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ABSTRACT

The purpose of this article is to briefly describe schema theory and indicate its relevance to early childhood development, with specific reference to children's acquisition of motor skills. Schema theory proposes an explanation of how individuals learn and perform a seemingly endless variety of movements. According to Schmidt (1975), goal directed movement leads to storage of initial conditions, response specifications, performance feedback, and result. These four sources of information combine to produce a motor schema that enables repetition of a movement or performance of a new variation of it. A major prediction of schema theory is that increasing variability in practice on a given task will result in increased transfer to a novel task of the same movement class. Numerous studies reporting support for the variability hyothesis have been generated using young children as subjects and gross motor skill as the task. These findings have important practical implications for the structure of practice sessions with children. Schema theory predicts that practicing a variety of movement outcomes within the same general skill class will provide a diverse set of experiences upon which a schema may be enhanced. Generally, schema theory supports the practice during the early years of problem-solving within the same class of movements and rules rather than instruction in specific sport skills. (RH)

Motor Skill Learning In Children

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Abstract

One of the recent major developments in the understanding of motor skill learning in children has been the establishment of schema theory (Schmidt, 1975). Few theories of motor behavior have stimulated as much inquiry and had the general support from the scientific community as this notion. This article presented a synthesis of the theoretical framework and implications for program application relevant to motor learning in children.

Motor Skill Learning in Children

The notion of a schema as the underlying mechanism in cognitive behavior held a central and well accepted place in Piaget's theory of child development (Piaget, 1952, 1970). While such a mechanism has been described in the motor behavior literature for some 65 years (Head, 1920; Bartlett, 1932), it nevertheless seemed to have been forgotten until Schmidt (1975) reintroduced it in his schema theory of motor learning. The purpose of this article is to briefly describe schema theory and its relevance in early childhood development.

Basic Theory

Schema theory proposes an explanation of how individuals learn and perform a seemingly endless variety of movements. The theory suggests that the motor programs we store in memory are not specific records of the movements to be performed, rather, they are a set of general rules, concepts and relationships (schemas) to guide performance. Basically, individuals store in memory past movement experiences. This storage of "movement elements" and their relationship to each other is called movement schema. An individual calls up the schema to program (i.e., in a sense "piece together") desired movements.

Schema theory suggests an explanation for two characteristics of human performance which existing theories had difficulty in clarifying (e.g., Adams, 1971). First, individuals rarely repeat a set of movements precisely in the same manner. If a separate program were required for each movement variation performed, our storage capabilities would be quickly surpassed. Second, individuals are capable of programming movements to fit seemingly novel situations. An example of the theory in practice is the performance of an individual playing shortstop in baseball or guard in basketball. The shortstop can field a ball from numerous positions, many novel (not practiced), and return the ball to first base, just as the basketball player can shoot successfully from almost any position on the court. Schema theory treats motor programs in much the same manner as concepts are negotiated in verbal learning. The motor program begins with the cognitive domain and perception of incoming information. The child who has practiced throwing far, hard, soft, or short, has a good cognitive sense of what may be in the middle.

The motor schema (concept) for a general skill area (e.g., throwing, jumping) is bounded by dimensions related to space, time and force. Each dimension represents a continuum that may (depending upon experience) be very limited or quite diverse. The greater the variety of experiences produced by the individual, the more diverse the schema becomes, hence an increased capacity to move. The motor schema enables the individual to select the appropriate level from each dimension to program a task that may be known or novel. In shooting a basketball, for example, the child calls upon a program consisting of a relationship among distance the ball has to travel, required

muscular force, arm speed and angle of release; all which may change from attempt to attempt.

In schema theory each performance is another instance of the relationship among the dimensions of the motor program. This is true in both closed and open skills. In closed skills (e.g., bowling, bean bag toss to fixed target), in which the goal and the environmental conditions are relatively constant, the development of the schematic rule leads to more and more accuracy. In open skills (e.g., soccer, basketball, tennis), in which the environmental conditions are in constant flux, the development of the schematic rule in relation to initial conditions enables the performer to generate novel responses. For schema theory, the essential difference between open and closed skills is in the unpredictability of the environment in the open skill situation. The motor response would be generated in the same way for open and closed skills, but for open skills the response is based upon the individual's best estimate of the changing environment.

According to Schmidt (1975), goal directed movement leads to storage of: a) initial conditions, or the state of the internal and external conditions; b) response specifications, e.g., release angle, muscular force, arm speed, etc.; c) sensory consequences of the movement (performance feedback); and d) outcome, success of the movement (result). These four sources of information combine to produce a motor schema that is diverse in conception and scope. Ultimately, though we may forget the specific instances of a movement, we retain the general schema which enables us to repeat a movement or perform a new variation of it.

Schmidt's theory holds that there are two schemata: recall and recognition. The recall schema is the relationship, developed from previous experience, between the response specifications and the actual outcome (knowledge of results). To produce a novel response the subject enters recall schema with the desired outcome and the initial conditions, and the schema rule generates the specifications for that response. Once the response specifications have been determined, the response can be executed by means of a motor program. Recognition schema is the relationship, built up over past experience, between the sensory consequences and actual outcomes. For each response the initial conditions are considered and the sensory consequences and actual outcome are coupled to build this relationship. During a response, the subject designates the desired outcome and by means of the recognition schema predicts the expected consequences of the response.

Variability in Practice

A major prediction of schema theory is that increasing variability in practice on a given task will result in increased transfer to a novel task of the same movement class. The strength of the schema, whether it be recall or recognition, is a positive function of the amount and variability of practice of responses within a movement class. The theory predicts that stronger schemata should (1) produce less error in the initial trials of a novel response governed by the schema, and (2) result in an increased rate of learning for a novel rapid response in the absence of knowledge of results. Most studies have tested these predictions by manipulating the variability of practice factor.

Based on the variability of practice hypothesis, it is predicted that subjects exposed to a high variability of practice regime while never experiencing the test condition, should perform as well or better than subjects who practice only on the test condition relevant to a final observation on that test condition. In addition, it is predicted that the high variability group would out-perform the specificity group with respect to transfer to novel tasks. Numerous studies reporting support for the variability hypothesis have been generated using young children as subjects and a gross motor skill as the task (e.g., Kelso & Norman, 1977; Kerr & Booth, 1977, 1978; Carson & Wiegand, 1979; Moxley, 1979).

The general finding are that children seem to have schemas and can use them to organize movements in slightly different movement situations. This has been demonstrated with 3-year-old children when pushing a toy car to different distances on a fixed trackway (Kelso & Norman, 1978) and with children (ages 6 to 8) when throwing at a target from different body orientations (Moxley, 1979). In the Moxley study, the children threw at the same target distance while changing the initial conditions. This was performed by having the children sit on the floor and throw with their right hand from five different locations. The force (distance) requirements were kept constant, but body alignment changed in relation to the target. For example, the children in one location faced the target almost directly and in another location had to turn their bodies considerably to the right to make the throw. These test conditions indicated how one source of information (initial condition) can be manipulated. Most studies of schema hold initial conditions constant and vary force or other response specifications.

Carson and Wiegand (1979) found young children (ages 3 to 5) with more variable practice experiences had greater overall success when throwing a bean bag of a new weight at a target on the floor and at a relocated target attached to a wall. The variable practice group also maintained their performance level in all conditions after a period of 2 weeks, in contrast with a loss in performance by the other groups (i.e., control, low variability, and specific practice group). Carson's and Wiegand's findings demonstrated that young children can establish a movement rule or relationship, use it, and retain it for later us. Kelso and Norman (1978) trained 3-year-old children to propel a ball-bushing car down a trackway with sufficient force so that it would coast to a stop at a specified target. The constant group practiced at a single target while a variability group practiced at four randomly assigned targets. During transfer, the groups were divided so that half of the subjects performed a novel task inside the range, and the other half transferred outside the range of previous experience. The variability group performed with less error than the constant group at both transfer targets. Hunter (1977), using the same task, had a high variability group experience eight variations of the task while the constant group only experienced one variation. The variability group performed the novel distance with significantly less absolute error than the constant group. Kerr and Booth (1977) trained 7-and 9-year-old children to toss beanbags. The variability group practiced at two distances while the

constant group practiced at only one. On a novel distance, the group experiencing variability performed with significantly less error than a constant group. Similar results were also reported with 8-and 10-year-old children (Kerr & Booth, 1978).

Theoretical Implications

According to Shapiro and Schmidt (1982), one conclusion that emerges from the literature when comparing studies using adults and children is that children's motor skills are apparently more easily affected by variability in practice. This observation suggests that the recall schemata of children are easily developed, while adults may have already developed schemata for the relatively simple tasks used in the investigations. The authors also note the fact that various rival theories (e.g., Adams, 1971) cannot explain how performance on variations of a task leads to essentially the same transfer performance (in adults) as does practicing the criterion task itself; with children, varied practice was consistently reported to be more effective than practicing the criterion task itself. These findings can easily be explained by schema theory. Each trial, whether it be the first one experienced on a novel criterion task or simply one in a long practice series on a constant criterion task, is seen as being novel; that is, subjects presumably prepare the movement on each trial "anew". With this view, since all responses are, in a sense, novel, then an effective way (more effective in children) to prepare for the criterion task is with varied practice. This finding, has important practical implications for the structure of practice sessions with children.

Gabbard (1984) and others (e.g., Graham, 1980; Schmidt, 1977; Schmidt, 1982; Kerr, 1982) suggest some strong implications of schema theory in the practical teaching setting. Generally, schema theory predicts that practicing a variety of movement outcomes within the same general skill class (e.g., throwing, jumping, catching) will provide a diverse set of experiences upon which the schema may be enhanced. The child who is limited to throwing experiences using an overhand pattern only, would not be as adept to the performance of a novel throwing task outside that position (sidearm, underhand, etc.) as the child who has thrown from a variety of positions. The same would apply to the child shown only the two-foot takeoff and landing, (i.e., Jumping pattern) and not supplemental variations that are frequently used in many movement activities.

Schema theory (and variability in practice) strongly suggests developing a solid foundation consisting of a variety of motor skill experiences early in life. As also proposed by eariler theorists, whether it be concrete ideas (Piaget, 1950) or motor skills (Bruner, 1973), children need a broad base on which to develop. Variability in practice is predictively more effective for children than for adults simply because young individuals have considerably more to learn. Typically, children learning to read are taught to recognize letters, then parts of words, then complete words, and finally sentences. Children studying mathematics learn to solve problems after they have grasped

the basic functions of numbers and signs. When a child is learning to play a musical instrument, he or she studies the scale before attempting a song. In physical education, however, children are frequently taught games and dances before they are able to perform the prerequisite skills. Too often children know the rules for a game or the formation of a dance but do not have the skills needed for successful and enjoyable participation. Generally, schema theory supports the practice of problem-solving (within the same class of movements and rules) during early years rather than the instruction of specific sport skills. With the establishment of a broad motor foundation (schema), children should be in a better position to acquire and apply specific skills.

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