Cognitive style and gender differences in children's motor task performance

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Ennis, C.D., & Lazarus, J.C. (1990). Cognitive style and gender differences in children's motor task performance. *Early Child Development and Care, 64,* 33-46.

Abstract:
Memory storage capacity and system flexibility of 7 year-old children were examined through performance on a novel ball-intercepting task. Field dependence/independence served as the theoretical base for the study. The task required students in 56) to analyze the speed and direction of a bell rolling down a ramp and adjust their speed and angle of approach to intercept it within a limited space. Data were collected using video cameras positioned behind and to the side of the child's pathway. Data were reduced using a qualitative categorical system and analyzed using a MANOVA. Results indicated that field-independent children used a sharper initial angle of approach than did field-dependent children. Males used both a sharper angle of approach and a more developmentally advanced grasping pattern than did females. Discussion focused on the field-dependent children's modifications of the task to decrease demands on storage capacity and preclude the development of alternative motor pathways or systems.

Article:
Until recently field dependence-independence has been considered a personality construct that reflected the style or manner in which learning occurred but did not influence the efficiency or accuracy of the performance that resulted (Cochran & Davis, 1987; Goodenough, 1976; Witkin, 1978). However, there is an expanding body of research indicating that field-dependent (FD) and field-independent (FI) individuals differ with respect to fundamental cognitive components that can lead to differentiated performance on certain tasks. Results of these studies suggested that field-independent individuals demonstrated a more accurate recall of factual information from texts (Spiro & Tirre, 1980) and lectures (Frank, 1984). They acquired a better understanding of ambiguous information (Lefever & Ehri, 1976) and possessed a more accurate memory for organization of information (Annis, 1979; Frank, 1983). These differences were hypothesized to be related to variations in information processing associated with -both working memory storage capacity (short-term memory) and system flexibility when retrieving previously stored information. Cognitive style appears to be associated with the capacity available within working memory, the ability to organize newly coded information, and the mental energy to integrate new information with prior knowledge previously stored in long-term memory. For children, these distinctions may be manifest in marked learning differences in reading comprehension (Davis, 1987), knowledge acquisition (Frank, 1983), and motor task integration (Todor, 1977).

THEORETICAL EXPLANATIONS FOR COGNITIVE STYLE DIFFERENCES
Within cognitive science explanations for cognitive style differences have been postulated within information processing and organismic structure theories. Both theories can be useful in conceptualizing performance differences exhibited by field-dependent and field-independent children on particular tasks.

Information Processing
Frank (1983) identified differences in working memory and memory retrieval between field-dependent and field-independent individuals. He asserted that riot only is the working memory capacity of field-dependent individuals smaller than that of field-independents, but that the memory retrieval abilities of FDs are less efficient due to rigidity within the information processing functions. Specifically, FDs use cues inefficiently to

stimulate recall of past information. Unless the retrieval cue is directly related to the manner in which the information was initially encoded, it is less likely that the FDs will be able to retrieve it successfully. Because the relevant cue appears irrelevant, it is of little assistance to the FD child when attempting to stimulate recall. Further, when presented with new cues, FDs find it difficult to efficiently use alternative associated pathways to gain access to previously stored information (Franks, 1983). Thus information, stored in association with a cue structure *different* from the one currently presented, is inaccessible. Parents or teachers who lament that some children simply cannot recall information that was recently discussed, may be asking these children to retrieve it using different cue structures. Although field-independent children may be able to complete this task successfully, field-dependent children often find this form of recall difficult.

Tulving and Osler (1968) described this phenomena within the principle of encoding specificity. Retrieval cues facilitate recall only if explicitly associated with the to-be-remembered stimuli at the time of original presentation of material, Retrieval cues that may be semantically related to the to-be-remembered stimuli will be ineffective unless they are compatible with the manner in which the stimuli were stored. Results of research by Frank (1983) indicated that field-dependent individuals are so inflexible that not only are the new cues irrelevant, but they may also have an additional confusing effect further limiting performance. This style of information processing typifies a spectator approach to learning, resorting to trial and error strategies and overlearning of content rather than comprehension of processes and relationships (Goodenough, 1976).

Conversely, FIs find it easier to identify alternative associated pathways that currently exist among the stimuli (Frank, 1983). Flexible retrieval systems make it feasible to deliberately consider several related alternatives increasing the likelihood of a positive match between the retrieval cue and the stored information (Tulving & Osler, 1968). Thus when previously useful cues become irrelevant due to the changing context of a task, the performance consequences are less severe for field-independent children. They are able to reformulate the given cues to address teacher questions or solve novel problems.

The greater capacity for cognitive flexibility demonstrated by field-independent children is consistent with the perspective of field dependence/independence as an ability dimension (Widiger, Knudson, & Rorer, 1980). Field-independent children demonstrate superior cognitive restructuring skills when compared to field dependents as exhibited by their ability to (a) identify and analyze basic components of a predefined structure, (b) impose a structure on otherwise ambiguous stimuli, and (c) reorganize a given field to reflect a novel structure. In other words, these children are better able to master educational problem solving tasks because of their ability to distinguish the parts of a problem, recall or design organizing concepts that make the information meaningful, and recognize new informational relationships that increase understanding.

Theory of Constructive Operators

Individual differences in learning and performance have also been addressed by Pascual-Leone (1970) using an organismic process-structural model within the Theory of Constructive Operators. The essence of the theory is organized into two separate but interacting psychological levels or systems. The first or *subjective system* represents organized patterns of behavior (schemes) that are a result of goal-directed activity. Subjective systems respond to information from the environment. The second system operates internally on the first level subjective system constructs and not directly on the input itself. This system is described as a *scheme booster*, determining which schemes will be activated at any given time. Scheme boosters are situation-free (unlike the subjective scheme's that are situation-specific). The scheme boosters either increase or decrease a particular scheme's likelihood of being activated. Of particular importance within this theory are the roles of the C factor, the L factor, and the M-operator and their relative degrees of strength in field-dependent and field-independent individuals (Pascual-Leone, 1974).

The C factor represents content learning, or in Piagetian terms, that which forms the "empirical experience." Content learning stimulates the selection of particular schemes, to match features of reality. A variety of low level schemes are considered in the process. Differentiation of schemes occurs as the characteristics of content are compared with the existing context. These low level schemes are often directly activated by the input from the environment itself. Structural learning, L, corresponds to Piaget's "logico-mathematical experience" and represents superschemes. As patterns or low level schemes are consistently repeated, a larger superscheme is abstracted and stored as an L structure.

L learning can be of two types, LC or structural overlearning and LM or structural learning boosted by mental energy. LC structures result from repeated coactivation of low level schemes until the schemes become interlocked into a structural chunk. The LC structures are rigid and inflexible much like programmed responses. LM structures, on the other hand, act as special programs that can select and integrate appropriate schemes to meet special task demands. They are monitored by a third level general problem-solving routine termed an executive scheme. Executives are very flexible and appear to effectively control a variety of analytical activities.

In order to create LM structures the organism must use mental energy or M-operators. Much Rice mental effort or functional working memory, this energy represents mental attentional energy or the concentration needed to boost task relevant schemes into superschemes. M-operators have the capability to override an overlearned LC structure, increasing the likelihood of activating task relevant executive schemes. Within this theory, the performance of field-dependent individuals appears to be dominated by inflexible LC structures. FDs may be unable to boost appropriate schemes to form LM structures and efficient executive schemes. Thus FD individuals have many negative learning experiences as a result of overlearning content rather than processes and relationships. They seem to adopt and maintain poor strategies (i.e., trial and error) even when ineffective. FDs utilize low mental energy processors and thus tend not to use maximum available mental capacity. Further they also are more likely to be rigid in their performance, resulting in a maintenance of poor strategies even when ineffective. Field independents, on the other hand, develop effective executive schemes with many flexible LM structures. Coupled with the fact that Fl subjects tend to be high mental energy processors, they create more positive successful learning experiences (Pascual-Leone & Goodman, 1979).

When cognitive ability as defined by field dependence/independence is described within the constructs of working memory capacity and cognitive flexibility, the implications for understanding individual performance differences are enhanced. Researchers have hypothesized cognitive style-related differences in performance in reading (Davis, 1987), communication (Frank 8r, Davis, 1982), sentence verification (Cochran & Davis, 1987), concept formation (Ohnmacht, 1966), perception of musical tempo (Schmidt & Lewis, 1987), and motor skill acquisition (Swinnen, Vandenberghe, & Van Assche, 1986; Todor & Lazarus, 1982).

Individual differences attributed to cognitive style are also influential in successful performance of motor tasks critical to the growth of young children (Todor, 1977; Todor & Lazarus, 1982). As the complexity of motor tasks increases, the individual's quantity and energy level of working memory capacity (M-capacity) becomes critical to successfully boosting low level schemes into superschemes and developing efficient executive programs to monitor their performance. If an overlearned LC continues to dominate the performance pattern, the child is unable to create or select a more complex LM necessary for successful performance. In complex motor tasks children must monitor not only their own performance but frequently that of an object or other children. Novel motor tasks demand increasing levels of flexibility to access appropriate responses and integrate knowledge of results from previous attempts. When motor decisions must be made within a time limitation caused by the speed or direction of an object or of oneself, the influence of mental storage capacity and cognitive flexibility that appear to be associated with cognitive style differences becomes increasingly pronounced.

It was the purpose of this study to examine the effects of cognitive style and gender on a motor task that required young children to analyze and adjust their performance to meet the demands of a complex environment. Field-dependent and -independent male and female children were asked to monitor the speed and angle of a ball rolled down an inclined plane and then adjust the speed and angle of their own movement to intercept the ball within a limited space as quickly as possible. It was hypothesized that field-independent children would demonstrate higher levels of cognitive restructuring and flexibility. The significance of the study lies in the use of a motor task to examine children's abilities to integrate information from a variety of internal and external stimuli necessitating a relatively large working memory capacity and high mental energy. Because the children could make adjustments during performance to increase the opportunity for success, the task also encouraged a form of cognitive flexibility.

METHOD

Subjects

Second grade students (N = 254) in four elementary schools were tested using the Children's Embedded Figures Test (CEFT) to identify their cognitive style (Witkin, Oltman, Raskin, & Karp, 1971). The test consists of two timed sections in which subjects locate and trace a simple figure, such as a triangle, embedded within increasingly more complex drawings. CEFT scores range from 0-24 with one point awarded for each figure traced. At the time of testing, the average age of the children was 7 years 4 months. Students (n= 25) with scores > 17 were categorized as field independent while those (n = 31) with scores < 8 were classified as field dependent. Thirteen of the field-independent children were female and 12 were male. Eighteen of the field-dependent children were female and 13 were male. A summary of demographic data by cognitive style and gender is reported in Table 1.

Table 1 Demographic Data for Cognitive Style and Gender

	Field Independent	Field Dependent
Gender		
Males	12	13
Females	13	18
Total	25	31

Motor Task

The children were directed to intercept a ball 8 inches in diameter that had been rolled down a 3 foot incline or ramp (task adapted from Gentile, 1980). The ramp ensured a constant ball velocity for all trials for all children. Children began moving from a marker 15 feet in front and 15 feet to the side of the base of the ramp. The child ran forward as the ball was released at the top of the ramp. The child was encouraged to intercept the ball as quickly as possible upon release by the investigator. At no time was the child instructed in which direction to run.

Data Collection

Data were collected using two video cameras. Camera I was positioned 8 feet behind the child's starting position. Camera 2 was placed opposite and 35 feet from the base of the ramp. Floor markings assisted in determining the angle of the child's path to intercept the ball. Children completed four trials of the ball interception task.

Data Reduction and Analysis

Data from cameras 1 and 2 were reduced' independently by two raters using a qualitative rating scale. The raters were blind to the field-dependent status of the children. Five categories of performance were evaluated: initial angle of approach, adjusted angle of approach, grasping pattern, foot position, and body position. Initial and adjusted angles were evaluated based on floor markings. In the grasp, foot, and body position categories, the child's performance was scored on 0-4 point scale based on the level of performance within the category. Children failing to contact the ball received 0 points. Raters trained prior to videotape analysis until interrater reliability on each of the five categories was .90 using the scored-interval approach (Hawkins & Dotson, 1975).

The initial angle of approach was defined as the pathway selected by the child at the time the ball began to roll down the ramp. Using a template over the video-tape image, the initial angle was assessed from the perpendicular markings on the floor at the child's starting point. A pathway that was perpendicular to the path of the ball was described as a 90 degree angle. Angles decreased as the child selected a pathway closer to the end of the ramp and increased as the child allowed more space (and time) to monitor the speed of the ball, intercepting it farther from the base of the ramp. This dependent measure was used to reflect the child's ability to structure the task.

The second dependent measure, the adjusted angle of the child's pathway, was used to assess the child's cognitive flexibility. Once both the ball and the child were moving, the child received perceptual feedback regarding his or her own speed and the speed of the ball. This provided an opportunity to adjust the angle of approach to intercept the ball more efficiently (using the smallest angle possible and still successfully intercept the ball). This angle was measured at the point where the ball was actually intercepted relative to the starting position.

The third category, grasp, provided an assessment of the developmental level of the child when attempting to intercept the ball. The developmental levels of catching, as outlined by Roberton and Halverson (1984), were modified to suit this particular experimental task because the ball interception task and the fundamental motor pattern of catching a tossed ball represent unique patterns. On the ball interception task, a one-hand grasp represented the most mature level followed by a scooping motion, a two-hand grasp, and a two-hand trap. A trapping position is one in which the child pins the ball to the floor without actually grasping it or traps the ball between the body and the hands. It requires less accuracy while still allowing the child to intercept the ball. A summary of the classification criteria is reported in Table 2.

Table 2 Criterion for Evaluating Ball Interception Task

INITIAL ANGLE OF APPROACH		angle at which subject initiated the run relative to starting position
ADJUSTED ANGLE OF APPROACH		angle at which subject contacted the ball relative starting postion
GRASP	4	one hand grasp
	3	scoop; scoop with one hand, grasp with two hands
	2	two hand grasp
	1	two hand trap; may involve legs/body
	0	fails to contact/drops the ball
FOOT POSITION	at contact;	relative angle to point of takeoff
	4	same angle
	3	one foot at same angle
	2	neither foot at same angle
	1	knee(s) touch floor
	0	fails to contact/falls
BODY POSITION	stride coordination at point of contact	
	5	reaching with no body turn, cross-pattern
	4	reaching with body turn, cross-pattern
	3	reaching with body turn, foot-plant, forward motion
	2	reaching with body turn, foot-plant, stop
	1	reaching with complete stop
	0	fails to contact/falls

Foot position at the time of contact of the ball, the fourth category, was also used as a developmental assessment. In order to contact the ball at its closest point to the base of the ramp, the child should be moving at an optimal angle at maximum speed. Therefore, contact should be made while continuing to move across the path of the ball, with the feet moving in the same line (or angle) as the original locomotor pathway. In less developmentally mature foot positions, only one foot is placed at the same angle, or neither foot is positioned on the same angle — a position that occurs when the child uses a larger than necessary angle of approach, arriving in position to grasp the ball before it reaches the location. This allows the child to turn his/her body 90 degrees to face the ramp thus intercepting or trapping the ball facing the ramp. Conversely, when children misjudged their own speed or the optimal angle of contact, they frequently arrived late, after the ball had rolled past their position. When this occurred, children often reached forward to stop the ball, allowing one or both knees to touch the floor. This was considered the least developmentally mature foot position (see Table 2).

The fifth category provided an overall assessment of body position. This developmental measure evaluated the stride coordination at the point of contact. The most developmentally mature pattern involved reaching with no body turn while using a crossed stride pattern. In this instance, the child had assessed both the speed of the ball and his/her own speed correctly and had been able to select an optimal pathway to grasp the ball while continuing to run forward. Less desirable temporal relation-ships were those in which the child reached with a slight body turn while continuing to use a cross-over pattern, reached with a body turn, planting one or both feet momentarily during contact and then continuing forward to maintain balance, and reached with body turn, foot plant, and complete stop (see Table 2).

The quantitative data on initial angle of approach, adjusted angle of approach, grasp, foot position and body position were analyzed using a nonparametric MANOVA with repeated measures to assess children's performance differences using cognitive style (FD, FI) and gender (M, F) as variables.

RESULTS

The MANOVA revealed a main effect for cognitive style ($F_{1,51} = 9.38$, $p < .0035$). Field-independent children selected a sharper initial angle of approach to the ball (62,2 degrees) than field-dependent children (78.2 degrees). Figure 1 presents a diagram of the initial angle of approach, FIs monitored the speed of the ball and selected an angle of approach to converge with the ball at an angle almost 30 degrees less than perpendicular. Although field-dependent children also selected an angle less than 90 degrees, they chose a wide angle of approach, allowing them to delay the contact point. Descriptive statistics are reported in Table 3.

Table 3 Descriptive Statistics for Dependent Measures by Cognitive Style

Dependent Variable	Field Independent	Field Dependent	*p*
Initial Angle	62.2(20.23)	78.17(24.11)	.0035*
Adjusted Angle	64.40(24.34)	76.00(24.02)	.0592
Grasp	1.78(0.51)	1.80(0.44)	.7258
Foot Position	2.70(0.81)	2.57(0.81)	.4976
Body Position	2.80(1.21)	2.63(0.99)	.6073

* $p < 0.01$

A second main effect was identified for gender ($F_{1,51} = 13.11$, $p < .0007$). Males demonstrated a sharper adjusted angle of approach (59.4 degrees) than females (80.2 degrees). Figure 2 provides a diagram of the adjusted angle. Males decreased their initial angle of approach from 68.4 degrees to 59,4 degrees at the point of contact with the ball, an adjustment of 9 degrees, while females *increased* their initial angle from 73 to 80.2 degrees. Descriptive statistics are summarized in Table 4.

Table 4 Descriptive Statistics for Dependent Measures by Gender

Dependent Variable	Male	Female	*p*
Initial Angle	68.40(28.31)	73.00(19.07)	.3959
Adjusted Angle	59.40(22.89)	80.17(22.28)	.0007**
Grasp	1.94(0.31)	1.67(0.54)	.0061*
Foot Position	2.68(0.74)	2.58(0.87)	.6266
Body Position	3.28(1.05)	2.23(0.89)	.0000**

* $p < 0.01$, ** $p < 0.001$

In addition, males demonstrated a more developmentally advanced grasping pattern ($F_{1,51} = 8.20$, $p < .0061$). They typically collected the ball using a two-hand grasp pattern while the females' were equally likely to use a two-hand grasp or a two-hand trap. Integration of running with reaching was also developmentally more advanced in males ($F_{1,51} = 21.17$, $p < .0001$). Males were more likely to reach with a body turn and momentary foot plant while the females reached with body turn and a permanent stop. Together these data suggested that females adjusted their approach angle to arrive at their chosen location prior to the arrival of the ball, stopped, turned toward the ramp, and grasped or trapped the ball as it came toward them. Males, on the other hand, narrowed their approach angle to the extent that they arrived at the point of contact almost simultaneously with the arrival of the ball, turned, and grasped the ball with two hands and then continued moving along the original pathway. There were no significant interactions between cognitive style and gender.

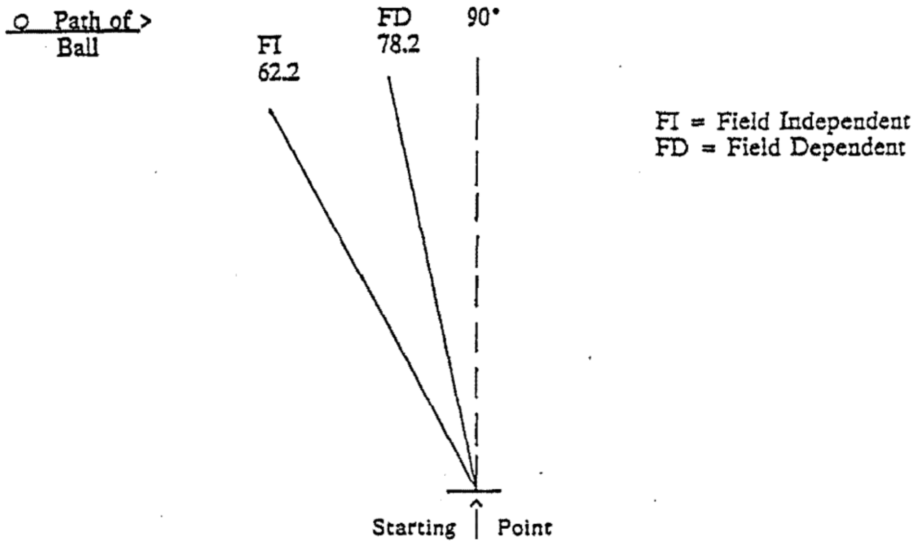

Figure 1 Mean Initial Angle of Approach by Cognitive Style.

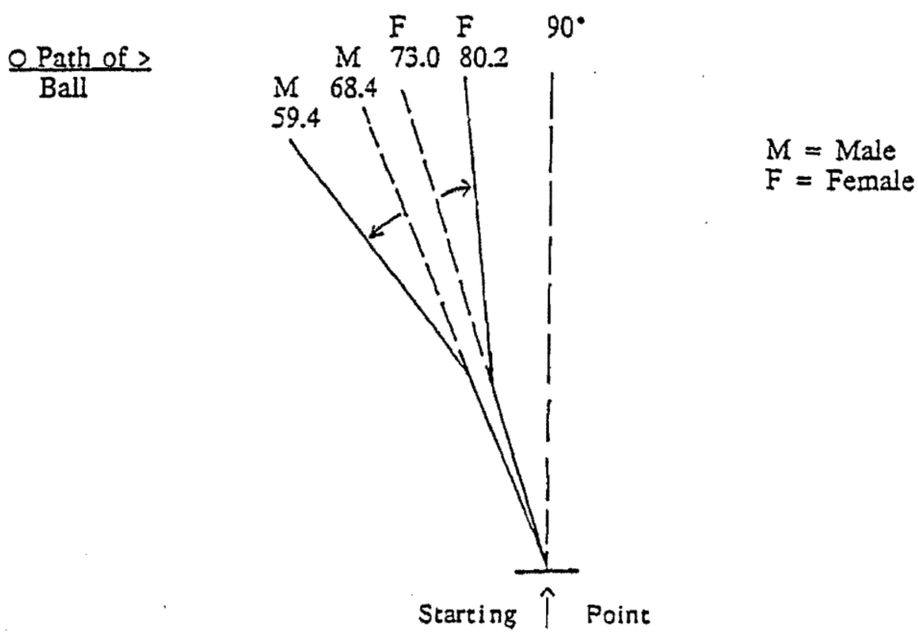

Figure 2 Mean Initial and Adjusted Angles of Approach by Gender.

DISCUSSION

The results suggested that individual differences associated with cognitive style and gender influenced the performance of children on this motor task. In this task, children were required to assess the requirements of the task and then structure their own performance to achieve success. As children performed, they monitored the speed and the direction of the ball 'and their own speed and angle of approach. FI children and male children were more likely to attempt to find an alternative angle for optimal success rather than using a larger angle that permitted more time to utilize a less efficient strategy.

Field-dependent children seemed to approach the task cautiously. They allowed for a larger approach angle that provided more time to monitor the speed of the ball. It also appeared that the additional time factor changed the task from a complex open skill in which the ball and the child were simultaneously in motion, to a closed task in which task demands occurred consecutively. In the modified task, field-dependent children initially ran to a point where they could turn and wait for the ball to come to them. In other words they divided the task into three components: (a) running to an appropriate location on the floor to wait for the ball's arrival, (b) turning to face the ramp, and (c) intercepting the ball. Within this new task, all of the actions could be performed more slowly and one at a time. From the perspective of Pascual-Leone's Theory of Constructive Operators, it appeared that FD children were not able to integrate running with reaching. By dividing the task into several subcomponents, they reduced the M energy (or storage capacity) required to integrate the task components. Because the larger angle increased the chances of initial success, the cognitive flexibility needed to search for alternative pathways or more optimal strategies was also minimized. The integration of several motor patterns included in the, original task, requiring a larger storage capacity and scheme boosters, was eliminated in the new task created by the field-dependent children.

Furthermore, because the larger angle increased the chances of initial success, the cognitive flexibility and mental energy needed to search for alternative pathways or strategies was also minimized. Subcomponents of the task (running, turning, grasping) occurred serially instead of simultaneously permitting the FD children to complete each LC component before beginning the next. With this strategy, the FD children never needed to integrate LM or boost schemes, They also performed the task less effectively. It appeared in this task that field dependent students focused only on the directions that were most concrete. They seemed satisfied simply to intercept the ball, disregarding the instruction to intercept the ball as *quickly as possible.* The most relevant cues to the FDs were those associated with the most concrete criteria — that of intercepting the ball.

Individual differences based on gender were reflected in the way children contacted the ball. Males were developmentally more advanced than females both in the manner of grasping and in the body position at point of contact. In addition, they approached the ball at a much sharper adjusted angle. MacLeod, Jackson, and Palmer (1986) suggested that the field-dependence construct is highly related to spatial ability. They argued that gender differences evident in studies of field dependence should be attributed to gender differences in spatial ability. The motor task examined in this research was rich in spatial requirements associated with angles of approach, timing, and body-object relationships. Children who were field dependent and children who were female may have found the spatial demands of the task too demanding and reverted to the less sophisticated task modification described above.

Small gender differences in favor of males have been found in many studies of fundamental motor skills, play-game skills, and strength for children of the age range studied here (Keogh, 1965; Malina, 1975), although there is considerable overlap in male/female distributions. Since biological make-up (i.e., physique, physiology) is not that different in 7-8 year old boys and girls (Iliff & Lee, 1952), these gender differences have been largely attributed to sex-related participation experiences.

Socialization of female children into "traditional female roles" in which movement and physical activity are frequently perceived to be of little value is believed to be a limiting factor in the development of certain motor skills. Specifically, females often have not been encouraged to participate in activities that require them to develop the coordination and control necessary for many motor tasks. Sex role stereotypes (Ruble, 1983) may also affect the expectations that parents and teachers have for female children. By inadvertently encouraging males to participate and to learn effective motor skills such as catching and throwing, adults reward young boys for the additional time and effort required to develop motor skills (Chepyator-Thomson, 1990; Griffin, 1985). Conversely, girls are often rewarded for demonstrating characteristics of nurturance, dependence, cooperation, and passivity *(Phoenix,* 1987) that are rarely consistent with success in competitive games (Griffin, 1984). Although there are few biological differences between boys and girls in this age range, performance differences are already evident by age seven. Additional research is needed to examine the extent to which gender differences can be modified through similar participation expectations and opportunities for males and females.

In summary, performance on this novel ball interception task demonstrated individual variations in FI and FD children's ability to structure the task for optimal performance and their flexibility in adapting their performance relative to environ-mental cues. The most efficient angle of approach was adopted by field-independent children. In addition, males demonstrated adaptation and integration of the component parts of this motor task, reflecting a more mature response than females. These results suggested that cognitive restructuring skills, flexibility, and integrative ability can result in individual differences on motor tasks based on cognitive style and gender/developmental level.

Notes

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