inter-task appraisal described a sequence of precursors to upright posture and bipedal locomotion. Other researchers have described intra-task stages (Roberton, 1978), detailing the development of a single skill from its first appearance through its "adult form." Wild (1938), for example, described four stages leading to an advanced pattern of the overarm throw. McGraw (1945, 1963) described phases of infant motor skill development for a number of activities such as swimming, erect locomotion, and climbing.

These researchers used both cross-sectional and longitudinal data to infer or verify changes they observed in motor skills. Cross-sectional study is a weaker methodology, however, since change cannot be observed directly when comparing several age groups. More time consuming and expensive longitudinal study is necessary for the direct observation of change (Wohlwill, 1973). Cross-sectional study is an appropriate first step toward identifying developmental sequences, since any sequence which is supported cross-sectionally can be tested further longitudinally. Those sequences which do not may be eliminated or revised (Roberton, Williams, & Langendorfer, 1980).

Roberton et al. (1980) have outlined a specific procedure for screening potential developmental sequences, using cross-sectional data. Briefly, the investigator hypothesizes a developmental sequence for the motor skill of interest. The proposed sequence may be based on filmed data or direct or videotaped observations. It represents the investigator's best-guess description of the order of changes occurring in the particular motor skill. Then, several groups of individuals of different ages are sampled and their performances are studied. High-speed cinematography is a useful data gathering technique for this purpose. Individual trials may be viewed in slow motion, and evaluated in terms of the criteria specific to the component sequence.

The observed cross-sectional data are then compared with the hypothesized longitudinal results. The pattern of results for both types of data should be similar. For example, if a group of children was observed longitudinally, they would be expected to demonstrate less mature behaviors when young, and more mature actions when they were older. When examining cross-sectional data, younger children would be expected to exhibit low level (less mature) behaviors, while older children would exhibit higher level (more mature) behaviors. Therefore, hypothesized sequences which appeared to be properly ordered when compared with cross-sectional data could be tested further longitudinally. Criteria for making these judgments will be outlined in a later section of this paper.

Whether they are based on cross-sectional or longitudinal data, most developmental sequences have been conceptualized as progressions of synchronous total body change (Wickstrom, 1977). That is, all body parts and segments are discussed as changing in unison. In contrast, Roberton (1976, 1978) found that development did not seem to occur at the same rate in all parts of the body. In her studies of the overarm throw for force, she found that changes in the trunk, for example, could be preceded or followed by changes in the legs or throwing arm. Segmental change was asynchronous.

To accommodate these intersegmental differences in developmental rate, Roberton (1976, 1978) formulated a "component approach" for describing motor skill development. Movement components were defined as "joint action combinations that together comprise the total body's movement as it performs a motor task" (Roberton & Halverson, 1977, p. 36). Each component exhibited hierarchically arranged levels of development called "steps." The rate of progression through the steps within and across components could vary from individual to individual.

Studies by Roberton and Halverson (1977) and Williams (Note 2) provided evidence suggesting that orderly changes were occurring throughout the development of the forward roll. In these previous investigations of the skill, developmental change had been analyzed in terms of total body configuration (Williams, Note 2) and using the component approach (Roberton & Halverson, 1977). The existence of these preliminary studies suggested a more extensive investigation of the forward roll was appropriate.

In each of the earlier studies, certain characteristics were hypothesized to occur as individuals gained skill in performing the task. Substantial agreement existed between the studies, although Williams (Note 2) admitted having to "force-fit" individuals into her originally described stages of development. "It was found that many children possessed characteristics which cut across several of the hypothesized stages. . . . Therefore, an attempt was made to determine a major characteristic which separated each stage" (Williams, Note 2). The implication of her finding was that the total body *does not* change in unison. Results from Roberton and Halverson (1977) also suggested that asynchronous change was occurring between body segments. They hypothesized three major components for the forward roll. As with the overarm throw, one segmental action might change while another remained the same.

A "component approach" for the description of developmental sequences for the forward roll seemed most compatible with existent data and was selected for use in this analysis. The following study was designed to investigate further the development of the forward roll. The study had two purposes: (1) to examine the validity of the hypothesized component steps as descriptors of observed movement and (2) to determine whether the category system described developmental sequences by identifying the relationship between component steps and the ages of the children.

Procedures

Development of the Component System

The components hypothesized in this study were based on (1) an analysis of longitudinal, filmed data from the Ontogenetic Study of Selected Motor Tasks (Halverson, Roberton, & Harper, 1973) at the University of Wisconsin-Madison motor development and child study laboratory; (2) analysis of films from other studies of the forward roll (Snowden, Note 1; Williams, Note 2); and (3) literature related to the forward roll (for example, Kirchner, 1974; Schurr, 1975). Filmed data included approximately 100 filmed trials of children ranging in age from 3 1/2 to 17 years of age.

Three major components were identified: hand/arm action, head/neck action, and hip/leg action. Within the components were temporally distinguishable divisions called initial, middle, and late phases. Within each phase were steps hypothesized to develop hierarchically from primitive to advanced. For example, the initial phase of the head/neck component described the beginning head placement on the surface. The three steps within this component phase hypothesized a trend toward using the head for increasingly less support while inverted. Table 1 illustrates the organization of the component system hypothesized for this study.

Data Collection and Reduction

The subjects for this study were 49 children aged 5, 7, and 9 years, randomly selected from a Madison (WI) elementary school. Within the 5- and 7-year-old age groups were eight boys and eight girls; within the 9-year-old age group were nine boys and eight

Table 1—Organization of the Component System for the Forward Roll

Component name:	Hand/Arm	Head/Neck	Hip/Leg
Phases:[a]	Initial (3)[b]	Initial (3)	Initial (2)
	Middle (4)		
	Late (3)	Late (3)	Late (4)

[a] Each phase is a temporally distinguishable division within the forward roll. For example, the initial phase of the hip/leg component encompasses the time period from inversion to loss of balance; the late phase encompasses that period following balance loss to hip and heel strike.
[b] Numbers in parentheses indicate the number of steps within each component phase.

girls. All received physical education instruction twice weekly. All but one child knew what a forward roll was.

The children were filmed individually, without prior instruction or demonstration. Five trials of a forward roll were filmed for each child. Each trial began in a standing position. A 16 mm, motor-driven Milliken camera (Model DMB-5) was used to film the trials from the side. The film speed was 64 frames per second. Subject to camera distance was 30 feet.

During data reduction, individual trials were projected onto a movie screen using a Lafayette Film Analyzer. The film analyzer permitted variable speed projection, stop action, and frame-by-frame viewing of individual trials. Each trial was classified according to specific criteria developed for individual component phases.[1] Two subjects had only four trials of sufficient clarity for viewing, making a total of 243 trials available for data analysis.

Reliability of Categorizations

A second judge, who was a graduate student specializing in motor development, was trained to use the category system. Following this training, 25 trials were chosen randomly and were categorized independently by the principal investigator and the second judge. Percent of exact agreement between judges was used as a measure of objectivity. Inter- and intra-judge scores were calculated and compared with an a priori criterion level of 84% exact agreement (Roberton, 1976). Across the component phases, inter-and intra-judge percent of exact agreement ranged between 84%-96%, indicating an acceptable level of objectivity for all component phases. The 243 trials were therefore analyzed and categorized by the principal investigator.

Analysis of the Data

Randomization of subjects was used to determine the ordering for the reduction of all first trials, second trials, and so on. This procedure was used to avoid possible biasing effects from viewing consecutive trials for a single subject. Even so, all the children were placed in the same category within each component phase in 50% or more of their trials. These children were consistent in their performance of a forward roll, as judged by this component system.

The data for each proposed category were then tabulated and graphed across all the

[1] A complete description of the component checklist and the criteria for judgment may be obtained from the author.

children, as well as by age. The graphed data were examined relative to these three criteria:

1. Comprehensiveness and inclusiveness of the categories. Were those movement behaviors described in the categories observed in the children? Were other behaviors observed that had not been seen previously?

2. Accuracy of the observed age-related ordering for each component sequence as compared with a hypothesized ordering (Roberton et al., 1980). Did the youngest children consistently demonstrate less mature behaviors while the oldest were characterized by more advanced behavior?

3. Accuracy of the sign of the slope of the age-related functions for each component phase (Roberton et al., 1980). Did graphs of immature behaviors exhibit a negative slope (i.e., a decrease in frequency of occurrence) with increasing age and the concomitant occurrence of other behaviors? Did functions for the intermediate steps have a positive slope (increase in frequency), as lower level actions decreased in their frequency of occurrence? Did the slope of the functions for intermediate steps become negative when more mature behaviors were simultaneously observed? Finally, did graphs of the highest steps (most mature) have a positive slope when paired with the negative slope of intermediate steps?

The questions posed in the latter two criteria explore the potential of the component steps to detect developmental changes in the actions of the forward roll. An affirmative answer to the questions suggests that the component steps tested in this study may be age-related. Generally speaking, younger children would exhibit less mature behaviors; older children would exhibit more mature patterns. Specific answers to these questions will be addressed in the following section of this paper.

Results and Discussion

The results of this study will be discussed in relation to the three previously outlined criteria:

Comprehensiveness and Inclusiveness of the Component System

The hypothesized system of components was a useful descriptive tool for the observation of movement configurations in the children studied. Every hypothesized step within each component phase was observed in the sample of children tested. Not unexpectedly, some steps occurred more often than others. As shown in Figure 1, step A of the initial phase of the hand/arm component (the most primitive) was observed in only 2% of the total trials. In contrast, step B of the initial phase of the hip/leg component (an intermediate level of development) occurred in 92.6% of the trials. The frequency of occurrence of other steps ranged between these extremes. Only one action that had not been hypothesized previously was observed among the children. This new action was seen in the middle phase of the hand/arm component. There were other difficulties with this particular phase, however, which will be discussed in the final section.

Age-Related Order of the Sequences and Sign of the Developmental Functions

Conclusions regarding the order of the sequences were made based on the degree of age-relatedness found when graphs of the observed data were compared with hypothetical, properly ordered curves (Roberton et al., 1980). Relationships between the hypothetical curves served as guides for comparison with observed data. Two relationships were of particular interest: (1) the order of the curves: Some portion of the curve representing the least mature level must precede the appearance of the curve represent-

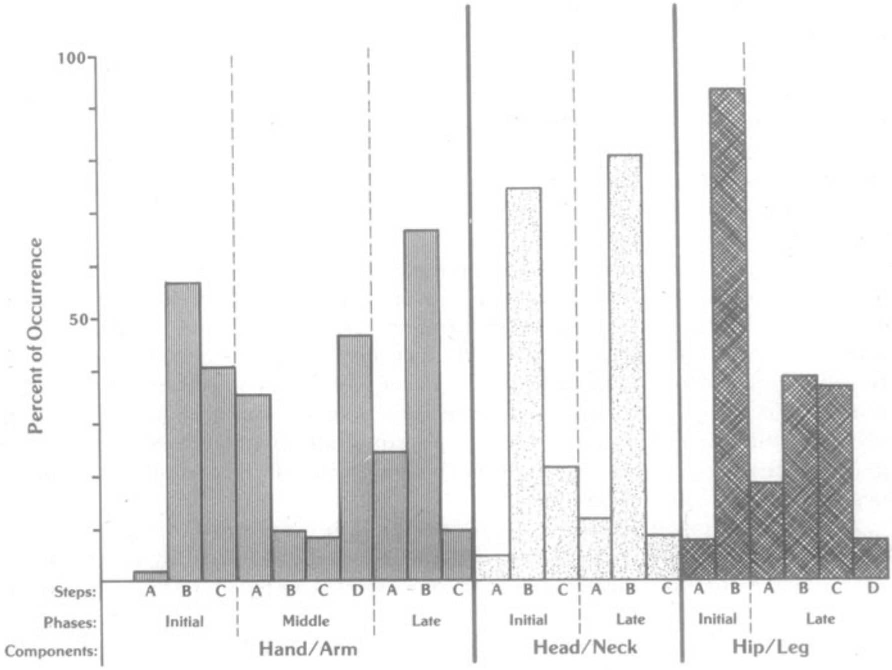

Figure 1—Percent occurrence of steps within component phases across the total sample. (Within each phase, step A is most primitive; the remaining steps are hypothesized to be hierarchically more advanced.)

ing the next level of behavior; intermediate levels will, in turn, precede the occurrence of higher levels; and (2) the sign of the slopes of the curves: This second characteristic is more easily visualized as the direction of the particular curve. The insert on Figure 2 illustrates these relationships. For example, the most primitive step (A) would be observed most often in the youngest children (and precedes the occurrence of step B). It would be found in progressively fewer children of increasing age. Step B would be found at an initially low level in the youngest children; it would first increase in incidence with age, and later decrease. This decrease in step B would coincide with an increase in the occurrence of step C (the highest level).

The skewness and kurtosis of curves generated from actual data could differ with different rates of development found within and between samples (Roberton et al., 1980). The relative order of the curves and the sign of the slopes for individual curves would not vary, however.

Five of the seven component phases appeared to be properly ordered. These were: initial and late phases of the hand/arm component; initial and late phases of the head/neck component; and late phase of the hip/leg component. Definitions for each component phase are given in Table 2. Although the curves generated by the cross-sectional data did not show a perfect correspondence to age, they resembled the hypothetical curves closely. The curves shown in Figure 2 were typical of these results. The figure was generated from the data for the late phase of the hand/arm component. In this example, step A occurred more frequently than the other steps at age 5. This lowest

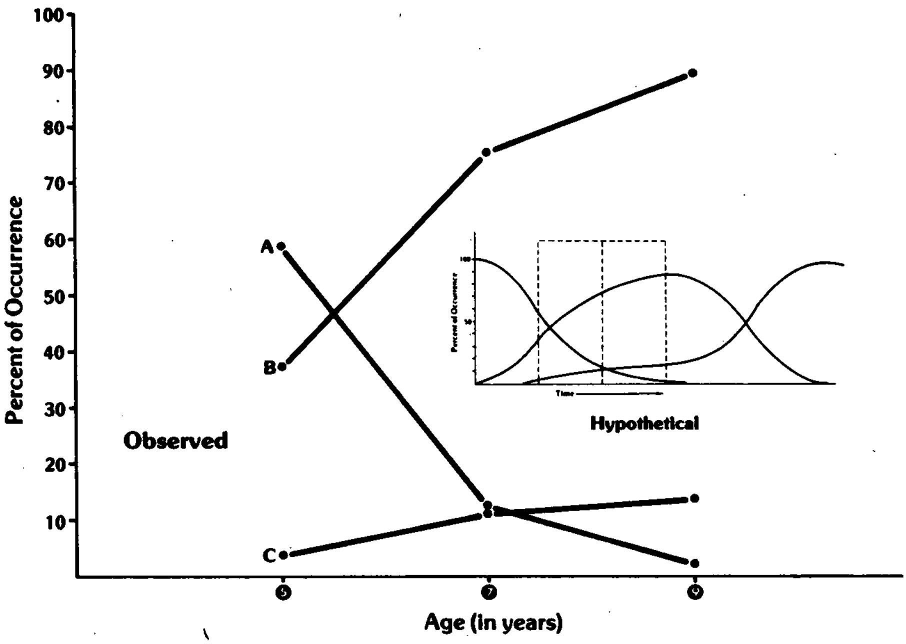

Figure 2—Late phase of the hand/arm component. (The insert illustrates the placement of the observed data on ideal age-related curves.)

step was observed in progressively fewer of the 7- and 9-year-olds, however. While step B was observed to a lesser extent than step A at age 5, it appeared more often than any step by age 7. Finally, the occurrence of step C increased gradually from age 5 to 9, suggesting it was on the rise, and would presumably continue to increase in occurrence if older children had been sampled.

The sign of the slope of each function in the late phase of the hand/arm component also closely approximated the model, as can be seen by comparing the enclosed portion of the insert in Figure 2, with the figure itself. That is, the function for step A exhibited a negative slope, while the function for step B had a positive slope. Between 7- and 9-years, the slope remained positive, but did not rise as steeply as in the younger children. The slope of the function for step C was also positive, but it rose very slowly in this sample of children.

Other component phases meeting this criterion were: initial phase of the hand/arm component, initial and late phases of the head/neck component, and late phase of the hip/leg component. They differed in the amount of skewness and kurtosis and their position along the horizontal axis. For example, the late phase of the head/neck component intersected the curves in a position that was far to the right (i.e., more children exhibited higher level behaviors).

The relatively low occurrence of step C for the late phase of the hand/arm component, and concomitant high occurrence of step B was characteristic of four other component phases. That is, intermediate steps were observed most often across the entire sample. These results can be interpreted to mean that an insufficiently wide range of skill was evidenced by the sample of children filmed for this study. Had a wider age

Table 2—Descriptions of Steps Within Component Phases for the Forward Roll[a,b]

Component	HAND/ARM	HEAD/NECK	HIP/LEG
STEPS[c]	INITIAL PHASE OF THE FORWARD ROLL		
A	*Hands used unequally* —collapse to side may occur —frontal alignment of hands is uneven —angle at elbow approximately 45°	*Vertex of head is initial point of contact* —dorsiflexion of head on neck with loss of balance	
B	*Broad base of support by hands* —ventrally or laterally —angle at elbow is greater than 90°	*Vertex is initial point of contact* —ventroflexion on chest with initiation of rotary action	
C	*Narrow base of support by hands* —hands in line, slightly ventral to head —elbow angle approximately 90°	*Crown of head is initial point of contact* —head remains ventro-flexed throughout rotary action	
	LATE PHASE OF THE FORWARD ROLL		
A	*Humeral abduction with balance loss* —elbow angle approximately 90° —elbow held laterally —wide base of support	*Shoulders remain on surface* —until lower back contacts surface	*Hip/knee extension exceeds 120°* —with lower back contact
B	*Hands contact surface next to hips with contact of hips* —active elbow extension with balance loss —hands used to push to feet	*Shoulders remain on surface* —until midback contacts surface —neck extension with thoracic contact	*Hip extension greater than 90°; knee flexion* —with lower back contact
C	*Arm position remains ventral (do not contact surface)* —active extension of elbows —humeri flexed horizontally	*Sequential loss of contact with surface* —neck remains ventro-flexed throughout	*Hip extension less than/equals 90°; knee extension to 120°* —with lower back contact
D			*Hip extension less than 90°; knee flexion 20° or less* —hip/knees remain flexed throughout

[a] Only the five component phases which showed some evidence of proper sequencing are listed.
[b] Full descriptions and decision rules for each component phase may be obtained from the author.
[c] Designates a step within a component phase: 'A' is most primitive; others are progressively more advanced.

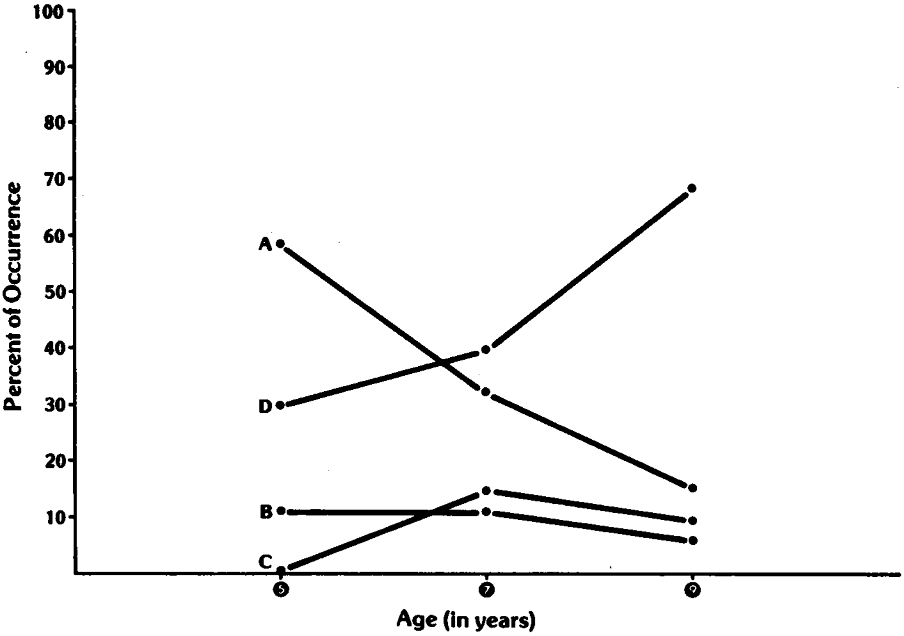

Figure 3—Middle phase of the hand/arm component. (The curves represent misordering within the sequence since the occurrence of step D was greater than the intermediate steps, even at age 5.)

range been selected, the age-relatedness of the steps within the component phases might have been shown more clearly. This conclusion seems appropriate since component phases were hypothesized originally from observations of children aged 3 1/2 to 17 years. Of course, longitudinal study is necessary for further verification.

The hypothesized developmental steps within two component phases did not approximate the age-related model. The phases were the middle phase of the hand/arm component and the initial phase of the hip/leg component. Steps within each appeared to be misordered. Figure 3 illustrates this misordering. Step A decreased with age, as would be expected. The intermediate steps, B and C, were observed almost equally across the ages sampled. The problem was that *at no time* was step D observed less often than the intermediate steps. Even at age 5, it was the category observed more often than B and C combined, and its occurrence continued to increase through age 9.

These results indicated that this component phase required further revision. It failed to meet the criterion for sequence order as proposed by Roberton et al. (1980). Analysis of the data suggested several possible causes for the misordering. First, at least one additional behavior was observed in the sample of children that had not been observed or hypothesized originally. Even when accounting for the new behavior, however, there remained a difficulty with misordering. An alternative explanation was that the component phase did not describe a developmental action at all. There were similar problems related to the initial phase of the hip/leg component which also required additional specification prior to further validation.

Finally, the data for each subject were studied. Component "profiles" were formed for individuals by graphing the observed steps for each component phase. These profiles were studied for any recurrent patterns or combinations of steps which occurred across several component phases. If particular steps for several component phases were repeated consistently, this would suggest the possibility of total body changes, or at least the presence of broader, more encompassing components. No such patterns were observed within the sample of children tested, however. Instead, a large number of different combinations were observed. Only one complete profile was repeated as many as five times. There were a number of combinations of two to four steps which were observed with greater regularity. The presence of these smaller groups of steps suggests that, following further study, some component phases might require redefinition. The failure to find more repetition across all the component phases supports the use of a component approach (Roberton, 1976, 1978) for studying the development of the forward roll.

Conclusions

Seven component phases, tracing the development of the forward roll, were hypothesized for this study. Actions of the hands and arms, head and neck, and hips and legs were defined as separate components. Certain results were apparent from this cross-sectional study. First, the hypothesized category system for the forward roll described observable movement configurations in the children tested. Second, five of the seven component phases met the criteria of sequence order and sign of the slope of the developmental functions suggested for the screening of potential developmental sequences. That is, younger children were categorized at lower component steps more often than older children; older children were more likely to be categorized at higher levels of behavior. These data showed a clear relationship to age. Further validation using longitudinal data would be appropriate for these five phases. In the same five component phases, intermediate steps were chosen most often. This overrepresentation indicated the need for a broader range of skill among the children tested, so that the age-relatedness of the steps within component phases might have been demonstrated more clearly.

Steps within the remaining two component phases were apparently misordered or ill-defined. They failed to meet the criterion for sequence order. Two reasons for the misordering were suggested: (1) at least one behavior was observed that had not been seen previously or (2) the processes described by these two component phases might have been nondevelopmental in nature. Further study of the phases was suggested to resolve these questions.

Finally, a component analysis of the forward roll was supported by the results of this study. When component profiles for each child were compared, very little repetition was observed across the sample tested. Smaller groups of two to four steps were repeated throughout the sample, suggesting that further study might lead to the regrouping or redefinition of some component phases.

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Submitted: 26 September, 1979
Accepted: 13 February, 1980