National Library
of Canada

Bibliothèque nationale
du Canada

Canadian Theses Service

Services des thèses canadiennes

Ottawa, Canada
K1A 0N4

CANADIAN THESES

THÈSES CANADIENNES

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C.,1970, c. C-30.

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

NL-339 (r. 86/06)

Canadä

THE UNIVERSITY OF ALBERTA

THE EFFECT OF INSTRUCTION ON TRACKING PERFORMANCE AT TWO LEVELS OF SKILL:
A KNOWLEDGE BASED APPROACH

BY

DEMETRA KOUTSOUKI KOSKINA

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

IN

DEPARTMENT OF PHYSICAL EDUCATION AND SPORT STUDIES

EDMONTON, ALBERTA
FALL, 1986

ISBN 0-315-32488-0

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Demetra Koutsouki-Koskina

TITLE OF THESIS: The Effect of Instruction on Tracking Performance at Two Levels of Skill: A Knowledge Based Approach.

DEGREE: Ph.D.

YEAR GRANTED: 1986

Permission is hereby granted to THE UNIVERSITY OF ALBERTA LIBRARY to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves other publiction rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

Demetra Koutsouki Koskinas

KAZANTZAKI 84 DRAPETSONA

PIRAEUS GREECE.

Date: August 12, 1986.

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE EFFECT OF INSTRUCTION ON TRACKING PERFORMANCE AT TWO LEVELS OF SKILL: A KNOWLEDGE BASED APPROACH submitted by Demetra Koutsouki Koskina in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Jane Watkins
Supervisor

Rick Alderman

P Mulcahy

James D McClements
External Examiner

Date: August 12, 1986

This thesis is dedicated to the woman's struggle for
equality and freedom in all spheres of social life.

ABSTRACT

The present study attempted to control certain aspects of knowledge as presented in the knowledge-based approach to motor development by Wall, McClements, Bouffard, Findlay, and Taylor (1985); that is, procedural, declarative and metacognitive knowledge.

The specific purpose of the study was to consider the effects of declarative and metacognitive knowledge on the performance of a tracking skill. Two basic questions were asked: 1. Does skill on tracking a moving target increase with age? If so, can the children in each age group be separated into novice and skilled tracking performers? and 2. When tracking a familiar pattern such as the figure eight, do the girls in the novice and skilled groups at grades 3 and 5 differentially respond to instruction conditions?

The results supported both questions. Specifically, tracking skill increases with age but, the most important finding was that the level of skill was a much more important determinant of performance than was the chronological age of the subjects. As regards to the second question, both grade 3 and 5 skilled and novice groups did respond differentially to the instructions.

Acknowledgements

I would like to express my deepest appreciation to my Supervisors Dr. Jane Watkinson and Dr. Ted Wall for their endless love, care, encouragement, and invaluable support during the last three years. I am particularly thankful to both for their dedication in helping me complete the wri[illegible] this thesis under extremely difficult time constraints.

My sincere thanks are extended to Dr. Bob Mulcahy, Dr. Rick Alderman, and to Dr. Jim McClements for their very helpful and stimulating contribution to this thesis.

I would also like to thank: George Carmichael for his programming expertise made possible the experimental task of the study and, all the students, teachers and principals of the Ekota, Glengary, Greenview, and Ormsby Elementary schools, for their assistance in collecting the data.

Finally, I would like to acknowledge my comrade and husband Kosta for his contribution to my refining of various theoretical and technical issues concerning my study, and also for his love and support when I needed it most. It would be unfair not to mention my daughter Ifigenia-Irene for her patience during the long hours of my absence and her love and understanding for all the stressful moments she went through along with me during my studies.

Table of Contents

Chapter Page

LIST OF FIGURES.

Figure Page

LIST OF TABLES.

I. CHAPTER ONE: INTRODUCTION.

~~A. A BRIEF~~ OVERVIEW.

For many years the study of motor development has been characterized by extensive descriptive research concerning a variety of gross and fine motor developmental tasks in an effort to evaluate children's development (Thompson, 1929; Gesell, 1940; McGraw, 1945). Such research has focussed on studying the nature of developmental stages, their timing and sequence, and to some extent the nature of the environment that triggered or fostered such development. The various methods and techniques employed for this kind of study include observation and behavioural description using both longitudinal and cross-sectional samples (Wickstrom, 1977; Seefeldt and Haubenstricker, 1982), cinematography, and subsequent biomechanical analysis (Roberton, 1978). Co-twin studies were also done to determine whether there was some effect of early practicing of gross motor skills on future motor development, as well as to assess the contribution of genetic endowment (McGraw, 1935).

Descriptive research conceptualized motor development as the identification of when sequential and orderly developmental stages occur (Rarick, 1973; Roberton, 1979). For example, Roberton (1977) has studied in great detail the developmental changes in the overhand throwing pattern in an attempt to identify the progressive changes that characterize children's development of mature and efficient skill patterns. Such identification has been useful in terms of its contribution to the understanding of innate factors such as age, gender, growth and maturity and their effect on early motor development. Also, its importance in developing appropriate child rearing practices cannot be ignored. Descriptive research has also provided the motor development area with an appreciable number of motor skill tests and other assessment tools that have influenced the development of motor skill programs for developing children.

However, development is characterized by change and may be better viewed as a cumulative process rather than a series of distinct chronological instances. The descriptive study of motor development focussed largely on the study of 'when' certain changes were expected to occur rather than seeking an explanation of 'how' and 'why' developmental changes take place. Many scholars have been concerned with the latter questions and have initiated extensive research on questions of "how" developmental changes occur. They also try to investigate "why" these developmental differences exist by manipulating variables to reveal age differences in the ability of children to process information in the performance of a task. For example, Clark (1982) studied the developmental differences in response processing in three age groups (Kindergarden children, grade 4, and adults). The task was a two choice reaction time (RT) with two levels each (high and low) of spatial compatibility and discriminability. Clark found that children were considerably slower in speeded responses than adults. It was also found that when the demand of the response increased, as in the case of the low compatibility condition, younger subjects needed more processing time before they responded; and, therefore, their reaction times were significantly higher than the adult group. Clark attributed the above findings to developmental differences in encoding and identification stages of stimulus processing. She suggested that children require more time to select the appropriate response for the perceived stimulus, and also to program (or organize the knowledge structures) for the execution of the selected response (Clark, 1982).

This study and others (for example Connolly, Brown, and Bassett, 1970; Barclay and Newell, 1980; Sugden, 1982) focussed on developmental changes in the child's processing of information in motor tasks. Developmental differences are explained in terms of children's ability to accomplish certain steps in the perceptual, cognitive and effector phases of performance.

Recently, some motor development theorists have begun to take a broader view about what develops in motor development. Wall, McClements, Bouffard, Findlay, and Taylor (1985) have suggested that a more effective approach to the study of motor development might be to stress the importance of the knowledge that children acquire about action during development. They suggest that knowledge about action develops in conjunction with physical growth and its resultant changes in body structure.

The knowledge-based approach to motor development recognizes the importance of genetic endowment and structural capacity; however, it also emphasizes the crucial role that experience plays in the development of knowledge about action. Furthermore, as Figure 1 indicates, it provides a broad overview of what develops by identifying five domains of knowledge about action: declarative, procedural, affective, and metacognitive knowledge as well as metacognitive skills.

Declarative knowledge is the factual knowledge which is accumulated through experience and consists of concrete concepts as well as abstract ideas about the world. Procedural knowledge is responsible for the instantiation of action: knowledge about the general and the specific features of each action that are about to be performed and about how to meet the requirements of the action. Affective knowledge includes the motives, the confidence and generally the "subjective feelings of the individual" about a particular skill or activity. Metacognitive knowledge develops through experience and it is directly related to the other three kinds of knowledge. It includes being aware of what an individual knows, of what he or she knows how to do, and of how well he or she can do it (Wall et al, 1985). Metacognitive skills develop as children develop sufficient procedural, declarative, affective and metacognitive knowledge about action. The use of different strategies, the planning and the monitoring of certain aspects of an action are examples of metacognitive skills.

The above approach predicts that skill development does not only depend on age and maturation but also on the learning experiences available to a person to acquire skills. It is argued that procedural knowledge, for instance, cannot develop without countless practice trials that allow learners to acquire information about the specific demands of a task.

Wall et al (1985) stress the importance of declarative and metacognitive knowledge in the conscious control of procedural action. They define declarative knowledge about action as the "factual information stored in memory which will influence the development and execution of skilled action" (p. 30). They note that declarative knowledge about action is developed through the countless experiences that children have with their environment. More importantly for our purpose, they contend that "declarative knowledge about action is continually modified and restructured into coherent packets of knowledge that can influence conceptually-driven thinking about action" (p. 30). In addition to this declarative and procedural knowledge base about action, children also develop metacognitive knowledge about action. "Metacognitive knowledge about action is knowing about knowing how to move" (Wall et al, 1985, p. 31). In addition to metacognitive, declarative, procedural and affective knowledge about action, children develop metacognitive skill in controlling their actions in certain situations. Thus, in novel, dangerous, or technically difficult situations children often use specific metacognitive skills to consciously control their attempts to learn.

B. PURPOSE OF THE STUDY.

The basic reason for undertaking this study was to operationalize some of the ideas that have been outlined in the knowledge-based approach to motor development. Specifically, the purpose of this study was to consider the effects of declarative and metacognitive knowledge on the performance of a tracking skill. In this study the skill of tracking the target was assumed to be the manifestation of the child's procedural knowledge in that the resultant error scores were indications of how well the child could follow the target to be tracked. The knowledge of particular shapes was considered to be declarative knowledge, that is, the knowledge of the concepts of "square", "circle", and "figure 8". For the purposes of this study, metacognitive knowledge was defined as the child's awareness of her knowledge of these concepts while the use of problem solving and monitoring strategies were assumed to be metacognitive skills.

Thus, the study attempted to control certain aspects of the procedural, declarative, and metacognitive knowledge bases of the children involved in it to determine the relative influences of these parameters on changes in skilled performance..

With respect to procedural knowledge, the manipulation included an initial assessment of the procedural skill of the subjects so that 'novice' and 'skilled' groups could be identified. A familiar geometric figure, the figure eight, was selected as the shape to be tracked. The effect of instructions that cue the subject to use her declarative knowledge about shapes was examined. It was recognized that 'declarative instructions', (that a figure eight is the shape to be tracked), might differentially affect the performance on tracking skill depending on the initial skill level of the subjects. It was hypothesized that at all or at least some ages, groups low in procedural knowledge in tracking may be limited in the use they can make of such declarative knowledge about action. In the same way, it was hypothesized that the metacognitive instructions (that the figure to be tracked is a common shape) may be used differentially by the different age groups and skill levels within them. In as much as this is the first study of this type, it must be viewed as an exploratory one.

C. RESEARCH QUESTIONS.

Based on the above rationale the following sequence of research questions was posed:

1. Does skill in tracking a moving target increase with

age? If so, can the children in each age group be separated into novice and skilled tracking performers?

2. When tracking a familiar pattern such as the figure eight used in this study, do the girls in the novice and skilled groups at grades 3 and 5 differentially respond to the following three instructional conditions:

a. a control condition in which the subject is simply asked to track the moving target,

b. a declarative condition in which the subject was shown the figure eight pattern that was to be tracked, and

c. a metacognitive condition in which the subject was asked to track the moving target but with the additional suggestion that the pattern to be tracked was a shape familiar to her?

D. DELIMITATIONS.

For the purpose of this study, only right handed girls, who attended public schools in the City of Edmonton Alberta were tested at ages 8 and 10 years.

E. LIMITATIONS.

There were no boundary conditions to establish the methods because of the lack of studies done using similar tasks.

The declarative information in the task (i.e. the figure eight shape) may have been too easy for the older subjects in that it became almost immediately apparent to many of the skilled subjects. Related to this is the relationship of the age of the subjects and their ability to comprehend the instructions. Furthermore, the number and the length of trials had not been established in previous tracking research for these age groups. For this reason, the pilot study is reported here.

Finally, the study may be limited in that the selection of novice and skilled groups resulted in relatively heterogeneous groups. In other words, the range of procedural skill in each of these groups was large.

II. CHAPTER TWO: REVIEW OF LITERATURE.

A. INTRODUCTION.

The initial section of this selective review of the literature briefly outlines Jerome Bruner's thoughts on early skill learning. It is followed by an introduction to Schmidt's Schema Theory of Discrete Motor Learning which stresses the important role that schemata play in the storage of action information. Building on the notion of a generalized motor schema the chapter includes a brief summary of some of the key concepts in Norman and Shallice's (1980) theory of skilled action.

The above three sections are followed by a discussion of Newell and Barclay's (1982) recent views on knowledge about action. The main thrust of the arguments put forward by these authors is that the development of skilled action must be viewed from a top-down as well as bottom-up perspective. Their comments on the strength and limitations of schema theory are also noted.

The final section of the chapter describe a knowledge-based approach to motor development which uses a number of different types of knowledge about action to highlight the breadth and depth of the knowledge-base that supports the development and control of action. A brief review of studies showing expert-novice differences in different knowledge domains is provided. The importance of domain-specific knowledge and the interaction of different types of knowledge about action is stressed as they relate to the acquisition of motor skills.

The final section includes a brief statement on the choice of task used in this study.

B. BRUNER'S VIEWS ON EARLY SKILL LEARNING.

Bruner (1973) in an important article on the development of early skilled action suggests that

> "goal-directed skilled action, then, may be conceived as the construction of serially ordered constituent acts, whose performance is modified towards less variability, more anticipation, and greater economy by benefit of feed-forward, feedback, and knowledge of results" (p. 173).

In discussing his view of skilled action, Bruner stresses that the constituents (sub-routines) from which skilled action is constructed should not be viewed as fixed action patterns but rather they should be seen as flexible units generated to meet the demands of specific situations. Bruner underlines the importance of feed-forward, feedback, and knowledge of results and emphasizes the important role of early play, (he calls it "mastery play") in the acquisition of skilled action.

He also notes the role that the modularization of sub-routines plays in the developmental skill learning process. Such modularization ensures that lower level subroutines are incorporated into higher order sequences such that only these larger units require attention. In addition, Bruner purports that as children grow older they gradually develop more and more automatized skills that allow them to act on their environment in an efficient and effective way. Furthermore, as actions become automatized they free up attentional capacity for more effective problem solving and monitoring activities.

Bruner's article is a classic one in the area of developmental skill acquisition in that it emphasizes the important role that environmental experiences, play, feedback, sub-routines, modularization, and the physical constraints of the body play in the development of skilled action. However, Bruner did not address the question of what made up the sub-routines (constituent acts) that underly skill. It was Schmidt (1975) in another important paper on skill acquisition who addressed some of the more basic problems related to this issue.

C. SCHMIDT'S SCHEMA THEORY.

Schmidt (1975) addressed two main issues in the skill learning literature; namely, the storage problem and the novelty problem. The storage problem refers to the fact that people perform countless numbers of acts in a lifetime; such a large amount of information if it were to be stored by a one-to-one mapping ratio in the central nervous system would, Schmidt contends, result in an overload of the memory system. Hence, he purports that such information on and about action must be stored in a more efficient way. He developed a schema theory of discrete motor skill learning to account for this storage problem. At the same time, he addressed the novelty problem by noting that people can flexibly generate novel responses quickly and accurately in a variety of situations. Schmidt used the early schema work of Bartlett (1932) and Adams (1971) to develop his theoretical account of motor skill learning.

The central feature of Schmidt's schema theory is the notion of a generalized motor program, which is an abstract memory structure that, when activated, causes movement to occur (Shapiro and Schmidt, 1982, p. 115). The theory is based on the notion of a generalized motor schema, so that every movement does not require a distinct motor program for it to be executed. Thus, schema theory purports that generalized motor programs govern a given set of movements which require a common motor pattern.

The theory has two major components: the recall schema and the recognition schema. The recall schema underlies response production while the recognition schema evaluates the appropriateness of a given response. It is the interaction of the recall schema with the recognition schema that is at the heart of the schema theory of motor skill learning.

Shapiro and Schmidt (1982) make an important point about schema theory, they note that the theory does not address the question of how a response is selected but rather it "focusses on the processes that occur after the generalized motor program has been selected (namely, parameter selection) to effectively execute the program" (p.

115).

Schmidt (1975) purports that a recall schema is associated with every generalized motor program. This recall schema is actually a rule generated from past experiences with running the program. It is based on the initial conditions including the position of the limbs, factors in the environment, the knowledge of results from executing the action(s), and the key parameters used when executing the program. As a person gains experience in executing an action, the above information is generated, analyzed, and eventually becomes abstracted into a rule relating the above three pieces of information which is stored in memory. The validity and the strength of the rule (generalized motor program) is directly dependent on the number of trials from which knowledge of results can be obtained and the variability of practice associated with the performance of the action; that is, the greater the number of practice trials within a response class the more effective a schema will be. Furthermore, the theory predicts that the better the schema or generalized motor program, the better will be the response specifications of any novel movement that is generated within that response class.

Once a schema has been used to execute a response, a recognition schema develops in conjunction with it. Again given a sufficient number of trials and varibility of practice, a recognition schema (rule) is developed relating initial conditions, past actual outcomes, and post sensory consequences. A well-formed recognition schema associated with a given response class permits a performer to accurately predict the expected sensory consequences associated with a novel movement in that class. Clearly, feedback plays a major role in the development of the recognition schema which in turn helps shape the effectiveness of a given action or a series of actions.

In summary, schema theory uses two independent memory states, the recall and recognition schemata, to account for the execution and evaluation of actions. The recall schema is responsible for the selection of the response specifications that underly the execution of the motor program designed to reach the desired objective. The recognition schema defines the expected sensory consequenses that allow the correctness of a given response to be evaluated.

Schmidt's schema theory postulates how the production of a movement takes place and describes the role of response specifications in it. Additionally, it provides a testable hypothesis for the value of the variability of practice hypothesis. However, it does not explain the difference between performing a well-learned task and a novel task nor does it describe differences in the quality of schemata. Furthermore, it does not mention the notion of hierarchical control of schemata and sub-schemata.

In fact, Brown (1979), in criticising schema theory, argues that schema theory is simply an assimilation model. In other words the build up of knowledge or creation of new schemata are "incorporated" into already acquired knowledge structures. For schema theory does not explain how new schemata are formed (in order to explain change which is the major feature of development) nor does it explain how pre-existing schemata are modified In fairness, Schmidt's schema theory (1975) was not written to explain individual differences nor to handle developmental issues. . However, more recent theories have begun to address such questions.

In conclusion, Schema theory has had a profound effect on the motor skill learning literature. Perhaps the most amount of research has been done on the variability of practice hypothesis that is such an important part of the theory. Briefly, schema theory predicts that a group attempting to learn a new task will learn that task more effectively if they experience many different experiences associated with an action within a response class than if the learners only practice under one or two conditions. The research on this topic is quite extensive; however, it is also quite equivocal; as it is not central to our view of skill learning it will not be reviewed at this time (Shapiro and Schmidt, 1982; Barclay & Newell, 1980).

D. NORMAN AND SHALLICE'S VIEWS OF SCHEMA.

Norman and Shallice (1980) view a schema as a package of knowledge which is formed out of learning and experience and which can be general or specific under different conditions. Such schemata are called into action when needed. They contend that there are source schemata and subschemata. It is through these schemata that people control their actions.

Norman and Shallice (1980) propose that schemata can be in three activation states: dormant, activated, and selected. The majority of schemata are usually dormant when they reside in permanent long-term memory. Activated schemata are those that are called into action when a situation arises. Many factors determine the degree of readiness of these activated schemata, for example, motivation, strength of schemata, appropriateness for the situation at hand. The degree of activation reflects the appropriateness and readiness of a schema to be called into action. The greater the activation value the more likely it will be selected for action. Finally, selected schemata are those that have activation values high enough to be chosen to guide action.

Horizontal Threads.

Norman and Shallice (1980) propose that an action sequence is comprised of a number of component schemata that are activated and selected to guide action. Horizontal threads represent automatized sequences of action which have a source schema and sub-ordinate component schemata. In fact, such horizontal threads remind one of Bruner's modularized sub-routines which, he suggests, guide action. A well-learned action sequence becomes automatized to the degree that it requires very little, if any, conscious control; but not all action sequences are well-learned. For this reason, the various schemata which are related to the action sequence are competing with one another for selection. Norman and Shallice contend that whenever competition occurs among two or more schemata a contention schedule mechanism comes into play which assesses the degree of activation such that the most appropriate action sequence is selected for a given situation.

Vertical Threads.

Vertical threads can influence lower-level schemata through changes in activation values. When confronted with a novel task the individual may not have available the appropriate schemata to guide action. Vertical threads represent a means by which control can influence existing action schemata (horizontal threads). They also can reflect changes in motivation. Thus, when new schemata have to be produced in order to respond to a specific situation the attentional mechanism (vertical threads) can influence already acquired knowledge structures. It is through the interaction of the existing knowledge structures that new schemata are formed to meet the demands of the task at hand.

Vertical threads influences come into play when a person does not have sufficient horizontal threads to meet the demands of a given task. In such novel situations the person must use higher-level control structures like verbal cues, action rules, or monitoring methods to generate an appropriate solution to the task or problem at hand. The cost of involving such higher-level systems is to reduce the speed of response. Hence, skilled individuals are those who have a great many horizontal threads to select, orchestrate and monitor their actions.

Norman and Shallice's theory (1980) seems to be a more wholistic approach to the acquisition of skill. The above authors see the value of distinguishing between skilled and unskilled action which underlies individual differences in performance on various tasks. Such a view acknowledges the importance of knowledge acquired with development and its role in guiding action.

The implications of the above theory are that practice must vary with the phase of skill acquisition of the learner. That is, perception and identification of the taks's demands will be perceived differently by individuals with different levels of knowledge in a particular skill.

E. NEWELL AND BARCLAY'S VIEWS ON KNOWLEDGE ABOUT ACTION.

In another important paper on developmental skill acquisition, Newell and Barclay (1982) provide a metatheoretical approach to the development of cognitive control of action. They discuss three main themes: the representation of knowledge about action, the development of metacognitive knowledge, and the key factors which influence the development of knowledge about action.

Newell and Barclay (1982) point out that, knowledge about action is represented (stored) "in terms of generic concepts rather than in a more direct one-to-one correspondence" (p.178). They note that such generic knowledge structures have been used quite widely and for quite some time. The labels associated with such generic knowledge structures include plans (Miller, Galanter, and Pibram, 1960), schemata (Rumelhart and Ortony, 1977), definitions, (Norman, Rumelhart, and LNR, 1975), and scripts, (Schank and Abelson, 1977). All of these terms refer to knowledge structures that "represent generic concepts at various levels of abstraction" (p. 178). They note that many of these ideas stem from the emerging field of cognitive science and [illegible] have had little influence in the action domain. However, Newell and Barclay point out such terms and the concepts associated with them are closely linked to Schmidt's (19[illegible] on schemata as they relate to motor skill learning.

Newell and Barclay (1982) review the basic premises of Schmidt's schema theory and make a number of important observations on it.

The initial observation that they make about the schema approach to motor skill learning theory is that it is too narrow a conception of the representation of knowledge about action. Newell and Barclay observe that:

> "The cognitive science approach has focussed principally on the representation of the act itself (e.g. Rumelhart and Ortony, 1977), without recourse to the details of movement per se. In contrast, the motor skill learning orientation gives principal emphasis in schema representation to details of the response specifications (e.g. Schmidt, 1975), such as the kinematic and kinetic features of the movement. Of course, these interpretations of schema are not mutually exclusive, but the gulf between them is wide, and the motor skills approach in particular is much narrower than it should be. The need for the link between the two orientations, even with their current assumptions, is eminently self-evident. Unless there is some conceptual action peg on which to hang response specifications the act will not be completed" (p.180-181).

They go on to note that the equivocal findings stemming from research studies on the variability of practice hypothesis might suggest that there may be

> "different levels of response generalization; a broad class of generalization that reflects the transference of the act to a range of circumstances and a narrow range of response generalization that reflects the transference of details relative to the precision of the movement pattern" (p. 181).

In addition, they provide some evidence from the mental practice literature (Minas, 1978) to support the notion that the broad generalization aspect might be more symbolic and require minimal physical practice in contrast to the physical practice required to improve the precision of specific movements. Thus, Newell and Barclay (1982) call for a broader view of what underlies skilled action, a view that might include different stages of differentiation from intention to the execution of the action.

Perhaps the most important observation that Newell and Barclay make is that schema theory approaches to the acquisition of skilled action are very static accounts that do not appreciate the importance of the organism - environment interaction. They suggest that schemata should be viewed as active entities that are continually being shaped by organism - environment interactions. Thus, they suggest that the acquisition of knowledge about action must include "top-down, knowledge to action, and bottom-up, perception to knowledge ", if they are to explain the acquisition of skilled action.

F. A KNOWLEDGE BASED APPROACH TO MOTOR SKILL ACQUISITION.

In a recent article, Wall, McClements, Bouffard, Findlay, & Taylor (1985) outline an heuristic approach to motor development which stresses the importance of knowledge about action in the skill acquisition process. They note that up until recently most studies of motor development have essentially been cross-sectional studies of children's motor performance with age, sex and a few trials as the major independent variables. The present review of the knowledge-based approach will be divided into two major sections. The first section reviews some of the main ideas in a knowledge-based approach to motor development, while the second section deals with some major developmental factors that influence the acquisition of motor skills.

Acquired Knowledge.

Acquired knowledge refers to knowledge that is gained through experience which increases with development. As Figure 1 shows, acquired knowledge about action can be categorized into three major types: procedural, declarative, and affective. In addition, metacognitive knowledge and skills can also be differentiated. A brief examination of each of these types of knowledge about action follows.

Procedural Knowledge About Action.

Procedural knowledge refers to the storage of action schemas that control the execution of skilled actions (Wall et al., 1985; Norman and Shallice, 1980). In the knowledge-based approach, as in schema theory, schemata are viewed as packets of knowledge that store information in a generalized manner. As such, they facilitate the storage and flexible use of large amounts of information. Furthermore, perceptual, decision-making and response execution schemata can be linked together to control complex skills. At each stage of an action sequence, considerable flexibility is provided by the use of control schemata that access relevant information from lower-level schemata

(Kozminsky, Kintsch, & Bourne, 1981). Such control schemata can access both declarative and procedural knowledge consciously or automatically. Thus, factual information on the rules of the game, pertinent biomechanical factors, or key contextual cues can readily influence the initiation or control of an action. In the same way, control schemata can access general or specific procedural knowledge about visual search, attention deployment, memory retrieval and executive processes. Thus it is postulated that procedural knowledge, stored in schema form, underlies the instantiation of all aspects of an action sequence including the stimulus identification, perception, decision-making, response selection and execution, and the evaluation of intrinsic and extrinsic feedback (Singer, 1980; Norman & Shallice, 1980; Gallistel, 1981; Stelmach & Diggles, 1982).

Acquired procedural knowledge, in schema form, operates within an heterarchical system that makes use of a myriad of feed-forward and feedback systems (Parker, 1981; Wolfe, 1983). Human evolution has ensured that motor skill acquisition will be influenced by both top-down and bottom-up processing (Arbib, 1980). At the same time, such flexible processing occurs within the constraints established by the anatomical and neuro-physiological features of the body. Recent developmental studies demonstrate how such constraints influence the early acquisition of procedural knowledge about action (Thelen, 1981; Thelen & Fisher, 1983; Von Hofsten, 1983; 1984).

A fundamental observation in the skill acquisition process is that deliberate attentional control is required at certain times in it. Fitts (1960) and Gentile (1972) postulated that motor skills are usually acquired in three distinct phases: cognitive, associative and autonomous. The cognitive or "getting the idea of the movement" phase requires the involvement of considerable cognitive resources, whereas the associative and autonomous phases are more automatically controlled. Such conscious cognitive control is relatively costly in terms of the speed and fluidity of a given performance (Norman & Shallice, 1980; Kinsbourne, 1981); furthermore, by definition, novices are usually operating in just such a costly control mode.

The developmental level of a person's procedural knowledge base about action may be viewed in terms of the quantity and quality of automatized skills that he or she has available to meet the tasks of a given domain. Hence, a skilled person with a large repertoire of automatized skills can more efficiently handle a broader range of tasks than a person with fewer skills. Furthermore, the skilled person will have to use deliberate attentional control much less often than a novice would simply because he or she has this greater repertoire of well-learned responses.

Declarative Knowledge About Action.

Declarative knowledge about action refers to factual information stored in memory that can influence the

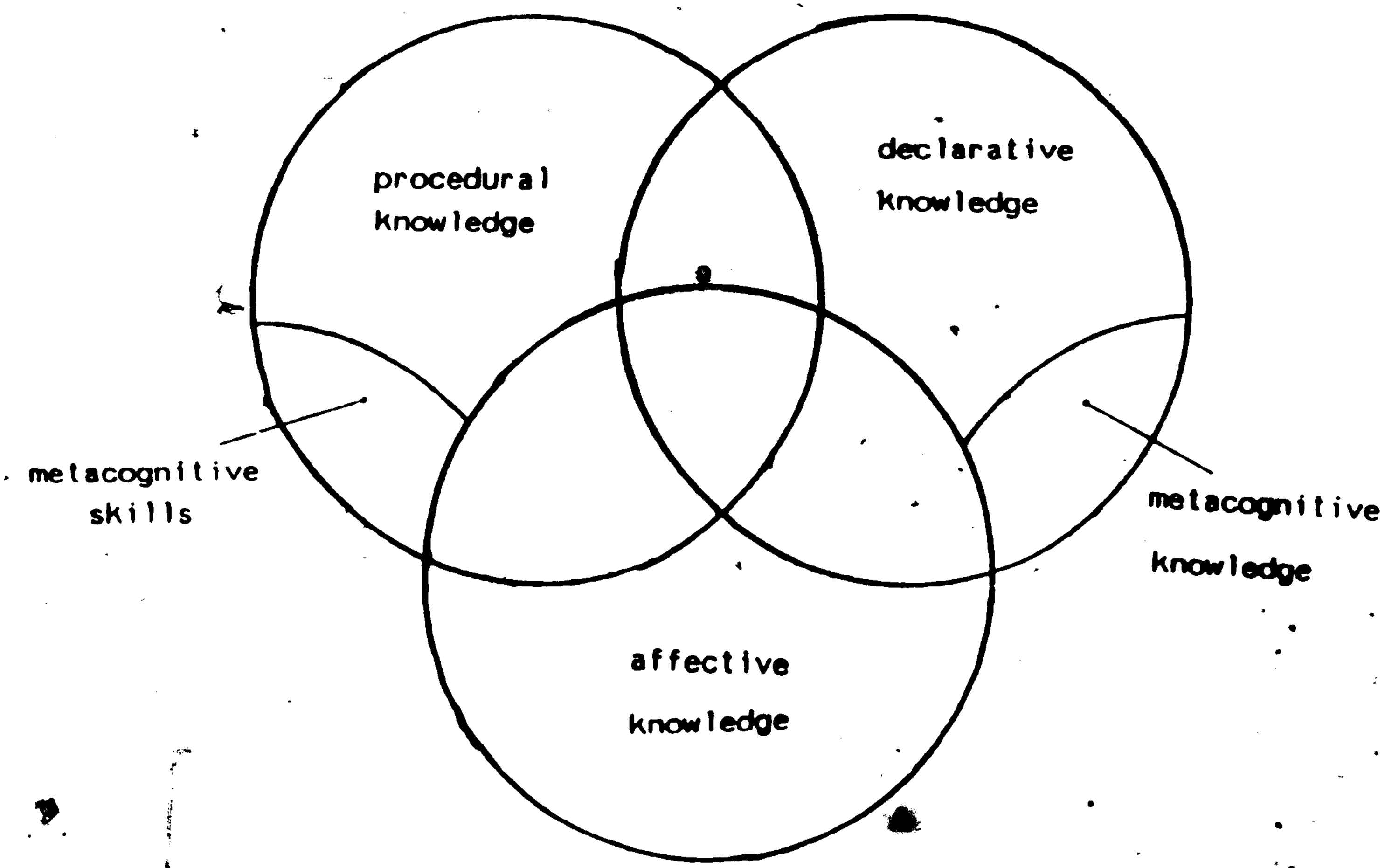


Figure 1.

A Knowledge-Based Approach for Skill Acquisition: The Model.

development and execution of skilled action. As children grow older, they begin to appreciate the morphological, biomechanical and environmental constraints under which they are operating. This movement-related knowledge about the self, others, and physical objects within the environment is a major product of cognitive-motor development. During the preschool years, declarative knowledge about action is essentially nonverbal. However, as children develop more knowledge about their actions, the actions of others, and the effects of their actions on objects and other people, they begin to use language to describe them. This movement vocabulary is particularly important when caregivers use language to guide the motor learning process.

One of the most important aspects of declarative knowledge about action is the information that children acquire about their own bodies and how they operate in space. Pick and Lockman (1975) have shown that children can handle progressively more complex spatial tasks as they grow older. They note that children acquire multiple reference systems for describing the way they move in three dimensional space. Starting with relatively simple egocentric coding of manipulatory tasks, children go on to use geocentric reference systems which ultimately lead to the flexible use of more sophisticated mental representations about space. As noted earlier, very early in life children begin to attach verbal labels to describe their self-referential spatial system and use this declarative knowledge in making decisions about their movements in spatial environments (Olson, 1975). Such declarative knowledge becomes a usefull tool in the cognitive control of action.

Affective Knowledge About Action.

Affective knowledge about action refers to the subjective feelings that children store about themselves in various action situations. Such feelings develop from the thousands of interactions that children have with objects and other people in a variety of action environments. As they grow older, children develop varying degrees of movement competence. Competent children experience a greater number of success experiences than less-skilled children simply because they more readily handle the increasingly difficult tasks which they must face as they grow older. Such positive experiences generate feelings of confidence that motivate children to try even more challenging tasks which further increases their skill level and general movement competence (Keogh & Griffin, 1982).

Metacognitive Skills.

Metacognitive skills are concerned with the control and effective use of stored knowledge through the selection, control, and monitoring of a person's cognitive processes. Higher-level executive processes are central to the control and execution of skilled action. Effective metacognitive control of cognitive processes underlying stimulus identification, response selection, and response programming can ensure that voluntary actions optimally meet the demands of the situation.

Metacognitive skills may be under conscious control or automattzed so that they operate unconsciously. The more skillful a learner is in a specific situation the more likely he or she will be to use both types of metacognitive processing. Again, the demands of the task and situation will affect the type of metacognitive skills that will be used.

Perhaps, the most important reason for considering the role of metacognitive skills is the intimate relationship they have with the motivation of the learner. Experienced instructors know that the effectiveness of a suggested metacognitive strategy will largely depend on the learner's ability to use it. The motivational state of the learner largely determines the degree to which such skills as planning, predicting, monitoring and evaluating will be used. Experienced, motivated learners are more likely to strategically enhance their learning by systematically controlling their own learning.

Metacognitive skills vary with the extent and specificity of a learner's knowledge base; recent studies in cognitive development show that these self-regulatory skills can have a dramatic effect on learning. Unfortunately, very few motor development studies have considered the role of these executive processes in the skill acquisition process. Studies are needed on the interaction among declarative, procedural and metacognitive knowledge about action with special attention to the role that metacognitive skills play in the skill acquisition process.

G. EXPERT-NOVICE DIFFERENCES AND THE KNOWLEDGE-BASED APPROACH.

In a developmental study of children's memory Chi (1978) found that young children who played tournament chess were much better able to recall chess positions than novice adults even though on a control task the adults obtained significantly higher digit-span results than the children.

Allard, Graham, & Paarsalu (1980) in a study of expert-novice differences in basketball also found that the skilled players remembered more structured offensive and defensive situations than their less-skilled peers; however, no differences were found between the two groups on the recall of unstructured situations. Jones & Miles (1978) also found that advanced tennis players were better able to predict where a ball would land than beginners could. All three of these studies underline the importance of considering domain-specific knowledge about action in the skill acquisition process.

The results of the above studies support the differences between experts and novices that have been found in the "chunking" of chess patterns (Chase & Simon, 1973).

Furthermore, such domain-specific differences have been found in the way experts approach problem solving in physics (Simon & Simon, 1978), and radiological diagnosis (Lesgold, Feltovich, Post, & Penner, 1984).

Chiesi, Spilich, & Voss (1979) studied high knowledge (HK) and low knowledge (LK) baseball players. They found that HK individuals were able to acquire new knowledge faster and easier in the baseball domain. LK individuals did not make equivalent progress as the HK players. The authors suggest that this is so because new information is mapped into already existing knowledge structures. Thus, HK players are able to acquire new knowledge in this specific domain because they have a larger knowledge base on which to map the new information.

In all of the above studies of domain-specific knowledge, skilled individuals were able to use their domain-specific knowledge to generate more effective problem solving strategies than their less-informed peers (Siegler, 1983). The above observations are certainly in keeping with the ideas outlined in the knowledge-based approach to motor development.

In summary, a number of points should be made about the knowledge-based approach to motor development and the process of skill acquisition. First, it is a developmental approach that simply adumbrates different types of knowledge about action which increase with experience. Second, the approach does not directly deal with the question of how skill is acquired but it simply identifies what types of knowledge are acquired. Third, the knowledge-based approach stresses that in any situation, action is the instantiation of procedural knowledge which may access other types of knowledge about action. The teasing out of different types of knowledge about action in a performance is extremely difficult and can only be done by inference when there are changes in performance. Fourth, the approach stresses the importance of domain-specific knowledge, expert-novice differences, and calls for the investigation of learning over trials when the key factors of a person's knowledge-base, the task at hand, the context and the environmental conditions are taken into consideration.

The major thrust of this investigation is to examine the effect that age, skill level, and different types of instruction have on performance over trials. The major premise under which the study is based is that learning requires the integration of different types of knowledge about action and the ability to go beyond the information given; however, such learning is directly related to the adequacy of the different knowledge-bases of the learner.

H. CHI'S VIEWS ON KNOWLEDGE AND LEARNING.

In a classic paper, Chi (1981) argues that "to understand learning, one must make a detailed examination of the structure and development of children's knowledge bases" (p.221). She asserts that the growth of a child's knowledge base is what accounts for improved memory performance and learning. Like others, Chi distinguishes among three types of knowledge: procedural, declarative, and strategic. She suggests that procedural knowledge may be viewed as knowledge of the use of rules; that is, knowing how to add or multiply two digits. Declarative knowledge refers to lexical or factual knowledge; that is, knowing a cat is a cat or a house is a house. She notes that:

> "the game of chess provides an excellent illustration of the differences between procedural and declarative knowledge. Knowledge about the chess pieces, game rules, and players corresponds to declarative knowledge, while knowledge about which move to make corresponds to procedural knowledge. Both procedural and declarative knowledge are domain-specific" (p. 222).

Chi goes on to note that in contrast to domain specific procedural and declarative knowledge, strategic knowledge can be "viewed as knowledge of heuristic rules that are presumably applicable across several domains". The rehearsal process in memorizing digits, letters, or words is an example of such strategic knowledge. Chi's three categories of knowledge are congruent with at least some of the content of declarative knowledge, procedural knowledge, and metacognitive skills in the knowledge-based approach proposed by Wall et al (1985). Chi makes a most important qualifying comment on the value of such categories of knowledge, namely,

> "although the distinction among procedural, declarative, and strategic knowldge may be artificial in the sense that a single formalism such as a production system may be able to capture all three types of knowledge, it provides a useful

> framework for the discussion of developmental research at the present time" (p. 222).

She also argues that to understand development one must consider the development of the entire knowledge base of the child. She asserts,

> "that development is mainly the increment of more content knowledge, both declarative and procedural. The greater use of strategies with increasing age is a byproduct of greater content knowledge, in the sense that strategies are a generalized form of specific procedural knowledge" (p. 223).

This position is entirely consistent with other recent views on learning (Siegler, 1983; Glaser, 1984).

In a more recent paper, Chi (1983) presents an initial learning framework for development in which she extends some of the above views. She contends that Anderson's (1976) ACT system and Rumelhart and Norman's (1976) ASN system are both excellent starting points for a developmental theory of learning.

Briefly, Anderson's (1976) ACT system divides knowledge into declarative and procedural categories. A node-link network represents factual knowledge while production rules represent procedural knowledge.

The ACT model suggests that the first stage of all learning is the acquisition of declarative knowledge. Procedural knowledge is acquired through practice by the conversion of existing factual knowledge. Thus, declarative knowledge provides the initial guidance for the learning of new production rules that with practice become automatic. With such practice the skill becomes faster and more reliable. Thus, the ACT system contends that it is the knowledge compilation process that drives the development of an extensive declarative and procedural knowledge base which allows the learner to accurately and efficiently handle a wider range of tasks.

The ASN learning system described by Rumelhart and Norman (1976) is similar in many ways to the ACT system. The ASN system is a more elaborate one as it uses schemata with hierarchical structures and variables as its basic unit. The ASN system represents both procedural and declarative knowledge through the node-link system. Thus,

> "a dinosaur schema may consist of the node 'dinosaur' linked to the node 'ferocious meat-eater', with links from this node to 'upright', 'lots of sharp teeth' and 'short neck'. This structure, which is probably part of a more general dinosaur schema, could be accessed as declarative knowledge. On the other hand, this same structure can represent a set of instructions for determining if a dinosaur is a ferocious meat-eater" (p. 93).

Like Anderson (1976), Rumelhart and Norman (1976) also contend that the acquisition of declarative facts is the first stage of learning. An accretion process is proposed in which existing schemas flexibly store new facts at the proper place within a given network. Schemata can also produce new schemata through a restructuring process if no existing schema fit the stimulus situation. This restructuring may occur through pattern generation or schema induction. Pattern generation is the process in which a new schema is created by modifying an old one while schema induction is the

> "creation of a new schema from two or more older ones which tend to occur together. This process is characterized as a sort of 'aha' phenomenon involving insight, and presumably occurs rarely" (p. 94).

Chi (1983) points out that there are certain similarities between these two views of learning. She notes that:

> An accumulation of declarative knowledge occurs in both, as well as complex learning involving refining and restructuring of knowledge. Existing knowledge can be tuned, either through specialization or generalization, and new structures can be built from old, either through generation of analogous structures, or through the combination and concatenation of old ones. This particular set of mechanisms of learning is not novel. Flavell (1972) described many of these ideas, and so did Gagne (1968), and more recently Fischer (1980). The uniqueness of the two models that we have discussed derives from the specificity with which their mechanisms are described. Our hypothesis for the time being is that either one of these models is perfectly adequate to simulate development" (p. 94).

A close examination of both Anderson's (1976) and Rumelhart and Norman's (1976, 1982) views on learning suggests that a great deal of theoretical and empirical work remains to be done on them. In the same way, the ideas of Norman and Shallice (1985) and Wall et al (1985) need to be extended to include more specific details on the developmental skill acquisition process. However, it is clearly evident that one must consider the match between a child's knowledge base and the task to be learned. Second, the context in which a task is learned must be considered. Third, the domain-specific procedural and declarative knowledge must not be ignored. Clearly these are important considerations that must be addressed in future developmental studies of skill learning. Some of these notions are addressed in the present study.

III. CHAPTER THREE: THE PILOT STUDY.

Research on the tracking performance of children, especially when the tracking pattern is a familiar one has not been done. Therefore, it was necessary to complete a pilot study in order to examine a number of factors related to the experimental task. This chapter presents the results of that pilot study.

A. PURPOSE OF THE PILOT STUDY.

The purpose of the pilot study was threefold:

1. to confirm the appropriateness of the task, by examining individual and age differences and the consistency of the performances within each age group;
2. to establish an appropriate method for assigning subjects to skilled and unskilled groups based on tracking performance; and,
3. to determine how many trials were feasible in a developmental study of skill acquisition.

B. METHODS.

Subjects.

Subjects were 36 female elementary school students aged 6, 8, 10, (12 in each age group) who attended Ekota Elementary School in Edmonton, Alberta. All subjects were righthanded and had no reported neuromuscular, sensory or behavioural disorders. All subjects who participated in the study were from urban middle class socio-economic backgrounds.

Apparatus.

An Apple II Plus computer was used with a NEC character display. An Apple joystick which was connected to the computer allowed the subjects to communicate with the computer. A computer program generated a target which appeared on the screen. The target was a 1X1.3cm rectangle which moved at a constant speed, and could form various shapes, such as a square, circle, bean shape and figure eight. A smaller filled square .3X.3cm was controlled by the subjects via a joystick connected to the computer. The computer screen was placed on a desk and the joystick was stabilized in front of the mid-line of the student. The experimenter was seated beside the subject and controlled the experimental protocol by way of the computer keyboard.

Procedures.

Pretest Session.

Once subjects were seated they were asked whether they had seen or used a computer before. If not, then a brief introduction was given regarding how the computer and the joystick operated. Following this introduction, all subjects were given the instructions for the pretest session. These instructions were as follows:

> "When you hear a beep, the target (experimenter indicated the target on the screen), will start

> moving. You also can see that the smaller dot will move when you move the joystick. O.K., try to move it now and see if you can keep the dot on the moving target. You should try to keep your dot on the moving target for as long as the target moves. Do you have any questions? If not you will start when I say "hold the joystick", and you hear the "beep" and the target starts moving. Remember try to keep the dot on the moving target for as long as the target is moving".

In the pretest session as well as the experimental condition the subjects were seated in front of the screen with the joystick in front of them. They were allowed to use only their right hand to move the stabilized joystick. The joystick was at a standard height for each child based on the child's sitting height. The target appeared on the screen (simultaneously with the cursor), and started moving on a predetermined path. It moved for 20sec., and the subject had to track the target with the cursor, trying to center the cursor on the moving target all the time. There was a 15sec interval during which the computer recorded the data of the previous trial before the next trial began. The experimenter motivated the subjects after every third trial by saying, "Good work, remember keep your dot on the target". Thirty pretest trials were given to each student. The shape to be tracked was a non-geometrical figure (see Appendix A). An initial three way ANOVA was applied on the pretest data. The first six subjects that obtained the best tracking scores during the pretest were then classified as the skilled group and the second six subjects as the non-skilled group.

Based on the above classification, the resulting experimental design for the pilot study included an age variable (6, 8, 10 years of age), a skill category variable (skilled, non-skilled), a treatment variable (control, declarative knowledge instructions, and metacognitive knowledge instructions), and 45 trials. The shape to be tracked was a figure eight (see Appendix B). Thus, the data were analyzed by a 3(age) X 2(skill level) X 3(treatment) X 45(trials) analysis of variance with repeated measures on the last factor.

Experimental Session.

Three experimental conditions were used during the test session. First, the same instructions were repeated for the testing session as for the pretest. For the control condition, no further instructions were given except: "remember keep your dot on the target whenever it is moving". For the second condition the following declarative knowledge instruction was given:

> "you should keep in mind that the target will be following a figure eight path as it moves on the screen. Remember, the target will be making a figure eight shape. Keep your dot on the target whenever it is moving".

For the metacognitive condition the instructions were as follows:

> "The target will be making a path of a shape that you know. If you can find the shape that the, target is making it should help you keep your dot on the target. So, try to figure out what the shape is; but remember, keep your dot on the target whenever it is moving".

At the end of the 45 trials all subjects were shown a sheet of paper where there were 8 shapes (see Appendix C). The students had to identify 4 of the shapes (rectangle, figure eight, circle, triangle), as a test of declarative knowledge about shapes. None of the subjects failed to identify the shapes.

C. DATA COLLECTION.

The points of the target and the child's response were recorded as X and Y values. The difference between the XY of the target and the XY of the child's response was calculated separately for each data point. The above difference between the target's XY and the response's XY, a and b, made up the two sides of a right angle triangle whose hypoteneuse was calculated and was used as the direct distance error of the child's response from the target.

D. RESULTS.

The above distance measure averaged over ten trials (16-25) was used as the dependent variable to determine tracking performance. The first 15 trials were considered to be learning trials. During the last 5 trials the subjects reported that they had started to feel tired; therefore, based on the feelings of the subjects and a visual analysis of the data, the ten trials from 15 to 25 were chosen for analysis as they reflected the most stable tracking performance.

For the 6 year old girls, the subjects' mean scores ranged from 6.16 to 10.36 and the average mean score was 8.88 (see Table 1). For the 8 year old girls the subjects' mean scores ranged from 5.96 to 12.26 with an average mean score of 8.62 and for the 10 year olds it ranged from 4.49 to 8.89 and the average mean score was 6.30. Two skill groups were formed out of the total number of subjects in each of the three age groups, based on the results of the distributions presented in Appendix D.

As indicated earlier, the experimental design had: 3 age levels, 2 skill groups, 3 experimental conditions and 45 trials. The results of the four way analysis of variance with repeated measures on the last factor (trials) was completed on the distance error scores and it is presented in Table 2.

As indicated in Table 2, the skill factor [illegible] not significant; however, it was nearly so ($\underline{F}(1,60)=3.03, \underline{p}<.10$). The age effect was significant with the mean error scores being significantly less for the grade 5 group in comparison to the grade 1 and 3 groups. There was no difference between the two younger groups. Unfortunately the instruction effects were not significant; however, there was a significant trial effect. Even though the trials factor was significant, a visual analysis of the trial means did not provide any meaningful interpretation of this factor as the means varied greatly across trials.

TABLE 1

Mean Pretest Error Scores for Girls in Pilot Study.

Grades	Subjects	High Score	Low Score	Average Score
1.	12	6.16	10.35	8.88
3	12	5.96	12.26	8.62
5	12	4.49	8.39	6.30

TABLE 2

Analysis of Variance of Distance Error Scores in Pilot Study

Source of Variation	SS	DF	MS	F	P	Greenhouse Geisser Prob.
Mean	126309.95	1	126309.95	792.89	0.000	
Skill Group (A)	482.18	1	482.18	3.03	0.099	
Grade (B)	3114.92	2	1557.46	9.78	0.0013	
Instruction (C)	203.46	2	101.72	0.64	0.539	
A * B	117.77	2	58.89	0.37	0.696	
A * C	22.01	2	11.01	0.07	0.933	
B * C	672.75	4	168.19	1.06	0.407	
A * B * C	144.17	4	36.04	0.23	0.920	
ERROR	2867.47	18	159.30			
Trials (D)	441.68	44	10.04	3.02	0.0	0.001
D * A	101.32	44	2.37	0.71	0.918	0.710
D * B	242.77	88	2.76	0.83	0.863	0.674
D * C	234.09	88	2.66	0.80	0.905	0.710
D * A * B	320.75	88	3.64	1.10	0.263	0.356
D * A * C	432.18	88	4.91	1.48	0.004	0.093
D * B * C	561.05	176	3.19	0.96	0.626	0.544
D * A * B * C	548.35	176	3.12	0.94	0.696	0.580
ERROR	2630.60	792	3.32			

E. DISCUSSION OF THE PILOT STUDY.

The results of the pilot study indicated that the task was for the most part an appropriate one in that it resulted in individual differences and fairly consistent age differences in tracking performance. The results indicated, however, that despite an age main effect there was no skill level effect. This was attributed to the small number of subjects in each age group (n=12); hence, only two subjects were in each cell of the design at each age. It was also attributed to the fact that the groups were determined by dividing the total number of subjects, within each age group, into two groups without the benefit of a mid-range group. Therefore, the range of scores for the skill split was very small. It was decided that in the experimental study the two skill groups would be chosen from a larger range of performers so as to ensure skilled- novice differences.

The most valuable information was obtained through the post-treatment interviews. The interviews of the subjects following the testing session revealed that the children were tired after they had completed 45 trials hence, they had a hard time focussing on the task during the later stages of the experiment. Also, the 'joystick' used to monitor the cursor on the computer screen was too sensitive, in that small movements of the hand produced large movements of the cursor on the screen. This made it extremely difficult for the subjects to move the cursor smoothly, resulting in greater error in their tracking performance.

In summary, three important adjustments were made before proceeding to the experimental study.

The apparatus was replaced with one that could be programmed to collect more data points as well as eliminate error due to poor mapping of the cursor with the 'joystick'. The number of iterations was reduced from 45 to 20 so that subjects would not get as tired. Also, the length of each iteration was reduced from 45sec to 15sec. Finally, a more sensitive tracking measure (Root Mean Square error) that has been widely used, and is highly recomended by many researchers (Poulton, 1974; Franks, Wilberg, & Fishburne, 1982), was chosen for the experimental study.

IV. CHAPTER FOUR: METHODS FOR THE EXPERIMENTAL STUDY

A. GENERAL METHODS.

In the experimental study a two-part research plan was used. An initial pretest session was conducted to establish tracking scores of the grade 3 and 5 subjects. Skilled and novice subjects were then selected from each grade. These subjects were then randomly assigned to three conditions (control, declarative and metacognitive) for the final test session, yielding a 2(grade levels) X 2(skill groups) X 3(instruction conditions) X 20(trials) research design. In the following pages the general description of the subjects, the apparatus, and the testing procedure is presented followed by a specific description of the pretest and the experimental test sessions.

B. EXPERIMENTAL TASK

The reason for using a tracking task is twofold: 1. it is a task which is included in the culturaly normative skills of today's young children and fullfills the requirement of being an ecologically-valid task with which to measure one aspect of motor development. Video games and home computers are a common phenomenon and many children have played games which require tracking of a moving target; and, 2. tracking tasks involve a great deal of redundancy and it assumes a certain amount of predictability in learning and performing the task due to its regularity during and over the trials. Therefore, it is suitable to test whether learning takes place and the kinds of general and specific strategies used by the individual in order to perform the task (Poulton, 1957). Another advantage of using this tracking task is the ability to simultaneously record the position of the target and of the S's response positions at any given point and time (Poulton 1957). Also difficulty and complexity of the task can be varied along various dimensions.

Subjects.

The subjects who participated in the study were enrolled in three elementary schools within the Edmonton Public School Board, during the academic year 1985-86. Only right handed girls as determined by writing hand preference and teacher assessment, from grades 3 and 5 (mean ages, 8.08 and 10.07 years), were involved in the study. Age ranges were restricted to 16 months to prevent overlap of grade 3 and 5 subjects. All subjects involved had no apparent neuromuscular, sensory or behavioural disorders.

Apparatus.

An Apple Macintosh computer with a "mouse" was used as the device to measure tracking performance. The computer program generated a dark dot (1cm in diameter), as the moving target to be tracked. A cross of equal size acted as the cursor which allowed the subject to track the moving target via the "mouse".

The computer screen was located on a desk directly in front of the subject. The "mouse" was carefully placed each time on the desk in front of the subject's mid-line. The seat was adjusted so that the subject was at a comfortable height. The experimenter was seated beside the subject and controlled the experimental protocol by means of the computer keyboard.

Procedures.

Subjects were tested during the school day and they were taken out of their classroom one at a time. Once subjects were seated they were given a brief introduction to the way the computer and the "mouse" operated. Then they were given the following instructions:

> "Notice that when I move the mouse on the desk the cross moves on the computer screen and it goes wherever I want it to go. As soon as you move your cross and place it on the dot and push the button on the mouse once, the dot will start moving to different places on the screen. I want you to move the cross with the mouse and take it wherever the dot goes.
>
> You have to keep your cross on the dot, if you can, for as long as the dot moves. Before you start, I am going to let you watch the dot moving. Do not do anything, just watch the dot". (Once the dot started moving), "see, you have to move the cross with the mouse, like this and try to keep it on the dot, if you can.
>
> If it is too hard to keep your cross on the dot, try to keep it as close to it as you can. You have to use only your right hand and you will start your own games by pushing the mouse button once. Do you have any questions? If not, remember do not stop moving your cross unless the dot stops moving. Hold the mouse, ready, push the button, go".

All of the subjects understood the instructions and seemed to have no difficulty controlling the 'mouse'.

C. PRETEST SESSION.

Subjects.

One hundred girls were tested (50 at each of the grades 3 and 5), to determine their tracking performance on a non-geometric shape. In transferring their data from the Macintosh to the MTS, the scores from the 11 subjects were lost, leaving 89 subjects in the study.

Apparatus and Procedures.

The apparatus described above was used to test for initial tracking skill. The general instructions were repeated to all subjects. Fifteen trials were given to each subject, the first two of which were demonstration trials, where the subjects were only observing the moving target. The following three trials were considered practice trials and they were not included in the data analysis. The target moved for approximately 15 sec., following the path of a shape that was not easily identifiable. There was a 3 sec. interval in between the trials during which the computer recorded the data. Subjects initiated their own trials. Reinforcement was given after the 5th, 8th, 11th, and 14th trial by saying, "good work, stay on the dot if you can."

Only the last ten trials were used to calculate the Root Mean Square Error (RMSE), for each trial. The mean of these ten trials' RMSE was calculated and used to determine the subject's level of tracking performance. This information allowed the subjects to be placed in two skill categories: the skilled and novice groups within each of the two age groups.

Results.

The results of the pretest session are presented in Appendix E. The mean performances for the two age groups were 37.99 and 28.85 with Standard Deviations of 15.16 and 10.66. Visual inspection of the data showed that three subjects in grade 3 and two subjects in grade 5 were well outside the normal distributi[illegible]cores and were excluded from the pretest sample. Subjects with the top 15 and bottom 15 scores in each grade were included in the target sample for assignment to the various experimental conditions of the study. Table 3 summarizes the data for the remaining subjects. The means of RMS error scores for grade 3 subjects (n=44) ranged from 21.64 to 56.96. The scores of the 'skilled group' (n=15) ranged from 21.64 to 32.57 and those of the 'novice group' (n=15) from 39.93 to 49.58 (see Table 4). For the grade 5 group (45 subjects), the total mean RMS Error scores ranged from 16.98 to 46.91. The scores of the skilled group (n=15) ranged from 16.98 to 25.63 and those of the novice group (n=15) from 29.39 to 42.57.

TABLE 3

Mean Pretest Error Scores for Subjects in the Experimental Study

Grades	Skilled	Novice	Subjects
3	21.64	56.96	44
5	16.98	46.91	45

TABLE 4

High and Low Pretest RMS Error Scores for Subjects in the Experimental Study: The Skilled and Novice Groups.

	Skilled		Novice	
Grades	High Score	Low Score	High Score	Low Score
3	21.64	32.57	39.93	49.58
5	16.98	25.63	29.39	42.57

TABLE 5

Analysis of Variance of RMS Error Scores for Grades 3 and 5 for the Pretest Session

Source of Variation	SS	DF	MS	F	P	Greenhouse Geisser P.
Mean	993882.78	1	[illegible]78	1366.12	0.000	
Grade (A)	18621.38	1	18621.38	25.60	0.000	
ERROR	63294.26	87	727.52			
Trials (B)	1051.53	9	116.84	0.74	0.669	0.641
A * B	1128.46	9	[illegible]25.38	0.80	0.618	0.594
ERROR	123043.	783	157.14			

D. EXPERIMENTAL TEST SESSION.

Subjects.

The 15 subjects with the best mean tracking scores and the 15 subjects with the poorest mean scores were selected from each grade to make up the sample for the experimental phase of the study. Thus, 60 of the initial 100 subjects (30 in each of the grades 3 and 5), were placed in two groups, the skilled and the novice groups, based on their pretest tracking scores (see Appendix E for raw scores of all groups). The subjects in each of the two grades and two skill groups were randomly assigned to the three instruction conditions.

Apparatus and Task.

The same apparatus was used as for the pretest. The task was the same, but the path of the target to be tracked was changed to that of a figure eight lying on its side. The exact shape of the figure eight is presented in Appendix B. A computer program recorded both the position of the target and the subject's response in terms of XY coordinates. There were 285 data points for the criterion compared to the 285 data points of the response, with time kept constant across data points. The difference of the criterion XY and the response XY coordinates was calculated.

Procedures.

Subjects were randomly assigned to three experimental condi[illegible] The first condition (condition I) was a control condi[illegible] in which instructions were given as they were in the pretest.

The second condition (condition II), included a demonstration trial in which the subjects could observe the target making a figure eight path. The trace of the pathway (the figure) was visible on the screen for only one trial. Subjects were given the following instructions: "the target will follow a figure eight path. Knowing the path you should be able to track the target easier."

For the third condition (condition III), subjects were given the following instructions, "the dot will be following a path of a figure that you know. If you can find out the figure the target is drawing it should help you to keep your cross on the dot. So, try to find out what the figure is." All subjects in all experimental groups were reminded that they should try to keep their cross on the dot whenever it was moving. Reinforcement was given after the 4th, 8th, 12th, 16th, and 18th trials, by saying "good work, try to keep your cross on the dot".

E. RESEARCH DESIGN.

The research design for this aspect of the study was a 2 (grade level) X 2 (skill group) X 3 (instruction conditions) X 20 (trials) in which subjects were randomly assigned to the three instruction conditions.

The Dependent Variables.

The first dependent variable was the Root Mean Square(d) error (RMSE). RMSE is a displacement measurement and thus it provided information of how far the response cursor (child's response) was from the target (criterion). It is the standard measure for tracking performance and it is recomended by a numbe rof researchers in the field. Poulton (1974) describes RMS with the formula shown below.

$$RMSE = \sqrt{\sum_{n}^{1} e^{2}_{di}}$$

Where e is the difference (error) between the stimulus and the response, measured in units of 1.85mm at data point d for trial i, and n is the number of data points per trial, i.e. 285 for a full trial and 35 or 36 when the figure is divided into eight sectors.

The second dependent variable used was the number of direct hits of the cursor on the target. For the purpose of this dependent variable a 'window' of 2 units was established surrounding the X and Y coordinates of the target.

V. CHAPTER FIVE: RESULTS AND DISCUSSION.

A. INTRODUCTION.

Two main questions were posed in this study:

1. Does skill in tracking a moving target increase with age? If so, can children in each age group be separated into novice and skilled tracking performers?

2. When tracking a familiar pattern such as the figure eight used in this study, do the girls in the novice and skilled groups at ages 8 and 10 differentially respond to the following three instructional conditions:

   a. a control condition in which the subject is simply asked to track the moving target,

   b. a declarative condition in which the subject was shown the figure eight pattern that was to be tracked, and

   c. a metacognitive condition in which the subject was asked to track the moving target but with the additional suggestion that the pattern to be tracked was a shape familiar to her?

Based on the knowledge-based approach to motor development it was expected that:

1. Grade 3 and 5 novice groups would differ in terms of error scores in that grade 5 girls would perform better initially based on their broader experience. Very little improvement was expected over trials for these groups.

2. Grades 3 and 5 skilled groups were expected to benefit from instructions more that their unskilled peers.

3. The grade 5 girls, novice and skilled, were expected to improve performance considerably in the early trials of the experiment. Grade 3 girls, because of fewer metacognitive skills, were expected to improve their performance more gradually.

4. Across all groups it was expected that the declarative instructions would benefit performance more than the metacognitive instructions.

5. In the skilled groups the performance of the metacognitive group should approach that of the declarative group in the latter trials because of recognizing the shape being tracked.

As outlined in the last chapter, data were collected in a pre-test tracking performance session on a MacIntosh computer system. Novice and skilled groups were established based on these pre-test results. Subjects at ages 8 and 10 were placed into novice and skilled groups and subsequently randomly assigned to the three following instruction conditions: control, declarative and metacognitive.

Two major dependent variables were used in this study. First, the Root Mean Square(d) Error was selected as the primary dependent variab[illegible]n order to reflect accurate and precise tracking behaviour as recomended by Poulton (1974), and Franks, Wilberg, & Fishburne (1982).

The secondary dependent variable was the number of times on target. This dependent variable reflects tracking performance to some extent; however, it certainly is not a valid measure of tracking performance on its own. It is included only as a supplement to the root mean square error dependent variable.

The results and discussion related to the above two questions will be presented as follows.

Chapter four described the means by which the novice and skilled groups were selected. The initial section of this chapter reports on the preliminary analysis which was completed on the data and the actions taken to correct outlying error scores. Two major sections follow, one based on the results related to the RMS error means and the second based on the number of times on target dependent variable.

Within each of these two sections, task factors are initially presented followed by subject and experimental conditions factors. Comments from the anecdotal records kept on the girl's performance are included where they help clarify or support the discussion. A general discussion of the results with implications for further study of skill acquisition from a knowledge-based approach is provided at the end of the chapter.

B. PRELIMINARY ANALYSIS.

The first dependent variable, that is, RMS error was calculated for all 20 iterations for each subject. An initial Analysis of Variance (2 grades X 2 skill groups X 3 instruction conditions X 20 iterations), was run on the RMS error scores. Table 6 on page 74 presents the results of this analysis. The first step in the analysis was the completion of a preliminary analysis of the data to examine the distribution of RMS error scores generated by each subject over the twenty trials. Using the mean and standard deviations associated with each iteration within each cell of the design, the individual means of each subject on each trial were reviewed and extreme scores which were two standard deviations above or below the mean of that particular cell mean were replaced by the median error score for that subject on the twenty trials under the same instruction condition. Scores were replaced [illegible] 3.8% of the data. Once this preliminary analysis and revision was done the following analyses were completed.

C. PRIMARY DEPENDENT VARIABLE: ROOT MEAN SQUARE ERROR.

Task Factors.

Tracking Performance over Trials.

Figures 2, 3, 4, and 5 present the root mean square error means for the four grade-skill groups; namely, the grade 3 skilled and novice groups, and the grade 5 skilled and novice groups respectively under the three instruction conditions over the twenty trials. The most striking feature of the skilled girls, no matter which grade, is the relative consistency of performance across the twenty trials regardless of the instruction conditions. In contrast, the novice group at each grade level shows marked variability between trials no matter which of the instruction conditions is considered.

In considering the data in Figures 2, 3, 4, and 5, it is clear that the level of skill within each group is a much more important determinant of performance than is the chronological age of the subjects. In fact, the skilled grade 3 groups are less variable than the novice grade 5 groups, and the accuracy of their tracking performance is similar to that of their older skilled counterparts. The grade 3 novice groups are certainly less skilled than their grade 5 counterparts; however, the inter-trial variability in performance is very similar in both the novice groups regardless of age. This rather high degree of inter-trial variability must be kept in mind when interpreting the

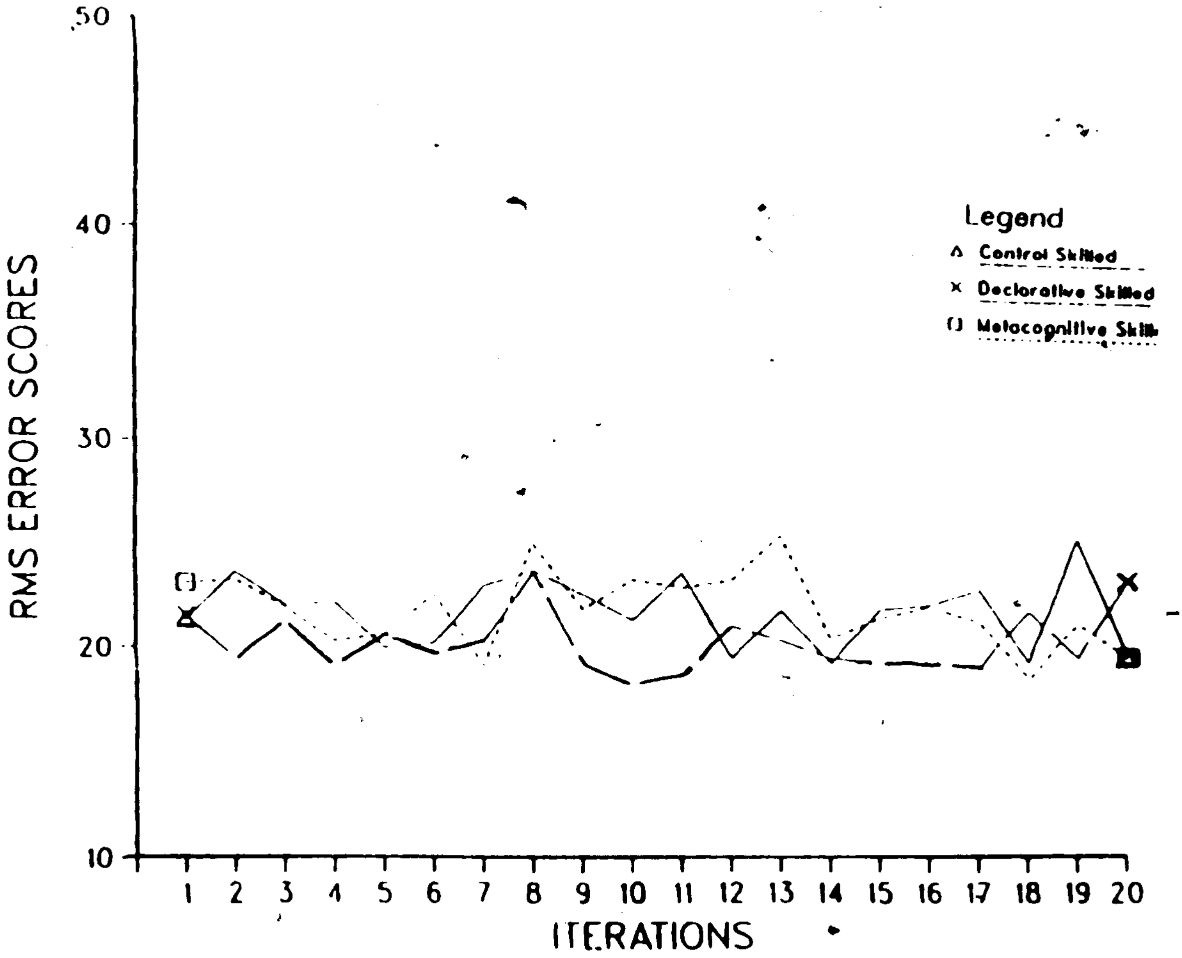


FIGURE 2.

RMS Error for the Grade 3 Skilled Groups Under the Three Instruction Conditions Over the 20 Trials

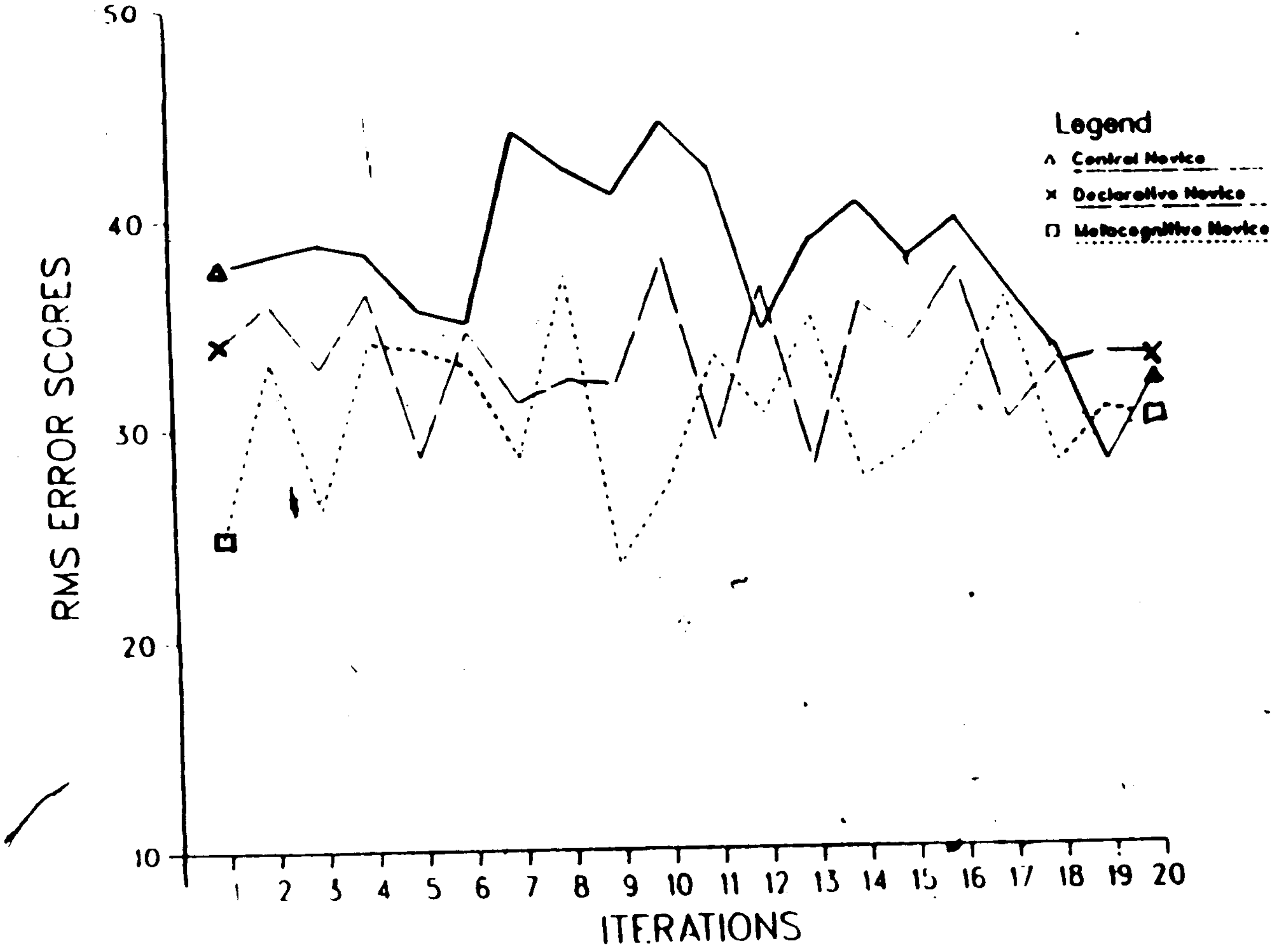


FIGURE 3.

RMS Error for the Grade 3 Novice Groups Under the Instruction Conditions over the 20 Trials

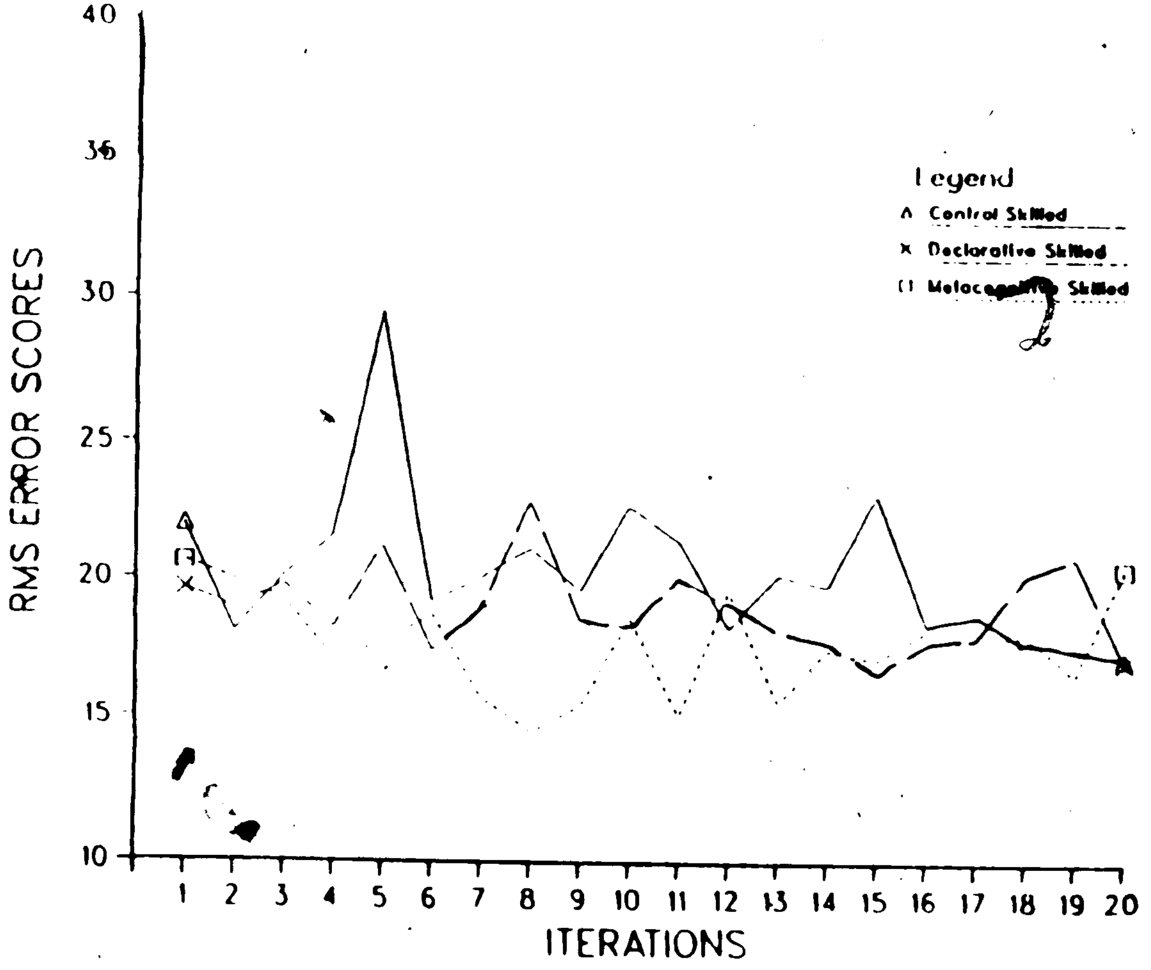


FIGURE 4.

RMS Error for the Grade 5 Skilled Groups Under the Three Instruction Conditions Over the 20 Trials

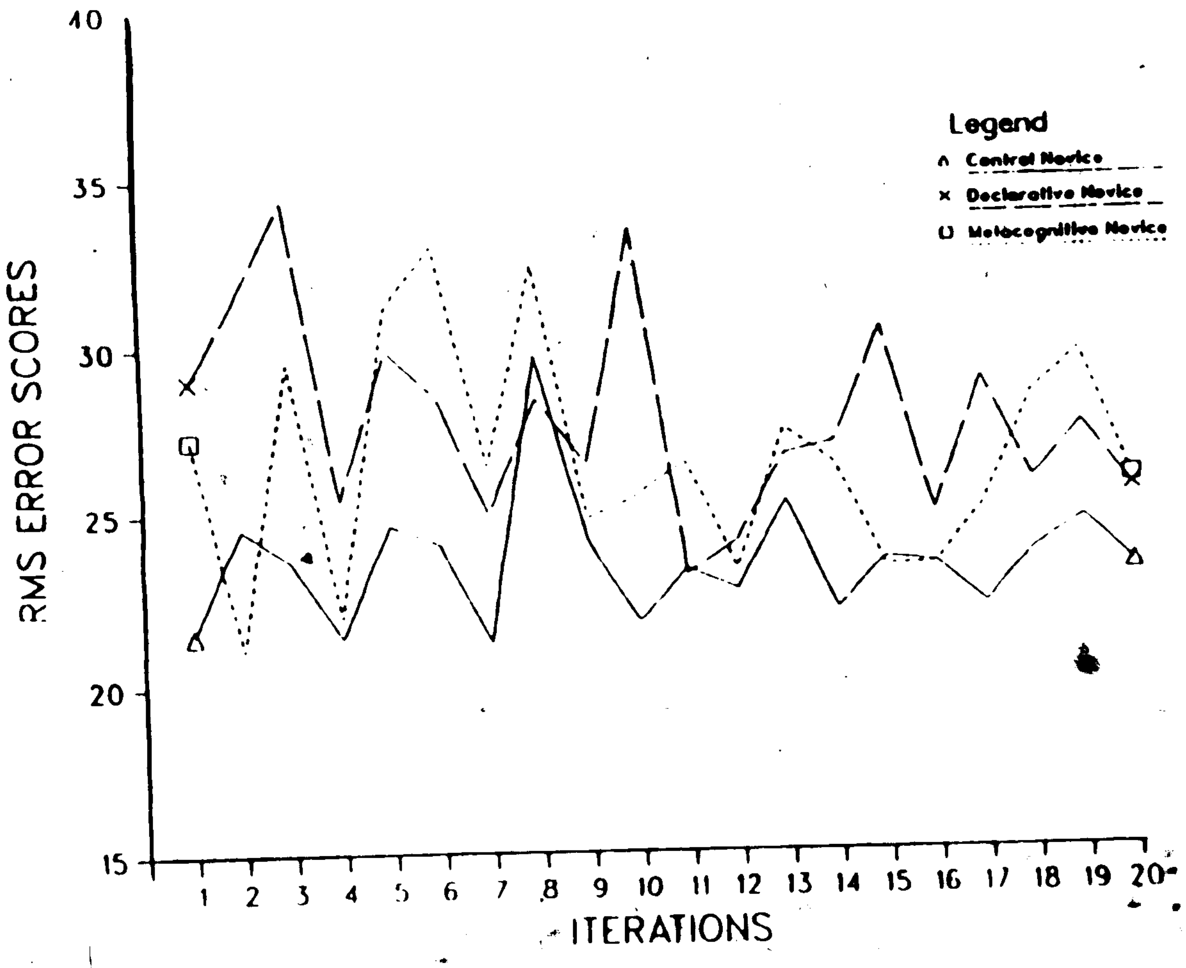


FIGURE 5
RMS Error for the Grade 5 Novice Groups Under the Three Instruction Conditions over the 20 Trials

results of this study.

These results provide strong support for the inclusion of the skilled and novice groups within the design of the study; however, the inter-trial variability found in the error scores of all of the novice instruction groups probably reflects the fact that the tracking task was too difficult for these subjects. Unfortunately, the cost of having such a high degree of inter-trial variability is to decrease the likelihood of finding significant instruction effects within the experiment.

<u>Tracking Performance over Sectors.</u>

It is interesting to note in Figure 6 that the two lowest RMS error means are found in sectors 2 and 6 (the break down of the tracking pattern yielded eight sectors as demonstrated in the legend of Figure 6. A consideration of the hand motion of the girls when tracking indicates that they were tracking the target towards the centre of the screen in sectors 2 and 6. In these sectors, the girls probably had established a mental image of the tracking pattern and so were able to use the centre of the figure eight, and the screen, as an anchor point to help them track the target more accurately in these sectors. The lower RMS error means in sectors 2 and 6 support such view. Further analysis of Figure 6 indicates that the girls found the path in sector 5 quite difficult. This was

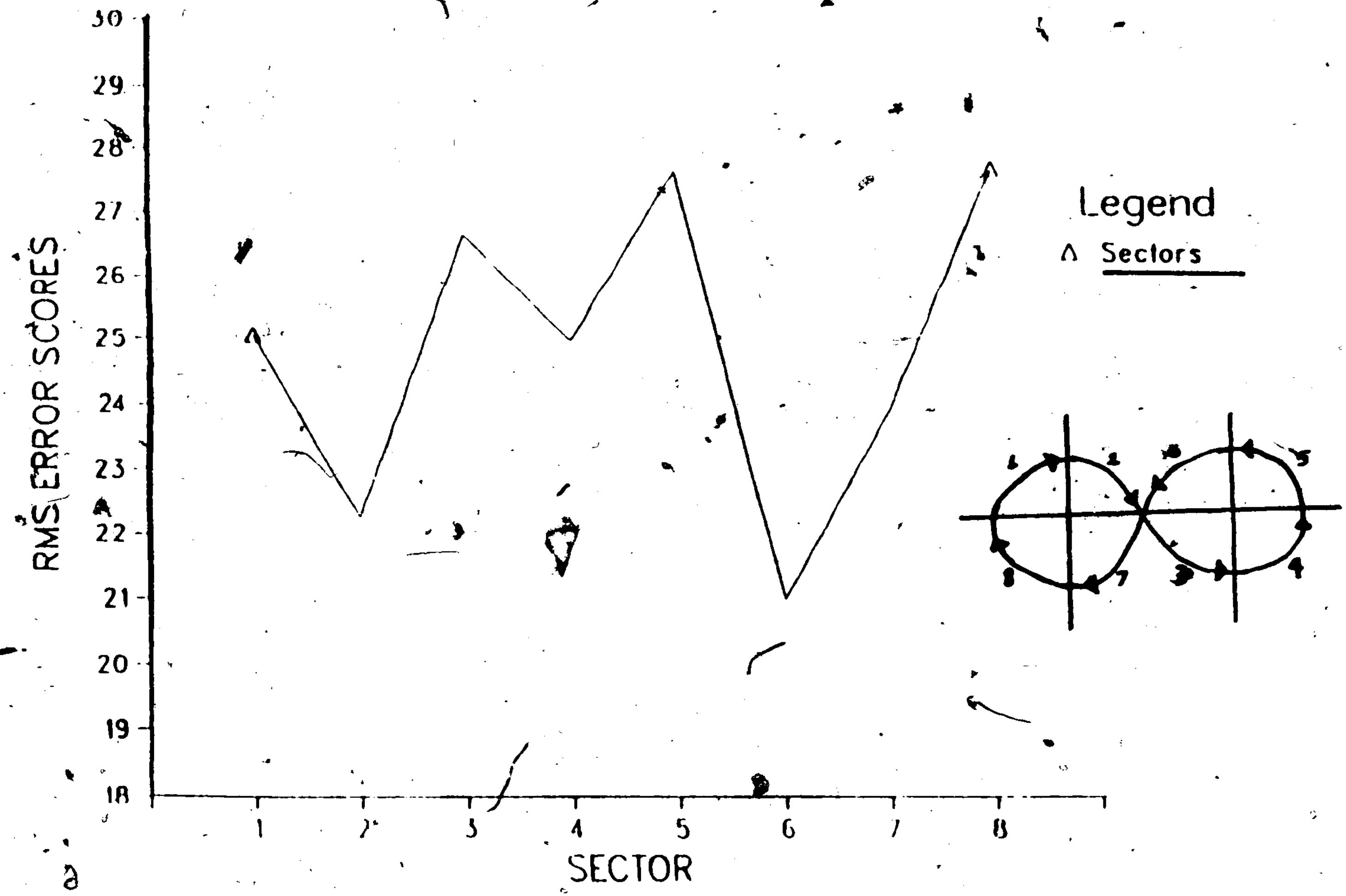


FIGURE 6.
Average RMS Error in Each Sector for All Grades, Groups, Instruction Conditions and Trials.

probably due to the change in direction that was required at the beginning of the sector. The relatively high RMS error in sector 8 was probably due to overshooting the target as visual observation of the girls' performance supported the fact that they had a clear mental picture of the tracking pattern but in moving quickly to reach the end point of the target their performance deteriorated.

With the above task factor results at hand, a presentation and discussion of the results due to subject and instruction factors will be made.

Subject Factors and Instruction Conditions.

As mentioned earlier, the primary dependent variable for this study was the RMS error score. Using the corrected error scores, a four way analysis of variance (2 grades X 2 skill groups X 3 instruction conditions X 20 iterations), using the statistical package BMDP:2V, was run. Table 6 (page 74) presents the results of this analysis of variance. The analysis revealed highly significant main effects for the two grades and the two skill groups ($F(1,60)=23.74$, $p<.05$, and $F(1,60)=98.22$, $p<.05$), as well as for iterations ($F(1,19)=1.70$, $p<.05$). The main effect for the instruction conditions was clearly not significant; however, a strong interaction between grade and skill group factors and an interaction of grade X skill group X instruction condition was found. These interactions are important and are discussed in the next section.

Figure 7 graphically presents the root mean square error for the significant grade X skill group interaction over all conditions and trials. Clearly, the skilled groups are significantly better at tracking the target at both grade levels; even more interestingly for our purposes, there is no significant difference in tracking performance between the grade 3 and 5 skilled groups. However, the final interpretation of this two way interaction must be considered in light of the significant three way grade X skill group X instruction condition interaction presented in Figure 8 which is discussed in the next section.

Figure 8 presents the average RMS error score means for each of the groups in the significant grade X skill group X instruction condition interaction ($\underline{F}(2,51) = 3.30$, $\underline{p} < .45$). As Figure 8 shows, distinctly different results were found for the novice and the skilled groups. First, there was no difference between the three instruction conditions in both grades for the skilled children. This finding may reflect the fact that the more highly-skilled children under the three instruction conditions probably realized very early on in the experiment that the shape the target was in fact following, was a figure eight pattern. In fact, the post-experiment interview data strongly supported this interpretation as all of the grade 5 subjects in the skilled group and most of the children in the grade 3 skilled group reported that they knew the shape was a figure eight by the fifth trial.

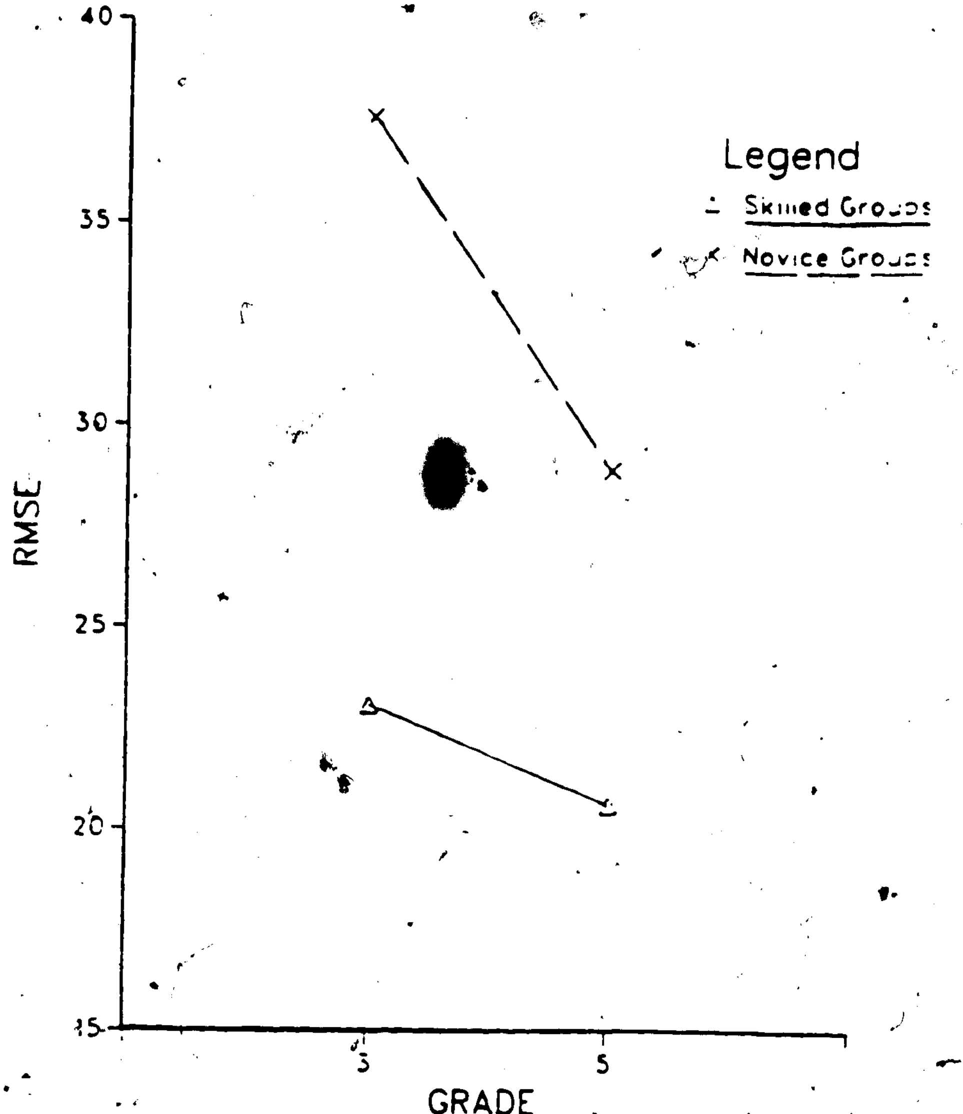


FIGURE 7.
Average RMS Error for Both Skill Groups
at Grades 3 and 5. Over All Instruction Conditions

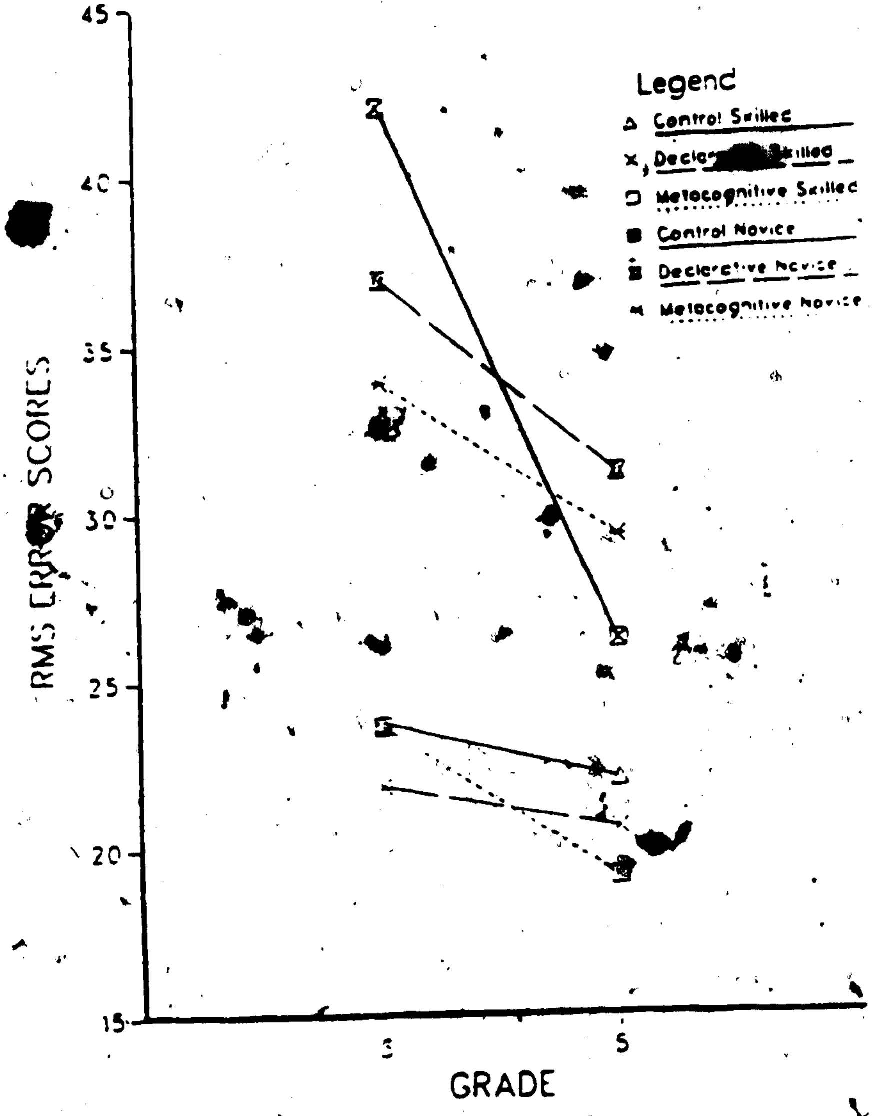


FIGURE 8.
Average RMS Errors for Each of the Treatment Groups in Grades 3 and 5

As Figure 8 shows, distinctly different results were found in grades 3 and 5 for the novice group. Simple effects tests show that at the grade 3 novice level the metacognitive group did significantly better than the control group over all trials ($t(60)=2.46$, $p < .01$), as did the declarative group ($t(60)=2.35$, $p < .025$).

This is an interesting finding which may have considerable value in the study. First, it must be stated that the [illegible] for the instruction conditions at the grade 5 novice level were not congruent with the experimental expectations underlying the study. However, rather than simply attributing the finding to difficulties of random assignement it might be suggested that the control group did better that the other two groups because they were old enough to have developed tracking strategies of their own. Thus when the declarative and metacognitive strategy instructions were given, they had the effect of disturbing the strategies that the girls had already decided upon using to track the target. This may have resulted in an actual decrease in tracking performance. In contrast the control group were able to actively use their own strategies without any instruction on them. The improved performance of the control group, even though it is not significant, might well be attributed to this explanation; especially when one notes the fact that, between grades 3 and 5, children are known to develop a number of cognitive strategies to use in a variety of situations.

In sum, the results shown in Figure 8, suggest that when the children were skilled enough to recognize quickly that the path of the target was a figure eight then the instructions condition had no effect due to the fact that they were redundant. Quite simply, the control group knew what the tracking pattern was early on in the test session; hence, there was no instruction effect for the skilled groups at both ages. However, the results for the grade 3 novices who were the least skilled of the subjects were exactly congruent with the predictions that were made prior to the start of the experiment; that is, tracking performance was definitely improved when the subjects realized that the figure to be tracked was, in fact, a figure eight.

It should be noted that it is impossible to clearly differentiate between declarative and procedural knowledge in any action situation; however, one can infer that knowing that the pattern to be tracked was, in fact, [illegible] eight certainly was a determining factor in the tracking performance differences that were found. In the same way, under the metacognitive condition one can infer that the children used their problem solving skills [illegible] decide that the pattern they were tracking was a figure eight, hence, improving their performance.

As the results of the analysis of variance in Table 6 show, the grade X skill group X instruction condition X trials interaction was not significant. However, the means

TABLE 6

Analysis of Variance of RMS Error Scores. Treatment Groups by Trials.

Source	SS	DF	MS	F	P	Greenhouse Geisser P.
MEAN	948582.18	1	948582.18	2311.11	0.0000	
Grade (A)	9745.29	1	9745.29	23.74	0.0000	
Group (B)	40312.65	1	40312.65	98.22	0.0000	
Condition (C)	872.45	2	436.23	1.06	0.3530	
A * B	3028.16	1	3028.16	7.38	0.0090	
A * C	1583.75	2	791.88	1.93	0.1557	
B * C	363.23	2	181.61	0.44	0.6449	
A * B * C	2707.36	2	1353.68	3.30	0.0450	
ERROR	20932.68	51	410.44			
Trials (D)	1556.32	19	81.91	1.70	0.0313	0.0615
D * A	1297.95	19	68.31	1.42	0.1104	0.1515
D * B	617.25	19	32.49	0.67	0.8479	0.7820
D * C	1921.88	38	50.58	1.05	0.3923	0.4007
D * A * B	1095.53	19	57.66	1.19	0.2539	0.2815
D * A * C	1803.56	38	47.46	0.98	0.4997	0.4871
D * B * C	2889.75	38	76.05	1.58	0.0155	0.0387
D * A * B * C	2151.27	38	56.61	1.17	0.2206	0.2575
ERROR	46768.10	969	48.26			

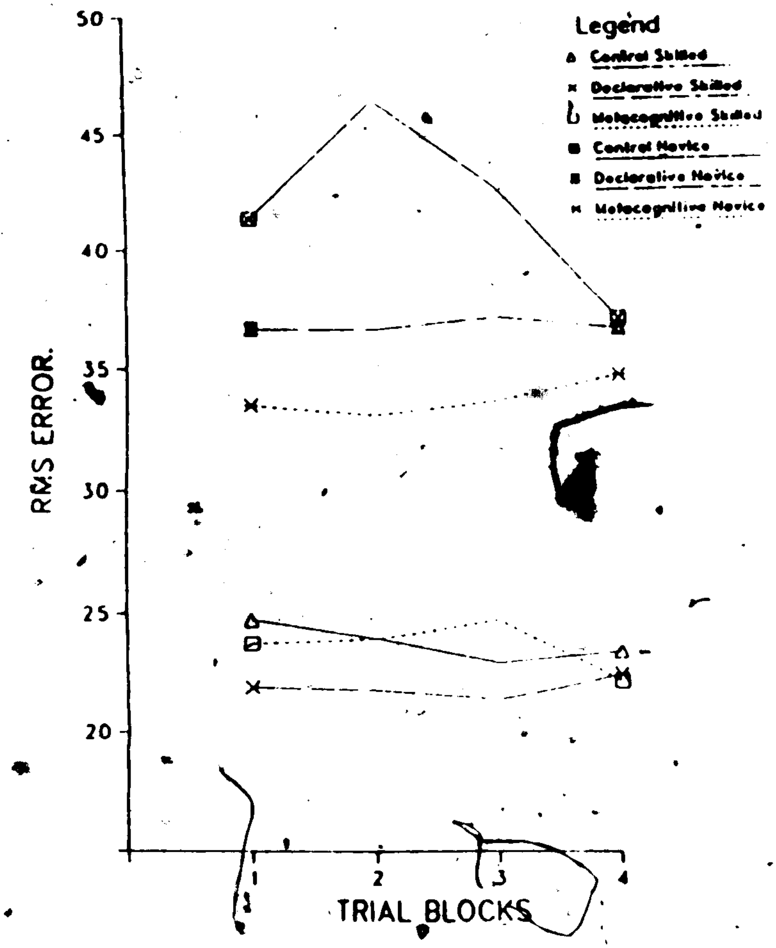


FIGURE 9.
Average RMS Error Scores for Grade 3 Skilled and Novice Groups Under the Three Instruction Conditions Over the Four Trial Blocks.

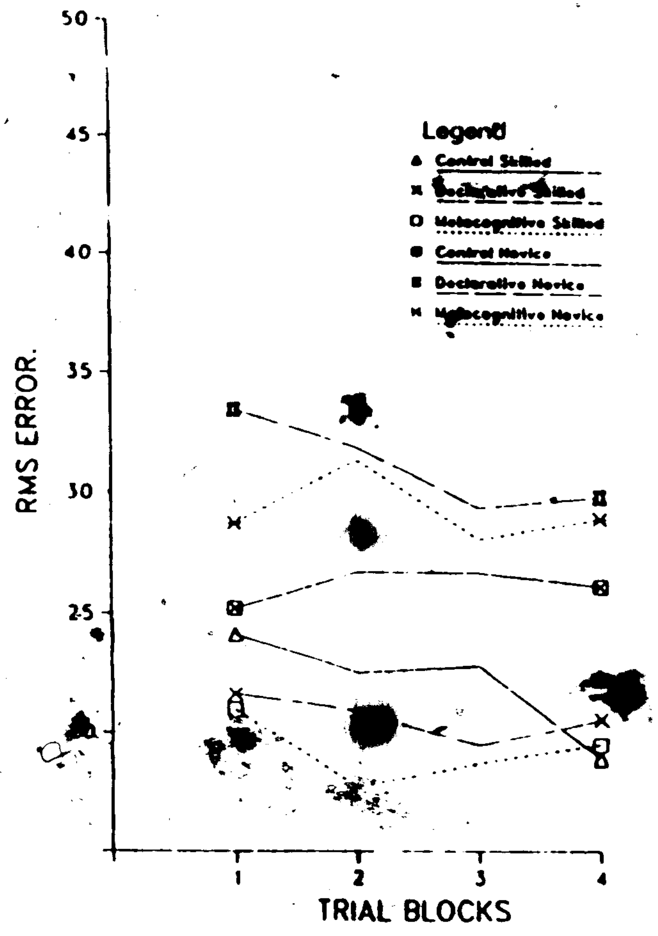


FIGURE 10.
Average RMS Error Scores for Grade 5 Skilled and Novice Groups Under the Three Instruction Conditions Over the Four Trial Blocks.

associated with this four-way interaction were plotted for visual analysis and were presented in Figures 2, 3, 4, and 5. The striking feature of these graphs was the high degree of inter-trial variability within the novice groups.

In order to analyse the trials effect further, another analysis of variance (see Appendix I) was completed in which the four means over the following trials 1-5, 6-10, 11-15, and 16-20 were used instead of the twenty trials. The effect of using the average of these four sections of the trial factor was to reduce the between trials variability to some extent. In doing so, the grade X skill group X instruction condition X trials interaction became significant. Figures, 9 and 10 report the means for this interaction. The results for the skilled groups at both grades support the earlier conclusion of no difference in tracking performance due to grade or to instructional condition. The results for the grade 3 novice groups show that the declarative and metacognitive instructions groups maintained their performance across trials right from the initial phase of the experiment. It is interesting to note that the control group was significantly poorer than the declarative and metacognitive groups; however, only the control group improved from the initial set of trials to the last set of five trials. One might speculate that the control group learned to recognize the figure eight after approximately 15 trials which resulted in significantly better perfomance during the last five trials. Again the results for the grade 5 novice group, while they do not support the earlier predictions, are congruent with the findings presented in the earlier discussion on Figure 8.

In conclusion, research question one can be clearly answered. In terms of average performance the older group of grade 5 girls was better in tracking the pattern than their grade 3 counterparts. However, considerable support for the notion of domain-specific knowledge and the effect of skill level was found when the two grades (ages) were divided into novice and skilled groups. Quite simply, the age differences were marked by differences in skill that probably [illegible]ct differential experience backrounds in fine-motor tasks within the age groups. Clearly more empirical evidence is required to firmly support this explanation of such performance differences.

The answer to the second question on whether children's age and the two skill levels would be differentially affected by the three instruction conditions must also be qualified. Novice children in grade three clearly benefitted from the metacognitive instruction and to a lesser extent from the declarative instruction condition.

As noted earlier, the skilled groups at both ages did not benefit from the instructions. The novice grade 5 group had rather unclear results due to the relatively better performance of this particular control group.

D. SECONDARY DEPENDENT VARIABLE: NUMBER OF HITS.

As mentioned earlier, the most common measure of tracking performance is the Root Mean Square(d) Error as it reflects both the accuracy and the precision of tracking performance. However, the number of times the subject is exactly on target (number of hits), can be used as complementary information to the primary dependent variable.

A second dependent variable, that is, number of hits, was included in the study and it was analysed using the statistical package SPSS-X: UANOVA 2.1. The following results were found, after the completion of a five way analysis of variance (grade X skill group X instruction condition X iteration X sector). As shown in Table 7, significant main effects were found for the factors grade, skill group, and sector. Additionally, significant two way interactions were found on the following factors: grade X instruction condition, grade X sector, skill group X sector, instruction condition X sector. Three way significant interactions were also found on the factors: grade X skill group X instruction condition, skill group X instruction condition X iteration, and skill group X instruction condition X sector. One four way interaction was found on the factors: grade X skill group X instruction condition X sector (see Table 7).

Perhaps the most important of the above interactions was the grade X skill group X instruction condition and it will be discussed first. As Figure 11 shows, the interaction was due to the changes in performance of the different instruction conditions within the novice groups. The relatively high performance of the grade 3 novice metacognitive group coupled with the relatively low performance of that group [illegible] grade 5 resulted in a significant interaction. Figure 11 shows clear skill group and grade performance differences; however, the only significant instruction effects were at the grade 5 skilled group level where the metacognitive group were better than the control group. Surprisingly, in direct contradiction of the predictions at the grade 5 novice level the metacognitive group was significantly lower than the control group. In contrast within the grade 3 novice groups, the metacognitive instruction group performed significantly better than the control group; however, there was no significant difference between the control and the declarative instruction group. These results are somewhat congruent with those generated by the RMS Error analysis and provide considerable support for the skill group and the grade effects, and at least some support for the effects of the instruction condition.

As noted earlier, Appendix B shows the eight sectors into which the tracking pattern was divided for further analysis by sector. As shown in Figures 12, 13, 14, and 15 the number of hits that subjects made varied with the sector of the figure eight. Clearly, as mentioned earlier under task factors, having to reverse the direction of the

TABLE 7

Analysis of Variance of Number of Times on Target Scores
Treatment Groups vs Iterations

Source of Variation	SS	MS	F	DF	P
Grade (A)	8855.60	8855.60	303.06	1	0.0
Group (B)	22237.55	22237.55	761.45	1	0.0
Instruction (C)	149.84	74.92	2.57	2	NS
Iteration (D)	708.52	37.29	1.28	19	NS
Sector (E)	11609.02	1658.43	56.79	7	0.0
A * C	184.47	92.23	3.16	2	0.043
A * E	463.74	66.25	2.27	7	0.026
B * E	1653.48	236.21	8.09	7	0.0
C * E	838.22	59.87	2.05	14	0.012
A * B * C	2020.03	1010.02	34.58	2	0.0
B * C * D	1607.45	42.30	1.45	38	0.037
B * C * E	858.53	61.32	2.10	14	0.009

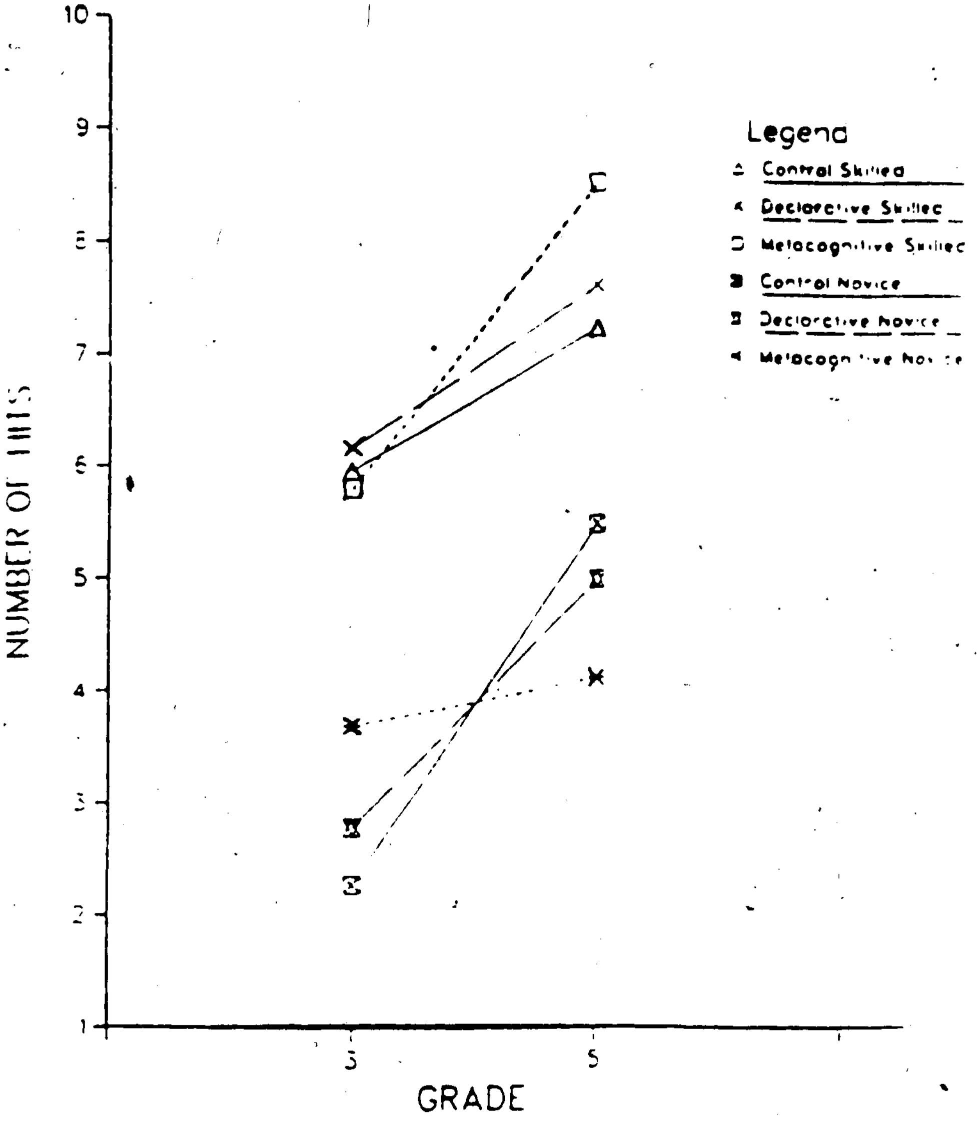


FIGURE 11.
Mean Number of Hits on Target for Grades 3 and 5
Skilled and Novice Groups Under the
Three Instruction Conditions

movement in sector five negatively affected the performance of the subjects. Furthermore, the relatively high results for the subsequent sector six indicates that the children were aware that the shape was a figure eight in that they swung back towards the center of the screen quite accurately. Visual observation of their performance also supported this contention.

The means for the significant grade X skill group X instruction condition X sector interaction were plotted as shown in the figures 12, 13, 14 and 15. Simple effect tests indicated that the major interaction was between the declarative and metacognitive groups in the grade 5 skilled level at sectors four, five, and six. Other minor shifts in performance were found within the grade 5 novice group by the control and declarative groups at sectors two, three, and four and again between the metacognitive and declarative groups at sectors seven and eight.

In conclusion, the results from the analysis of the number of hits support and extend the findings from the RMS error. It is interesting to note that the novice group results are very similar to those found with the RMS error dependent variable.

It is interesting to note that with this dependent variable the results at the skilled level are quite supportive of the predictions made prior to the study in that the grade 5 skilled group, who were given metacognitive instructions, were better than the skilled control group.

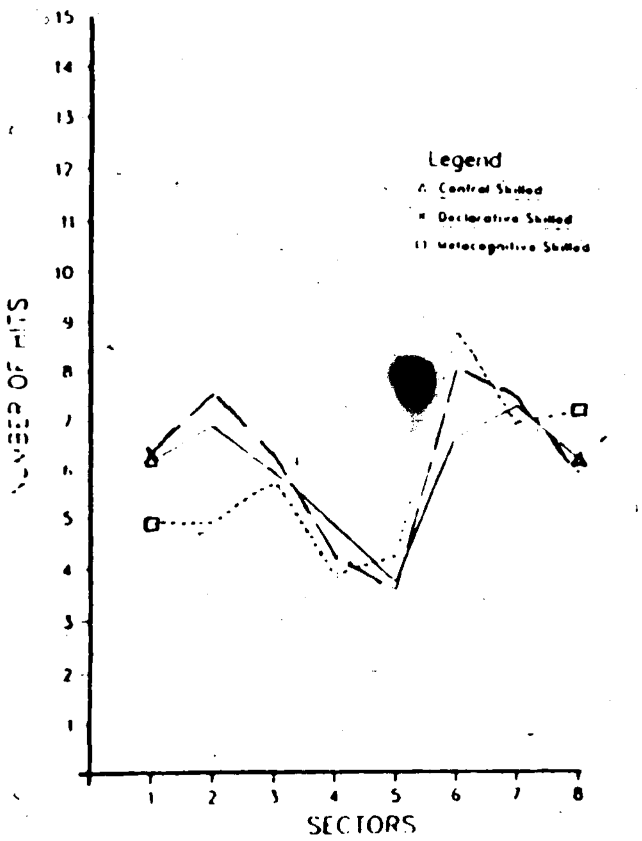


FIGURE 12.
Number of Hits for the Grade 3 Skilled Groups Under the Three Instruction Conditions Over the 8 Sectors

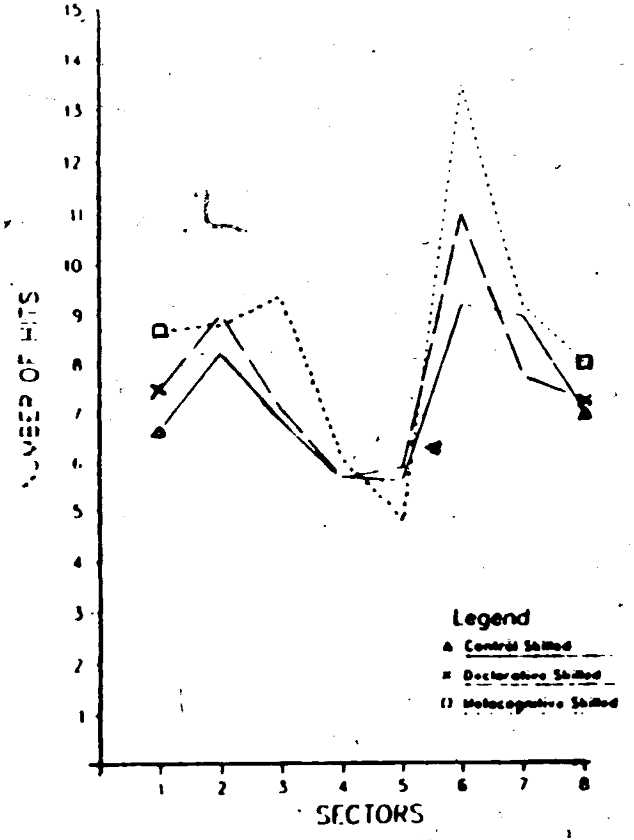


FIGURE 13.
Number of Hits for the Grade 5 Skilled Groups Under the Three Instruction Conditions Over the 8 Sectors

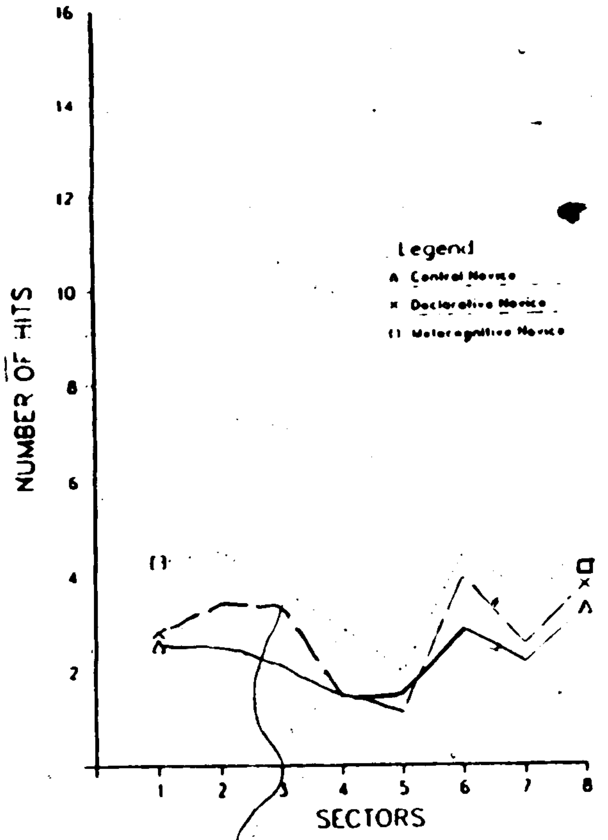


FIGURE 14.
Number of Hits for the Grade 3 Novice Groups Under the Three Instruction Conditions Over the 8 Sectors

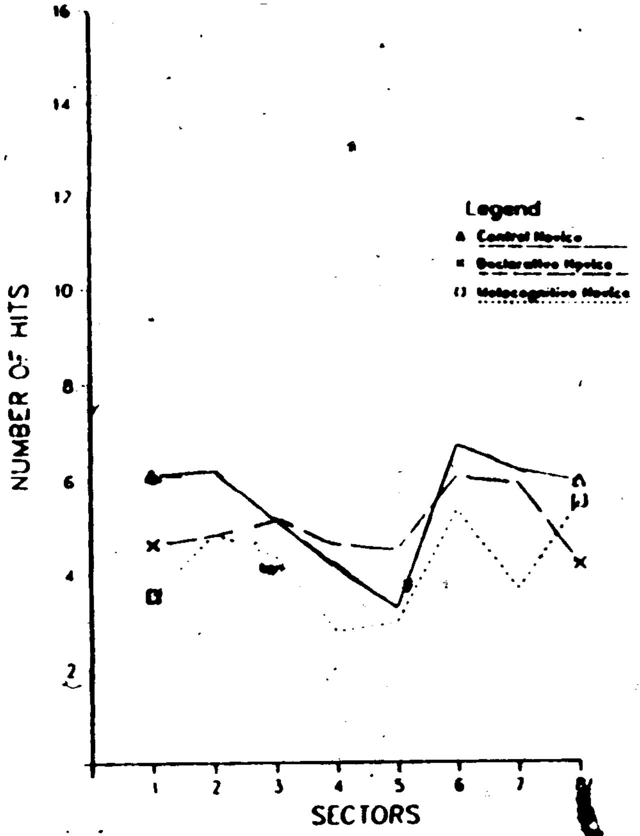


FIGURE 15.
Number of Hits for the Grade 5 Novice Groups Under the Three Instruction Conditions Over the 8 Sectors

However, this finding must be interpreted cautiously due to the earlier finding from the primary dependent variable of RMS error which was not significant.

E. GENERAL DISCUSSION.

Two factors made this developmental study of tracking skill acquisition unique. First, the subjects were divided into skilled and novice groups prior to the experimental intervention. Second, the instructional conditions stem from a knowledge-based approach to motor development which suggests that declarative and metacognitive knowledge are extremely important in the learning and performance of motor tasks, especially when such tasks are novel ones.

Two other factors made the study even more unique. First, the tracking task that was used was a familiar shape, a figure eight, which allowed the subjects to anticipate the future path of the target relatively easily. In contrast to many other tracking studies, this study used a task which allowed the subjects to generate a mental image of the tracking pattern that could certainly help their performance. The use of such a tracking pattern ensured that the instruction conditions could be easily given; that is, the declarative instruction used the concept and familiar pattern of the figure eight and the metacognitive instruction allowed the instructional hint that there was a familiar shape to be used. Second, the use of the MacIntosh 'mouse' and the relatively sophisticated software made the task very user-friendly while also ensuring that the tracking performance would be measured extremely precisely. The fact that the children were tested in their familiar school surroundings was also an important factor in the study.

As mentioned in the review of literature, the knowledge-based approach to motor development stresses the importance of five types of knowledge about action. The tracking performance of the girls was viewed as a manifestation of their procedural knowledge in the tracking domain while their ability to use concepts such as the figure eight shape and their ability to follow the verbal instructions that were given reflect the use of declarative knowledge about action. The knowledge-based approach emphasizes the importance of domain-specific knowledge that directly relates to the task or tasks being learned or performed. Clearly, the concepts staying on the target, knowing the shape of the tracking pattern and being able to select it out of the other shapes that they knew, all reflect the importance of the girls' declarative knowledge base in performing this task. The study also assumed that girls in grade 3 and 5 would be able to use simple problem solving skills that reflect their metacognitive skill base. It was assumed that because the pattern the target was following was a familiar shape, the girls would be able to quickly realize that the tracking pattern was a figure eight. Hence, the study was based on the interaction between procedural, declarative, and metacognitive knowledge and skills.

The results clearly support the importance of dividing the two age groups into novice and skilled groups.

Novice and skilled performers differ in their procedural skills as evidenced by differences in the present scores on the random tracking task. The fact that differential instructions to the skilled group resulted in [illegible]ence in their performance, while such instructions had clear and powe[illegible] on younger (grade 3) novice performers, may indicate that skilled performers already possess sufficient declarative and metacognitive knowledge, as well as metacognitive skill, to optimize their performance. Moderately skilled performers (such as the grade 5 novice groups) reacted differently to these instructions and it might be that at this level of skill subjects have generated their own strategies, based on some declarative, metacognitive and procedural knowledge, which may be interrupted or interfered with the provision of instructions from the experimenter. Furthermore, the results support a basic contention of the knowledge-based approach, that is, domain-specific knowledge will often not follow a purely developmental trend as measured simply by the age of the children. The fact that the grade 3 skilled group was clearly more accurate, precise, and less variable over trials in their tracking performance when compared to the novice grade 5 group strongly supports this view. Such expert-novice difference in domain-specific knowledge is congruent with a number of other studies of skilled performance (Chi, 1978; Allard, Graham, & Paarsalu, 1980; Jones, & Miles, 1978).

As mentioned earlier, the tracking task used in this study is a unique one. The task factor results demonstrate that it may be quite a valuable one to use for the study of skill acquisition in tracking. The fact that it can be accurately measured, easily controlled in terms of task difficulty, readily influenced by instruction conditions, and is subject to predictable learning changes within the different sectors, all speak well for its use as an experimental task. The results support all of the above factors even though predictions related to the instructional conditions that were used in this study met with only qualified success.

The central research question of this study was related to the effects of the different instructional conditions. Unfortunately, it must be admitted that the instruction conditions met with mixed success; however, some findings are particularly important and will certainly be instructive for future research.

First, in contrast to the pre-study hypotheses, the skilled groups did not benefit from the instructions given. This probably reflects the fact that the girls either were sufficiently skilled in tracking not to need to know the shape that the target was following, or, more likely, they quickly realized that the target was following a figure eight pattern and used this information from the very earliest trials. It is interesting to note that the girls in both skilled groups, that is, in grades 3 and 5, did not improve their tracking performance over the twenty trials. Furthermore, they were extremely consistent across trials which is a characteristic of skilled performance.

The results for the novice groups performance are somewhat more difficult to interpret. The results for the grade 3 novice groups were in fact exactly as predicted. The fact that the metacognitive group clearly was significantly better that the control group and the declarative group was nearly so supports the pre-experimental predictions on the effect of the different types of instructions. Given the fact that the inter-trial variability was very high in both groups it is interesting to note that the instructional effects were sufficiently robust to be significant.

The grade 5 novice group findings resulted in no significant differences among the groups, even though the control group did somewhat better than the other two groups.

In conclusion, the study demonstrates the importance of studying development in a domain specific task such as tracking from both a developmental and skill level perspective. Clearly, the grade 3 skilled girls who were two years younger performed better than their grade 5 novice counterparts. Furthermore, the study provides strong support for the value of both declarative and metacognitive instruction prior to trying to track a target that is following a familiar shape. More research needs to be completed on the value of such instruction to skilled children. Perhaps, a more difficult tracking pattern would have allowed the skilled children to use the declarative or metacognitive instructions to improve their tracking performance.

F. RECOMMENDATIONS FOR FUTURE RESEARCH.

The following recommendations may be of help in future research projects on this topic.

1. It would be valuable to include more complex targets and a greater number of tracking speeds in future studies. These targets and speeds should be more closely related to the developmental levels of the subjects.
2. The tracking pattern should be broken down into segments as this can be helpful when analyzing the tracking performance of the subjects. Clear performance differences in the sectors of the figure eight, indicate that part of the task are much more difficult than others, and may be differentially influenced by declarative and metacognitive knowledge.
3. The motivation of the subjects must be taken into consideration. A pretest session to familiarize the subjects with the operation of the computer is essential. Care must be taken that the instructions do not give the subjects the feeling that their efforts are part of a test. Knowledge in the affective domain may influence performance differentially for skilled and novice performance.
4. It should be noted that some children really enjoyed

using the computer while others were frightened by it. Clearly, care must be taken to reduce or account for this factor.

5. Future studies should include a wider age-range and perhaps some adult performers in order to establish better boundary conditions for the task.

VI. BIBLIOGRAPHY.

Adams, J. A. (1971). A Closed-Loop Theory of Motor Learning. *Journal of Motor Behaviour*, *3*, 111-150.

Allard, F., Graham, S., & Paarsalu, M. E. (1980). Perception in Sport: Basketball. *Journal of Sport Psychology*, *2*, 14-21.

Allard, F., & Starkes, J. I. (1980). Perception in Sport: Volleyball. *Journal of Sport Psychology*, *2*, 22-33.

Anderson, J. R. (1976). *Language, Memory and Thought*. Erlbaum, Hillsdale.

Arbib, M. A. (1980). Interacting Schemas for Motor Control. In G. E. Stelmach & J. Requin (Eds.), *Tutorials in Motor Behaviour* (pp. 71-81). New York: North Holland Publishing.

Arend, S. (1980). Developing the Substrates of Skillful Movement. *Motor Skills: Theory into Practice*, *4*(1), 3-10.

Baltes, P. B., Reese, H. W., & Nesselroade, J. R.

(1977). <u>Life-Span Developmental Psychology: Introduction to Research Methods.</u> Monterey, California: Brooks/Cole Co.

Barclay, C. R., & Newell, K. M. (1980). Children's Processing of Information in Motor Skill Acquisition. <u>Journal of Experimental Child Psychology</u>, <u>30</u>, 98-108.

Bartlett, F. C. (1932). <u>Remembering: A Study in Experimental and Social Psychology</u>. Cambridge: Cambridge University Press.

Birch Lipps, L. (1978). Baseline Differences, Attention, and Age Differences in Time - Sharing Performance. <u>Journal of Experimental Child Psychology</u>, <u>25</u>, 505-513.

Birch Lipps, L. (1976). Age Trends in Children's Time Sharing Performance. <u>Journal of Experimental Child Psychology</u>, <u>22</u>, 331-345.

Bogartz, R. S. (1976). On the Meaning of Statistical Interactions. <u>Journal of Experimental Child Psychology</u>, <u>22</u>, 178-183.

Borkowski, J. G., & Cavanaugh, J. C. (1981). Metacognition and Intelligence Theory. In M. P.

Friedman, J. P. Das, & N. O'Connor (Eds.), Intelligence and Learning. New York: Plenum Press.

Brown, A. L., (1975). The Development of Memory: Knowing, Knowing about Knowing and Knowing how to Know. In A. W. Reese (Ed.), Advances in Child Development and Behavior, Vol. 10. New York: Academic Press.

Brown, A. L. (1978). Knowing When, Where, and How to Remember: A Problem of Metacognition. In R. Glacer. (Ed.), Advances in Instructional Psychology, Vol. 1. Hillsdale New Jersey: Erlbaum.

Brown, A. L. (1979). Theories of Memory and the Problems of Development: Activity, Growth, and Knowledge. In C. Cermak (Ed.), Levels of Processing in Human Memory. Hillsdale, New Jersey: Lawrence Erlbaum.

Brown, A. L., & Campione, J. C. 1981). Inducing Flexible Thinking: The Problem of Access. In M. P. Friedman, J. P. Das, & N. O'Connor (Eds.), Intelligence and Learning. New York: Plenum Press.

Brown, A. L., & Deloache, J. S. (1978). Skills Plans and Self-Regulation. In R. S. Siegler (Ed.), Children's Thinking: What Develops? New Jersey:

Hillsdale Erlbaum.

Bruner, J. S. (1971). The Growth and Structure of Skill. In K. J. Connolly (Ed.), *Motor Skills in Infancy*. London & New York: Academic Press Inc.

------------- (1973). The Organization of Early Skilled Action. *Child Development*, *44*, 1-11.

Carson, L. M., & Wiegard, R. L. (1979). Motor Schema Formation and Retention in Young Children: A Test of Schmidt's Schema Theory. *Journal of Motor Behavior*, *11*(4), 247-251.

Cavanaugh, J. C., & Perlmutter, M. (1982). Metamemory: A Critical Examination. *Child Psychology*, *53*, 11-28.

Chase, W. G., & Simon, H. A. (1973). Perception in Chess. *Cognitive Psychology*, *4*, 55-81.

Chi, M. T. H. (1978). Knowledge Structures and Memory Development. In D. Siegel (Ed.), *Children's Thinking: What Develops*? Hillsdale, New Jersey: Erlbaum.

Chi, M. T. H. (1981). Knowledge Development and

Memory Performance. In M. P. Friedman, J. P. Das, & N. O'Connor (Eds.), Intelligence and Learning. New York: Plenum Press.

Chi, M. T. H. (Ed.). (1983). Trends in Memory Development Research. New York: Karger.

Chi, M. T. H. (1985). Changing Conception of Sources of Memory Development. Human Development, 28, 50-56.

Chiesi, H. L., Spilich, G. J., & Voss, J. F. (1979). Acquisition of Domain Related Information in Relation to High and Low Domain Knowledge. Journal of Verbal Learning and Verbal Behaviour, 18, 257-273.

Clark, J. E. (1982). Developmental Differences in Response Processing. Journal of Motor Behaviour, 14(3), 247-254.

Connolly, K., Brown, K., & Bassett, E. (1970). Developmental Differences in Response Processing. Journal of British Psychology, 61, 259-266.

Cratty, B. J. (1973). Movement Behavior and Motor Learning. LEA and Febiger.

Feltz, D. L. & Landers, D. M. (1983). The Effects of Mental Practice on Motor Skill Learning and Performance: A Meta-Analysis. Journal of Sport Psychology, 5, 25-57.

Fitts, P. M. (1964). Perceptual Motor Learning. In A. W. Melton (Ed.), Categories of Human Learning. New York: Academic Press.

Fitts, P. M. & Posner, M. I. (1967). Human Performance. California: Brook/Cole Publishing.

Flavell, J. H. (1977). Cognitive Development. New Jersey: Prentice Hall.

Flavell, J. H., Wellman, H. M. (1977). Metamemory. In R. V. Kail, & J.W. Hagen (Eds.), Perspectives on the Development of Memory and Cognition. New York: LEA.

Franks, I. M., Wilberg, R. B., & Fishburne, G. (1982). Consistency and Error in Motor Performance. Human Movement Science, 1, 109-123.

Furby, L. (1973). Interpreting Regression Towards the Mean in Developmental Research. Developmental Psychology, 8(2), 172-179.

Gallistel, C. R. (1980). The Organization of Action: A New Synthesis. Lawrence Erlbaum Associates.

Gallistel, C. R. (1981). Precis of Gallistel's The Organization of Action: A New Synthesis. The Behavioural and Brain Sciences, 4, 609-650.

Garvey, W. D., & Mitnick, L. L. (1957). An Analysis of Tracking Behaviour in Terms of Lead-Lag Errors. Journal of Experimental Psychology, 53(6), 372-378.

Gentile, A. M. (1972). A Working Model of Skill Acquisition with Application to Teaching. Quest, 17, 3-23.

Gesell, A. L. (1940). The First Five Years of Life. New York: Harper.

Gesell, A. (1928). Infancy and Human Growth. New York: Macmillan and Co.

Griffin, N. S., & Keogh, J. F. (1982) A Model of Movement Confidence. In J.A.S. Kelso, & J.E. Clark (Eds.), The Development of Movement Control and Coordination. John Wiley and Son Ltd.

Hogan, J. C., & Hogan, R. (1975). Organization of Early Skilled Action: Some Comments. Child Development, 46, 233-236.

Jones, C. M., & Miles, T. R. (1978). Use of Advance Cues in Predicting the Flight of Lawn Tennis Ball. Journal of Human Movement Studies, 41, 231-235.

Kail, R., & Hagen, J. W. (1982). Memory in Childhood. In B. B. Wolman (Ed.), Handbook of Developmental Psychology. Engelwood Cliffs, New Jersey: Prentice Hall.

Kail, R., & Hagen, J. W. (1977). Perspectives on the Development of Memory and Cognition. Hillsdale, New Jersey: LEA.

Kail, R. (1979). The Development of Memory in Children. Freeman and Co.

Kelso, J. A. S., & Clark, J. E. (1982). The development of Movement Control and Coordination. John Wiley and Son Ltd.

Kazdin, A. E. (1982). Single Case Experimental Design. New York: Oxford University Press.

Keppel, W. S. (1982). Design and Analysis. New Jersey: Prentice Hall.

Kinsbourne, M. (1981). Single Channel Theory. In D. Holding (Ed.), Human Skills. New York: Wiley.

Kitchener, K. S. (1983). Cognition, Metacognition, and Epistemic Cognition: A Three Level Model of Cognitive Processing. Human Development, 26, 222-232.

Konorski, J. (1967). Integrative Activity of the Brain. The University of Chicago Press.

Kopp, C. B. (1982). Antecedents of Self Regulation: A Developmental Perspective. Developmental Psychology, 18, 199-214.

Kozminsky, E., Kintsch, W., & Bourne, L. E. (1981). Decision Making with Texts: Information Analysis and Schema Acquisition. Journal of Experimental Psychology: General, 110, 363-380.

Kurtz, B. E., & Borkowski, J. G. (1984). Children's Metacognition: Exploring Relations Among Knowledge Process, and Motivational Variables. Journal of Experimental Child Psychology, 37, 335-354.

Lerner, R. M. (1978). Nature, Nurture and Dynamic Interactionism. *Human Development*, *21*(1), 1-20.

Lerner, R. M. (1976). *Concepts and Theories of Human Development*. Addison - Wesley Publishing Company Inc.

Lesgold, A. M. (1984). Acquiring Expertise. In J. R. Anderson, & S. M. Kosslyn (Eds.), *Tutorials in Learning and Memory*. New York: W. H. Freeman and Company.

Lesgold, A. M., Feltovich, P. J., Glaser, R., & Wang, V. (1981). The acquisition of Perceptual Diagnostic Skill in Radiology (Technical Report). Learning Research and Development Center, University of Pittsburgh.

Lincoln, R. S. (1953). Visual Tracking: The Instrumental Dimension of Motion in Relation to Tracking Accuracy. *The Journal of Applied Psychology*, *37*(6), 489-493.

Loftus, G. R. (1978). On Interpretations of Interactions. *Memory and Cognition*, *6*(3), 312-319.

Luria, N. (1966). *Human Brain and Physiological Processes*. Harper and Row.

Mackay, D. G. (1981). The Problem of Rehearsal or Mental Practice. Journal of Motor Behaviour, 13, 274-2[illegible]5.

Marx, [illegible] H. & Hillix, W. A. (1973). Systems and Theories in Psychology. McGraw Hill Inc.

McGraw, M. B. (1935). Growth: A Study of Johnny and Jimmy. New York: Appleton Century.

McGraw, M. B. (1945). The Neuromuscular Maturation of the Human Infant. Hafner Publishing Company.

Miller, G. A., Galanter, E., and Pibram, K. H. (1960). Plans and the Structure of Behaviour. New York: Henry Holt.

Miller, S. A. (1982). Cognitive Development: a Piagetian Perspective. In Ross Vasta (Ed.), Strategies and Techniques in Child Study. Academic Press.

Minas, S. C. (1978). Mental Practice of a Complex Perceptual-Motor Skill. Journal of Human Movement Studies, 4, 102-107.

McNemar, Q. (1933). Twin Resemblances in Motor Skills and the Effects of Practice Thereon. Journal of Genetic Psychology, 42, 70-97.

Navon, D., & Gopher, D. (1980). Task Difficulty, Resources and Dual Task Performance. Attention and Performance, 8.

Newell, K. M. (1978). Some Issues on Action Plans. In G. E. Stelmach (Ed.), Information Processing in Motor Control and Learning. Academic Press.

Newell, K. M., & Barclay, C.R. (1982). Developing Knowledge about Action. In J.A.S. Kelso, & J.E. Clark (Eds.), The Development of Movement Control and Coordination. John Wiley and Son Ltd.

Noble, M., Trumbo, D., Urlich, L., & Cross, K. (1966). Task Predictability and the Development of a Tracking Skill under Extended Practice. Journal of Experimental Psychology, 72, 232-240.

Norman, D. A., & Bobrow, D. G. (1975). On Data Limited and Resource Limited Processes. Cognitive Psychology, 7, 44-64.

Norman, D. A., Rumerhart, D. E., and the LNR Research Group. (1975). Explorations in Cognition. San

Francisco: Freeman.

Norman, D. A., & Shallice, T. (1980). Attention to Action: Willed and Automatic Control of Action. Unpublished paper.

Norman, D. A., & Shallice, T. (1985). Attention to Action: Willed and Automatic Control of Behaviour. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), Consciousness, and Self Regulation: Advances in Research. New York: Plenum Press.

Olson, D. R. (1975). On the Relations Between Spatial and Linguistic Processes. In J. Elliot & H. J. Salkind (Eds.), Children's Spatial Development (pp.67-110). Illinois: C C. Thomas.

Piaget, J. (1928). Judgement and Reasoning in the Child. New York: Harcourt.

Piaget, J. (1969). The Child's Conception of Time. London: Routledge and Kegan Publishers.

Piaget, J., & Inhelder, B. (1973). Memory and Intelligence. New York: Basic Books.

Pick, H. L., & Lockman, J. J. (1981). From Frames of Reference to Spatial Representations. In L. S. Liben (Ed.), Spatial Representation and Behaviour across Lifespan (pp. 39-61). New York: Academic Press.

Pigot, R.E., & Shapiro, D.C. (1984). Motor Schema: The Structure of the Variability Session. Research Quarterly for Research and Sport, 55(1), 41-45.

Posner, M. I. (1969). Reduced Attention and the Performance of Automated Movements. Journal of Motor Behavior, 1(4), 245-258.

Poulton, E. C. (1957). On Prediction in Skilled Movements. Psychological Bulletin, 54(6), 467-478.

Poulton, E. C. (1962). On Simple Methods of Scoring Tracking Error. Psychological Bulletin, 59, 320-328.

Poulton, E.C. (1974). Tracking Skill and Manual Control. New York: Academic Press.

Rarick, G. L. (1973). Physical Activity. Human Growth and Development. Academic Press Inc.

Rarick, G. L. (1982). Descriptive Research and Process-Oriented Explanations of the Motor Development of Children. In J.A.S. Kelso, & J.E. Clark (Eds.), The Development of Movement Control and Coordination. John Wiley and Son Ltd.

Ridenour, M. V. (1979). Programs to Optimize Infant Motor Development. In M. V. Ridenour (Ed.), Issues and Motor Development. Academic Press.

Ridenour, M. V. (1979). Issues and Motor Development. Academic Press.

Roberton, M. A. (1977). Stability of Stage Categorization across Trials: Implications for the 'Stage Theory' of Overarm Throw Development. Journal of Human Movement Studies, 3, 49-59.

Roberton, M. A. (1979). Stages in Motor Development. In M. V. Ridenour, (Ed.). Issues and Motor Development. Academic Press.

Rumelhart, D. E., & Ortony, A. (1977). The Representation of Knowledge in Memory. In R. C. Anderson, R. J. Spiro, &W. E. Montague (Eds.), Schooling and the Acquisition of Knowledge. Hillsdale, New Jersey: Lawrence Erlbaum.

Sage, G. H. (1977). Introduction to Motor Behavior: A Neuropsychological Approach. Addison Wiley

Publishing Company.

Schank, R. C., & Abelson, R. P. (1977). Scripts, Plans, Goals, and Understanding. Hillsdale, New Jersey: Lawrence Erlbaum.

Schiffman, H. R. (1976). Sensation and Perception. John Wiley.

Schmidt, R. A. (1975). A Schema Theory of Discrete Motor Skill Learning. Psychological Review, 82(4).

Schmidt, R. A. (1982). Motor Control and Learning. Human Kinetics Publ. Inc. 1982.

Schneider, W., & Shiffrin, R. M. Controlled and Automatic Human Information Processing: I. Detection, Search and Attention. Psychological Review, 84(1).

Seefeldt, V. D., & Haubenstricker, J. (1982). Patterns, Phases, or Stages: An Analytical Model for the Study of Developmental Movement. In J.A.S. Kelso, & J.E. Clark (Eds.), The Development of Movement Control and Coordination. John Wiley and Son Ltd.

Shallice, T. (1978). The Dominant Action System: An Information Processing Approach to Consciousness. In

K. S. Pope, & J. L. Singel (Eds.), The Stream of Consciousness. Plenum Press.

Shapiro, D.C., & Schmidt, R.A. (1982). The Schema Theory: Recent Evidence and Developmental Implications. In J.A.S. Kelso, & J.E. Clark (Eds.), The Development of Movement Control and Coordination. John Wiley and Son Ltd.

Shiffr[illegible] M., & Schneider, W. (1974). Controlled and Automatic Human Information Processing: II. Perceptual Learning, Automatic Attending and a General Theory. Psychological Review, 84(1).

Siegler, R.S., & Richards, D.D. (1979). Development of Time, Speed, and Distance Concepts. Developmental Psychology, 15, 288-298.

Siegler, R.S. (1983, March). Five Generalizations about Cognitive Development. American Psychologist.

Simon, D. P., & Simon, H. A. (1978). Individual Differences in Solving Physics Problems. In R. Siegler (Ed.), Children's Thinking: What Develops? Hillsdale, New Jersey: Erlbaum.

Singer, R. N. (1972). Reading in Motor Learning .

LEA and Febiger.

Singer, R. N. (1980). Motor Behaviour and the Role of Cognitive Processes and the Learner Strategies. In G. E. Stelmach, & J. Requin (Eds.), Tutorials in Motor Behaviour. New York: North Holland Publishing.

Singer, R. N. (1980). Motor Learning and Human Performance. McMillan Publishing Company.

Stelmach, G. E. (1982). Information Processing: Framework for Understanding Human Motor Behavior. In J. A. S. Kelso (Ed.), Human Motor Behavior. An Introduction. LEA Publ. Inc.

Stelmach, G. E. (1978). Information Processing in Motor Control and Learning. Academic Press.

Stelmach, G. E., & Diggles, V. A. (1982). Control Theories in Motor Behaviour. Acta Psychologica, 50, 83-105.

Sternberg, R. J. (Ed.), Handbook of Human Intelligence. Cambridge University Press.

Sternberg, R. J., & Detterman, D. K. (1979). Human Intelligence. Alex Publishing Corporation.

Sternberg, S. (1969). The Discovery of Processing Stages: Extensions of Donder's Method. In W. G. Koster (Ed.), Attention and Performance, 2. North Holland.

Sugden, D. A. (1980). Movement Speed in Children. Journal of Motor Behavior, 12, 125-132.

Thelen, E. (1981). Rhythmical Behaviour in Infancy: An Ethological Perspective. Developmental Psychology, 17(3), 237-257.

Thelen, E., & Fisher, D. M. (1983). The Organization of Spontaneous Leg Movement in Newborn Infants. Journal of Motor Behaviour, 15(4), 352-382.

Trumbo, D., Noble, M., Cross, K., & Urlich, L. Task Predictability in the Organization, Acquisition and Retention of a Tracking Skill. Journal of Experimental Psychology, 70(3), 320-328.

Von Hofsten, C. (1983). Catching Skills in Infancy. Journal of Experimental Psychology: Human Perception and Performance, 9(1), 75-85.

Wellman, H. M. (1977). The Early Development of

Intentional Memory Behaviour. Human Development, 20, 86-101.

Welford, A. T. (1968). Fundamentals of Skill. Methuen and Co. Ltd.

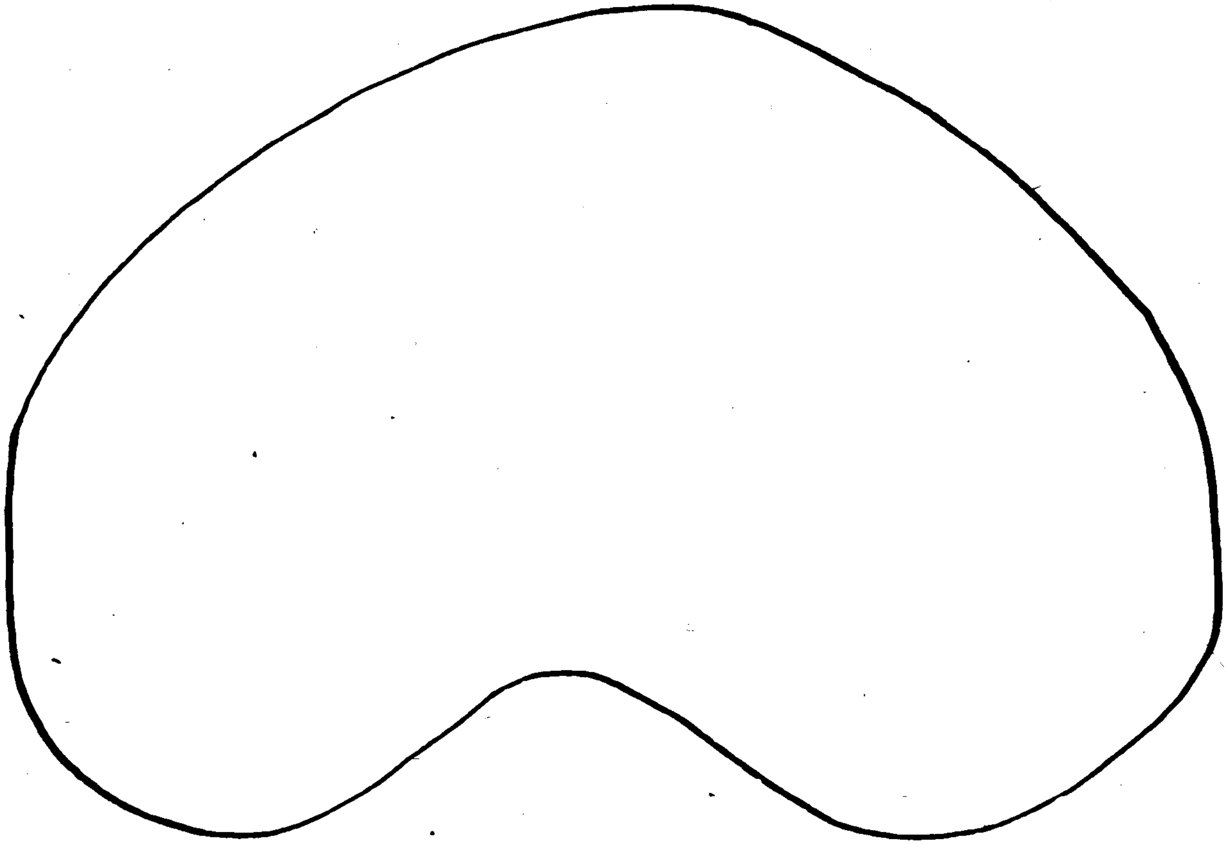
Wickstrom, R. (1977). Fundamental Motor Patterns. Philadelphia: LEA and Febiger.

Wilkening, F.C. (1981). Integrating Velocity, Time, and Distance Information: A Developmental Study. Cognitive Psychology, 13, 231-247.

William, H. G. (1983). Perceptual and Motor Development. Prentice Hall, Inc.

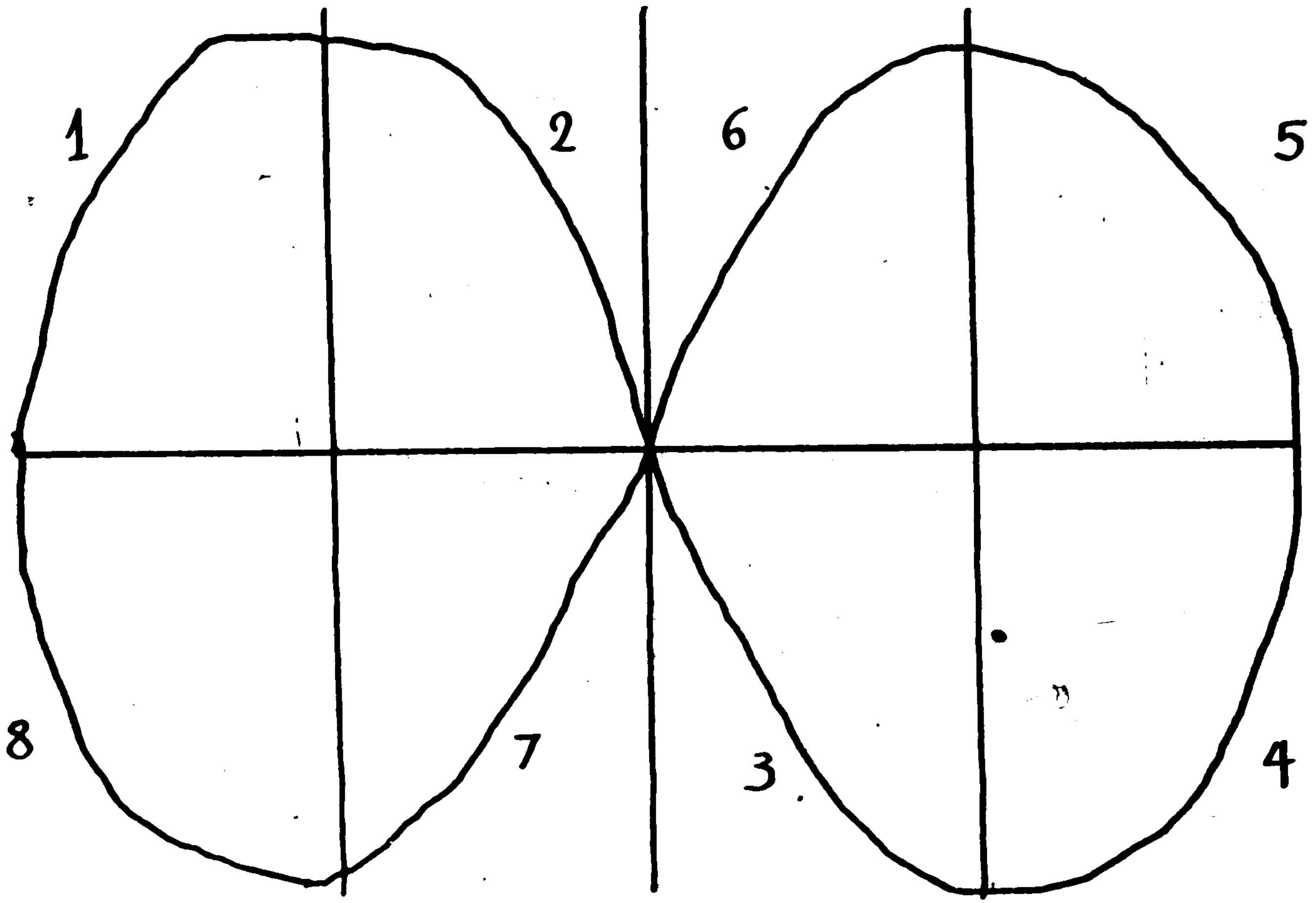
APPENDIX A

The Shape to be Tracked for the Pretest Session



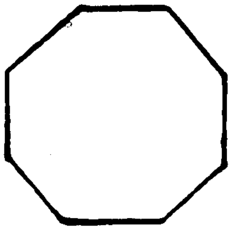
APPENDIX B

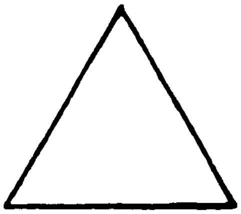
The Shape to be Tracked for the Test Session

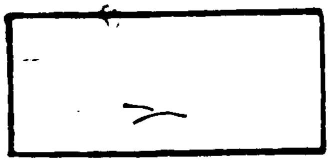


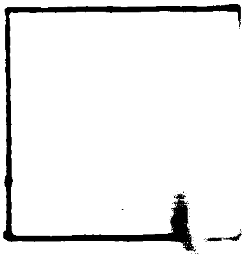
APPENDIX C

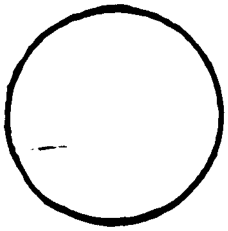
The Test for Declarative Knowledge of the Shapes

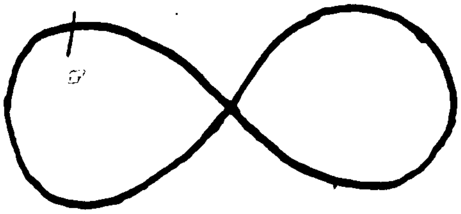


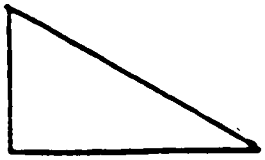












APPENDIX D

Pretest Error Scores for All Subjects who Participated in the Pilot Study

Grade 1	Grade 3	Grade 5
6.16	5.96	4.50
7.48	6.10	5.32
7.94	7.28	5.55
8.33	7.31	5.69
8.47	7.61	5.75
8.56	8.34	6.51
9.23	9.05	6.63
9.62	9.29	6.79
10.01	9.43	6.83
10.18	9.47	7.05
10.21	11.34	7.22
10.36	12.26	8.89

APPENDIX E

Pretest RMS Error Scores of all Subjects who Participated in the Study

Grade 5	Grade 3
16.98	21.64
18.12	22.69
18.46	23.14
21.25	24.02
21.67	25.70
21.86	26.15
22.47	27.14
22.48	27.95
22.82	28.48
22.90	29.55
23.39	31.10
24.22	31.34
24.42	31.73
24.67	32.22
25.33	32.57
25.70	33.20
26.10	33.28
26.25	34.15
26.45	35.65
26.56	36.11
27.06	37.35
27.14	37.74
27.15	38.36
27.44	38.89
27.77	39.78
28.60	39.93
28.81	40.51
29.39	40.53
29.47	42.27
29.90	42.27
32.12	42.73
32.27	43.45
32.87	45.66
34.70	46.08
35.21	46.26
36.40	47.69
37.56	47.87
38.28	48.40
38.31	48.55
40.15	49.58
42.27	52.48
42.57	54.89
45.43	55.67
46.91	56.96

APPENDIX F

Analysis of Variance of Number of Hits Scores. Treatment Groups by Trials

Source	SS	MS	F	DF	P
MEAN	289632.02	289632.02	9917.54	1	0.0000
Grade (A)	8850.60	8850.59	303.06	1	0.0000
Group (B)	22237.55	22237.54	761.45	1	0.0001
Condition (C)	149.84	74.92	2.57	2	0.0769
Trials (D)	708.52	37.29	1.28	19	0.1868
Sector (E)	11609.02	1658.43	56.79	7	0.0000
A • B	12.31	12.31	0.42	1	0.5162
A • C	184.47	92.23	3.16	2	0.0426
A • D	365.16	19.22	0.66	19	0.8628
A • E	463.74	66.25	2.27	7	0.0264
B • C	121.61	60.80	2.08	2	0.1247
B • D	449.74	23.67	0.81	19	0.6968
B • E	1653.48	236.21	8.09	7	0.0000
C • D	1174.42	30.91	1.06	38	0.3729
C • E	838.22	59.87	2.05	14	0.0116
D • E	3526.09	26.51	0.91	133	0.7673
A • B • C	2020.03	1010.02	34.58	2	0.0000
A • B • D	526.02	27.69	0.95	19	0.5218
A • B • E	241.86	34.55	1.18	7	0.3086
A • C • D	959.09	25.24	0.86	38	0.7063
A • C • E	463.25	33.09	1.13	14	0.3221

Continued on next page......

Source	SS	MS	F	DF	P
A • D • E	3005.02	22.59	0.77	133	0.9746
B • C • D	1607.45	42.30	1.45	38	0.0368
B • C • E	858.53	61.32	2.10	14	0.0094
B • D • E	3142.23	23.63	0.81	133	0.9471
C • D • E	6399.80	24.06	0.82	266	0.9824
A • B • C • E	1338.49	35.22	1.21	38	0.[illegible]
A • B • C • E	911.87	65.13	2.23	14	0.0053
A • B • D • E	3203.74	24.09	0.82	133	0.9293
B • C • D • E	5350.20.11	20.11	0.69	266	1.0
A • B • C • D • E	6346.05	23.86	0.82	266	0.9860
RESIDUAL	238304.90	29.20	••••	•••	•••

APPENDIX G

The Letter to the Teachers.

Dear Teacher,

I am a doctoral student in Physical Education working with Dr. A.E.Wall, Chairman of the department of Physical Education and Sport Studies, at the University of Alberta. We are interested in the development of motor skills and particularly in the development of fine-motor tracking behaviours.

My project is concerned with the manner in which children use their knowledge of different shapes to guide their movements in tracking situations. Specifically, I am asking two questions:

1. Does age affect the development of tracking skills:
2. How does the knowledge of shapes affect the tracking perfromance of girls at ages 8 and 10.

A MacIntosh computer presents the target (dot) to be tracked. A cursor is controlled by the 'mouse' linked to the computer. The girls track the moving target for twenty seconds each trial. Their errors are recorded by means of X and Y values in relation to the target. The girls will complete approximately 40 trials in two, ten minute each, testing sessions. The children who participated in the pilot study certainly enjoyed the task.

The results of the testing will be kept strictly confidential and will be used only for research purposes.

I require 100 girls, fifty in each of the following grades: Grade 3 and 5. The girls who will be involved in my study should have no visual impairements, no neuromuscular problems, nor have emotional or behavioural difficulties. The girls should also be of normal intelligence. We certainly would appreciate your help with the selection of the sample.

I realize that this is a busy time for you; however, I will try to do my research as efficiently as possible and with as little interruption of you, your schedule and your students as is possible. Thank you very much for attending to our request.

Sincerely,

Demetra Koutsouki

APPENDIX H

The Letter to the Parents.

Dear Parent,

I am involved in a doctoral research project at the University of Alberta that is concerned with the development of fine-motor control in children eight and ten years of age. I am interested in how children learn to track a moving target on a computer screen. I use a MacIntosh computer to present the task to be learned. A dot moves on the screen and the children have to move the computer 'mouse' to follow the dot. The children who participated in the pilot study certainly enjoyed the task. The children will be performing the the task for approximately fifteen minutes. The principal of your scholl has reviewed the project and has given his/her approval to it. The scores that I will obtain from the project will be kept completely confidential and they will be used only for research purposes.

I do hope that you will allow your child to participate to the project. If you have any questions about it, please do not hesitate to contact me at the number 437-2005.

Sincerely,

Demetra Koutsouki

Please print the child's name and birthdate ------------------

Sign one,

I grant my permission--

I do not grant my permission ---------------------------------