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ABSTRACT

This is the final report on a three year project designed to investigate the development of problem-solving strategies in elementary school children. In this project the personality of the child as it is reflected in problem solving style is examined. The hybothesis that reflective children are more competent problem solvers than impulsive children was tested. Some evidence suggests that reflection/impulsivity is related to task-oriented and social behavior in the classroom as well as to individual differences in academic achievement. Four separate tasks were selected which permitted a detailed analysis of hypothesis-testing strategies in sequential problem solving. Each task was administered to a sample of reflective and impulsive 7, 9, and 11 year olds in 1974, and available subjects were retested in 1975 and 1976. The primary objective of this research was to describe the development of problem solving strategies in reflective and impulsive children during the elementary school period. A second major objective for this research was to determine the effects of training impulsive children to use more efficient problem-solving strategies. The final objective for these studies was to assess the construct validity of the reflection/impulsivity dimension by determining whether reflective and impulsive children differ in observed classroom behavior. Collectively, these studies provide rather strong support for the notion that cognitive style, as indicated by response tempo in situations of response uncertainty, reflects individual differences in the development of essential problem-solving skills. (JD)

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Problem-Solving Strategies in Reflective and Impulsive Children

James D. McKinney, *Senior Investigator*
and
Ron Haskins, *Research Associate*
Melvin G. Moore, *Research Assistant*

Submitted to:
U.S. Department of Health, Education, and Welfare
National Institute of Education
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July 1, 1977

Frank Porter Graham Child Development Center
The University of North Carolina at Chapel Hill

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Preface

The studies described herein were conducted as part of a 3-year longitudinal project designed to investigate the development of competent problem-solving strategies in elementary school children. During the elementary school years, increased emphasis is placed on the child's ability to evaluate independently information he extracts from the environment and to abstract general principles and concepts from his classroom experience. One of the most consistent findings in studies of problem solving is that competent problem solvers tend to process task information according to some systematic plan and that performance is facilitated when a strategy is provided for the subject.

Until the past decade, individual differences in the development of problem-solving strategies were usually attributed to variation in general intelligence. However, in recent years, several dimensions of cognitive style have been shown to contribute to academic progress and success on a variety of problem-solving tasks independently of IQ. An aspect of cognitive style that has been studied extensively is reflection/impulsivity. Kagan and his associates found that in problem situations with high response uncertainty, some children proceed by slow deliberation and make few errors, while others respond in a hasty, impulsive fashion and make many errors. This disposition toward either a reflective or impulsive style has been shown to be stable over time and to generalize to a variety of different problem-solving tasks.

Over the past decade, an extensive literature has evolved which indicates that reflective children are more competent problem solvers than impulsive children. Also, some evidence suggests that reflection/impulsivity is related to task-oriented and social behavior in the classroom, as well as to individual differences in academic achievement. At the same time, it is not clear from previous research exactly how reflection/impulsivity influences performance while the child is engaged in problem solving. As a result, reflection/impulsivity has remained a rather poorly understood phenomenon, and modification of impulsive responding has been notably unsuccessful in increasing the quality of performance by impulsive children. Therefore, a key assumption underlying the present research was that there was both theoretical and practical merit in focusing on the manner in which information is processed by reflective and impulsive children as opposed to the speed of processing.

Toward these ends, we selected four separate tasks from the literature which permitted a detailed analysis of hypothesis-testing strategies in sequential problem solving. Each task was administered to a sample of reflective and impulsive 7, 9, and 11 year olds in 1974, and available subjects were retested in 1975 and 1976. In addition to comparing the developmental trends displayed by reflective and impulsive children, this study yielded data on the stability and generality of strategy behavior, as well as the relationship between decision time on each task and individual differences in performance. The results of this longitudinal study are reported in Chapter II.

As originally conceptualized by Kagan and his associates, reflection/impulsivity referred to individual differences in decision time in problem situations of response uncertainty. In subsequent studies the Matching Familiar Figures test was used to identify reflective and impulsive children by using the joint criteria of decision time and accuracy. However, in the past 2 years the utility of this operational definition has been questioned on the grounds that it leads to theoretical confusion and presents a number of methodological difficulties which may influence the correct interpretation of results. In response to these concerns an extensive re-analysis of the data from the first year was undertaken by using an alternative design strategy based on multiple-regression techniques. Also, this analysis was carried out in order to describe the relationship between reflection/impulsivity and academic achievement for the longitudinal sample. These results are presented in Chapter III of the report.

Since the preliminary results from the longitudinal study suggested that the superior performance of reflective subjects could be attributed to the use of more systematic and/or developmentally mature strategies compared to impulsive subjects of the same age, a series of studies was undertaken during the second year of the project to explore the efficacy of strategy instruction as a means of modifying impulsive and/or immature problem-solving behavior. The first experiment reported in Chapter IV assessed the effects of teaching young children, who exhibited a random approach, a systematic strategy for avoiding errors. Since this approach proved to be highly effective, it was decided to compare the effects of training in this relatively simple strategy to those obtained by training in the most complex strategy. The findings from this study are reported in Experiment II of Chapter IV. The final study in this series was carried out the third year of the project, and compared the relative effects of strategy training and style training which featured an enforced delay of responding on the performance and response tempo of impulsive, random problem solvers. The results of this study are also reported in Chapter IV.

The final study, reported in Chapter V, was carried out in order to explore the behavioral implication of reflection/impulsivity in the classroom. Since reflective and impulsive children have been found to differ in academic achievement, it would be important from the standpoint of future intervention and educational practice to determine whether reflective and impulsive children displayed characteristically different patterns of behavior in classroom learning activities. In this study, children who were consistently classified as either reflective or impulsive in the longitudinal sample were compared on 15 categories of overt task-oriented and social behavior. Also, this study provided an opportunity to explore the effects of age and contextual setting on specific classroom behaviors.

As with any long-term project, it is often the case that existing points of view will be challenged by new evidence and by the failure of existing evidence to completely satisfy all of the questions that can be asked about a relatively new concept. During the course of this project several important issues were raised concerning the conceptualization and interpretation of response latency as a measure of cognitive style and, more generally, of reflection/impulsivity research. These issues and concerns were generated in part from work in other laboratories as well as our own. In Chapter VI we suggest an alternative explanation for performance differences between reflectives and impulsives in the absence of differences in general intelligence, and discuss the implications of our findings for future research and educational practice.

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Table of Contents

Table of Contents (continued)

Table of Contents (continued)

Table of Contents (continued)

List of Tables

List of Tables (continued)

List of Figures

List of Abbreviations and Symbols

% AT	proportion of attribute questions
% C	proportion of constraint-seeking questions
CA	chronological age
CI	concept identification
CS	constraint-seeking question
DFC	standardized discrimination function coefficient
E	experimenter
Es	experimenters
F	obtained F value from analysis of variance
% FO	proportion of focus responses
% H	proportion of hypothesis responses
HO	House Task (Twenty-Questions)
HS	hypothesis-seeking question
IQ	intelligence quotient
IS	information score (in bits of information)
L	lower socioeconomic status
M	middle socioeconomic status
MFF	Matching Familiar Figures Test
MS	Matrix Solution Task or mean square
N	number of subjects
NI	non-informative responses
p	probability of obtaining stated value on the basis of chance alone
PCS	pseudo-constraint-seeking question
PICT	Pictures Task (Twenty-Questions)
PM	Pattern Matching Task
20-Q	Twenty-Questions Task (house, pictures, or verbal)
r	correlation coefficient (product moment)
S	subject
Ss	subjects
SD or s	standard deviation of distribution
SES	socioeconomic status
% SI	proportion of specific-instance questions
U	upper socioeconomic status
VERB	Verbal Task (Twenty-Questions)
WISC	Wechsler Intelligence Scale for Children
χ^2	Chi square
$\bar{X}$	mean of distribution

I. Introduction and Review of Literature

The term cognitive style has been used to describe individual preferences in the manner in which children sample and organize information from the environment (Kagan, Moss, & Sigel, 1963). One dimension of cognitive style which has been shown to be an important determinant of academic progress and success on a number of different problem-solving tasks is conceptual tempo (Kagan, 1965a; Kagan & Kogan, 1970). Kagan (1965a) has demonstrated that in problem situations with high response uncertainty, some children proceed by slow deliberation and make few errors while others test hypotheses quickly and make many errors. This disposition to respond in either a reflective or impulsive fashion has been shown to generalize across a variety of tasks and to be stable over time (Kagan & Kogan, 1970; Ward, 1968).

The child who answers impulsively and fails to think through and concentrate on a problem is at a distinct disadvantage in the classroom. Impulsive children generally show poorer achievement on measures of reading (Kagan, 1965b) and arithmetic (Cathcart & Liedtke, 1969) compared to reflectives at the same grade level. Messer (1970) found that boys who failed a grade between the ages of 6 and 8 years were significantly more impulsive than their peers, although they were highly comparable in verbal intelligence. Also, classroom teachers perceive impulsive children as less attentive and task-oriented than reflective children (Ault, Crawford, & Jeffrey, 1972; McKinney, 1974).

Impulsive children have been found to make more errors than reflective children on serial learning (Kagan, 1966), discrimination learning (Massari & Schack, 1972), and inductive reasoning tasks (Kagan, Pearson, & Welch, 1966a). A number of studies have found that impulsive children use less efficient strategies for scanning the stimulus array in matching-to-sample tasks compared to reflectives (Drake, 1970; McCluskey & Wright, Note 1; Siegelman, 1969; Zelniker, Jeffrey, Ault, & Parson, 1972). Also, Odom, McIntyre, and Neale (1971) found that impulsive children were less likely than reflectives to process information according to distinctive features on a perceptual learning task.

Thus, an extensive literature has evolved over the past decade which indicates that reflective children are more competent problem solvers and show better achievement than impulsive children. At the same time, it is not clear from previous studies exactly how individual differences in conceptual tempo influence performance during problem solving or in the classroom environment. Consequently, reflection/impulsivity has remained a rather poorly understood construct.

Motivational Factors

According to Kagan (1966), conceptual tempo influences performance during the hypothesis-testing and evaluation phases of problem solving. Specifically, he suggests that the impulsive child either fails to generate a sufficient number of hypotheses or does not adequately evaluate the information that has been gained prior to his report of the solution. Although Kagan (1966) has proposed the possibility of constitutional factors, his most frequent explanation for this behavior is that impulsive children have developed an expectancy for failure and are anxious about their ability to deal with situations of high response uncertainty (Kagan, Rosman, Day, Albert, & Phillips, 1964; Kagan & Kogan, 1970). Accordingly, they are motivated to remove themselves from the test situations as quickly as possible at the expense of accuracy. On the other hand, reflective children are overly concerned with making errors. However, since they are confident in their ability to deal with the problem, they adopt a very careful, time consuming approach that insures accuracy at the expense of a quick solution.

Nevertheless, the evidence for a motivational explanation of the problem-solving behavior of reflective and impulsive children has been minimal. Block, Block, and Harrington (1974) found that impulsive preschool children were described as anxious, hypersensitive, vulnerable, and structure seeking on the California Child Q set. Reflective preschoolers, on the other hand, were viewed as calm, considerate, competent, and task-oriented. Nevertheless, studies that have compared school-aged reflectives and impulsives on measures of test anxiety and other personality variables have not found systematic or impressive differences (Bentler & McClain, 1976; Bush & Dweck, 1975; Messer, 1970). Although Ward (1968) found that impulsive children slowed down more following an error than reflective children, other studies that have manipulated success and failure during problem solving have not found differences between the two style groups (Messer, 1970; Reali & Hall, 1970).

Modification of Impulsivity

Since impulsive children have been found to perform poorly in relation to reflectives on a variety of problem-solving tasks, a number of investigators have attempted to modify impulsive responding in the hope that an alteration in response style would result in improved performance. In general, these studies have shown that the response latencies of impulsive children can be increased by using a variety of techniques (Albert, 1970; Briggs & Weinberg, 1973; Kagan, 1966; Kagan, Pearson, & Welch, 1966b; Reali & Hall, 1970; Yando & Kagan, 1968).

However, with the exception of the Briggs and Weinberg (1973) study, treatments such as modeling, enforced delay, and reinforcing slow responding have not resulted in lower error rates.

On the other hand, training procedures which have attempted to teach impulsive children more efficient information processing skills have been more successful in improving performance (Debus, 1970; Egeland, 1974; Meichenbaum, Note 2; Ridberg, Parke, & Hetherington, 1971; Zelniker et al., 1972). The results of these studies suggest that greater attention should be devoted to the manner in which task information is processed by reflective and impulsive children, rather than to the tempo of processing. If impulsive children have not learned efficient strategies for processing the task information necessary for solution, then training procedures which merely operate on response latency cannot be expected to improve the quality of their performance.

Problem-Solving Strategies

In a recent experiment, McKinney (1973) investigated the problem-solving strategies used by reflective and impulsive second graders on a matrix solution task. The subjects were shown a 4 X 4 matrix of flowers which varied according to three dimensions and were asked to discover the correct flower by asking questions that could be answered as yes or no. Reflective children extracted more information with their questions than impulsive children and more often used an optimal strategy. Impulsive children were less likely than reflectives to form hypotheses based on conceptual categories and tended to process information in a random, trial-and-error fashion. Similarly, Ault (1973) and Denney (1973) found that reflective children asked more mature questions in twenty-questions games than their impulsive peers. Moreover, Ault (1973) found that the strategy behavior of younger reflectives was highly comparable to that of older impulsives.

More recently, McKinney (1975a) gave reflective and impulsive 7, 9, and 11 year olds a series of five problem-solving tasks in which the subject was required to determine the correct solution from a number of equiprobable solutions by gathering information that eliminated incorrect alternatives. Results indicated that the effect of cognitive style on problem solving varied with developmental level and the type of problem that was solved. Nevertheless, when cognitive style was a significant contributor to performance, the data indicated that reflective children processed task information more efficiently than impulsive children and used more systematic and/or mature strategies.

One of the more interesting findings by McKinney (1975a) was that the results from measures of response tempo during problem solving paralleled those obtained for the performance measures on a given task; that is, reflectives responded more slowly than impulsives on those tasks in which they demonstrated better performance. Also, slow responding was associated with more mature strategy behavior and fast responding was associated with less mature strategies on those tasks that differentiated reflectives and impulsives at each age level. Therefore, it appears that when reflective children perform more efficiently than impulsive children on a given task, their response tempo can be attributed to the use of more sophisticated and necessarily time-consuming strategies.

Research Objectives

The primary objective of the present research was to describe the development of problem-solving strategies in reflective and impulsive children during the elementary school period. While evidence has accumulated to suggest that reflective and impulsive children differ in the way they process task information, the course of strategy development in the two style groups is unknown. Similarly, little is known about the generality of strategy behavior within age and style groups. One limitation of previous research on strategy behavior has been the tendency to concentrate on a single task or class of problems. If reflective and impulsive children adopt characteristically different strategies in one problem situation, it would be important to learn whether such differences represent generalized approaches to a variety of problems, or whether they are unique to a given problem with particular stimulus and/or response properties.

A second major objective for this research was to determine the effects of training impulsive children to use more efficient problem-solving strategies. Several studies have shown that young elementary school children can acquire and transfer rather complex problem-solving strategies (Anderson, 1965; Keislar & Stern, 1970; McKinney, 1971). If reflective and impulsive children differ in the way they process task information and if tempo of responding can be attributed to individual differences in strategy behavior, then strategy training should not only enhance performance but also alter response style as well. Similarly, training in different types of strategies should differentially influence problem-solving efficiency and tempo of responding.

The final objective for these studies was to assess the construct validity of the reflection/impulsivity dimension by determining whether reflective and impulsive children differ in observed classroom behavior.

One of the most serious criticisms of reflection/impulsivity research is that it attaches too much surplus meaning to individual differences in response latency during problem solving, and in particular to performance on the Matching Familiar Figures test (Block et al., 1974, 1975; Kagan & Messer, 1975). While evidence has been gathered which indicates that impulsive children as defined by the MFF test show poorer achievement than reflectives, it has not been demonstrated conclusively that children who are impulsive on a cognitive task are also impulsive in classroom learning activities.

II. Development of Problem-Solving Strategies in Reflective and Impulsive Children

Introduction

According to White (Note 3), one of the characteristics of the competent child at age 6 is the ability to plan and carry out a sequence of activities and to use resources effectively in the solution of multi-stage problems. During the elementary school years increased emphasis is placed on the child's ability to independently evaluate information he extracts from the learning environment and to abstract general principles and concepts from his experience. Although substantial progress has been made in recent years in understanding the development of problem-solving skills, relatively few studies have focused on individual differences in information-processing in complex problems (Berlyne, 1970, Kagan & Kogan, 1970; Lipsitt & Eimas, 1972).

Several techniques are now available that permit the investigation of problem-solving strategies in children which do not depend entirely upon the interpretation of verbal responses. For example, Neimark and Lewis (1967) developed a task in which the child was shown a card containing eight patterns composed of binary elements (white or black dots), and a problem board in which one of the eight patterns was placed behind movable shutters. The child's task was to discover the correct pattern by uncovering as few of its elements as possible. Also, Eimas (1969) studied hypothesis behavior and information processing in elementary school children by using a concept identification task with a blank trials procedure developed by Levine (1966). A third technique which has been used is a variation of the selection paradigm for concept attainment developed by Bruner, Goodnow, and Austin (1956). In this task, the child is shown a multidimensional stimulus array and is required to locate the correct stimulus pattern by asking questions that can be answered as yes or no (Eimas, 1970; Mosher & Hornsby, 1966).

In each of these procedures the child is given a problem with a finite number of equiprobable solutions, and his task is to discover the correct solution by gathering information which eliminates incorrect alternatives. Common examples of this type of problem are medical diagnosis, trouble shooting of mechanical failure, the game of twenty questions, and solving for unknown substances in a chemistry experiment. In each case strategy behavior can be measured by applying information theory principles (Neimark & Lewis, 1967; Eimas, 1970).

The most efficient strategy in these problems is similar to the conservative focusing approach described by Bruner et al. (1956). In this strategy the subject tests each stimulus dimension in the array in succession and thereby reduces the number of equiprobable alternatives by half with each response. For example, if the child is shown a 16-element array with four binary dimensions and is instructed to locate the correct element by asking questions, an initial question such as, "Is it in the top half?" or "Is it red?" would eliminate eight stimuli. If this strategy is followed correctly, the subject could achieve solution in as many trials as there are dimensions in the array.

Although focusing is a highly efficient approach, it does involve greater cognitive strain than an hypothesis-scanning strategy in which the subject tests specific alternatives one at a time (Bruner et al., 1956; Eimas, 1970). In order to use a focusing strategy effectively, the subject must be able to partition the stimulus array into categories and then construct the correct solution from the conjunction of all relevant attributes. Therefore, it is not surprising that previous studies with these tasks have found a low frequency of focusing behavior below the sixth grade (Eimas, 1969, 1970; Neimark & Lewis, 1967). In general, these studies have shown systematic increases in average information obtained to be a function of age, with a stage-like progression from essentially a random approach in the first and second grades to an hypothesis-scanning approach, and finally to a focusing approach in the eighth grade through high school.

In a recent experiment, Mckinney (1973) investigated the problem-solving strategies used by reflective and impulsive second graders on a matrix solution task. The subjects were shown a 4 X 4 matrix of flowers which varied according to three dimensions and were asked to discover the correct flower by asking questions that could be answered as yes or no. Reflective children extracted more information with their questions than impulsive children and more often used a focusing strategy. Impulsive children were less likely than reflectives to form hypotheses based on conceptual categories and tended to process information in a random, trial-and-error fashion. Similarly, Ault (1973) and Denney (1973) found that reflective children asked more mature questions in twenty-questions games than their impulsive peers. Moreover, Ault (1973) found that the strategy behavior of younger reflectives was highly comparable to that of older impulsives.

The major objectives of the present study were to describe the development of problem-solving strategies in reflective and impulsive children during the elementary school period, and to assess the generality of strategy behavior in the two style groups across a variety of different problem-solving tasks. One limitation of previous research on strategy behavior has been the tendency to concentrate on a single task or class of problems. Consequently, little is known about the generality of strategy behavior within age and subject groups. If reflective and impulsive children adopt characteristically different strategies in one problem situation, it would be important to learn whether such differences reflect generalized approaches to a variety of problems, or whether they are unique to a given problem with particular stimulus and/or response properties.

Method

Study Sample

The total sample obtained during the first year of the project was composed of 109 7 year olds, 83 9 year olds, and 80 11 year olds. All of the children were enrolled in a single elementary school and represented the total number of children available. Each child was tested with the Matching Familiar Figures (MFF) test in the fall of 1973 to select groups of reflective and impulsive children. In this test subjects are shown a standard stimulus and six similar variants. The child is instructed to point to the one variant that is identical to the standard. If he responds incorrectly, he is informed of the error and is told to choose another alternative. The average latency to first response and total number of errors were calculated for the 12 MFF items.

Following the procedure recommended by Kagan (1966), subjects who scored above the group median for their age in response latency and below the median in errors were classified as reflective. The opposite criteria were used to classify subjects as impulsive. This procedure resulted in an initial longitudinal sample of 87 reflectives and 86 impulsives. Each child who was classified as either reflective or impulsive was given the Wechsler Intelligence Scale for Children (WISC), verbal scale. Subjects who scored more than one standard deviation below average were excluded from the sample.

A total of 43 subjects were lost the second year of the project, and an additional 38 were not available the third year. Although this attrition rate (46%) was greater than anticipated, an adequate sample size was maintained for longitudinal comparisons. A total of 40 children in the youngest age group (Cohort A) were tested at 7, 8, and 9 years; 51 subjects in the middle age group (Cohort B) were tested at 9, 10, and 11 years; and 31 subjects in the oldest age group (Cohort C) were tested at 11, 12, and 13 years. Table 1 provides a summary of subject characteristics in the longitudinal sample for each year of the project. Inspection of these data indicated that the ages, IQs, and socioeconomic status of children in the reflective and impulsive groups remained comparable from year to year which suggests that subject attrition was not selective.

The final sample was composed of 39 boys and 53 girls. An analysis of variance on WISC verbal IQ scores indicated that reflective and impulsive children in each age group were comparable, although reflectives tended to score somewhat higher than impulsives at each age level. The sample contained 76 white children and 16 black children. The socioeconomic status of each child was classified as either upper, middle, or lower by using the Hollingshead scale for parental occupation. Table 1 shows the proportions of children in each SES category for each group. A series of Chi-square analyses for each age group in the final sample failed to show significant differences in the SES distribution for reflectives and impulsives.

Experimental Design

The primary design was a 2 X 2 X 3 X 4 mixed factorial. The between-subjects factors were sex (male and female) and cognitive style

Table 1

Subject Characteristics for Each Age Group in the Longitudinal Sample for Each Project Year

Cohort A		7 years R	7 years I	8 years R	8 years I	9 years R	9 years I
n		30	30	21	24	14	16
CA (months)	M	88.97	88.37	96.81	96.17	107.85	109.12
	SD	3.17	2.93	4.61	3.81	4.86	4.36
IQ	M	118.13	109.76	116.19	108.96	117.29	112.00
	SD	11.80	15.93	10.56	16.03	11.28	17.37
SES	U	.63	.30	.66	.33	.71	.37
	M	.37	.57	.33	.29	.28	.50
	L	.00	.13	.00	.14	.00	.12
Cohort B		**9 years R**	**9 years I**	**10 years R**	**10 years I**	**11 years R**	**11 years I**
n		30	29	26	20	22	17
CA (months)	M	115.23	113.24	125.38	122.25	136.86	134.52
	SD	4.15	3.35	4.22	4.81	4.29	4.88
IQ	M	113.93	109.89	115.38	112.10	115.54	110.59
	SD	13.66	11.86	14.05	11.72	15.01	11.82
SES	U	.57	.52	.53	.50	.66	.35
	M	.40	.34	.42	.30	.28	.47
	L	.03	.14	.04	.20	.04	.17
Cohort C		**11 years R**	**11 years I**	**12 years R**	**12 years I**	**13 years R**	**13 years I**
n		27	27	21	18	13	10
CA (months)	M	138.44	137.67	153.90	152.22	165.69	164.80
	SD	3.65	3.28	4.71	4.54	4.80	3.67
IQ	M	112.03	106.18	111.95	104.89	114.31	107.00
	SD	11.81	14.22	11.30	14.41	10.10	16.06
SES	U	.55	.41	.57	.55	.61	.70
	M	.37	.44	.33	.27	.38	.10
	L	.07	.15	.09	.16	.00	.20

(reflective and impulsive). The within-subjects factors were age within developmental levels (Group A, 7, 8, and 9 years; Group B, 9, 10, and 11 years; Group C, 11, 12, and 13 years) and order of problem administration for each task. The order of problem administration for each task was varied by Latin squares, and each subject was randomly assigned to one of the possible orders.

Procedure

Subjects were tested individually in two separate sessions each year of the project. With the exception of the MFF, which required approximately 10 minutes, the sessions lasted from 30 to 45 minutes. In order to control for age variability in the longitudinal analysis, each subject was tested within 3 weeks of his original test date each year. The testing procedures and instructions were the same each year; however, specific problem solutions were changed to eliminate guessing. Subjects were reminded of the fact that they had participated the previous year and were told that they would be given the same kinds of problems but that the solutions would be different. With the exception of 12 and 13 year olds in Group C, subjects were escorted to a laboratory at the Frank Porter Graham Center which was adjacent to the school. Children in the oldest age group who had transferred to junior high were tested in rooms provided by the school.

Experimental Tasks

In addition to the Matching Familiar Figures test, each subject was given four tasks to assess his problem-solving efficiency and strategy behavior.

Matrix solution. The stimuli for the matrix solution task were 16 drawings of flowers which varied according to size (large or small), color (red or blue), number of petals (four or six), and context element (yellow square or triangle in center). The stimuli were randomly arranged in a 4 X 4 matrix of 3-inch (7.62 cm) squares and were presented on a 12-inch (30.48 cm) square card. Subjects were given four problems in which they were instructed to find the correct flower in the array by asking questions that could be answered as yes or no. If the child asked a question that could not be answered as yes or no, the experimenter said, "Remember, I can't give you any answer but yes or no." A more detailed description of this procedure can be found in Eimas (1970) and McKinney (1973).

One convenient measure of the efficiency of information processing on this task is the expected or average amount of information obtained by each question. The expected information score for each response was computed as the sum of the informational outcomes in bits weighted by the probabilities of occurrence. For example, if the subject guessed one element of the 16-element array on the first trial, he would be correct with a probability of 1/16 and would reduce uncertainty by 4.0 bits ($\log_2 16 - \log_2 1$). He would be incorrect with a probability of 15/16 and would reduce uncertainty by .10 bits ($\log_2 16 - \log_2 15$). Accordingly, expected informational outcome for this strategy would be .34 bits [(1/16 X 4.0) + (15/16 X .10)]. The mean expected information score for each problem was obtained by summing the information scores for each response and dividing by the number of responses.

Since the mean information scores also reflect the number of errors made by the subject, it was considered desirable to provide a measure of the general approach or type of strategy followed by the subject as well as the efficiency with which the strategy was used. Each response or question was scored as either an attribute, spatial, specific instance, or noninformative hypothesis. An attribute hypothesis was defined as a question about one of the four stimulus dimensions in the array, e.g., "Is it small?". A spatial hypothesis was defined as a question about the position of the correct element in the array, such as, "Is it in this row?". A specific instance hypothesis was scored when the subject selected a single stimulus. A noninformative hypothesis was scored when the subject asked a question that could not be answered as yes or no, or when he asked a question that provided redundant information.

If the subject tested single attribute hypotheses and extracted 1.0 bits of information on each informative trial, the strategy was classified as focusing. If the subject tested one stimulus pattern at a time in an orderly fashion such as by going down the columns or across the rows, the strategy was classified as scanning. A random strategy was scored when the subject tested specific instances without following a discernible pattern. Lastly, a mixed strategy was scored when the subject followed a combination of focusing and scanning, or focusing and random strategies. Consistent multiple hypothesis-testing strategies ("Is it small with four petals?") were not observed in this sample of children, and protocols which contained single questions of this type were classified as mixed strategies.

Pattern matching. The stimuli for the pattern matching task were eight circular patterns composed of binary elements (black or white dots). Each pattern was drawn on a 4 X 6 inch (10.16 X 15.24 cm) card which contained four black dots and four white dots. The eight stimulus cards were displayed in a 2 X 4 array on a wooden board which was tilted at a 15° angle. For each problem one of the eight patterns was concealed behind eight movable shutters in a 10-inch (25.4 cm) square problem board.

The procedure was similar to that used by Neimark and Lewis (1967). The child was told that his task was to identify the concealed pattern by uncovering as few of its elements as possible. In each problem, the stimuli were constructed such that on the first trial, four of the shutters would eliminate half of the patterns and four would eliminate single patterns. Each response which eliminated half of the remaining patterns on a given trial was classified as a focusing response and each response which eliminated a single pattern was classified as a scanning response. The stimuli were arranged so that scanning would not "pay off", i.e., the concealed pattern was never one that contained a single position that would identify the pattern. On succeeding trials subjects could make noninformative responses by opening shutters that provided redundant information.

Each subject first underwent a task familiarization procedure in which the relationship between the dot positions and shutter positions was explained by using a four-pattern display. Subjects were then given a demonstration problem with six patterns followed by one with eight patterns. In order to facilitate scoring, subjects were taught to turn over incorrect patterns after responding. If the subject demonstrated that he understood the task, he was given four test problems. Each problem used a different set of eight patterns and was introduced by saying, "Now find the pattern inside the board by opening as few windows [shutters] as possible." The expected information obtained by each response was computed in the same fashion as that for the matrix solution task. Additional dependent measures were the number of noninformative responses and proportion of focusing responses. Response latency was measured by timing the interval between the subject's turning over the last pattern and opening the next shutter. Timing on the first trial began when the experimenter completed the instructions to the subject, and on non-informative trials when the subject indicated that he could not turn over any of the patterns.

Twenty questions. Each subject was given a series of four problems which used a twenty-questions procedure similar to that developed by Mosher and Hornsby (1966). Two problems were administered under each of two conditions. In the first set of problems subjects were shown the array of pictures used by Mosher and Hornsby (1966), and their task was to discover which picture the experimenter had in mind by asking questions that could be answered as yes or no. The second set of problems was presented verbally, and the subject was required to construct the alternative solutions as well as to determine the correct one.

The stimuli for the pictures problems were 42 colored drawings of common objects (e.g., shoe, bike, cow) which were arranged in a 7 x 6 array. First, subjects were instructed to name each of the objects and the experimenter accepted whatever name the subject supplied, or provided a name if the subject could not recognize the object. Each subject was asked to locate two pictures in the array. The solution in the first problem was a coat, and that for the second was a bicycle. Subjects were allowed a maximum of 20 questions. If the child asked a question such as, "What color is it?", the experimenter said, "Remember, I can't give any answer but yes or no.

The verbal problems differed from the twenty questions pictures problems in that the experimenter described an event for the subject and then asked the subject to find out how it had happened by asking questions. In the first problem the subject was told that a boy (girl) left school in the middle of the morning and was asked to try to find out what happened by asking questions that could be answered as yes or no. The solution to the problem was that the child had been injured and had to go to the doctor or to the hospital. Subjects were allowed to ask a maximum of 20 questions, but also were allowed to give up after two, 30-second periods of silence. If the subject guessed part of the answer, e.g., "Was he hurt?", the experimenter said, "Yes. That's part of the reason. Would you like to ask another question?". If the subject persisted in naming various injuries, the experimenter attempted to prompt more appropriate responses by saying, "Why did he leave school?".

Regardless of the subject's performance on the first problem, he was given a second one in which the experimenter said, "Now let's try one more. A man (woman) was driving down the road in his (her) car. The car went off the road and hit a tree. Why did the car go off the road?". The solution in the second problem was that it was snowing and the car skidded on the icy pavement. As with all other problem-solving tasks, the specific solutions for the verbal problems were changed each year of the project.

Subjects' responses on each of the twenty questions problems were recorded verbatim. A question was classified as hypothesis-seeking (HS) when it referred to a single alternative (e.g. Pictures--"Is it the cow?", Verbal--"Did he fall asleep?"). Questions were scored as constraint-seeking (CS) when they eliminated two or more alternatives (e.g., Pictures--"Is it an animal?", Verbal--"Was he hurt?"). A pseudo-constraint-seeking (PCS) question was scored when the response was in the general form of a constraint-seeking question, but nevertheless only referred to a single alternative (e.g., Pictures--"Does it bark?"). A question was scored as noninformative if it could not be answered as yes or no, or if it provided redundant information.

Results

Problem-Solving Behavior

In order to compare the problem-solving efficiency of reflective and impulsive children, a 2 (sex) X 2 (cognitive style) X 3 (age) multivariate analysis of variance was performed on selected dependent measures for each task. This analysis was performed separately for each age group in the longitudinal sample. The within-subjects analysis on longitudinal trends within age groups was carried out by computing the linear and quadratic contrasts for the repeated measures effects. The developmental trend for each variable and the resultant interactions with sex and cognitive style were tested by a multivariate analysis of variance on the two sets of contrast scores (McCall & Appelbaum, 1973). The relationships between dependent measures were determined by standard bivariate correlations and forward stepwise multiple regression procedures for all the subjects in each age group regardless of cognitive style classification.

Matching Familiar Figures test. The means and standard deviations of the error and latency scores on the Matching Familiar Figures (MFF) test are shown in Table 2 for each style group. In general, the latency/error correlations for the entire sample at each age level were consistent with those reported in the literature and were highly stable from year to year. The correlations between MFF latency and errors for the youngest sample ($\underline{n}$ = 40) were -.52 at year 7, -.56 at year 8, and

Table 2

Average Latency and Error Scores on the Matching Familiar Figures Test

Cohort A		7 years		8 years		9 years	
		R	I	R	I	R	I
Latency	M	18.18	8.07	19.16	15.12	20.70	18.76
	SD	7.16	2.22	8.61	6.37	12.22	9.47
Errors	M	8.71	18.94	7.36	10.31	5.50	7.88
	SD	2.05	3.36	4.58	6.00	3.67	4.77

Cohort B		9 years		10 years		11 years	
		R	I	R	I	R	I
Latency	M	30.02	10.83	24.34	13.12	23.80	11.56
	SD	9.94	4.27	12.83	6.08	13.38	4.31
Errors	M	3.23	11.35	5.41	10.18	2.50	7.77
	SD	1.93	2.67	4.85	5.10	2.58	3.19

Cohort C		11 years		12 years		13 years	
		R	I	R	I	R	I
Latency	M	[illegible].60	10.14	20.22	12.84	17.40	11.48
	SD	14.92	2.13	9.05	5.79	5.41	3.19
Errors	M	2.77	10.40	3.46	6.00	1.85	4.20
	SD	2.20	2.46	3.76	3.43	2.12	2.62

-.66 at year 9. In the middle age sample (n = 51), the correlations were -.65, -.62, and -.62 at 9, 10, and 11 years, respectively; and in the older sample (n = 31), they were -.59, -.65, and -.67 at 11, 12, and 13 years, respectively.

As expected, the analysis of cognitive style effects within each cohort showed highly significant differences between reflective and impulsive children on MFF error scores [Cohort A--$F(1/26) = 21.80$, $p < .001$, Cohort B--$F(1/35) = 44.62$, $p < .001$, and Cohort C--$F(1/19) = 18.16$, $p < .001$]; and latency scores [Cohort A--$F(1/26) = 4.85$, $p < .03$, Cohort B--$F(1/35) = 46.71$, $p < .001$, and Cohort C--$F(1/19) = 13.82$, $p < .001$]. No significant sex effects were found for Cohort A and Cohort B; however, in the oldest age group boys made more errors on the MFF than girls; $F(1/19) = 4.48$, $p < .04$.

In general, the within-subjects main effect was highly significant (all ps < .001) for each cohort; however, the pattern of developmental change varied considerably across cohorts. The repeated measures analysis for the youngest cohort (A) yielded a significant linear trend for the style X age level interaction, $F(1/26) = 23.25$, $p < .001$, which indicated that impulsives showed a greater decline in MFF error rate between the ages of 7 and 9 than did reflectives. At the same time, impulsives in the same cohort displayed a greater linear increase in response latency than reflectives, $F(1/26) = 4.03$, $p < .05$.

The analysis of change in MFF error scores for Cohort B yielded a significant overall quadratic trend, $F(1/35) = 6.91$, $p < .01$, as well as a linear trend, $F(1/35) = 17.28$, $p < .001$. Thus, the error scores for both reflectives and impulsives were relatively stable between 9 and 10 years and declined between 10 and 11 years. Nevertheless, a significant style X age level interaction showed that impulsive children had a greater decline in error scores than reflectives over this period of development, $\underline{F}(1/35) = 17.28$, $\underline{p} < .001$. The same analysis on MFF latency scores failed to show significant developmental changes between the ages of 9 and 11 years.

The within-subjects analysis for Cohort C yielded results that were similar to those obtained in Cohorts A and B with respect to MFF error scores, i.e., there was an overall decline in error rate between the ages of 11 and 13, $\underline{F}(1/$[illegible]$) = 34.47$, $\underline{p} < .001$, and impulsives showed a greater decline than reflectives, $\underline{F}(1/19) = 21.52$, $\underline{p} < .001$. However, over this age span, impulsive children displayed a greater decline in error rate between 11 and 12 years compared to reflectives, and performance in both groups approached ceiling between 12 and 13 years, $\underline{F}$ quadratic $(1/19) = 5.53$, $\underline{p} < .03$. The same analysis on response latency for Cohort C showed that while there was an overall decrease in latency with age, $\underline{F}(1/19) = 15.36$, $\underline{p} < .001$, reflectives displayed a more rapid decline than impulsives, $\underline{F}$ linear $(1/19) = 19.$[illegible]3, $\underline{p} < .001$. In general, there were no sex effects in the data for Cohort C.

In sum, the longitudinal results for the MFF test suggest two associated trends in development with respect to accuracy of processing and style of processing visual information on this match-to-sample task. In general, error scores decline rapidly over the early elementary school period, tend to stabilize between the ages of 9 and 11 years, and show a less dramatic decline during early adolescence, approaching perfect performance. Impulsives as a group show the greatest improvement in performance early in development, and reflectives show relatively little gain later in development. With developmental increases in accuracy, there is a corresponding increase in tempo of responding over the early elementary period. However, after 9 to 10 years this trend is reversed and there is a general, progressive increase in speed of processing. At the same time, it was interesting to note that this increase in both accuracy and speed in early adolescence was more characteristic of reflectives than impulsives.

The correlations among error scores over a three-year period for each cohort are shown above the diagonals in Table 3. Those for response latency are reported below the diagonals and those between errors and latency are reported on the diagonals. These data were based on the entire longitudinal sample regardless of cognitive style classification.

Inspection of the data in Table 3 indicated that both response latency and error performance were moderately stable over a three-year period for all three cohorts. The average intercorrelation of latency scores of each cohort tended to increase with age, .35 ($p < .05$), .43 ($p < .01$), and .68 ($p < .01$); while that for error scores was greater in the middle age cohort ($r = .58$, $p < .01$), than that for the younger ($r = .31$, $p < .05$) and older ($r = .35$, $p < .05$) cohorts. As Table 3 shows, the error-latency correlations for each year ranged from -.52 to -.67 and remained fairly constant from year to year.

Thus, the data on MFF stability was quite consistent with that reported previously in that both latency and errors were moderately correlated over a period of one year and somewhat less stable over a two-year period. Similarly, the finding that errors were less stable than latencies was consistent with available evidence from other investigators (Kagan, 1965a; Messer, 1970, Yando & Kagan, 1968).

Table 3

Intercorrelation of Error Scores and Latencies on the MFF Test for Each Cohort

Cohort A	7 years	8 years	9 years
7	-.52**	.32*	.31*
Age 8	.32*	-.56**	.31*
9	.09	.65**	-.66**
Cohort B	**9 years**	**10 years**	**11 years**
9	-.65**	.58**	.62**
Age 10	.40**	-.62**	.54**
11	.47**	.44**	-.62**
Cohort C	**11 years**	**12 years**	**13 years**
11	-.59**	.34*	.25
Age 12	.55**	-.65**	.46**
13	.79**	.71**	-.67**

Note: Correlations for errors above the diagonal and latency below the diagonal: error/latency correlations each year are on the diagonal.

*$p < .05$.

**$p < .01$.

Matrix solution. Figure 1 shows the average expected information scores in bits for reflective and impulsive subjects at each age level. The analysis of variance on the scores for each cohort failed to show significant main effects for either reflection/impulsivity or sex. Since the same finding was obtained for all other measures on this task, the means and standard deviations for other variables were not reported here (see Appendix A).

The multivariate analysis of age effects for the information scores revealed a significant linear increase for all cohorts, and significant quadratic trends for Cohorts B and C. The general absence of interaction in the within-subjects analysis indicates that the pattern of strategy development on this task was the same for reflectives and impulsives and for boys and girls. Inspection of data in Figure 1 suggests that the quadratic trend for Cohorts B and C can be attributed to ceiling effects between the ages of 10 and 13 years for this task.

Although the results for the oldest children in the longitudinal sample were not surprising given previous findings (McKinney, Haskins, & George, Note 4), it should be noted that the failure to find performance differences between reflectives and impulsives in the youngest cohort is inconsistent with previous results (McKinney, 1974; McKinney et al., Note 4) on this task based on cross-sectional comparisons.

Pattern matching. The average information scores, noninformative responses, and percent focusing responses for reflective and impulsive subjects at each age level within cohorts are shown in Table 4. Comparisons between reflectives and impulsives within the youngest cohort revealed significant differences in favor of reflectives on information scores, $F(1/26) = 3.67$, $p < .06$, and noninformative responses,

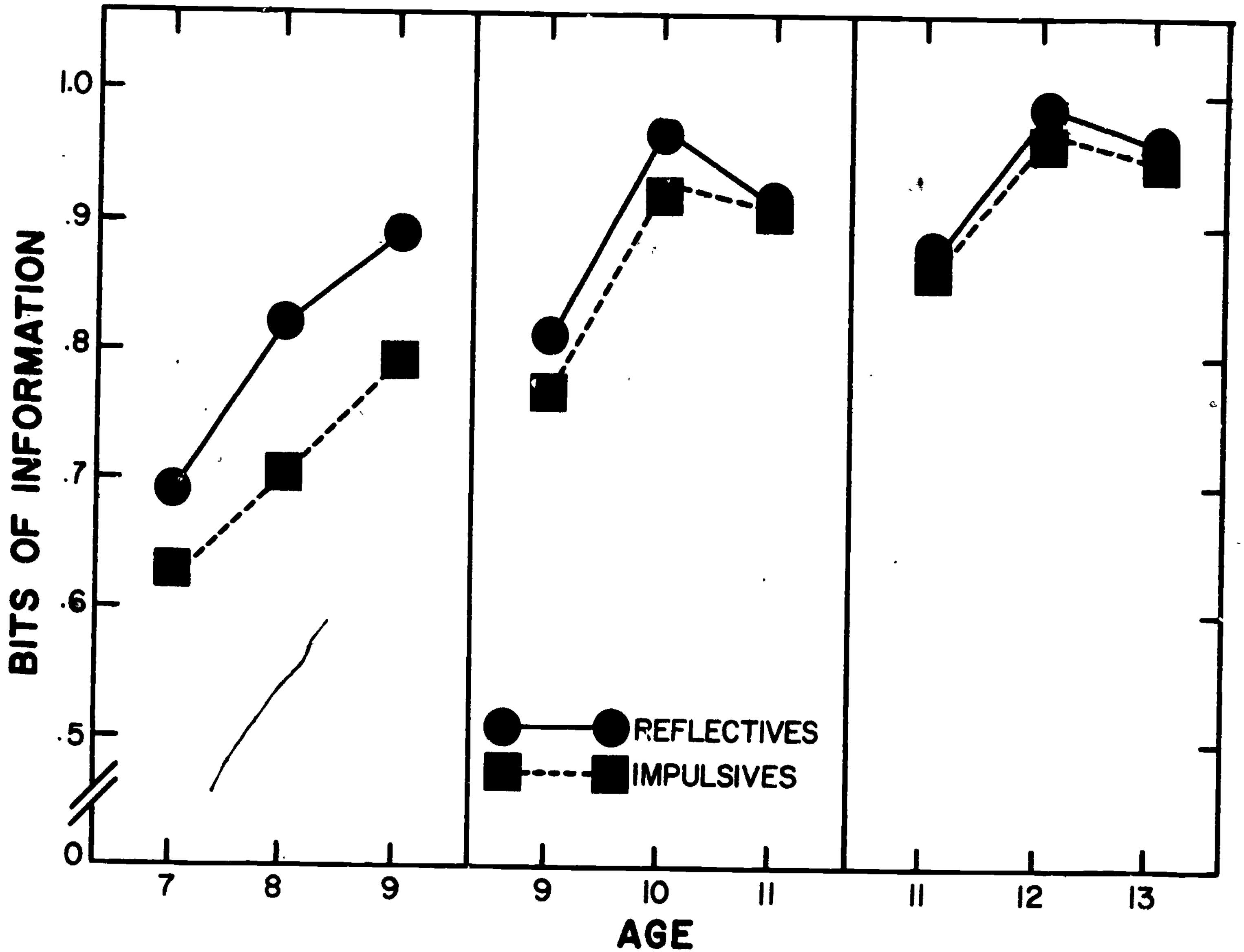

Figure 1. Longitudinal Changes in Average Information Scores (BITS) on the Matrix Solution Task by Reflective and Impulsive Children in Three Cohorts

29

Table 4

Mean Performance on Each Dependent Measure for Pattern Matching

Cohort A		7 years R	7 years I	8 years R	8 years I	9 years R	9 years I
Information Score	M	.72	.67	.81	.70	.93	.81
	SD	.16	.15	.15	.17	.06	.17
Noninformative Responses	M	5.79	7.38	3.57	6.06	.50	3.75
	SD	4.71	4.36	4.48	4.92	.86	4.37
Percent Focusing Responses	M	41.20	45.60	57.30	43.60	71.20	58.20
	SD	10.20	18.40	16.30	14.80	20.20	21.50
Cohort B		**9 years R**	**9 years I**	**10 years R**	**10 years I**	**11 years R**	**11 years I**
Information Score	M	.83	.77	.90	.84	.95	.91
	SD	.17	.15	.11	.14	.06	.10
Noninformative Responses	M	3.00	4.65	1.46	2.53	.32	1.06
	SD	4.69	4.09	2.54	3.66	.78	2.22
Percent Focusing Responses	M	58.40	54.60	73.00	63.60	77.60	69.00
	SD	20.10	21.10	18.20	20.40	19.40	22.80
Cohort C		**11 years R**	**11 years I**	**12 years R**	**12 years I**	**13 years R**	**13 years I**
Information Score	M	.94	.82	.99	.93	.99	.93
	SD	.05	.12	.01	.11	.02	.06
Noninformative Responses	M	.39	3.10	0	1.00	.08	.70
	SD	.77	3.25	0	2.16	.28	1.06
Percent Focusing Responses	M	77.20	53.80	95.30	83.40	95.10	75.40
	SD	16.70	15.30	7.40	23.70	8.40	17.80

$F(1/26) = 3.48$, $p < .07$. Similarly, the repeated measures analysis indicated that reflectives showed a greater increase in information scores between the ages of 7 and 9 years than impulsives, $F(1/26) = 3.39$, $p < .07$. Also, although the main effect for cognitive style on the frequency of focusing responses was not significant, reflectives, nevertheless, displayed a more accelerated gain in focusing over the early elementary period than did impulsives, $F(1/26) = 8.30$, $p < .008$. No significant sex effects or interactions were found in the between-groups analysis for Cohort A; however, the within-subjects analysis showed that girls made greater gains in focusing than boys, $F(1/26) = 5.22$, $p < .03$. These developmental trends are illustrated in Figure 2 by the average information scores for each cohort.

In general, no significant main effects or interactions were found for any of the pattern matching variables for Cohort B. Similarly, although significant linear trends were found for all variables (ps all < .001), no significant differences in the patterns of development were noted between reflectives and impulsives or between boys and girls.

On the other hand, highly significant and consistent effects were found within the oldest cohort. Reflectives in Cohort C extracted more information, $F(1/19) = 15.39$, $p < .001$, made fewer errors, $F(1/19) = 10.17$, $p < .005$, and displayed more focusing behavior, $F(1/19) = 12.68$, $p < .002$, than impulsives. Boys processed information less efficiently, $F(1/19) = 12.68$, $p < .002$, and made more noninformative responses, $F(1/19) = 6.41$, $p < .02$, than did girls. The within-subjects analysis for the oldest cohort yielded a significant quadratic, $F(1/19) = 8.59$, $p < .009$, as well as linear trend, $F(1/19) = 16.02$, $p < .001$. Thus, the performance of both groups improved between the ages of 11 and 12

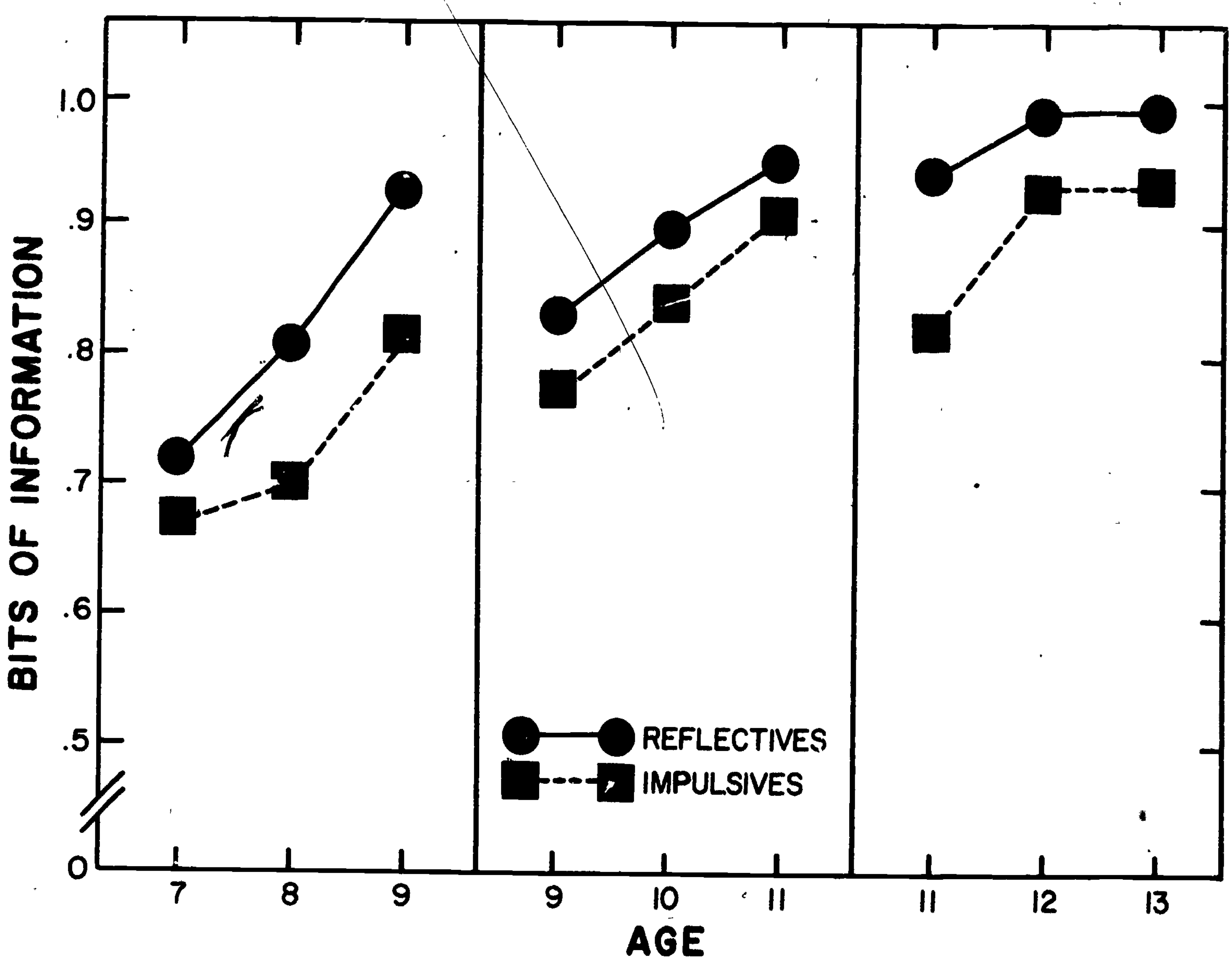

Figure 2. Longitudinal Changes in Average Information Scores (BITS) on the Pattern Matching Task by Reflective and Impulsive Children in Three Cohorts

32

years and tended to stabilize at near ceiling between 12 and 13 years.

However, boys showed greater gains in information scores, $F(1/19) = 5.81$, $p < .02$, and a greater decline in errors, $F(1/19) = 5.53$, $p < .03$, than girls. Similarly, impulsives showed a more rapid decline in noninformative responses than reflectives, $F(1/19) = 4.24$, $p < .05$. Therefore, although boys and impulsives displayed a greater deficit in performance at year 11, they made greater gains between the ages of 11 and 13 as the performance of girls and reflectives approached ceiling.

In summary, the longitudinal results with the pattern matching task were generally consistent with the hypothesis that reflective and impulsive children show different patterns of strategy development. Although differences between the two style groups were not found for Cohort B, reflectives in the younger cohort and those in the older cohort made fewer errors and obtained more information with their responses than impulsive children of the same age. In the younger group reflective children adopted a more systematic strategy for searching the visual array earlier than impulsive children who showed a spurt in development between the ages of 8 and 9. The performance of both groups tended to stabilize between 9 and 10 years and was characterized by an informative hypothesis-scanning strategy in which focusing responses were used on approximately half of the trials. Reflective children as a group showed a rather stable increase in focusing strategies, and at year 11 differences between reflectives and impulsives were found in both problem-solving efficiency and focusing behavior. Between 11 and 12 years, impulsive children displayed another marked gain in problem-solving efficiency, and both style groups approached optimal performance between 12 and 13 years.

Twenty questions - pictures. The percentage of hypothesis-seeking and constraint-seeking questions for each group for each cohort is shown in Figure 3. The analysis of these data for Cohort A indicated that reflective subjects asked significantly fewer hypothesis-seeking questions than impulsive subjects, $F(1/26) = 4.09$, $p < .05$. Also, the repeated measures analysis indicated that reflectives tended to show a greater linear decrease in hypothesis-seeking questions than impulsives between the ages of 7 and 9 years, $F(1/26) = 3.55$, $p < .07$. Although the overall effect for cognitive style did not approach significance, the longitudinal trend was for reflectives to show a greater linear increase in constraint seeking than impulsives, $F(1/26) = 6.74$, $p < .01$. No significant sex effects or interactions were found for Cohort A.

However, the analysis for Cohort B did yield a highly significant sex X cognitive style interaction for the percentage of constraint-seeking questions, $F(1/35) = 5.43$, $p < .02$. Similarly, the sex X style interaction for hypothesis-seeking questions approached significance, $F(1/35) = 2.93$, $p < .09$. Inspection of the cell means indicated that reflective girls displayed more advanced strategies than reflective boys, whereas impulsive boys were superior to impulsive girls. No other significant main effects or interactions were found in the data for Cohort B.

The data from Cohort C on the twenty questions - pictures task indicated that reflectives asked reliably more constraint-seeking questions, $F(1/19) = 8.74$, $p < .008$, and fewer hypothesis-scanning questions, $F(1/19) = 4.60$, $p < .04$, than impulsives. Also, girls asked

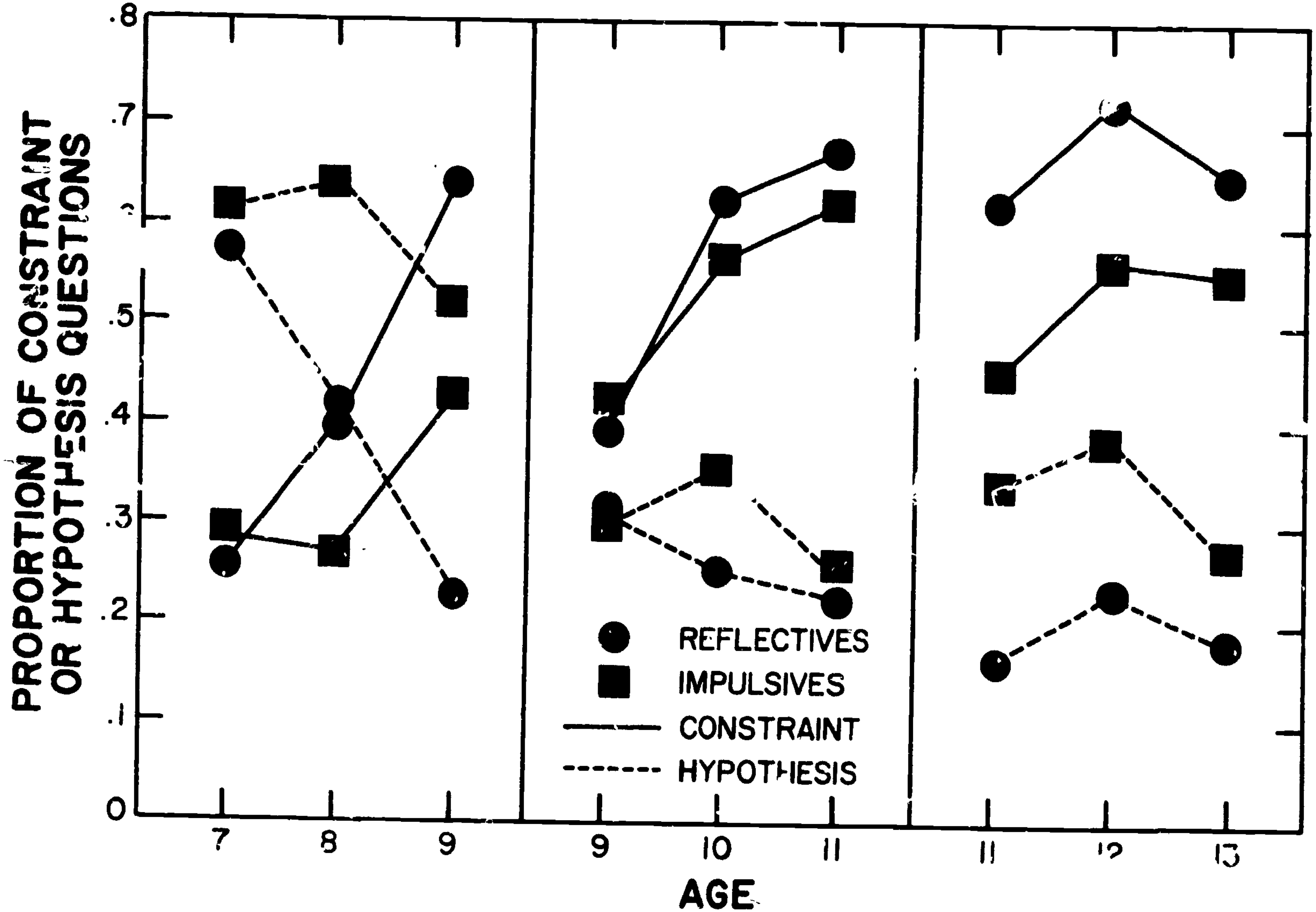

Figure 3. Longitudinal Changes in Proportion of Constraint and Hypothesis (Spec...c Instance) Questions on the 20 Question - Pictures Task by Reflective and Impulsive Children in Three Cohorts

more constraint-seeking questions than boys, $F(1/19) = 7.91$, $p < .01$. Although the main effect for repeated measures was significant ($ps < .001$) in every case, neither cognitive style nor sex interacted with occasions of measurement, thereby suggesting that the pattern of development over this period was the same for both style groups and sexes.

Therefore, the re s with the twenty questions - pictures task were quite similar to those reported above for the pattern matching task. At the youngest age level both reflectives and impulsives tended to follow an hypothesis-scanning approach almost exclusively; however, between the ages of 7 and 8 reflectives showed a significant decline in guessing specific alternatives in relation to impulsives, and an associated increase in constraint seeking. The data for the middle cohort suggest that both groups adopted a mixed strategies approach between 9 and 10 years followed by further gains in constraint seeking. The results for the oldest cohort again indicated an initial deficit for 11-year-old impulsives and another marked gain in relation to reflectives between the ages of 11 and 12.

Twenty questions - verbal. The percentage of hypothesis-seeking and constraint-seeking questions on the twenty questions - verbal problems are presented in Figure 4. Inspection of the data in Figure 4 confirmed the initial impression from preliminary evidence that this was an exceedingly difficult task, even for the children in the oldest cohort. In fact, the between-subjects analysis for each cohort yielded only one significant effect. Reflectives in Cohort A asked more constraint-seeking questions than impulsives at the 8-year level, $F(1/26) = 4.05$, $p < .05$.

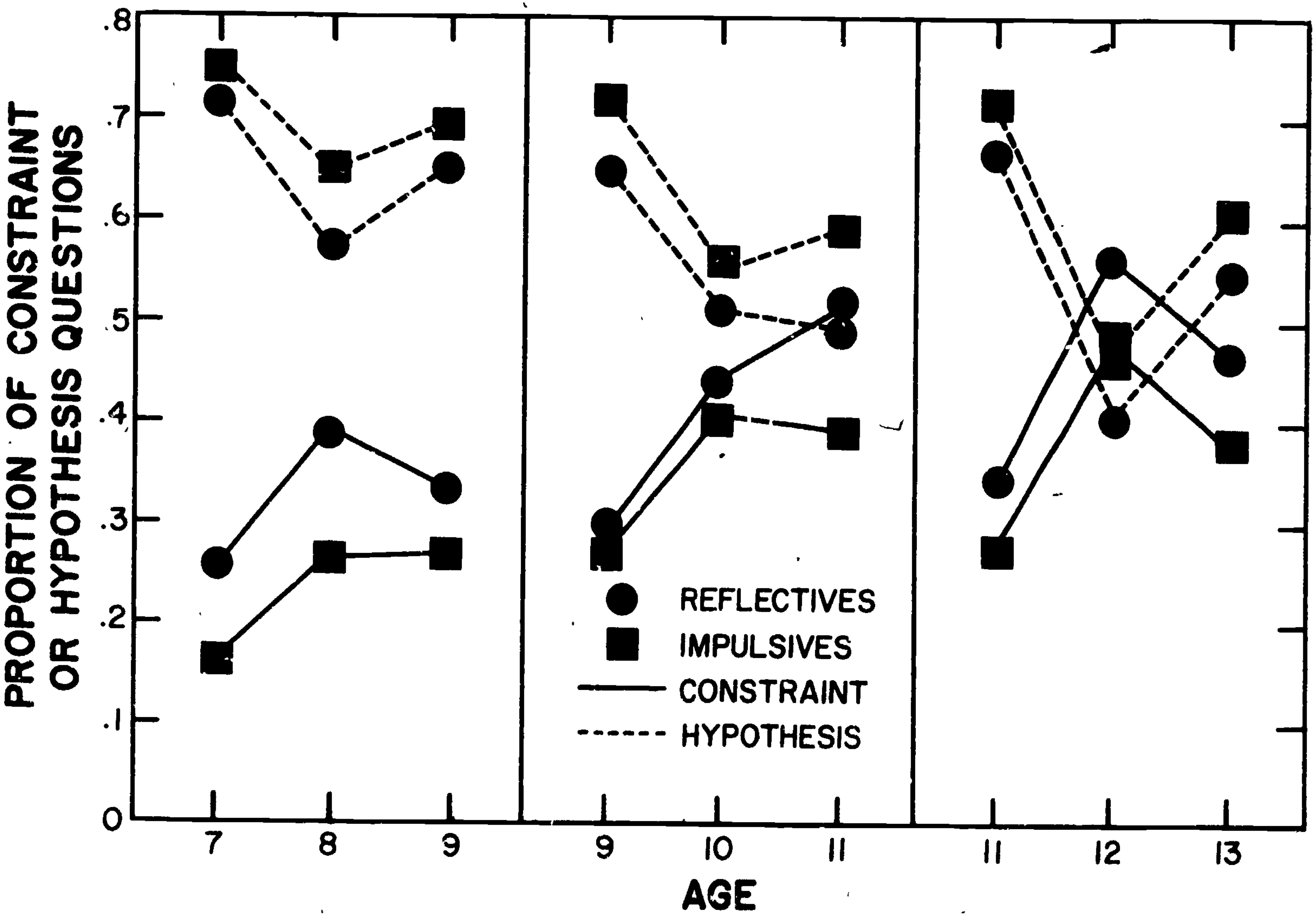

Figure 4. Longitudinal Changes in Proportion of Constraint and Hypothesis (Specific Instance) Questions on the 20 Questions - Verbal Task by Reflective and Impulsive Children in Three Cohorts

However, the analysis of developmental changes indicated an unusual pattern of quadratic trends within each cohort. With the exception of reflectives in Cohort B, subjects in each cohort tended to increase in constraint seeking and decrease in hypothesis seeking between the first and second year measures, and to display the opposite trend between the second and third year measures. Given the difficulty of this task and the fact that the solutions were changed each year, this effect might be due to the relative probability of guessing the correct solution in a given year.

Response Tempo During Problem Solving

In order to determine the effects of cognitive style and age on response tempo for each task, the solution time for each subject was recorded in seconds on each problem and divided by the number of responses on that problem. Table 5 shows the average solution times on each task for reflectives and impulsives in each cohort.

Developmental trends. In general the between-subjects analysis of the data in Table 5 yielded few significant effects for cognitive style. In Cohort A reflective children responded more slowly than impulsive children on the pattern matching task, $F(1/26) = 5.71$, $p < .02$. In Cohort B reflectives were slower than impulsives on the twenty questions - pictures task, $F(1/26) = 4.89$, $p < .03$. No significant sex effects in response tempo were found.

The repeated measures analysis for the matrix solution task yielded significant quadratic trends for Cohort A, $F(1/26) = 5.63$, $p < .02$, and Cohort B, $F(1/35) = 15.55$, $p < .001$. Thus, subjects in these cohorts tended to show increases in response tempo in the second year of study and decreases in the third. By comparison, no significant changes in

Table 5

Average Solution Time in Seconds for Each Task

Cohort A		7 years		8 years		9 years	
		R	I	R	I	R	I
Matrix Solution	M	6.99	6.01	8.88	6.11	6.20	6.62
	SD	2.05	2.40	3.25	2.22	5.18	4.08
Pattern Matching	M	6.82	5.28	9.23	4.30	9.69	5.82
	SD	4.58	5.06	5.86	4.70	5.91	3.63
20 Questions - Pictures	M	6.46	5.68	10.71	7.70	9.47	7.49
	SD	2.19	4.21	6.80	3.30	4.49	3.90
20 Questions - Verbal	M	26.41	32.92	39.07	40.69	25.37	29.52
	SD	7.57	22.33	12.33	28.34	13.86	14.93

Cohort B		9 years		10 years		11 years	
		R	I	R	I	R	I
Matrix Solution	M	4.97	5.24	5.46	5.58	3.94	3.97
	SD	1.55	1.85	1.72	1.72	1.40	1.62
Pattern Matching	M	8.62	6.80	6.77	5.94	6.99	6.56
	SD	4.39	5.62	3.42	2.52	2.65	
20 Questions - Pictures	M	6.66	5.55	9.36	9.06	9.18	7.98
	SD	2.62	2.44	3.38	3.52	5.20	3.26
20 Questions - Verbal	M	20.64	21.69	22.79	19.32	19.56	18.31
	SD	9.00	10.67	9.29	5.26	8.56	8.13

Cohort C		11 years		12 years		13 years	
		R	I	R	I	R	I
Matrix Solution	M	4.18	4.63	4.34	3.54	4.87	3.87
	SD	1.28	1.51	1.05	1.02	1.90	0.57
Pattern Matching	M	9.42	5.40	6.24	7.42	4.78	4.39
	SD	3.71	2.51	2.06	3.45	1.99	1.83
20 Questions - Pictures	M	8.02	5.02	9.65	8.07	9.68	8.93
	SD	3.18	1.78	3.77	2.92	2.70	3.22
20 Questions - Verbal	M	17.98	14.32	17.63	17.37	14.95	13.67
	SD	7.59	5.74	3.61	6.66	6.47	5.81

tempo were found for Cohorts A and B on pattern matching. However, in Cohort C reflectives and impulsives showed qualitatively different patterns of change, F(quadratic, 1/19) = 13.96, $p < .001$, in that reflectives showed a steady increase in response speed, while impulsives decreased between 11 and 12 years and increased between 12 and 13 years. Response tempo on the twenty questions - pictures task showed a general linear increase for all three cohorts, Fs > 6.64, ps < .01. Tempo of responding on the twenty questions - verbal task was stable within Cohorts B and C; however, in Cohort A, subjects were slower at 8 years than at 7 years, and faster at 9 years than 8 years, F(quadratic, 1/26) = 6.53, $p < .01$.

Therefore, the data do not provide impressive evidence that reflectives and impulsives differed in response tempo on the problem-solving tasks that were used, nor is there strong evidence to suggest that they show different developmental trends in tempo of responding on these tasks. Similarly, with the exception of the twenty questions - pictures problems on which subjects showed a trend toward longer response times over the three periods of study, no consistent developmental pattern emerged that would suggest systematic changes in response style with age.

Relationship between tempo and strategy. Table 6 shows the correlations between average solution times on each task and selected measures of strategy behavior on the same task each year of the study. These results generally support the conclusion that slow responding was positively associated with efficient strategy behavior. However, the magnitude of this relationship varied greatly across tasks and age levels within cohorts.

Table 6

Correlations Between Response Tempo and Strategy Measures

			Cohort A	
		7	8	9
Matrix Solution:	Information Score	03	01	-38*
	% Attributes	24*	02	-27*
Pattern Matching:	Information Score	73*	79*	61*
	% Focusing	70*	67*	54*
Twenty Questions - Pictures:	% Constraints	40*	20	05
	% Hypotheses	-48*	-29*	-12
Twenty Questions - Verbal:	% Constraints	16	36*	01
	% Hypotheses	-04	-29*	01
			Cohort B	
		9	10	11
Matrix Solution:	Information Score	-18	14	-12
	% Attributes	04	09	-35*
Pattern Matching:	Information Score	64*	56*	44*
	% Focusing	44*	86*	61*
Twenty Questions - Pictures:	% Constraints	36*	21	23*
	% Hypotheses	-49*	-32*	-39*
Twenty Questions - Verbal:	% Constraints	08	31*	12
	% Hypotheses	-04	-30*	-06
			Cohort C	
		11	12	13
Matrix Solution:	Information Score	-64*	-01	-54*
	% Attributes	-42*	-18	-63*
Pattern Matching:	Information Score	28*	37*	03
	% Focusing	18	32*	27
Twenty Questions - Pictures:	% Constraints	-10	35*	27
	% Hypotheses	00	-35*	13
Twenty Questions - Verbal:	% Constraints	31*	27*	37*
	% Hypotheses	-32*	-31*	-38*

*$p < .05$.

The positive relationship between response tempo and information processing efficiency was most evident for the pattern matching task. Highly significant correlations between information scores and response tempo were found for all three age levels within each cohort with the exception of 13 year olds in Cohort C. Positive correlations between tempo and constraint-seeking and/or negative correlations with hypothesis-seeking on twenty questions - pictures were found for ages 7 and 8 in Cohort A, ages 9, 10, and 11 in Cohort B, and age 12 in Cohort C. The same pattern of relationship was found for 8 year olds in Cohort A, 10 year olds in Cohort B, and 11, 12, and 13 year olds in Cohort C on the twenty questions - verbal task.

Although slow responding was modestly correlated with attribute responses on matrix solution for 7 year olds, the opposite relationship was found for 9 year olds in Cohort A. Similarly, for 11 year olds in Cohort B and Cohort C and for 13 year olds in Cohort C, fast responding was associated with more efficient performance. In order to interpret this finding it should be noted that the matrix solution task was particularly easy for older children and was quite susceptible to practice effects. In fact, there was a progressive increase in the frequency of the optimal strategy from approximately 75% at year 9 to 95% at year 12. Thus, once competent problem solvers had acquired a focusing strategy for solving matrix problems and thoroughly practiced this strategy in repeated assessments, they were able to process information very rapidly in relation to less competent problem solvers.

These findings suggest that response tempo during problem solving is determined by the type of strategy that is used by a given child on that particular problem and the extent to which he/she can use the strategy effectively. Thus, when children proceed slowly and perform efficiently on a given task, their response tempo may be attributed to the use of more systematic and time-consuming strategies. However, once the optimal strategy has been fully acquired and well practiced it can be followed with greater speed without diminished accuracy.

Relationship Between Style Measures and Strategy Measures over Age

In order to investigate the long-term versus short-term predictive value of the Matching Familiar Figures test, cross-age correlations were computed between MFF error scores and response latencies and the various measures of strategy behavior. This analysis used the entire longitudinal sample regardless of cognitive style classification and was carried out for the two MFF measures separately within each cohort. These results can be found in Appendix A.

MFF latency. In general, response latency on the MFF test proved to be a rather poor predictor of performance on all tasks and when significant correlations were obtained they were quite modest, ranging from .27 to .46. Only 1 of 18 correlations between MFF latency and information scores on matrix solution was significant and only three were found between the same measures on pattern matching. Six out of 36 correlations for twenty questions - pictures were significant, and 4 out of 36 were significant for twenty questions - verbal.

MFF errors. Although MFF error scores were negatively correlated with information scores on matrix solution in 4 out of 18 cases, in only one instance was there prediction from one year to the next. By contrast, 12 of 18 correlations between MFF error and information scores on pattern matching were significant and cross-age correlations ranging from -.27 to -.42 were found for all three cohorts. A total of 14 out of 36 correlations were significant between error scores and strategy measures on twenty questions - pictures and 8 of these were found within Cohort C. On the other hand, only two correlations were significant for the twenty questions - verbal measures and both of these were obtained in Cohort C.

Thus, the relationships between error scores on the MFF and measures of strategy behavior were considerably stronger and more evident than those for response latency, and some evidence was obtained for prediction over a three-year period with two problem-solving tasks. These results suggest that individual differences in response accuracy as measured by the MFF test rather than response tempo account for the superior performance of reflectives when they are compared to impulsives on problem-solving tasks. Also, these results suggest that MFF error scores may be a more useful measure for identifying competent problem solvers than MFF latency or both MFF latency and errors, as is the usual practice.

Generality and Stability of Strategy Behavior Across Age

Tables H through J in Appendix A show the intercorrelations among strategy measures over age within cohorts. In general, the degree f intercorrelation among the four tasks was greater in Cohort A than in Cohort B which was greater than Cohort C. In Cohort A, 11 out of 16 correlations among tasks given in the first year and those given in the second year were significant, *rs* = .44 to .63, *ps* < .01. The test-retest correlations were .63 for matrix solution, .61 for pattern matching, .62 for twenty questions - pictures, and .27 for twenty questions - verbal. The test-retest correlations for the same tasks between the second and third years were .73, .64, .46, and .22, respectively. Also, 11 of these 16 task intercorrelations were significant at the .05 level or higher. Finally, the correlations between performance the first year and that of the third year were .55, .61, .33, and .33 for matrix solution, pattern matching, twenty questions - pictures, and twenty questions - verbal, respectively. The intercorrelation of the first and third year's data yielded 14 significant correlations out of a possible 16, rs = .33 to .61, ps < .05 to .001.

Of the 16 possible correlations among tasks in each analysis for Cohort B, 8 were significant between year 01 and year 02, 7 between year 02 and year 03, and 6 between years 01 and 03. Performance on pattern matching displayed the greatest stability from year 01 to year 02, $r = .55$, $p < .001$, from year 02 to year 03, $r = .69$, $p < .001$, and from year 01 to year 03, $r = .61$, $p < .001$. The data for twenty questions - pictures yielded a correlation of .50 ($p < .001$) between year 02 and year 03. The test-retest rs for twenty questions - verbal were .57 ($p < .001$) between years 01 and 02, .47 ($p < .001$) between years 02 and 03, and .44 ($p < .01$) between years 01 and 03. Test-retest rs for matrix solution were not significant for Cohort B.

In Cohort C, 6 of the year 01-02, 4 of the year 02-03, and 5 of the year 01-03 correlations among tasks were significant. The matrix solution, pattern matching, and twenty questions - verbal tasks showed moderate stability between the first and second years, rs = .30, .55, and .45, respectively. Only the pattern matching and twenty questions - verbal tasks had significant test-retest rs of .58 and .39 between year 02 and 03. However, significant correlations for all tasks except matrix solution were found between the first and last year measures for Cohort C.

In sum, these results indicated that the performance and strategy behavior of children between the ages of 7 and 9 was generally consistent across all tasks except twenty questions - verbal problems. Children who performed well on matrix solution problems also tended to show efficient performance on pattern matching and twenty questions - pictures problems. The poor intercorrelation of the twenty questions - verbal problems with other tasks in the youngest cohort was undoubtedly due to the difficulty of this task which produced little individual variation in performance. Similarly, it was noted that intercorrelation of the matrix solution task with other tasks dropped out in Cohorts B and C as performance approached ceiling in the older groups, thereby producing little variability in the data. The two tasks that intercorrelated consistently across age levels and within cohorts, and showed the greatest stability from year to year were pattern matching and twenty questions - pictures. Apparently these tasks were sensitive to individual variation in information processing over the entire elementary school age range.

Discussion

The results of the present study generally support the conclusion that reflective children as identified by the Matching Familiar Figures test were more likely to adopt more systematic and/or mature problem-solving strategies on tasks that require sequential hypothesis testing and information processing than were impulsive children of the same age. Also, longitudinal analysis of problem-solving data over a three-year period supports the conclusion that reflective children displayed a more accelerated acquisition of efficient strategies over the early elementary years than did impulsive children. At the same time, the relative impact of reflection-impulsivity varied systematically with developmental level over the elementary age range, the relative difficulty of the problem for children at different stages of cognitive development, and repeated experience with the type of problem at hand.

Developmentally, the impact of cognitive style on problem solving was most evident in the behavior of children between the ages of 7 and 9 years on Pattern Matching and Twenty Questions - Pictures problems. Over this period reflectives extracted more information with their responses on Pattern Matching, made fewer errors, and displayed a higher incidence of focusing behavior. Similarly, reflectives showed a higher frequency of constraint seeking and a lower frequency of hypothesis seeking on Pictures problems compared to impulsives. Moreover, reflective subjects showed a more rapid acquisition of the optimal strategy for both tasks than impulsive subjects between 7 and 9 years, and also displayed more constraint seeking than impulsives on the Twenty Questions - Verbal problems at year 8.

Reflective and impulsive children who were followed between the ages of 9 and 11 years did not differ in problem-solving efficiency on any of the tasks that were used and both groups showed the same pattern of linear development over three years. Nevertheless, reflectives who were tested initially at 11 years in the oldest cohort were superior to impulsives on all measures of efficiency and strategy behavior for both the Pattern Matching and Twenty Questions - Pictures tasks. Following this initial discrepancy, the performance of both groups tended to stabilize at near ceiling levels between 12 and 13 years.

In general, the longitudinal results with respect to cognitive style differences in problem solving confirm those reported previously in cross-sectional studies (McKinney, 1973; McKinney, Haskins, & Mason, Note 5; McKinney et al., Note 4). However, the failure to find differences between reflectives and impulsives on Twenty-Questions - Pictures at year 9 in Cohort B was not consistent with the data reported by Ault (1973). Also, the negative findings for Cohort B were not consistent wi Cameron's (1976) data on the Pattern Matching task which replicated McKinney's (1975) results for 7 and 11 year olds but not for 9 year olds. In order to elucidate this apparent discrepancy in findings for children between 9 and 11 years of age it is necessary to consider two factors--the effects of practice due to repeated measures in the longitudinal design, and the possibility of sampling bias in the original subject selection procedures.

In interpreting the evelopmental trends displayed by reflectives and impulsives it should be noted that the performance of the oldest children in each cohort was probably facilitated by prior experience with the task. Thus, developmental changes shown in Figures 1 - 4 were confounded in part by practice effects due to repeated measures. Accordingly, the large discrepancy between the performance of 9-year-old reflectives in Cohort A and 9 year olds in Cohort B might be attributed to cumulative experience with the task over a three-yea eriod. Similarly, the performance of experienced impulsives in Cohort B is clearly superior to that of inexperienced impulsives in Conort C.

An alternative explanation for differences between reflectives and impulsives at year 9 in Cohort A and at year 11 in Cohort C with no differences at years 9 and 11 in Cohort B may be sampling bias However, the data that are presented on subject characteristics in Tables 1 and 2 do not lend support to this interpretation. While the 9 year olds in Cohort A were on the average 7 months younger than those in Cohort B, the two samples were highly comparable in IQ, SES, and racial distribution. Similarly, MFF test data in Table 2 show that

9 year olds in Cohort B were relatively more reflective and more impulsive than the two style groups in Cohort A. However, if MFF performance was the primary factor, then one would expect greater differences in Cohort B than in Cohort A.

Therefore, it is unlikely that sampling bias per se was responsible for the differences between subjects of the same age in different cohorts. On the other hand, differences in sample characteristics may well account for inconsistent findings across different studies for 9 year olds. Reflective third graders in Ault's (1973) study were on the average 10 months younger than those in the present study and approximately 20 seconds slower on the MFF test. While Cameron's (1976) 9 year olds were highly comparable to those in the present study with respect to age, IQ, and MFF scores, they were drawn from a culturally different sample that contained no minority students.

Although the results for Cohort B cannot be fully explained within the context of the present study, they do illustrate an important problem with the conventional methodology of cognitive-style research. Since reflective and impulsive children are selected based on sample-specific criteria, the potential for generalizing across different studies is often limited. Nevertheless, it is worthy of note that the results for Cohorts A and C were consistent with both those that were reported previously and those available from other studies with the same tasks.

With respect to the course of strategy development in general, the longitudinal analysis of problem-solving behavior within cohorts revealed a rather continuous pattern of improvement in problem-solving efficiency that was accompanied by three basic changes in strategy behavior between the ages of 7 and 11 years. At an initial level, the most primitive strategy that was observed consisted of merely guessing solution possibilities in a trial-and-error fashion or, in the case of Pattern Matching, opening response shutters in a random sequence. The first major change that appeared was an inhibition of random responding which resulted in an informative hypothesis-scanning strategy. Although the child still tested specific, concrete hypotheses, he did so in a systematic fashion and thereby avoided noninformative responses.

In general, this change in strategy behavior occurred between 7 and 9 years of age and was followed by an increase in the frequency of categorical responses. This behavior seemed to reflect a gradual transition from a concrete mode of hypothesis testing to a more abstract one. During this period, from approximately 8 to 10 years, children tended to follow a mixed strategies approach both within tasks and across tasks. For example, on the Matrix Solution task, an 8 or 9 year old might begin by asking, "Is it red?", and if the experimenter said "yes", he would begin to guess red flowers without attempting to eliminate other dimensions in the stimulus array.

Between the ages of 9 and 12 years, the frequency of categorical responses increased progressively and children began to obtain the maximum information with their responses by systematically eliminating half of the solution possibilities with each response. By year 12 the focusing strategy, as described by Bruner et al. (1956), Eimas (1970), and Neimark and Lewis (1967) was the dominant approach on all tasks except the 20-Questions Verbal problems.

As expected from previous research (Kagan, 1965a; Messer, 1970; Yando & Kagan, 1968), response latency and error scores on the Matching Familiar Figures test were moderately stable over a period of 1 year and both measures were less stable over a period of 2 years. In general, MFF error scores were less stable than MFF latencies. However, MFF errors were more highly correlated with measures of problem solving efficiency than were MFF latencies. Therefore, the data suggest that response accuracy, as measured by the MFF test, rather than response tempo, accounted for performance differences between reflective and impulsive children.

These results tend to support those of Block, Block, and Harrington (1974) and underscore their concerns regarding the interpretation and utility of the tempo dimension. A key assumption in much of the research on cognitive tempo has been that MFF latency reflects a generalized predisposition to respond either slowly or quickly in situations of high response uncertainty. However, comparisons between reflectives and impulsives failed to show consistent or marked differences in tempo of responding on the four problem-solving tasks used in this study, nor was there evidence that they showed different developmental patterns with respect to tempo measures during problem solving.

Further, the analysis of the relationships between response tempo during problem solving and performance on the same task showed that the child's tempo of responding was a function of his/her strategy behavior. Thus, the data suggest that when reflective children performed more efficiently than impulsive children on a given task, their superior performance could be attributed to the use of more sophisticated strategies for processing task information, rather than their tempo of processing per se. Accordingly, these results offer an explanation for the frequent finding that the response latencies of impulsive children can be increased by using a variety of modification techniques without necessarily improving the quality of their performance (Albert, 1970; Debus, 1970; Kagan, 1966; Kagan, Pearson, & Welch, 1966; Reali & Hall, 1970: Yando & Kagan, 1968). If a child has not acquired the cognitive skills that are necessary for more efficient hypothesis testing, then merely slowing him down cannot be expected to improve his performance.

Therefore, one implication of these results is that modification of the impulsive style might be accomplished by either manipulating task variables during problem solving and/or by specific instruction in more efficient strategies. For example, McKinney and Banerjee (1975) found that impulsive children performed as well as reflectives on a concept attainment task when given memory support. Similarly, Eimas (1970) and Van Horn and Bartz (1968) have found that increasing stimulus saliency enhances strategy behavior. Also, a number of studies have shown that young elementary school children can acquire and transfer rather complex problem-solving strategies (Anderson, 1965; Keislar & Stern, 1970; McKinney, 1972). Accordingly, there appears to be both practical and theoretical merit in focusing on the manner in which children process task information as opposed to their tempo of processing.

III. Relative Effects of Response Tempo and Accuracy on Problem Solving and Academic Achievement

Introduction

Recently, several important issues have been raised regarding the conceptualization, construct validity, and interpretation of the Matching Familiar Figures test and, more generally, of reflection-impulsivity research (Block, Block, & Harrington, 1974, 1975; Kagan & Messer, 1975; Salkind, Note 6). As originally conceptualized by Kagan, "the reflection-impulsivity dimension describes the child's consistent tendency to display slow or fast response times in problem situations with high response uncertainty" (Kagan, 1965a, p. 134). However, impulsivity has been operationally defined with reference to response accuracy as well as response tempo. Thus, in employing Kagan's widely used Matching Familiar Figures (MFF) test, children who respond slowly and make few errors are classified as reflective, while those who respond quickly and make many errors are classified as impulsive.

In recent years a rather extensive literature has evolved indicating that impulsive children, as compared to reflective children, demonstrate poor academic achievement and poor performance on a variety of problem-solving tasks (e.g., see Kagan & Kogan, 1970; Block et al., 1974). Nevertheless, since the criterion for selection of subjects in these studies confounds response accuracy and decision time, the relative contribution of these MFF variables to individual differences in problem solving and achievement is not clear. Should differences between reflective and impulsive children be attributed to differences in their tempo of responding, to differences in their accuracy of responding, or to the joint effect of latency and accuracy as measured by the MFF?

In addition to the conceptual difficulty created by confounding error and time measures on the MFF, the usual classification procedure excludes approximately 30% of the study sample; i.e., those classified as fast-accurate and slow-inaccurate. Therefore, in order to evaluate fully the relative effects of the joint classification criterion, it is necessary to include these two groups of children who are usually excluded from MFF studies. Although a few recent studies have compared fast-accurates and slow-inaccurates to reflectives and impulsives (Ault, 1973; Ault, Crawford, & Jeffrey, 1972), the relative contributions of the MFF accuracy and tempo dimensions to performance were not evaluated.

Such an evaluation, however, was an explicit objective of recent research by Block et al. (1974). These investigators examined the separate contributions of decision time and accuracy on the MFF by using a 2 (fast versus slow) X 2 (accurate versus inaccurate) factorial design. Significant main effects for the tempo factor were obtained for only 2 of 100 personality attributes, whereas 32 of the 100 variables were significantly related to response accuracy. Significant interactions between tempo and accuracy were found on 18 variables. Although these results suggest that the MFF dimension of consequence is accuracy and not tempo, or that tempo is important only when considered jointly with accuracy, the conclusions of Block et al. are necessarily limited by several factors.

First, studies supporting the generality of reflection-impulsivity, as measured by the MFF, have typically used cognitive tasks that involve stimulus and/or response uncertainty. By contrast, the data reported by Block et al. (1974) concerned personality attributes derived from the judgments of nursery school teachers using a Q-sort rating. Second, since most studies that provide support for the construct validity and generality of the MFF were done with elementary school children, it would be important to replicate the Block et al. (1974) results with older samples. Third, since latency and errors are continuously distributed variables, using analysis of variance designs to determine the effects attributable to MFF latency and MFF errors would seem inappropriate. This argument is particularly compelling since, as Ault, Mitchell, and Hartmann (1976) have determined, the low reliability of MFF error scores can cause misclassification of up to 24% of a given sample.

The goal of the present study, then, was to evaluate the relative contributions of MFF latency and MFF error measures to individual differences in problem-solving efficiency and academic achievement in samples of 7, 9, and 11 year olds. The two problem-solving tasks used in this study were selected because they involved a high degree of response uncertainty, and because they were similar to tasks used in previous studies of reflection-impulsivity (Ault, 1973; Denney, 1973; McKinney, 1973, 1975a). In order to avoid the methodological problems inherent in factorial designs, while at the same time making use of the total sample at each age level, regression procedures were used to assess the separate and combined contributions of MFF latency and error scores to performance.

Method

Subjects

Data for this study were taken from children participating in the first year of a longitudinal study of cognitive tempo and problem solving (see McKinney, Haskins, & Mason, Note 5). The MFF was administered to all children within 6 months of 7, 9, and 11 years of age in a single elementary school. This criterion for selection resulted in a total sample of 109 7 year olds, 83 9 year olds, and 80 11 year olds. Children classified as either impulsive or reflective were given the verbal scale of the Wechsler Intelligence Scale for Children. From the total sample of 272 children, 7 were dropped because their IQ scores were at least one standard deviation below average or because they failed to understand the instructions of one or more of the problem-solving tasks; 16 were used in pilot work, and 16 were dropped because they moved during the course of the school year.

Thus, the final sample of 233 students consisted of 40 male and 43 female 7 year olds (mean age = 84.37 months, SD = 4.58), 35 male and 41 female 9 year olds (mean age = 110.29 months, SD = 4.67), and 31 male and 43 female 11 year olds (mean age = 134.50 months, SD = 4.97). There were 190 white children and 43 black children in the sample. The socioeconomic status of each subject was estimated using a modified version of Hollingshead's (Note 7) Two-Factor Index of Social Position in which his categories "2," "3," and "4" were collapsed to yield category "2," and his categories "5," "6," and "7" were collapsed to yield category "3." Using this index of SES, the mean ratings of 7, 9, and 11 year olds were 1.59 (SD = .64), 1.58 (SD = .66), and 1.65 (SD = .67).

Tasks

Within 12 weeks of MFF testing, two problem-solving tasks were administered. In each task, the child was given a problem with a finite number of equiprobable solutions, and was required to determine the correct solution by gathering information to eliminate incorrect alternatives. The first task, called Matrix Solution (McKinney, 1973), consisted of drawings of 16 flowers that varied systematically along four binary dimensions--color (blue or red), size (large or small), number of petals (4 or 6), and geometric figure in the center (square or triangle). The stimuli were randomly arranged on a 4 X 4 matrix of 3-inch (7.62 cm) squares and presented in a 12-inch (30.48 cm) square card. Presenting this matrix of flowers, the experimenter told each subject that he was thinking of one flower, and that the subject's job was to locate the flower by asking questions that could be answered "yes" or "no." The children were further instructed that they could use as many questions as necessary in locating the flower, but that they should try to locate the flower with as few questions as possible.

The second task, first used by Neimark and Lewis (1967; see also McKinney, 1975a), was called Pattern Matching. Each subject was given three demonstration problems requiring the location of a correct pattern from among _n_ displayed patterns--four patterns on the first problem, six on the second problem, and eight on the third problem. Each pattern consisted of a unique combination of four binary elements (black or white dots) drawn on a 4 X 6 inch (10.16 X 15.24 cm) card. A pattern exactly like one of the _n_ displayed patterns was concealed inside a standard manilla folder that had four, one-inch (2.54 cm) holes cut in its face. Covering each hole was a movable cardboard strip. The child was told the task involved finding which of the displayed patterns was concealed inside the folder, but by opening as few shutters as possible. After each shutter opening, the child was instructed to eliminate any patterns with a corresponding dot of a different color than the one he had just uncovered. After completing the first demonstration problem, the child was given the second and third problems, requiring, respectively, identification of the correct pattern from among six and eight alternatives. Thus, all demonstration problems used patterns with four binary elements and a pattern board with four shutters. Only the number of displayed patterns was varied.

After completion of the demonstration problems, the test problems were administered. Each test problem required identification of the correct pattern from among eight displayed alternatives. The displayed patterns consisted of eight binary elements; i.e., one-half inch (1.27 cm) black or white dots located at equal intervals around the circumference of a nine-inch (22.86 cm) circle. The correct pattern was concealed inside a 10 X 10 X 1 inch (25.40 X 25.40 X 2.54 cm) wooden box with eight movable shutters covering three-quarter inch (1.90 cm) holes. As with the manilla folder used in demonstration problems, each dot on the pattern inside the pattern box could be seen when its respective shutter was opened.

In addition to the two problem-solving tasks, the Iowa Test of Basic Skills was administered by classroom teachers as part of the school's evaluation program. The Iowa achievement test yields subtest scores for vocabulary, reading, and mathematics as well as a composite score based on the three subtests.

Dependent Variables

Although a number of dependent variables were scored with each of the problem-solving tasks (see McKinney, 1975a), only two will be considered here. The first, expected information in bits of information (Eimas, 1970, p. 226), is the single best measure of information processing efficiency The expected reduction in uncertainty for each response as computed by summing the informational outcomes in bits weighted by probabilities of occurrence. For example, in the Matrix Solution problems, if the child guessed that a specific flower was correct on the first trial, he would be correct with a probability of 1/16 and would reduce uncertainty by 4.0 bits ($\log_2 16 - \log_2 1$). He would be incorrect with a probability of 15/16 and would reduce uncertainty by .09 bits ($\log_2 16 - \log_2 15$). Thus, the expected information outcome for this response would be .34 bits (1/16 X 4.0 bits + 15/16 X .09 bits). Noninformative responses received an information score of zero bits; maximally efficient responses; i.e., those that eliminated exactly one-half the remaining alternatives on a given trial, received an information score of 1.0 bits. The mean expected information score for each problem was computed by summing the expected information scores across all responses, and dividing by the total number of responses.

The second dependent variable, latency, was scored for the Pattern Matching task only. Timing commenced when the subject had turned over the last card from the previous window opening. In the case of a previously noninformative response, timing commenced when the child looked up from the pattern and said, "Oh, I can't turn over any," or made some similar verbal or physical movement indicating his knowledge that no pattern could be eliminated. Timing stopped when the child opened a shutter. Mean latencies were computed by dividing the sum of latencies across responses within a problem by the number of responses for that problem. No latency measure was scored for the Matrix Solution task because the exclusively verbal nature of the children's responses on this task did not permit measurement of the time children waited before asking each question.

Four problems were given for each task. Since a multivariate analysis of variance, using the technique recommended by McCall and Appelbaum (1973), failed to reveal significant repeated-measures effects for either information or latency scores, data analyses for both tasks were based on mean scores averaged across the four problems.

With regard to the Iowa achievement test, only the composite standard scores will be reported here since the use of subtest scores in the analyses reported below produced similar results.

Data Analysis

The question raised by this research was whether response tempo, as measured by MFF latency, or response accuracy, as measured by MFF errors, provided the best prediction of scores on problem-solving tasks and academic achievement. A preliminary answer to this question, we reasoned, could be found in the univariate correlations between the two MFF variables and the criterion variables. However, even if one MFF variable consistently provided better prediction than the second MFF variable, it was still possible that the second MFF variable was a useful predictor. Such would be the case if the second MFF variable were correlated with that part of the criterion variables uncorrelated with the first MFF variable. Thus, stepwise multiple regression was used to determine the additional variance in criterion variables accounted for by two-variable prediction models.

Finally, part correlations were computed between the criterion variables and each of the MFF variables with effects of the other MFF variable partialled out. The purpose of this analysis was to determine the exact relationship between the criterion variables and that part of each MFF variable orthogonal to the other MFF variable.

Results

MFF Classification

Although MFF classification as such was not used in the primary analyses reported in this paper, MFF performance by children in this sample will be reported briefly to demonstrate the similarity between this sample and samples reported in previous MFF studies.

Following the recommended double-median-split procedure (Kagan, 1966), the error and latency distributions of each age group were divided at their medians. The respective error and latency medians for the 7-, 9-, and 11-year groups were 14 errors and 11.22 seconds, 6 errors and 18.00 seconds, and 6 errors and 15.00 seconds. The error and latency means and standard deviations for each MFF group at each age level, as well as the number of children classified in each of the MFF categories, are presented in Table 7.

Correlations between MFF errors and latency, in order of increasing age, were -.39, -.57, and -.38. Separate oneway ANOVAs revealed no significant differences between the four MFF groups in age or SES at ages 9 or 11, but a significant main effect was found for both age ($F = 2.93$, $p < .04$) and SES ($F = 3.12$, $p < .03$) at age 7. Newman-Keuls' individual comparisons revealed that only the reflective versus impulsive comparison was significant for SES, with reflectives having significantly higher SES. With regard to age, the slow-inaccurates were significantly older than the other three MFF groups.

Regression Analyses

Table 8 presents the univariate, multiple, and part correlations between the two MFF variables and the problem-solving and achievement variables. In general, the data in Table 8 indicate that MFF errors

Table 7

Means and Standard Deviations for MFF Error and Latency Scores by MFF Group and Age Level

Age	MFF Classification	n	Error Scores		Latency in Seconds	
			$\bar{X}$	SD	$\bar{X}$	SD
7	Reflective	30	8.67	2.97	22.80	20.47
	Impulsive	30	20.40	4.63	7.58	2.27
	Fast-Accurate	13	11.23	2.01	8.42	1.98
	Slow-Inaccurate	10	16.80	1.75	18.44	6.11
		83				
9	Reflective	29	3.48	1.88	27.79	9.53
	Impulsive	28	11.21	3.10	10.84	3.75
	Fast-Accurate	10	4.90	1.10	13.82	3.29
	Slow-Inaccurate	9	8.22	1.92	29.15	8.92
		76				
11	Reflective	27	3.07	1.77	25.55	12.01
	Impulsive	27	10.89	3.29	10.03	2.29
	Fast-Accurate	11	4.64	1.86	10.57	3.42
	Slow-Inaccurate	9	9.22	2.11	26.33	20.33
		74				

Table 8

Univariate, Multiple and Part Correlations Between MFF Variables and Problem-solving and Achievement Variables

Task	Age	Univariate Correlations MFF Errors	Univariate Correlations MFF Latency	Multiple Correlations	Part Correlations MFF Errors with Latency Out	Part Correlations MFF Latency with Errors Out
Information Score in Bits						
Matrix Solution	7	-28*	-03	31*	-31*	15
	9	-28*	-01	35*	-36*	-22*
	11	-01	19	20	07	20*
Pattern Matching	7	-31*	07	31*	-31*	-06
	9	-31*	19	31*	-25*	01
	11	-32*	34*	40*	-22*	25*
Latency						
Pattern Matching	7	-24*	06	24	-23*	-04
	9	-21*	20	23	-13	10
	11	-16	25*	25	-07	21*
Academic Achievement						
Iowa Test of Basic Skill	7	-46*	17	46*	-40*	-02
	9	-35*	04	40*	-23*	-14
	11	-53*	33*	55*	-47*	17

*p 05.

was a relatively better predictor of both problem-solving efficiency and academic achievement than MFF latency.

Pearson product-moment correlations demonstrated that MFF errors was significantly correlated with problem-solving efficiency for both tasks at all ages with the single exception of the Matrix Solution task at age 11. On the other hand, MFF latency was significantly correlated with problem-solving efficiency in only one instance, i.e., Pattern Matching at age 11. Although the correlations between MFF errors and problem-solving efficiency were significant at the .01 level in five of six cases, converting these correlations to the proportion of variance in problem-solving efficiency accounted for by MFF errors reveals that none of the correlations accounted for more than 11% of the variance.

With regard to univariate correlations between MFF latency and problem-solving latency, only at age 11, where the correlation was .25 ($p < .03$), was a significant relationship found. On the other hand, MFF errors was significantly correlated with Pattern Matching latency at both age 7 and age 9, with correlations of -.24 ($p < .03$) and -.21 ($p < .05$) respectively. Thus, MFF errors was at least as strongly related with problem-solving latency as was MFF latency.

Nor can the poor correlation between MFF latency and problem-solving latency be attributed to the possibility that problem-solving latency was unrelated to problem-solving performance. The univariate correlations between Pattern Matching latency and Pattern Matching bits, in order of increasing age level, were .74 ($p < .001$), .63 ($p < .001$), and .45 ($p < .001$). Clearly, these correlations are very strong, and account for 55%, 40%, and 20% of the variance in problem-solving scores for 7-, 9-, and 11-year-old children respectively.

The relatively greater prediction provided by MFF errors as against MFF latency was also apparent in the correlations with academic achievement. As indicated in the lower portion of Table 8, correlations between MFF errors and achievement were significant at all three ages, and accounted for 21%, 12%, and 28% of the variance in achievement scores by 7, 9, and 11 year olds respectively. By way of contrast, MFF latency was significantly correlated with academic achievement in only one case, accounting for 11% of the variance in achievement scores by 11-year-old children.

As indicated by the "multiple correlations" column of Table 8, two-variable models did not substantially increase the prediction already available in the one-variable models. In fact, the two-variable models added a mean of only .036 to univariate correlations between MFF errors and problem-solving bits. Further, multiple regression actually reduced the significance of predictions for the latency variables. Thus, whereas MFF errors was significantly correlated with Pattern Matching latency at ages 7 and 9, and MFF latency was significantly correlated at age 11, none of the two-variable prediction models was significant. Finally, the two-variable models added a mean of only .023 to univariate correlations between MFF errors and academic achievement.

Part correlations, presented in the last two columns of Table 8 indicate that the component of MFF errors orthogonal to MFF latency was significantly related with information score and achievement test variables at every age except age 11 for Matrix Solution bits. Further, only in the case of Pattern Matching latency at age 9 did a significant univariate relationship between MFF errors and a criterion variable fail to remain significant when the common variance between MFF errors and latency had been removed. Similarly, part correlations between MFF latency and the criterion variables revealed few changes in the simple univariate correlations. Thus, although the nonsignificant univariate correlation between latency and Matrix Solution bits at age 11 became significant when shared variance was partialled out, it was also true that the significant univariate correlation between latency and achievement at age 11 became nonsignificant when shared variance was partialled out. In general, then, it would appear that part correlations did not substantially change the relationships revealed by univariate correlations; namely, MFF errors was a better predictor of the criterion variables than MFF latency. What part correlations did show, however, was that the relatively stronger relationships between MFF errors and performance on the criterion variables did not result from variance that MFF errors and MFF latency had in common.

Two final points concerning the regression analyses should be made. First, neither MFF latency nor errors, nor even their effects combined, accounted for a substantial proportion of variance in the problem-solving variables. Collapsing across age groups, the two-variable models accounted for a mean of only 10% of the variance in problem-solving bits and 6% of the variance in Pattern Matching latency. Second, it might be noted that all significant univariate correlations between MFF latency and the criterion variables were for 11-year-old children. The only exception to this generalization was the -.22 correlation for the Matrix Solution information scores of 9 year olds, but this correlation was in the wrong direction--long latencies on the MFF were negatively correlated with high information scores.

Discussion

The results of this study do not support the generalization that response tempo, as operationalized by MFF latency, is an important determinant of problem-solving efficiency and academic achievement. The variance in criterion variables associated with MFF latency was slight, and this variance was not substantially different from that already accounted for by MFF errors. Therefore, the findings of this study generally support those of Block et al. (1974) and underscore many of their questions regarding the meaning and utility of the MFF decision time variable.

A key assumption underlying much of the research with the MFF is that cognitive tempo represents a predisposition to respond slowly or quickly in problem situations involving uncertainty (Kagan, 1966), and that this predisposition is manifested by children in a trait-like fashion. However, this assumption received little support from the data of the present study. The finding that MFF latency was correlated with Pattern Matching latency only at age 11 suggests that, far from being a unitary trait, the generality of the tempo dimension bears a critical relationship with the level of cognitive development of children being tested and the particular demands of the task at hand.

In reference to the generality of reflection-impulsivity, Kagan and Kogan (1970) have argued that children learn a set of skills which are specific to a particular class of problems. Therefore, if a child's tempo of responding is related to his strategy for processing information at a given developmental level, then response latency on the MFF may not correlate with latency measures on other tasks such as Pattern Matching because different skills or strategies are required by the two tasks. The MFF, after all, is primarily a visual-matching task, and there seems to be little theoretical or practical reason for expecting MFF latency to generalize to other tasks which differ in both the amount and kind of information that is processed.

If this is the case, the MFF loses much of its attraction as a general index of cognitive style. The relatively better prediction of MFF errors as against MFF latency in the present study implies that differences in problem-solving efficiency and academic achievement between children classified by the MFF may be attributed to the acquisition of more competent information processing skills by accurate children rather than to the ability of slow children to inhibit inappropriate responses. If these findings are replicated in subsequent research, then the conceptualization of decision time on the MFF as a general index of impulsive behavior would be in considerable doubt.

At the same time, such a conclusion does not imply that measures of response latency are without value. In the present study, measures of response latency taken on the Pattern Matching task were highly correlated with performance on that task. Thus, although latency measures may not correlate across tasks that vary in structure and difficulty, they may be useful in identifying children who use more sophisticated strategies in a given problem situation. Our view, then, is that greater attention should be focused on the manner in which task information is processed by competent and less competent problem solvers than on their tempo of processing.

IV. Effects of Strategy Training on Problem-Solving and Cognitive Style

The primary objective of the experiments reported here was to investigate whether young children could improve their problem-solving performance by learning rules for efficient solution strategies. The work is based on the assumption that what Belmont and Butterfield (1976) have called the "instructional approach" to cognitive research can be used to identify competencies underlying overt behavior that distinguish the problem-solving performance of older and younger children. Thus, we reasoned, if younger children could be taught a rule that would make their performance comparable to that of older children, it might be concluded that possession or generation of such rules is a competency that improves with age and accounts in part for mature problem-solving strategies by older children.

A second objective of this work was to examine the relationship between problem-solving performance and response latency. A substantial literature has now accumulated around the issue of cognitive tempo (for reviews see Block, Block, & Harrington, 1974; Messer, 1976), much of which implies that, in situations of response uncertainty such as problem-solving tasks, some children are predisposed to use long response latencies and therefore perform more efficiently than children who use short response latencies. Although a number of methodological and conceptual issues have been raised about the Matching Familiar Figures test (Ault, Mitchell, & Hartmann, 1976; Bush & Dweck, 1975; Haskins & McKinney, 1976), the primary instrument used to assess cognitive tempo (Kagan, 1965a), these issues are not at the center of the recent debate over cognitive tempo. Rather, stated most directly, the question is whether cognitive tempo and its operational equivalent response latency determine problem-solving efficiency, or whether problem-solving efficiency determines response latency. Although a number of authors have attempted to improve performance by manipulating response latency, with a nearly uniform lack of success (e.g., Albert, 1970; Kagan, Pearson, & Welch, 1966; Meichenbaum & Goodman, 1971), our reasoning was that it should be possible to increase response latency by improving children's problem-solving efficiency. Thus, if efficient performance led to increased response latency, and moreover if children taught more complex rules used longer latencies than children using less complex rules who in turn used longer latencies than children using no rule, then the position that latency was an artifact of problem-solving strategy would be supported.

The primary task employed in these experiments, used originally by Neimark and Lewis (1967, 1968), requires children to discover which of eight equiprobable solutions is correct by gathering information to eliminate incorrect alternatives. More specifically, children are shown eight patterns, each composed of eight black or white dots, and a problem box in which one of the patterns is concealed with each of its dots behind a movable shutter. Children proceed by opening a shutter to reveal the black or white dot, and then eliminating any pattern that has an incorrectly colored dot in that position. This procedure of opening shutters and eliminating incorrect patterns is repeated until only one pattern--the correct one--remains.

The Pattern Matching task is well suited for these experiments for a number of reasons. First, the materials place only minimum emphasis on previous knowledge or experience. Requirements for solving the task can be easily taught to children as young as 6 or 7 (McKinney, 1975a). Second, two years of study with this task have demonstrated rather consistent improvement with age between 7 and 13 years (McKinney, Haskins, & George, Note 4; McKinney, Haskins, & Mason, Note 5). This implies that whatever accounts for improvement in solution efficiency, older children have more of it than younger children. Third, the task provides an objective means of assessing information processing efficiency (bits of information) and a means of identifying solution strategies.

Previous research in our laboratory has revealed a developmental progression through three generic solution strategies on the Pattern Matching task. The most primitive strategy, used by nearly all 7 year olds and some 9 and 10 year olds, involves opening shutters in random order. Thus, children simply open a shutter at random, and eliminate patterns with an incorrectly colored dot in that position. This random strategy results in an average of six responses to achieve solution and .56 bits of information per response. Generally, this strategy is characterized by very short response latencies of 1 or 2 seconds per response.

In the second strategy, children examine dots on the remaining patterns before deciding which shutter to open. Apparently, the purpose of examining dots is to avoid shutter openings that are noninformative; i.e., do not permit any patterns to be eliminated. Such shutters can be avoided by examining the dots in a particular position on all the remaining patterns to insure that the position selected does not have dots which are all the same color. This Noninformative Response strategy characterizes the performance of some 9 and many 10 year olds, and permits solution in four responses with approximately .8 bits of information per response. Children who use this strategy typically emit longer latencies than children using the Random strategy--about 8 to 10 seconds per response.

The third strategy, called Focusing (Bruner, Goodnow, & Austin, 1956), requires children to locate a shutter position that has half black and half white dots, thereby insuring that regardless of the dot color behind the shutter, half the patterns can be eliminated. The Focus strategy, used by very few 9 year olds and perhaps 50% of 12 year olds, always produces a solution in three responses and yields 1.0 bits of information per response. Further, children using this strategy typically emit very long latencies of approximately 15 seconds per response.

From this overview of strategies children use to solve the Pattern Matching task, it can be concluded that the task's critical feature is comparing dots on the remaining patterns before deciding which shutter to open. The purpose of the first experiment was to confirm this generalization by giving some children a rule for comparing dots and letting other children proceed without the benefit of rule instruction. In addition, since a number of investigators, generalizing from work with problem-solving and conservation tasks, have suggested that memory requirements interact with performance (Bryant & Trabasso, 1971; Eimas, 1970a, 1970b; McKinney & Banerjee, 1975), the effect of memory support on problem-solving efficiency was also manipulated. Comparison of children receiving and not receiving memory support would both permit direct assessment of memory requirements of the Pattern Matching task, and the degree to which memory support facilitates the acquisition of solution rules.

Experiments II and III, building on the results of Experiment I, involved teaching children rules of differing complexity and examining how children generalize these rules to new tasks for which they were not trained. In addition, these experiments and particularly Experiment III, were designed to examine the relationship between rule complexity and response latency.

EXPERIMENT I

Method

Subjects

Forty of 52 students between the ages of 95 and 101 months in a single elementary school were randomly selected and randomly assigned to one of four experimental conditions. The sample included 24 males and 5 black children, with a mean age of 98 months (*SD* = 1.9) and a mean IQ (Primary Mental Abilities Test) of 109.5 (*SD* = 11.7). Analyses of variance on age and IQ revealed no reliable differences between the four groups on either variable. Similarly, Chi Square analysis of socioeconomic status, based on a modified version of Hollingshead's (Note 7) two-factor index of social position, revealed no reliable differences between the groups.

Procedure

Demonstration problems. Children were brought from their classrooms to an adjacent research building for individual testing. Each child was given three demonstration problems requiring the location of a correct pattern from among *n* displayed patterns--four patterns on the first problem, six on the second problem, and eight on the third problem. Each pattern consisted of a unique combination of four binary elements (black or white dots) located at equal intervals on the circumference of a 14.1 cm diameter circle. A pattern exactly like one of the *n* displayed patterns was concealed inside a standard manilla folder that had four, one-inch (2.5 cm) holes cut in its face. Covering each hole was a movable cardboard strip. Children were told the task involved finding which of the displayed patterns was concealed inside the folder, but by opening as few shutters as possible. After each shutter opening, children were instructed to turn over any patterns with a corresponding dot of a different color than the one they had just uncovered.

On the first demonstration problem, the experimenter opened a shutter that eliminated two of the four displayed patterns. After children had identified the two eliminated patterns, they were asked which of the remaining three shutters should be opened next. Two of the remaining shutters were noninformative (allowed the elimination of no patterns); the other shutter would solve the problem. Children then opened a shutter and removed the eliminated pattern if appropriate. If the noninformative shutter was opened, children were instructed to open the remaining shutter and eliminate the correct pattern.

After completing the first demonstration problem, children were given the second and third problems, requiring, respectively, identification of the correct pattern from among six and eight patterns.

Test problems. After completion of demonstration problems, four test problems were administered. All test problems required identification of the correct pattern from among eight displayed alternatives. Each pattern consisted of eight binary elements; i.e., one-half inch (1.3 cm) black or white dots located at equal intervals around the circumference of a nine-inch (22.9 cm) circle. The correct pattern was concealed inside a 10 X 10 X 1 inch (25.4 X 25.4 X 1.5 cm) wooden box with eight movable shutters covering three-quarter inch (.64 cm) holes. As with the manilla folder used in demonstration problems, each dot on the pattern inside the pattern box could be seen when its respective shutter was opened.

The eight alternative patterns were constructed in such a way that, on the first response, four shutters would allow the elimination of four of the eight patterns, while the other four shutters would eliminate only one pattern. Thus, the child's first response on each problem was necessarily informative, but on subsequent responses the probability of informative outcomes decreased. The four sets of test patterns were constructed by permuting the positions of black and white dots within each pattern such that the solution could not be discovered until only one or two patterns remained.

Experimental Design, Manipulations, Data Analysis

The experiment was a 2 (rule) X 2 (memory support) X 4 (problems) factorial design with repeated measures on the last factor. Children in the Rule condition were given a rule for avoiding noninformative responses. This Noninformative Response Rule, which was given to children each time they opened a noninformative shutter during demonstration and test problems, was repeated as follows:

> When you open this shutter, that is a bad or wasted move. The reason it is a bad move is that this shutter has dots over here [point to appropriate dots on the two remaining patterns] that are all the same color. Then when you open this shutter [open the shutter], you can't get rid of any patterns. To make sure you never make this bad move, before you open a shutter over here [point to folder], compare the dots over here [point to dots on patterns]. If the dots are all the same color, either all black

or all white, do not open that shutter. Find another shutter that has dots of different colors.

In the Memory Support condition, each pattern was drawn on a 5 X 7 inch (12.7 X 17.8 cm) card, and the eight patterns were displayed in two columns on a 13 X 18 inch (33.0 X 45.7 cm) pattern board. Children were instructed to turn over the patterns (if any) eliminated by each shutter opening. In the No Memory Support condition, all eight patterns were drawn on a 14 X 20 inch (35.6 X 50.8 cm) card, thereby eliminating the possibility of physically removing patterns from the array. Thus, unlike in the Memory Support condition, children's performance was facilitated by remembering which patterns had been eliminated by previous shutter openings.

Data were analyzed using the McCall and Appelbaum (1973) approach to repeated measures. Change across the four problems was summarized by subtracting the mean of problems 1 and 2 from the mean of problems 3 and 4 for each of the three variables defined below. This number was then used to test the repeated-measures effect and appropriate interactions for each variable separately. Main effects for the corrective feedback and memory support factors, and their interaction, were tested using mean performance across the four problems.

Dependent Variables

Three dependent variables were scored. First, the mean expected information, in bits of information, was computed by summing the informational outcomes from all responses within each problem and dividing by the total number of responses on that problem. Expected information scores for each response were computed by weighting each informational outcome by its likelihood of occurrence (see Eimas, 1970b, p. 226; Neimark & Lewis, 1967, pp. 108-109). Number of noninformative responses, as defined above, was the second dependent measure. Third, latency was taken for each response. Timing commenced during the Memory Support condition when children turned over the last card from the previous shutter opening and during the No Memory Support condition after children pointed out the last pattern eliminated by the previous shutter opening. In the case of a previous noninformative response, the experimenter commenced timing when the child looked up from the patterns and said: "Oh, I can't turn over any," or made some similar verbal or physical movement indicating his knowledge that no patterns could be eliminated. Timing stopped when the child opened a shutter. Mean latencies were computed by dividing the sum of latencies across responses within a problem by the number of responses for that problem.

Results

The information presented in Table 9 indicates the clearly superior performance of children in the two Rule groups. These children obtained a mean of .84 bits of information per response, reliably more than the .64 bits achieved by children in the No Rule groups, $F(1/36) = 32.02$, $p < .001$. Further, the performance of children in the Rule groups appeared to substantially exceed the .65 bits Neimark and Lewis (1967) estimated would result from random performance, and even more substantially from the .56 bits that resulted from 100 random solutions using the materials employed in this study (see Table 9). On the other hand, children not receiving rule support performed essentially at a chance level. Children in the Rule groups improved their performance by a mean of .20 bits on the last two, as compared with the first two problems, whereas children who received no rule instruction improved their

Table 9

Means and Standard Deviations for Three Measures of Problem-solving Performance Observed in Four Experimental Groups and Estimates of Random Performance

Group	Expected Information[b]		Noninformative Responses[c]		Latency[b]	
	M	SD	M	SD	M	SD
Rule - Memory Support	.88	.07	1.30	1.06	13.08	3.96
Rule - No Memory Support	.80	.10	3.20	2.62	18.66	10.50
No Rule - Memory Support	.66	.14	7.60	4.50	5.89	3.96
No Rule - No Memory Support	.62	.13	7.80	3.42	4.57	5.38
Random Performance[a]	.56	.16	11.00	1.50		

[a]Based on 100 problems solved by random opening of shutters

[b]Averaged across all responses on all test problems

[c]Total across four test problems

performance by only .13 bits. However, although the main effect for repeated measures was reliable [$F(1/36) = 13.47$, $p < .001$], none of the interactions involving repeated measures were significant. Thus, it cannot be concluded that children in the Rule groups improved their performance across the four problems more than children in the No Rule conditions. Memory Support did not contribute to more efficient performance, nor did it interact with rule instruction, $Fs(1/36) \leq 2.60$, $ps > .11$.

The comparatively high average information scores of children in the Rule groups can be explained by their ability to employ the rule for avoiding noninformative responses. The mean of 2.25 noninformative responses committed by these children on the four test problems was significantly lower than the 7.70 noninformative responses made by children in the No Rule groups [$F(1/36) = 29.73$, $p < .001$], and much lower than the 11.00 noninformative responses to be expected from random opening of shutters. As with the bits measure, the main effect for repeated measures was reliable [$F(1/36) = 11.15$, $p < .002$], though none of the interactions involving repeated measures were reliable. Nor did Memory Support contribute to reduction in the use of noninformative responses, $Fs(1/36) < 1.10$, $ps > .30$.

As a reading of the Rule instructions will reveal, children in these two groups were instructed to compare dots on the remaining patterns before deciding which shutter to open, and avoid shutters corresponding to dots of the same color on the remaining patterns. Therefore, if children followed these instructions, they should have had longer response latencies than children who did not compare dots before opening a shutter. Table 9 demonstrates that the latencies of children in the Rule groups were greater than those of children in the No Rule groups by a factor of three--15.87 as against 5.23 seconds, $F(1/36) = 26.55$, $p < .001$. The main effects for repeated measures and Memory Support were not significant, nor were any of the interactions involving the latency variable, $Fs(1/36) \leq 2.41$; $ps > .13$.

The results of Experiment I demonstrate that 8 year olds were capable of acquiring and using a rule to avoid noninformative responses and thereby increase their problem-solving efficiency. Indeed, the information scores of children in the two Rule conditions appeared to equal or exceed those for all groups age 12 or below reported by Neimark and Lewis (see their Figure 2, p. 112; and Figure 3, p. 113 in Neimark & Lewis, 1967). Experiment I, then, demonstrates the flexibility of children's problem-solving performance, and their ability to profit from instruction to attain levels of performance characteristic of much older children. This result suggests that the primary difference between the performance of older and younger children on this task is that older children spontaneously generate the rule for avoiding noninformative responses. Younger children perform poorly, not because they are incapable of using the rule employed by older children, but because they do not spontaneously generate this rule.

Unlike Rule instruction, Memory Support did not facilitate children's performance, nor did it improve their ability to acquire the Noninformative Response Rule. This result is probably explained by one of two considerations. First, because the shutters were not closed after each response, children not receiving Memory Support could look at the previously revealed dots on the pattern inside the pattern board and figure out which patterns had already been eliminated. Second, children may have been able to develop strategies for remembering which patterns had been eliminated by previous shutter openings, and thereby consider only patterns that were still logically correct in deciding which shutter to open next. In fact, many children in the Rule-No Memory Support condition used their fingers, hands, and even elbows to cover patterns as they were eliminated by shutter openings. In any case, it can be concluded that memory requirements of the Pattern Matching task are not substantial, and are easily handled by 8 year olds.

Eight year olds also demonstrated the ability to delay their choice of shutters for relatively long periods of time. This result implies that tempo follows problem-solving efficiency and not vice versa. Children who knew a rule for efficient solution took longer because they were comparing dots on the remaining patterns before deciding which shutter to open; their peers who were following no rule simply opened shutters at random and therefore had relatively short latencies. Thus, response latency appeared to be an artifact of rule use.

The results of Experiment I are limited in at least three respects. First, as outlined in the Introduction, there is a more abstract and efficient rule that can be used to solve the Pattern Matching task. This rule requires children to find a shutter on the problem board that will eliminate exactly one-half the remaining patterns with each response. This Focus Strategy produces the most efficient possible solution to the Pattern Matching task, as well as a variety of other laboratory tasks and real-life situations (Bruner et al., 1956). Previous studies in our laboratory reveal that this strategy is used consistently by only about 10% of 11 year olds; further, more than 40% of 13 year olds fail to use focusing consistently (McKinney, 1975a;

McKinney et al., Note 4). Thus, if 8 year olds could acquire this Focus Strategy, the extreme flexibility of children's problem-solving ability would be supported.

Experiment I was also limited by the lack of a test for generalization. Implicit in the use of generalization tests is a hierarchy of successful outcomes for instructional experiments. It could be argued that learning is demonstrated when a training method results in performance change on a given task; on the other hand, it could also be argued that learning is demonstrated only when children can exhibit efficient performance on new materials for which they were not directly trained. Perhaps the important issue in the use of a generalization series is the specification of situations to which children will and will not generalize particular information or strategies. A comparison of tasks to which children will and will not generalize might be expected to yield information concerning task features that help children recognize an opportunity to apply information or strategies they already possess.

Third, the effect of rule use on response latency could be explored more adequately by teaching children rules of differing degrees of complexity. If latency is an artifact of rule use, then more complex rules, as compared with less complex rules, should require more time for application to the stimulus materials. If the implication of Experiment I is correct, children using more complex rules should emit longer latencies than children using less complex rules, who in turn should emit longer latencies than children using no rule.

EXPERIMENT II

The objectives of Experiment II, then, were: (a) to replicate the finding that 8 year olds could learn and use the Noninformative Response

Rule; (b) to determine whether 8 year olds could learn and use the more abstract and difficult Focus Rule; (c) to determine whether children would generalize their use of rules to different tasks; and (d) to find whether children using the relatively more complex Focus Rule would emit longer latencies than children using the Noninformative Response Rule. In addition, a different instruction technique was employed in Experiment II. This technique, as explained below, involved both modeling and direct tuition.

Method

Subjects

Forty-five, 8-year-old ($\underline{X}$ = 97.2 m, SD = 3.9 m) children, including 19 females and 7 blacks, participated in this study. These children were randomly selected from those who had returned parent permission notes ($\underline{n}$ = 73); the notes had been given to all second grade children ($\underline{n}$ = 104) in a single elementary school.

Children were ordered by Wechsler Intelligence Scale for Children verbal IQ and assigned randomly to one of three groups--control (IQ = 113.9, SD = 15.2), Noninformative Response Rule (IQ = 113.5, SD = 14.0), and Focus Rule (IQ = 114.8, SD = 14.2). Oneway ANOVAs revealed no reliable age or IQ difference between the groups.

Tasks

Three tasks were used. The Pattern Matching task was similar to that used in Experiment I except the patterns were altered to minimize the possibility of focus moves. In addition, the demonstration problems were constructed in such a way that noninformative responses were impossible. This change was made to insure that no children were given experience with noninformative responses during their initial introduction to the Pattern Matching task.

To test for generalization, two additional tasks were used--one more and one less similar to the Pattern Matching task. Both, however, could be solved by using similar strategies. The first generalization task consisted of eight, 7.5 X 12.5 X 3.5 cm blocks and a 35 5 5.5 cm tray with eight slots. The blocks, with either red or blue faces, fit loosely into the eight slots of the tray, and when turned face down their color could not be seen. The sides and back of each block and the tray were painted black. Eight patterns of eight red and blue rectangles were displayed on the same board used with the Pattern Matching task. The 2.5 X 3.7 cm red and blue rectangles on each pattern were cut from construction paper and pasted on an 8 X 11 cm black background centered on 4 X 6 inch (10.2 X 15.2 cm) white note cards.

The object of the Blocks task was to discover which of the eight displayed patterns was concealed in the tray. Children proceeded by turning over blocks to expose their colored face and then eliminating any of the eight patterns that had an incorrectly colored block in that position. Materials on the Blocks task were constructed so that the probabilities of eliminating patterns were id ntical to probabilities on the Pattern Matching task.

The second t :k consisted of 42, 2.5 X 1.5 cm water-color drawings (see Mosher & Hornsby, 1966) of familiar objects--vegetables, toys, tools, animals. The pictures were arranged in a 6 X 7 matrix on a 22 X 2: cm card divided into 42 cells by black lines. Children were told that the experimenter was thinking of one picture in the array, referred to as the experimenter's "secret", and that they should attempt to locate the "secret" picture by asking questions that could be answered "yes" or "no". Thus, as with the Pattern Matching and Blocks tasks, children could ask hypothesis questions ("Is it this picture"), constraint-seeking questions ("Is it an animal?"), or focus questions ("Is it in this half of the board?"). The Pictures task differs from the other two tasks in the physical appearance of stimulus items and in the number of stimulus items.

Procedure

Children were brought separately from their classroom to a testing room in an adjoining building. The Pattern Matching task was then introduced, and after solving the three demonstration problems with the four-element patterns, children in all three groups solved two test problems that served as a baseline measure of their problem-solving performance. Children in the Control group then solved four more problems without instruction

Children in the Noninformative Response Rule group, however, were shown a five-response (five shutter openings) solution by the experimenter who began by saying:

> Now I'm going to show you a little trick. You can use this trick to be sure you can turn over a pattern every time you open a shutter. I'm going to find a shutter over here (point to pattern box) that has dots of different colors over here (point to patterns on pattern board). Look at this shutter (point to a noninformative shutter). I'm not going to open this one because it would be a bad

move. The dots on the patterns in this position are all the same color (point to dots in this position on all eight patterns), so if I open this shutter I won't be able to turn over any patterns. Now I'm going to find a shutter over here (point to pattern box) that has dots over here (point to patterns) that are not all the same color. Oh good, this one will do it.

The experimenter proceeded in this fashion through the first three responses repeating the words given above each time. On the last two responses, the experimenter did not repeat the words, but carefully examined the dots on the remaining patterns before opening a shutter.

Children in the Focus Rule group were also given a demonstration problem. In this case, however, a three-move Focus solution was modeled. Looking at dots on the eight patterns, the experimenter said:

> Now I'm going to show you a little trick. I know a way to turn over half the patterns each time I open a window. Watch me. I'm going to find a shutter over here (point to problem box) that has four white dots and four black dots over here (point to patterns). Then I can turn over four patterns no matter what color dot is behind the shutter.

The experimenter then demonstrated two shutter positions that would not eliminate four patterns, concluding each time with the statement: "This window is no good because it has six black dots and two white ones. I must find a window that has four white and four black dots." After demonstrating the correct shutter and turning over the four eliminated pat rns, the experimenter repeated the above procedure with four remaining patterns and then two remaining patterns.

For both the Noninformative Response and Focus Rule groups, children were given one problem with corrective feedback after the model problem. Corrective feedback was given if children did not follow the procedure demonstrated to them by the experimenter; i.e., if they did not use the Noninformative Rule or the Focus Rule respectively. The corrective feedback consisted of the following sentence, repeated to children as they started to open an inappropriate shutter:

> No. Don't open that shutter. Find one that will allow you to turn over a pattern (or "turn over half the patterns" for the Focus Rule group).

Children in both groups were then given two problems without any assistance from the experimenter.

After completing the Pattern Matching problems, each child was given two problems with the Blocks task. Following a brief introduction to the mechanics of the task, and after having children point to the particular block on each of the eight patterns that corresponded with particular blocks in the tray, the experimenter said:

> Now remember, your job is to find the correct pattern over here (point to patterns), but by turning over as few blocks as possible over here (point to tray). Try to do it just like you did in the last game.

Following the two Blocks problems, children were given two problems with the Pictures task. If, after asking 20 questions, children had not solved the problem, they were given hints until they named the correct picture. Only the first 20 questions, however, were scored. To insure an adequate number of questions from each child, if the solution were achieved before the sixth question, a second solution picture, consistent with information from all previous questions, was used. Response time was recorded by starting a stopwatch at the beginning of each problem and stopping the watch when children located the correct picture, gave up, or completed 20 questions; average response time was computed by dividing total time by the number of questions.

Results

Baseline Performance on Pattern Matching Task

Performance levels of the three groups, as measured by the proportion of noninformative and focus responses, bits, and latency, was nearly identical during baseline. Oneway ANOVAs performed on the data in the top panel of Table 10 revealed no reliable differences between the groups on any variable ($Fs \leq 1.87$, $ps \geq .17$). Further, the performance of all three groups was consistent with random performance as based on computer simulation. In solving 500 problems with random shutter openings, the compute used noninformative responses and focus responses with probabilities of .35 and .18 respectively, and achieved a mean of .58 bits of information with each response. The comparable figures during baseline, averaged across the three groups of children, were .32, .18, and .58. Thus, not only did children from the various groups perform similarly, but the performance of all groups was essentially random.

Table 10

Mean* Performance Efficiency and Latency by Three Groups During Baseline, Test, and Generalization Phases

	Noninformative Responses	Focus Responses	Bits	Latency
Baseline Performance				
Control	.34	.19	.56	2.02
Noninformative Rule	.28	.20	.61	4.32
Focus Rule	.33	.15	.56	3.78
Test Performance				
Control	.28	.12	.62	1.89
Noninformative Rule	.00	.26	.89	14.82
Focus Rule	.06	.87	.93	42.70
Generalization Task Performance				
Control	.28	.17	.61	1.78
Noninformative Rule	.05	.35	.83	15.86
Focus Rule	.08	.70	.88	25.54

*Each entry based on the mean of two problems.

Test Performance on Pattern Matching Task

Performance changes between baseline and test phases were assessed by t-tests for related samples. Although absolute performance changes by Control children were small, their performance as measured by the bits variable did improve reliably [$t(14) = 2.56$, $p < .02$]. None of the other changes, however, were reliable, thereby permitting the conclusion that repeated-measures effects were slight.

As expected from the results of Experiment I, children in the Noninformative Response group reliably reduced their use of noninformative responses. Indeed, none of the 15 children in this group used any noninformative responses. Similarly, the Focus Rule group reliably increased its use of focus responses ($t = 9.75$, $p < .001$). The Noninformative Rule group also exhibited a moderate improvement in the incidence of focus responses ($t = 2.09$, $p < .06$). A oneway ANOVA and subsequent Newman-Keuls comparisons, however, revealed significant differences between the groups [$F(2/42) = 78.22$, $p < .001$] and reliably more focus responses by Focus group children than Noninformative Response group children. Thus, although both groups of children made more focus responses during the test series, Focus Rule children made significantly more of these maximally efficient responses.

Response latency data presented in Table 10 demonstrate that increases in performance efficiency by Noninformative and Focus Rule children were accompanied by reliable and substantial changes in response latency [$t(14) = 5.64$, $p < .001$ and $t(14) = 7.06$, $p < .001$ respectively]. By contrast, latency for the Control group actually declined slightly though unreliably [$t(14) = -.45$, $p > .60$].

The statistical tests reported above give ample indication of performance increases by Noninformative Response and Focus Rule children, but little information about the degree to which individual children were capable of learning the respective rules and employing these rules to guide their problem-solving behavior. Thus, it is of interest that only 1 of 15 children in the Noninformative Response group was able to avoid noninformative responses during baseline, whereas all 15 children avoided these moves during the test phase. In the Focus Rule group, none of the 15 children achieved a focus solution during baseline, whereas 13 children achieved at least one focus solution, and 11 children focused on both problems, during the test phase.

Generalization Performance on Blocks Task

Each group generalized its performance to the Blocks task, though with some decrement in performance efficiency by the experimental groups. Oneway analyses of variance, testing group differences in performance as measured by the four variables in Table 10, yielded reliable main effects for all four variables, $Fs(2/42) \geq 14.97$, $ps < .001$. Individual comparisons with the Newman-Keuls procedure demonstrated: (a) that Noninformative Response Rule children made reliably fewer noninformative responses than Control children, (b) that Focus Rule children made reliably more focus responses than either Control or Noninformative Response Rule children who did not differ from each other; and (c) that Focus Rule children had reliably longer latencies than Noninformative Response Rule children who in turn had longer latencies than Control children.

Generalization Performance on Pictures Task

Despite the fact that children generalized their performance to the Blocks task, as indicated by the substantial differences in performance efficiency between the three groups, there were no differences between the groups on any variable for the Pictures task. The respective mean proportion of hypothesis questions for Control, Noninformative Rule, and Focus Rule children were .37, .43, and .45 [$F(2,42) = .234$, $p > .65$]; the respective mean number of constraint-seeking questions were .35, .45, and .28 [$F(2,42) = 2.07$, $p > .13$]; and the respective latencies were 7.70, 9.20, and 7.76 seconds [$F(2,42) = 0.62$, $p > .60$]. Interestingly, no children in any group used a Focus question.

Discussion

The results demonstrate that young children are capable of acquiring and using problem-solving rules that typically would be used by much older children. With regard to the Noninformative Response Rule, previous work in our laboratory (McKinney et al., Note 4, Note 5) and other laboratories (Neimark & Lewis, 1967) had indicated that not until age 10 or 11 did 50% of children tested use this rule. However, both Experiments I and II demonstrated that, although 8-year-old children do not spontaneously generate this rule, they are quite capable of using it when instructed to do so. Experiment II also demonstrated that 8 year olds were capable of using the more abstract Focus Rule--a rule generated spontaneously by only about 50% of 12 year olds (McKinney et al., Note 4, Note 5). Further, if the criterion for successful training had been perfect performance on the Pattern Matching task, more than 73% of the experimental group children succeeded; if the criterion had been perfect performance on both the Pattern Matching and generalization (Blocks) task, 60% of the children succeeded.

The implication of the finding that most children in both the Noninformative Response and Focus Rule groups generalized their performance to the Blocks task indicates that children did not simply memorize something specific to the task on which they were trained. Rather, they must have understood the principle underlying the Noninformative Response and Focus Rules. As a result, they were able to recognize a new situation to which the recently learned rules could be applied.

On the other hand, none of the 30 children in the Noninformative or Focus Rule groups recognized a second situation--the Pictures task--to which they could apply their rule. Whether they failed to generalize to this task because there were more stimulus items to take into account (42 as against 8 in the Pattern Matching and Blocks tasks) or because the stimulus items themselves were more complex (pictures of animals, vegetables, means of transportation, and so on) as against simple binary dots or rectangles, cannot be determined from the design of this experiment. Nevertheless, this result suggests the principle that children will generalize their performance across similar materials, but will often fail to recognize an opportunity to apply their rule to new materials if these materials are substantially different than those on which they were trained.

This failure to generalize rules to a new situation is perhaps closely related with young children's failure to spontaneously generate rules without instructional support. Performance by children in the experimental groups of both studies demonstrate that 8 year olds are in command of the basic competencies requisite for both the Noninformative Response Rule and the Focus Rule. These children understand, for example, the concepts black, white, red, and blue; the concepts same and different; the concepts one-half, less than, and more than; and so on. In Resnick and Glaser's (1976) terms, these children were in possession of the necessary "component routines". But they did not put them together to achieve the performance efficiency characteristic of children in the instructional groups.

Why not? This question is now at the heart of the instructional approach to cognitive development, as demonstrated by recent work with memory development (e.g., Flavell, 1970; Butterfield, Wambold, & Belmont, 1973) and the development of problem-solving skills (e.g., Resnick & Glaser, 1976). The principle that seems to be emerging from this research is that even very young children have the component cognitive skills requisite to mature performance, but they often fail to combine these skills and apply them to the problem at hand. In addition to supporting the generalization that young children are capable of very sophisticated performance, these experiments suggest that their partial failure to generalize performance and to spontaneously invent rules is closely related with the particular type of stimulus materials at hand, and the relationship between these materials and materials with which they have had previous experience.

Experiments I and II also revealed an interesting relationship between problem-solving efficiency and latency. In a between-subjects design, Experiment I showed that children using the Noninformative Response Rule had latencies greater by a factor of three than children performing randomly. a combination within-subjects and between-subjects design, Experiment II demonstrated that: (a) children greatly increased their response latencies when using a rule as compared to when performing randomly; (b) children using a more abstract (Focus) rule emitted latencies three times greater than children using a less abstract (Noninformative Response) rule, who in turn used latencies about seven times greater than children using no rule; and (c) all groups generalized their latencies to a new task (Blocks) similar to the original task on which they continued to use their respective rules, but group differences in latency disappeared in a subsequent task (Pictures) to which children did not generalize their rules. These results support the conclusion reached by Messer (1976) in his recent review of tempo studies; namely, that the most effective method of increasing response latency and reducing errors by impulsive children on the MFF test is to teach them a scanning strategy. In addition, our results extend Messer's conclusion to task materials other than the MFF test itself, and suggest that any individual differences in cognitive tempo can be overcome by teaching children an efficient solution strategy.

EXPERIMENT III

Experiment III was designed to directly test the conclusion that impulsive children could be taught to improve their problem-solving performance, and that this improvement in performance would be accompanied by increases in response latency. In addition to the experimental group of impulsive children receiving strategy training, three other groups of children were tested. First, an experimental group of impulsive children was forced to use long latencies before each response. This group was included to discover whether merely increasing response latency would result in improved performance by impulsive children. Two control groups, one of impulsive and one of reflective children receiving no training, were also tested. These groups were included to provide control for repeated-measures effects, and to find out whether impulsive children receiving training could perform more efficiently and with longer latencies than reflective children receiving no training. Such a finding would provide strong support for the position that latency is an artifact of rule use, and would imply that a primary difference in MFF performance between reflective and impulsive children is that reflectives possess more systematic scanning strategies.

Method

Subjects

The MFF test was individually administered to all second grade children from two elementary schools who had returned a parent permission form. Subjects who scored below the median (11) on total number of errors and above the median on average response latency (13.05 seconds) were classified as reflective. Similarly, subjects who scored above the median on total number of errors and below the median on average response latency were classified as impulsive. Of the 59 children so classified (29 impulsives and 30 reflectives), 27 impulsives and 9 reflectives were randomly selected to participate in this study. The final sample contained 14 girls and 5 black children.

These 36 children were then administered the verbal subtests of the Wechsler Intelligence Scale for Children - Form R in order to obtain a measure of verbal ability. Nine impulsives were then randomly assigned to each of the following training groups: Focus Rule Training, Delay Training, and Impulsive Control.

Table 11 provides a summary of subject characteristics for each group. A one-way ANOVA on each variable for the three impulsive groups showed no reliable differences. Individual contrasts between

Table 11

Subject Characteristics

Variable		Group			
		Strategy Training	Delay Training	Impulsive Control	Reflective Control
CA (Months)	$\bar{X}$	98.33	98.67	95.55	97.78
	SD	3.04	3.87	4.16	2.11
IQ	$\bar{X}$	110.70	112.10	116.00	121.40
	SD	12.87	11.14	11.22	17.24
MFF Errors	$\bar{X}$	19.10	17.89	17.22	5.67
	SD	5.64	4.94	4.35	2.83
MFF Latency	$\bar{X}$	8.32	8.07	8.00	20.44
	SD	3.25	2.89	2.64	8.30

the reflective and each of the impulsive groups resulted in statistically significant differences on MFF errors [$F(3,32) = 16.92$, $p < .001$] and MFF latency [$F(3,32) = 14.43$, $p < .001$]. In each case, the Reflective Control group displayed longer response latencies and fewer errors on the MFF compared to each impulsive group. There were no differences between reflectives and impulsives in verbal IQ or age.

Tasks

The same three tasks used in Experiment II were used in this experiment (Pattern Matching, Blocks, and Pictures).

Procedure

The study was conducted in four phases which were carried out in one session of approximately 50 minutes. During the first phase, each subject was individually administered two Pattern Matching problems in order to establish baseline performance and to compare the initial performance of the three impulsive groups and the Reflective Control group.

Immediately following baseline problems, the experimenter introduced the training procedure by using the instructions described below. Children in the experimental groups (Focus Rule and Delay Training) were given two training problems on the Pattern Matching task by one of two experimenters. Children in the Impulsive Control and Reflective Control groups were given two Pattern Matching problems under standard instructions; i.e., without the benefit of any instruction.

Following training, children in all four groups were administered two problems with each of the three tasks. Thus, all subjects received the same number of problems with each task during the session.

Training Procedures

Strategy training. Impulsive children in the Strategy Training group received the same instructions as children in the Focus Rule group of Experiment II. It will be recalled that this training involved a combination of modeling and direct instruction, the objective of which was to teach children to eliminate half the remaining patterns with each response.

Delay Training. Impulsive children in the Delay Training group were given the following instructions:

> We have found that children do better on these problems when they take their time and think carefully about which window they want to open before they open the window. On the next two problems, I am going to help you take more time. I am going to make sure that you have enough time to think about which window you want to open. Do not open a window until I stop my watch and say, "Okay, you can open one now." Remember, use the time to think carefully about which window you want to open. You can use as much time as you need to think, so when I stop my watch and say, "Okay, you can open a window now," you don't have to open a window. If you need more time to think, go ahead and think as long as you want to. Okay. Let's do a problem now.

On the first three trials of each problem, the experimenter reminded children they were to delay responses and use the time to think about which window they would open next. Children were required to delay their responses for 10 seconds--the approximate amount of time used by efficient 9-year-old problem solvers (see Experiment I above).

Data Analysis

In order to compare the problem-solving behavior of children in the three impulsive groups, a oneway ANOVA was carried out on each dependent measure for each task. Individual comparisons among the impulsive groups were made with the Newman-Keuls procedure. Comparisons between each impulsive group and the Reflective Control group were carried out separately by computing single degree of freedom contrasts. Finally, related t-tests were computed to assess the magnitude of change between baseline and test measures on the Pattern Matching task. Since a preliminary analysis of sex effects failed to reveal significant differences between boys and girls on each of the measures used, sex was not considered as a factor in subsequent analyses.

Results

In general, the results of this experiment demonstrated that impulsive children receiving strategy training performed reliably better than the other groups of children, and that they used reliably longer latencies than children, including reflectives, in the other groups.

Baseline Performance on Pattern Matching Task

Table 12 shows the means and standard deviations for each variable on the Pattern Matching task during baseline. Analysis of variance for the three impulsive groups yielded significant main effects for the proportion of focus responses, $\underline{F}(2,24) = 3.34$, $\underline{p} < .05$, and for response latency, $\underline{F}(2,24) = 4.39$, $\underline{p} < .05$. In order to remove the effects of this difference in initial performance, test data were analyzed with the baseline data covaried, for these two variables.

The single degree of freedom constrasts between the reflective control group and each of the impulsive groups failed to yield reliable

Table 12

Means and Standard Deviations of Baseline Performance Measures on the Pattern Matching Task

Variable		Group			
		Strategy Training	Delay Training	Impulsive Control	Reflective Control
Information Score	$\bar{X}$	.53	.58	.60	.56
	SD	.05	.03	.09	.09
Noninformative Responses	$\bar{X}$	.36	.31	.31	.35
	SD	.03	.05	.10	.09
Focus Responses	$\bar{X}$	.12	.15	.21	.21
	SD	.08	.07	.08	.13
Response Latency	$\bar{X}$	2.78	1.46	1.90	2.13
	SD	1.52	.26	.64	.90

differences for any of the measures, thereby demonstrating that reflectives and impulsives performed similarly during baseline.

Test Performance on Pattern Matching Task

Table 13 gives the means and standard deviations for each measure on the Pattern Matching task following training. ANOVAs for the three impulsive groups yielded significant main effects for each measure: bits of information, $F(2,24) = 13.75$, $p < .001$; number of noninformative responses, $F(2,24) = 7.77$, $p < .003$; number of focus responses, $F(2,24) = 21.98$; $p < .001$; and response latency, $F(2,24) = 22.99$, $p < .001$. Individual comparisons indicated that for all four measures, the Focus Rule group differed from both the Delay Training and Impulsive Control groups. The latter two groups did not differ significantly on any measure. Thus, training impulsive children in a focus strategy was successful in significantly improving performance and in producing longer response latencies on the post-training Pattern Matching problems.

Comparisons with Reflective Control children indicated that impulsive children in the Focus Rule group: (a) were reliably more efficient in their information processing, $t(32) = 4.12$, $p < .0001$; (b) had a smaller number of noninformative responses, $t(32) = -2.939$, $p < .006$; (c) had a greater number of focus responses, $t(32) = 6.747$, $p < .0001$; and (d) had longer response latencies, $t(32) = 6.835$, $p < .001$. By contrast, these tests failed to show significant differences between Reflective Control children and impulsive children in the Delay Training and Control groups.

Generalization Performance on Blocks Task

Table 14 summarizes the means and standard deviations for each dependent variable on the Blocks task and demonstrates that gains

Table 13

Means and Standard Deviations of Post-training Measures on the Pattern Matching Task

Variable		Group			
		Strategy Training	Delay Training	Impulsive Control	Reflective Control
Information Score	$\bar{X}$	.88	.62	.65	.65
	SD	.16	.06	.10	.12
Noninformative Responses	$\bar{X}$	.09	.29	.24	.25
	SD	.13	.07	.12	.12
Focus Responses	$\bar{X}$	.71	.15	.15	.13
	SD	.35	.04	.08	.07
Response Latency	$\bar{X}$	38.36	2.80	2.20	2.10
	SD	22.30	1.68	1.77	1.73

Table 14

Means and Standard Deviations of Dependent Measures on the Blocks Task

Variable		Strategy Training	Delay Training	Impulsive Control	Reflective Control
Information Score	$\bar{X}$	.74	.63	.60	.65
	SD		.07	.07	.13
Noninformative Responses	$\bar{X}$	.18	.28	.29	.26
	SD	.15	.13	.10	.12
Focus Responses	$\bar{X}$	.40	.17	.14	.23
	SD	.37	.09	.05	.15
Response Latency	$\bar{X}$	14.76	2.09	1.80	2.21
	SD	18.10	1.23	.94	2.20

in performance generalized to the Blocks task. An analysis of variance for the three impulsive groups resulted in significant main effects for the following measures: bits of information, $F(2,24) = 3.182$, $p < .05$; number of focus responses, $F(2,24) = 3.966$, $p < .03$; and response latency, $F(2,24) = 4.462$, $p < .02$.

Individual comparisons among the impulsive groups indicated that the Focus Rule group had a significantly greater number of focus responses than either the Delay Training or Impulsive Control groups. The same results were obtained for the latency measure. No significant differences were found on any of the measures between the Delay Training and Impulsive Control subjects.

Single degree of freedom contrasts indicated that subjects who received Focus Rule training showed a reliably greater response latency, $t(32) = 2.91$, $p < .007$, than the Reflective Control group. In addition, impulsive children in the Focus Rule group tended to make more focus responses than children in the Reflective Control group; however, this difference did not reach an acceptable level of significance, $t(32) = 1.76$, $p < .08$. None of the remaining contrasts were significant.

Generalization Performance on Pictures Task

The data in Table 15 demonstrate the nearly identical performance on the Pictures task of children in the three impulsive groups; none of the differences among these groups were reliable. By contrast, t-tests demonstrated that Reflective Control children asked fewer hypothesis questions [$ts(32) \geq 2.16$, $ps < .03$] than children in any of the three impulsive groups. In addition, Reflective Control children asked reliably more constraint-seeking questions than children in the Delay Training group, $t = 2.50$, $p < .01$.

Table 15

Means and Standard Deviations of Post-training Measures on the Pictures Task

Variable		Group			
		Strategy Training	Delay Training	Impulsive Control	Reflective Control
Hypothesis-seeking Responses	$\overline{X}$	.62	.66	.40	.30
	SD	.32	.35	.36	.22
Constraint-seeking Responses	$\overline{X}$	.26	.17	.36	.44
	SD	.27	.19	.28	.15
Noninformative Responses	$\overline{X}$	.03	.02	.01	.02
	SD	.03	.04	.02	.02
Response Latency	$\overline{X}$	6.86	5.72	9.09	8.13
	SD	4.02	2.11	4.49	2.73

Discussion

The results of Experiment III confirm and extend the results of both previous experiments. Experiments I and II were replicated in four respects. First, relatively young children were successfully trained to use complex strategies on a problem-solving task (Pattern Matching). Second, they extended the use of this strategy to a generalization task (Blocks) with which they had had no previous experience. Third, there was a direct relationship between strategy use and latency, with children using a relatively simple strategy emitting longer latencies than children using no strategy, and children using a complex strategy emitting longer latencies than children using a simple strategy. These results held for both the Pattern Matching and Blocks task. Fourth, children did not generalize their performance to a second generalization task (Pictures), and this decrease in performance efficiency was associated with a decrease in latency. Taken together, these last two results demonstrate that the same child used long latencies when performing efficiently, and shorter latencies when performing inefficiently.

Experiment III extended the previous experiments by directly comparing the problem-solving performance of impulsive children who were forced to use long response latencies with the performance of impulsive children who were taught to use efficient problem-solving rules. The finding that teaching impulsive children a rule for efficient performance increased their response latency, but that forcing impulsive children to use longer latencies did not improve their performance, would constitute strong support for the position that response latency is an artifact of solution efficiency.

In this respect, the results of Experiment III seem straightforward. Impulsive children given the benefit of rule instruction increased both their response latency and problem-solving performance; children forced to use longer latencies but given no rule instruction did not improve their problem-solving performance and returned to the use of short latencies as soon as permitted to do so. Further, reflective children receiving no training both performed less efficiently and with shorter latencies than trained impulsive children. These results obtained for both the training task and a generalization (Blocks) task. Finally, when given a second generalization task (Pictures) to which impulsive children did not generalize their strategy, both the latency and performance efficiency differences between reflectives and impulsives once again emerged.

The results of Experiment III provide evidence that impulsive children can perform reflectively when they know efficient rules for solving the problem at hand. By contrast, when forced to delay responding, they continue to perform poorly. The implication of these findings is that reflective children use longer latencies because they have more efficient rules for solving problems, and not that they have more efficient rules because they take longer to reflect on the task at hand. It follows that procedures designed to assist impulsive children should concentrate on teaching them efficient rules rather than attempting to slow them down. The results of this experiment suggest that when taught to proceed efficiently, the response latency of impulsive children will of necessity increase.

V. Classroom Behavior of Reflective and Impulsive Children

Over the past decade an extensive literature has accumulated which indicates that impulsive children as defined by Kagan's Matching Familiar Figures (MFF) test show poorer achievement and performance on a variety of problem-solving tasks than reflective children (Kagan & Kogan, 1970; McKinney, 1975a; Messer, 1976). Nevertheless, several important issues have been raised recently concerning the conceptualization of reflection/impulsivity research, and the construct validity and interpretation of the MFF test (Block, Block, & Harrington, 1974, 1975; Haskins & McKinney, 1976; Kagan & Messer, 1975). While some of these concerns are methodological in nature (Haskins & McKinney, 1976), Block et al. (1974) noted that since many behavioral traits are associated with the concept of reflection/impulsivity, there has been a tendency to attach too much surplus meaning to individual differences in response tempo on the MFF test. More specifically, they pointed out that:

> It is a heavy responsibility for one measure . . . to be taken as the sole and sufficient criterion of impulsive and reflective behavior. If conclusions relating reflection/impulsivity to . . . diagnosis and educational practices (Kagan, 1965, p. 627) are to be offered . . . the interpretation of the criterion measure of reflection/impulsivity, the MFF test, must be well founded (p. 612).

At the same time, relatively few studies have been made of the classroom behavior patterns of reflective and impulsive children. According to Kagan's (1965a) report of unpublished data, reflective children persist longer with difficult tasks, show higher standards for mastery, and avoid social interaction. Impulsive children have been variously described as being restless, distractible, emotionally undercontrolled, risk taking, gregarious, and aggressive (Kagan, 1965a, 1966; Kagan, Rosman, Day, Albert, & Phillips, 1964; Kagan & Kogan, 1970).

Recently, several studies have indicated that teachers perceive impulsive children less favorably than reflectives on rating scales that relate broadly to the concept of impulsivity in the classroom. Ault, Crawford, and Jeffrey (1972) found that teachers rated impulsives as less attentive and more hyperactive than reflectives. Also, McKinney (1975b) found that impulsive boys were described as less task-oriented and considerate than reflective children of either sex; however, impulsive girls and reflectives were rated comparably. On the other hand, Bjorklund and Butter (1973) found minimal relationship between teacher ratings and MFF variables, and McKinney (Note 8) was unable to replicate his 1975 study with a substantially larger sample at three different grade levels.

At the preschool level, Block et al. (1974) reported that reflective children were described as calm, considerate, competent, and task-oriented on the California Child Q set. Impulsive preschoolers were characterized as anxious, hypersensitive, and structure seeking. Contrary to Kagan's view (Kagan & Kogan, 1970), fast/inaccurate children on the MFF were not described as impulsive, minimally concerned, and unanxious. Moreover, when Block et al. (1974) examined the relative contributions of MFF errors and response latency in a 2 X 2 design, only 2 of 100 personality attributes could be attributed to the tempo factor, whereas 32 were related to response accuracy. Significant interactions between tempo and accuracy were found for 18 attributes.

More recently, two studies have appeared in which overt classroom behaviors have been related to reflection/impulsivity; however, both studies involved preschool children. Welch (Note 9) found that impulsive 4 year olds spent less time engaged in task activities and spent more time in transition from one activity to another. Also, when distracted, impulsives had greater difficulty maintaining on-task activities, whereas reflectives were better able to engage in two or more activities simultaneously. Huston-Stein, Susman, and Fredrich (Note 10) correlated 15 categories of behavior with impulsivity scores on the Kansas Reflection-Impulsivity Scale for Preschoolers (Wright, 1971). No significant correlations were obtained between impulsivity scores and behavior in a highly structured preschool classroom; however, 10 of the 15 categories were correlated with KRISP scores in relatively unstructured preschool classes.

In sum, studies supporting the generality of reflection/impulsivity as measured by the MFF test have typically used cognitive tasks that involved stimulus and/or response uncertainty. However, a key assumption involved in much of the research on reflection/impulsivity is that cognitive tempo represents a response predisposition that has broad behavioral implications. If this is not the case, the concept and its primary index, the MFF test, lose much of their attraction as useful predictors of academic progress and learning style in the classroom. At present, it is not clear exactly how reflection/impulsivity is manifested in a typical elementary classroom environment, although evidence has been obtained to suggest a relationship to several categories of task-oriented and social behavior in preschool children.

The general aim of the present study, then, was to investigate the classroom behavior patterns of reflective and impulsive elementary school children in several different contextual settings. The specific behaviors that were studied were selected according to three criteria. First, categories were selected that were conceptually similar to those behavior patterns that have been attributed to reflective and impulsive children in the literature (Block et al., 1974; Kagan, 1965a, 1966; Kagan & Kogan, 1970; Welch, Note 9). Secondly, several categories were adapted from existing observational systems that have been shown to predict academic achievement (Cobb, 1970; McKinney, Mason, Perkerson, & Clifford, 1975). Thirdly, some categories were developed based on teacher rating scales that were refined through pilot work in third and fourth grade classrooms (McKinney, 1975b; Schaefer, Note 11; Kohn & Rosman, 1974). Finally, since the subjects were drawn from those participating in a 3-year longitudinal study, it was possible to select children who had been consistently classified as reflective or impulsive, thereby assuring that extreme cases were studied. Also, this selection procedure minimized the possibility of misclassification due to the moderate reliabilities of MFF test scores (Ault, Mitchell, & Hartmann, 1976).

Method

Subjects

The children in the present study had participated in a 3-year longitudinal study of problem-solving strategies and had been given the Matching Familiar Figures (MFF) test during the fall of each year. A complete description of the study sample can be found in Chapter II of this report. Only children classified as reflective or impulsive in at least 2 of the 3 years were selected. This selection procedure minimized the problems caused by moderate reliabilities of MFF error scores (Ault et al., 1976).

The sample of 79 children included 37 9 year olds and 42 11 year olds. Of the 9 year olds, 6 were black and 18 were female; the comparable figures for 11 year olds were 9 and 24. Age, IQ, and SES of the reflective and impulsive children in both age groups are summarized in Table 16. No significant differences were found between reflectives and impulsives at each age level in CA or WISC-R verbal IQ. However, an analysis of Hollingshead ratings for SES showed that impulsives were significantly lower in SES than reflectives at both age levels, $\underline{t}$ (35) = 5.27, $\underline{p} < .01$, and $\underline{t}$ (40) = 2.26, $\underline{p} < .05$.

Observation Procedure

The System for Classroom Observation and Recording Behavioral Events (SCORBE) was developed specifically for this study. SCORBE was designed to record children's classroom behavior into predetermined categories that were assumed to be representative of reflective and impulsive behavior.

The definitions of 16 behavioral categories used in this study are given in Table 17. Two composite categories were also computed. First, to obtain an indication of the number of separate off-task episodes, each protocol was scored for the number of off-task blocks that were preceded by an on-task block. Second, off task, mean length was obtained by dividing the total number of off-task blocks by the number of off-task episodes.

Behavioral codes were checked on a specially prepared form with columns representing the 16 behavioral categories and rows representing

Table 16

Summary of Subject Characteristics

MFF Classification[a]	N	Age (Months)		IQ[b]		SES[c]	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
		9 Year Olds					
Reflectives	21	110.10	5.92	115.52	15.34	1.5	.51
Impulsives	16	113.19	5.58	110.75	15.97	2.0	.63
		11 Year Olds					
Reflectives	22	137.50	4.36	116.91	16.28	1.6	.67
Impulsives	20	135.40	5.13	113.70	14.85	1.7	.73

[a]Based on consistent MFF classification in 2 of 3 years for original longitudinal group; or 2 of 2 years for children added in year 2 of this project.

[b]Verbal scale of WISC-R.

[c]Since only the occupation of parents was available, socio-economic ratings were based on this single factor in partial accord with Hollingshead's (1965) two-factor index of social position. Hollingshead's category "1" was retained; categories "2", "3", and "4" were collapsed to yield category "2"; and categories "5", "6", and "7" were collapsed to yield category "3".

Table 17

Definitions of Behavioral Categories

Category	Definition	Example
Out-of-Seat	Child's legs and/or buttocks not in contact with chair or seat of desk	Sitting on back of chair, standing beside chair, leaning on desk, walking about
On-Task	Engaged in completion of a task specified by teacher	Retrieving items for task completion, going to teacher for assistance
Off-Task	Not engaged in completion of an assigned task	Wandering about room, play with items on the floor, social conversation
Independent Work	Works alone, using own materials, toward completion of a teacher-assigned task	Reading, writing, computing math problems
Attending	Visually fixates teacher or another child while either is explaining something to group of which child is a member	Eye contact with teacher giving instruction, responding to a teacher's question
Distracted	Visually fixates items or individuals other than those directly related to task at hand	Watch child walking past desk, visual wandering, daydreaming
Self-Verbalization	Speech-like movements of the lips and/or verbalization not directed toward another person	Self-directions, singing, mumbling
Nonfunctional Movement	Repetitive or persistent motoric, nonverbal movement not directly related to task completion	Rocking, bouncing leg, tapping pencil, scratching head, playing with mouth, sitting in tilted chair

(continued)

Table 17 (continued)

Category	Definition	Example
Physical Interference	Physically delays another child from completion of an assigned task	Grabbing another person or his material
Aggression	Physical motion toward another person or object, with or without contact, but with potential to inflict pain or damage	Swinging at or hitting another person with one's own body or other object, destruction of property
Teacher-Interaction-Task	Verbalizations between teacher and child related to the assigned task	Asking questions about assignment, answering teacher's questions about task
Teacher-Interaction-Social	Verbalizations between teacher and child about non-task topics	Talking about teacher's appearance, what will be done after school, something seen on television
Teacher-Interaction-Blurt	Verbalization to teacher about any topic or responses to a question asked of the group or another student	Blurting out an answer to teacher's question when no individual has been singled out for an answer, interrupting teacher
Child-Interaction-Task	Verbalizations between children related to the assigned task	Seeking or giving assistance, asking questions about the assigned work
Child Interaction-Social	Verbalizations between children about non-task topics	Talking about parties, planning after school activities, talking about a friend
Child-Interaction-Argue	Remarks toward another child are above general volume of classroom speech and involve conflicting point of view	Lo[illegible] voices, making faces, name calling

5-second blocks. Blocks were marked by tones generated by a cassette tape player carried by the observer. At the termination of each tone, which the observer heard by means of an earplug, the observer checked each appropriate behavior for that block. After checking the appropriate behaviors, the observer moved his pencil to the next block and awaited the next tone.

Two, 5-minute blocks of data were recorded for each subject in each of the three settings, yielding a total of 30 minutes of data per subject. Observations were scheduled with teachers each week, and an attempt was made to observe as many children as possible in a given classroom on the day that classroom was visited. No child was observed twice in the same contextual setting on a given day, and no child was observed during consecutive 5-minute periods. Within a given classroom, the order of observations was determined at random.

Observer Agreement

Behavioral categories were developed over a 4-month period by observations of classroom behavior. The categories selected for study represent those behaviors that were seen with some minimum frequency (at least daily) and that a naive observer would be likely to describe as typical of reflective or impulsive children.

After the 16 categories of impulsive or reflective behavior had been developed, two observers practiced simultaneous scoring of the categories until a mean agreement of 85% had been obtained. Approximately 12 hours of simultaneous observation was needed to reach this criterion.

Calculation of observer agreement was based on six 10-minute blocks on the final day of training and five 10-minute blocks on each of 4 days spread haphazardly over the 10 weeks of data collection. Computation of agreement was obtained, separately for each category, by dividing the number of blocks in which both observers scored a given category by the number of blocks in which both observers scored the category plus the number of blocks either observer scored the category but the other observer did not. Mean observer agreement averaged across all categories ranged between .840 and .932 with a mean across all 5 days of .871. Table 18 presents a breakdown of percentage agreement by behavior category.

Contextual Setting

The degree of task-oriented and appropriate social behavior in the classroom may well be a function of the extent of teacher supervision within a particular classroom setting. That is, if differences in classroom behavioral styles of reflective and impulsive children exist, it is possible that such differences are the result of degrees of direct teacher supervision of individual children during various periods of the day. Specifically, one would anticipate that a child would exhibit more task-oriented behavior and less non-task-oriented and socially inappropriate behavior in situations in which the teacher had direct supervision through proximate positioning than if the child were physically and attentionally distant from the teacher.

Therefore, behavioral observations were conducted in each of three settings conceptualized to represent a continuum of from low to high degrees of teacher supervision. A child was considered to be working in an individual setting if he was assigned seat work and had his own materials. Large group setting referred to situations in which the teacher or another adult was instructing a group of 15 or more students. The third setting, small group, was similar to large group

Table 18

Interobserver Agreements, Disagreements, and Percentage of Agreements by Individual Behavioral Category

Category	Number of Agreements	Number of Disagreements	Percentage Agreement[a]
Out-of-Seat On-Task	75	4	94.94
Out-of-Seat Off-Task	18	0	100.00
Independent Work	413	34	92.39
Attending	501	44	91.93
Distracted	161	57	73.85
Self-Verbalization	26	10	72.22
Nonfunctional Movement	170	46	78.70
Physical Interference	N.O.[b]	N.O.[b]	-
Aggression	N.O.[b]	N.O.[b]	-
Teacher-Interaction-Task	39	5	88.64
Teacher-Interaction-Social	N.O.[b]	N.O.[b]	-
Teacher-Interaction-Blurt	N.O.[b]	N.O.[b]	-
Child-Interaction-Task	46	19	70.77
Child-Interaction-Social	70	11	86.42
Child-Interaction-Argue	N.O.[b]	N.O.[b]	-
Overall Agreement			87.06

[a]percent agreement = $\frac{\text{agreements}}{\text{agreements + disagreements}}$

[b]Behaviors within this category were not observed (N.O.) during sessions in which observer agreements were being obtained.

in that it involved direct instruction by the teacher or another adult, but differed from large group in that the group contained 10 or fewer students.

Data Analysis

The experimental design was a 2 (MFF classification) X 2 (age group) X 3 (classroom contextual setting) factorial design with the first two factors repeated across the three levels of the third factor. Specifically, 10 minutes of observational data were obtained in each of the three contextual settings (individual, large group instruction, and small group instruction) for each child within the MFF classification (reflective versus impulsive) and age group (9- versus 11-year-old) factors.

Since the experimental design had more than one independent variable (MFF classification, age group, and contextual setting) and several dependent variables (observation categories), a multivariate analysis of variance (MANOVA) was appropriate (McCall, 1970). Consequently, a MANOVA technique was used to determine if the observation categories would differentiate between the two levels of the MFF classification and age group factors. Since the observation system consisted of 11 discrete observation categories, four non-discrete observation categories, and two composite categories, it was necessary to carry out separate analyses to insure independence among categories. In general, MANOVA was used as the primary analysis for discrete categories of behavior, and separate ANOVAs were carried out on non-discrete and composite categories.

In order to test for contextual effects, the linear (individual versus small group) and quadratic (individual versus the mean of the large and small groups) contrasts were computed for each category and analyzed by MANOVA (McCall & Appelbaum, 1973). The justification for these comparisons was that the individual versus small group comparisons would evaluate maximum differences between the three settings in which observations were made. The comparison of the individual setting with the mean of the two group settings would provide information from both group settings. Additional comparisons were not warranted because the two a priori contrasts would exhaust the available degrees of freedom.

Results

The means and standard deviations for each of the 15 observation categories and two composite categories by age group and MFF classification are shown in Table 19. Collectively, the 11 discrete categories presented in Part A of Table 19 were found to be poor discriminators between reflective and impulsive children. No significant multivariate or univariate main effects were found for cognitive style.

On the other hand, the analysis for discrete categories did yield a significant multivariate main effect for age group, F (11, 65) = 2.07, $p < .03$, and a total of five categories discriminated 9 from 11 year olds. Inspection of the univariate tests indicated that as a group 11 year olds: a) exhibited more independent work, F (1, 75) = 6.35, $p < .01$; b) attended more frequently, F (1, 75) = 10.14, $p < .002$; c) were less distracted, F (1, 75) = 6.37, $p < .01$; d) interrupted the teacher less with blurted comments, F (1, 75) = 4.18, $p < .04$; and e) engaged in less social conversation with their peers, F (1, 75) = 7.46, $p < .008$. These results indicate what appears to be a developmental trend toward more controlled and task-oriented behavior by older children in the study sample.

Table 19

Means and Standard Deviations of Observation[a] and Composite[b] Categories Averaged Across Contextual Setting

Category		9-year-olds Reflective (N=21)	9-year-olds Impulsive (N=16)	11-year-olds Reflective (N=22)	11-year-olds Impulsive (N=20)
A. Discrete Observation Categories[c]					
Independent	X̄	10.373	10.302	13.576	11.717
	SD	4.237	3.354	3.742	5.123
Attending	X̄	22.484	24.979	27.894	27.258
	SD	5.763	6.207	4.578	5.789
Distracted	X̄	13.238	12.167	9.016	10.533
	SD	6.679	5.868	3.318	4.865
Physical Interference	X̄	.508	.083	.030	.233
	SD	1.300	.122	.084	.617
Aggression	X̄	.000	.000	.000	.017
	SD	.000	.000	.000	.051
Teacher-Interaction-Task	X̄	2.000	1.771	2.091	2.550
	SD	2.180	1.885	2.114	3.114
Teacher-Interaction-Social	X̄	.000	.094	.000	.108
	SD	.000	.161	.000	.376
Teacher-Interaction-Blurt	X̄	.032	.167	.030	.017
	SD	.067	.304	.084	.051
Child-Interaction-Task	X̄	3.341	3.198	4.053	3.083
	SD	2.654	2.925	4.387	3.709

Table 19 (continued)

Category		9-year-olds Reflective (N=21)	9-year-olds Impulsive (N=16)	11-year-olds Reflective (N=22)	11-year-olds Impulsive (N=20)
Child-Interaction-Social					
	X̄	5.913	4.427	2.508	3.058
	SD	4.587	2.898	4.408	3.709
Child-Interaction-Argue					
	X̄	.825	.229	[illegible]	.025
	SD	3.706	.459	.000	.112
B. Non-Discrete Observation Categories[d]					
Out-of-Seat On-Task					
	X̄	3.143	2.844	1.114	1.625
	SD	4.062	3.671	1.520	1.996
Out-of-Seat Off-Task					
	X̄	.976	2.052	.212	.783
	SD	.975	2.519	.780	1.472
Self-Verbalization					
	X̄	2.468	2.583	1.318	1.417
	SD	1.855	1.464	1.322	1.358
Non-Functional-Movement					
	X̄	10.556	10.167	13.409	11.400
	SD	6.453	4.512	6.119	5.216
C. Composite Categories					
Off-Task. Incidence					
	X̄	4.921	4.875	3.947	5.158
	SD	.938	1.215	1.334	1.599
Off-Task: Mean Length					
	X̄	5.298	3.802	3.000	2.802
	SD	4.076	1.713	2.540	1.247

[a] Column means for observation categories are in excess of 60, the number of scoring time blocks per observation, because more than one non-discrete category could be scored during a given time block.

[b] The information in composite categories was obtained by reanalysis of observation categories (See definition of categories on pp. 117-118).

[c] Only one category could be scored during any given 5-second time block.

[d] Any three categories or two categories plus a discrete category could be scored during a 5-second time block.

The multivariate F fo~ the age X cognitive style interaction was not significant. However, univariate analysis revealed that 9-ye..'-old impulsives interrupted the teacher more frequently than 9-year-old reflectives and with greater frequency than either reflective or impulsive 1 year olds.

The analysis for the four non-discrete categories presented in Part B of Table 19 indicated that impulsive children were observed to be out-of-seat and off-task more often than were reflective children, F (1, 75) = 5.57, $p < .02$. Nine year olds were observed to be out-of-seat both on-task, F (1, 75) = 6.18, $p < .01$, and off-task, F (1, 75) = 8.49, $p < .005$, more often than 11 year olds. Also, 9 year olds tended to talk aloud to themselves more frequently than 11 year olds, F (1, 75) = 11.32, $p < .005$. None of the age X style interactions for non-discrete categories were significant.

Two composite categories were created to measure the incidence c ansition from on-task to off-task behavior, and the duration of off-task behavior once these behaviors were ex'ibited. These data are presented in Part C of Table 19. The results indicated a significant main effect for cognitive style, F (1, 75) = 4.50, $p < .03$, as well as a significant age X style interaction, F (1, 75) = 4.63, $p < .03$, for the incidence of off-task behavior. While minimal differences were found between reflectives and impulsives in the incidence of off-task behavior at the 9 year level, impulsive 11 year olds were off-task an average of 5.16 times per 5 minutes compared to 3.94 times per 5 minutes for reflective 11 year olds. No significant differences between reflectives and impulsives were found for the mean length of off-task behavior; however, 9 year olds stayed off-task longer than 11 year olds, F (1, 75) = 7.86, $p < .006$.

The mean frequency of behavior in the various categories as a function of contextual setting is shown in Figures A through I of Appendix B for the two style and age groups. The results of the within-subjects analysis of main effects due to setting are reported in Table 20. As Table 20 shows, a total of 9 out of 13 observation category contrasts indicated significant differences between individual and small group settings in the frequencies of the behavior observed. Specifically, these contrasts showed the following: a) more out-of-seat on-task behavior in individual work than small group; b) more out-of-seat off-task behavior in individual work than small group; c) less distraction in individual work than small group; d) more self-verbalization in individual work than small group; e) less physical interference in individual work than small group; f) less teacher-interaction-task in individual work than small group; g) less teacher-interaction-blurt in individual work than small group; h) less child-interaction-task in individual work than small group; and i) more child-interaction-social in individual work than small group. Also the test for the composite category of off-task:incidence reveals significantly less frequent occurrences of general off-task behavior in individual work than the small group setting.

The second set of tests for contextual setting was the comparison of the individual work setting against the mean of the large and the small group combined. The results of these tests are also presented in Table 20. Essentially, the results of individual versus small group and individual versus the combination of large and small group are statistically equivalent. With the exception of the teacher-interaction-task category in the combined group comparison, all differences were highly significant.

Table 20

Summary of Statistical Tests for Linear and Quadratic Trends (Main Effects for Contextual Settings)

Averaged Across MFF Classification and Age Group

Category	df=1,75	Contrast			
		Linear (Individual vs Small Group)		Quadratic (Individual vs $\bar{x}$ large plus Small Group)	
		F	P	F	P
A. Observation Categories					
Out-of-seat on-task		21.652	.001	24.176	.001
Out-of-seat off-task		8.998	.004	6.032	.016
Independent		------a	----a	------a	----a
Attending		------b	----b	------b	----b
Distracted		17.625	.001	45.017	.001
Self-verbalization		22.226	.001	26.591	.001
Non-functional-movement		7.748	.007	18.717	.001
Physical interference		1.558	NS	1.220	NS
Aggression		.999	NS	.192	NS
Teacher-interaction-task		11.831	.001	4.003	.049
Teacher-interaction-social		.034	NS	.460	NS
Teacher-interaction-blurt		8.211	.005	10.641	.002
Child-interaction-task		32.632	.001	31.795	.001
Child-interaction-social		15.626	.001	15.425	.001
Child-interaction-argue		.628	NS	.556	NS
B. Composite Categories					
Off-task:Incidence		19.161	.001	34.427	.001
Off-task:Mean Length		1.688	NS	.069	NS

No significant interactions were found for any of the observation categories between setting and cognitive style. However, a significant style X setting interaction was found for the incidence of off-task behavior in the individual versus small group contrast, F (1, 75) = 5.53, p < .02, and individual versus large and small group contrast, F (1, 75) = 4.40, p < .03. Reflective children at both age levels were more likely to be off-task in individual activities than in either small or large group activities, whereas impulsive children did not differ in frequency of off-task behavior across settings. In general, none of the age X setting interactions were significant for the individual versus small group contrasts. However, two interactions were significant for the individual versus large and small group contrasts. Nine year olds were observed out-of-seat and on-task more often in individual settings compared to 11 year olds, while the two age groups showed comparable frequencies of this behavior in group settings, F (1, 75) = 4.25, p < .04. Similarly, 9 year olds more often interrupted the teacher in group settings compared to 11 year olds, while the age group did not differ in individual settings, F (1, 75) = 4.14, p < .04.

An analysis of sex differences on the various observation and composite categories resulted in only one significant effect--boys interrupted the teacher more often than girls, F (1, 71) = 5.56, p < .02. However, further analysis revealed that impulsive boys in the 9-year group accounted for this finding, F (1, 71) = 4.01, p < .04. In general, children in the other groups did not differ in the frequency of interruption regardless of sex.

Discussion

In sum, the results of the present study do not support the general hypothesis that reflective and impulsive elementary school children display characteristic patterns of task-oriented and social behaviors in the classroom. Thus, the portrait of the impulsive child as being restless, distractible, uncontrolled, gregarious, and aggressive (Block et al., 1974; Kagan, 1965a, 1966; Kagan & Kogan, 1970) was not evident in the analysis of discrete overt classroom behaviors. Neither was evidence obtained to suggest that reflective children are more attentive, independent, and socially reserved than impulsive children.

Although no differences were found between reflective and impulsive children in the amount of time spent off-task, impulsive 11 year olds went off-task more frequently than reflective 11 year olds. Also, impulsive children as a group were observed to be out of their seats more often when they were off-task compared to reflective children. Thus, although the two style groups did not differ in the type of task-oriented behavior that was displayed, some evidence was found to suggest that impulsive children have greater difficulty in maintaining on-task behavior, and that they have a tendency toward greater mobility when not actively engaged in an appropriate task. The latter finding was somewhat consistent with previous studies which suggested that impulsive preschool children spend more time in transition from one activity to another than reflectives (Huston-Stein et al., Note 10; Welch, Note 9). However, the comparison of results from these studies and those from the present study is extremely tenuous given the differences in age levels and observational techniques.

The results from the present study revealed several significant classroom behavior differences between 9 and 11 year olds. In all these instances the behavior level exhibited by the older children indicated more task orientation. As a group, the 11 year olds spent less time out of their seat (both on- and off-task), were distracted less, talked less to their teachers about non-task-oriented topics, and when going off-task spent less time off-task before returning to the task than did 9 year olds. Further, 11 year olds spent less time vocalizing to themselves and interrupted the teacher less often than did 9 year olds.

Kagan (Kagan & Kogan, 1970) has reported that with increases in chronological age, children demonstrate less impulsivity in laboratory test situations. Sutton-Smith and Rosenberg (1959) report significantly less impulsive behavior in fifth graders than fourth graders as measured by self ratings. All of these studies, then, demonstrate a general pattern of behavior change over time for elementary school students. First, an increase in academic skills; second, as demonstrated in this study, an increase of more task-oriented behaviors in the classroom; third, more reflective responding on the MFF; and fourth, less impulsive behavior as measured by self-ratings. The extent to which the changes are interrelated is largely speculative. However, the possibility exists that behavioral differences between reflective and impulsive children may be more evident during the early elementary grades than during the developmental period covered by the present study.

With respect to the effects of contextual setting, it was anticipated that a general trend would be found in which increased frequencies of task-oriented behavior would be observed across the individual, large group and small group setting. This expectation was based solely on an increased degree of direct teacher supervision and probable physical proximity of the teacher. In general, the effects of the classroom contextual settings were powerful. In the individual versus small group comparison, a total of 13 of the 15 observation categories were appropriate for analysis. A total of 9 of these 13 categories revealed significant contextual effects. Further, the composite category of off-task incidence also yielded a significant setting effect. For the individual versus the mean of the small plus large groups comparison, the same 9 of the 13 observation categories and single composite category also yielded significant contextual effects at similar levels of significance.

An unexpected result was that students exhibited increased amounts of distracted behavior in the group settings. Perhaps this result can be explained by the nature of the task demands. For a child to complete an assigned task in the individual setting, it is required that the student focus his attention on the written materials. However, in the group instructional settings many of the tasks involved auditory, and sometimes visual, attention for processing the information that was being given by the teacher or another child. Frequently, that information could be acquired without direct visual focusing on the appropriate individual. It could be argued, therefore, that were the input demands similar in the individual and group settings, a decrease in distraction would result in the group settings.

Several inappropriate social behaviors also followed the expected relationship to setting. Self-verbalization and aggression categories were observed less frequently in the group than the individual settings. However, other inappropriate social behaviors did not follow the anticipated reduction with increased teacher supervision. Rather, non-functional movement, physical interference, child-interaction-argue, and teacher-interaction-blurt were observed to increase in group settings. Each of these behavioral categories can be expected to occur in group settings based upon the physical and verbal characteristics of the settings. During group instruction, when his hands are idle, a child is more likely to play with his shoestring, scratch his head, or annoy his neighbor. By sheer proximity, it is also likely that the occurrence of a disruptive or annoying behavior directed toward another peer will result in some form of retaliation. Finally, the teacher frequently asks questions of the group in general, anticipating an answer, but from no child in particular. Most group instruction follows a reasonably spontaneous dialogue between the teacher and students. Therefore, it is not surprising that in group instruction, children have a higher rate of "interrupting" the teacher than in the individual work setting where the child is to work quietly in his seat, while the teacher works with a group of students across the room.

In conclusion, the findings reported above cast considerable doubt on the validity of the MFF test as an index of reflective and impulsive classroom behavior. A recent review of the literature on reflection/impulsivity (see Chapter I) indicates that while there is a wealth of evidence which shows that cognitive tempo is an important predictor of problem-solving and academic progress, attempts to explain individual differences in tempo in terms of motivational factors have met with little success. Similarly, attempts to modify impulsivity by altering response tempo have been notably unsuccessful. On the other hand, considerable evidence has been obtained to suggest that reflective children differ in the way they process task information during problem solving, and that strategy instruction results in an increase in both performance and response tempo. Thus, we conclude that response tempo as measured by the MFF test is an indirect index of strategy behavior, as opposed to a generalized response style or predisposition.

If this is the case, then the MFF test may be of some value in identifying competent and incompetent problem solvers at a given age level when more direct measures are not appropriate or available. However, if the goal is to identify impulsive children for classroom intervention, observational measures or informant ratings may be more appropriate. Similarly, since a number of recent studies have shown that classroom behaviors, such as those observed in this study, are important determinants of academic achievement (Cobb, 1972; McKinney et al., 1975), perhaps the focus of attempts to modify impulsivity should be on behavioral rather than cognitive styles.

VI. Conclusion: Reflections on Impulsivity

The studies described herein were designed to: 1) investigate the development of problem-solving strategies in reflective and impulsive children during the elementary school period; 2) assess the generality of conceptual tempo and strategy behavior across a number of different problem-solving tasks; 3) determine the efficacy of instruction in more advanced strategies as a means of modifying impulsive and/or immature problem-solving behavior; and 4) explore the behavioral implications of reflection/impulsivity in the classroom.

Although impressive evidence has been gathered over the past decade indicating that reflection/impulsivity is an important dimension of cognitive style that contributes to performance on a variety of problem-solving tasks and achievement measures, those factors that account for individual differences in accuracy and response tempo independently of IQ have remained rather poorly understood. Kagan has proposed that performance differences between reflective and impulsive children are the result of anxiety over potential failure in situations of high response uncertainty (Kagan & Kogan, 1970). However, the anxiety hypothesis has not been generally supported in the literature (Bentler & McClain, 1976; Bush & Dweck, 1975; Messer, 1970; Reali & Hall, 1970).

The analysis of strategy development in this research suggests an alternative explanation for the consistent finding that reflective children are more efficient problem solvers than impulsive children. The results of the first study described in Chapter II showed that when performance differences were found between reflectives and impulsives, reflectives used more systematic and/or developmentally mature strategies. However, the effects of reflection/impulsivity on problem solving varied with developmental level over the elementary age range, the relative difficulty of the problem for children of a given age, and repeated experience with the type of problem at hand.

The course of strategy development over the elementary school period was marked by three basic changes in approach. The most primitive strategy that was observed consisted of guessing solutions in a trial-and-error fashion, or responding in a random sequence. Between the ages of 7 and 9 years, virtually all of the children in the study sample learned to avoid noninformative responses and adopted an informative hypothesis-scanning strategy. This behavior was accompanied by the gradual appearance of categorical hypotheses in which children began to group solution possibilities together. Between the ages of 8 to 10 years, the dominant approach was a mixed strategy in which both concrete and abstract hypotheses were used. Gradually, the frequency of categorical hypotheses increased between 9 and 12 years, and by year 12 most children displayed the optimal focusing strategy on all but the most difficult task that was used.

Developmentally, cognitive style had the greatest impact on problem-solving behavior during the early elementary school years. Between the ages of 7 to 9 years reflective children performed more efficiently than impulsive children on two of the four tasks that were used, and showed a more accelerated rate of strategy development. Reflective and impulsive children who were studied between the ages of 9 and 11 years were not found to differ in either performance or pattern of development. However, reflectives who were tested initially at year 11 in the oldest cohort were superior to impulsives on two tasks. Following this initial deficit at year 11, the performance of both groups tended to stabilize at optimal levels between 12 and 13 years. Thus, longitudinal results with respect to strategy differences between reflective and impulsive children confirm those reported previously in cross-sectional studies with the same tasks (Ault, 1973; Cameron, 1976; McKinney, 1973; McKinney, 1975a); however, the present studies suggest that cognitive style may be a more potent factor in the performance of younger children than in that of older children.

As expected from previous research, response latency and error scores on the MFF test were moderately stable over a 2-year period in the longitudinal study. However, MFF errors were more consistently correlated with measures of problem solving than were MFF latencies. These results suggested that response accuracy, as measured by the MFF test, rather than response tempo, accounted for performance differences between reflective and impulsive children. In order to test this possibility, an extensive re-analysis of the data from the first year of the longitudinal study was undertaken by using multiple regression and part correlational methods to evaluate the combined and separate contributions of the MFF test variables to performance. Also, this analysis was carried out to determine the relationship between reflection/impulsivity and academic achievement for the longitudinal sample.

The results of this study reported in Chapter III indicated that response tempo, as measured by the MFF test, was not an important determinant of problem-solving efficiency and achievement. Thus, response accuracy rather than response tempo was the dimension of consequence. In each case the variance in problem solving and achievement associated with MFF latency was small and did not contribute variance to performance over and above that accounted for by MFF errors. Moreover, MFF latency did not show a consistent pattern of intercorrelation with tempo measures on problem-solving tasks over time in the longitudinal sample.

These findings provide very little support for the assumption that cognitive tempo on the MFF test reflects a predisposition to respond carefully or hastily in problem situations involving uncertainty (Kagan, 1966). Rather, the most tenable and parsimonious interpretation of these results is that response tempo is an artifact of the child's strategy behavior. Stated simply, when reflective children perform more efficiently than impulsive children on a given task, their slower response tempo can be attributed to the use of more sophisticated and necessarily time-consuming strategies.

Accordingly, the results reported in Chapters II and III suggest an explanation for previous findings that the response latencies of impulsive children on the MFF test can be increased by using a variety of modification techniques without necessarily improving the quality of their performance (Albert, 1970; Debus, 1970; Kagan, 1966; Kagan, Pearson, & Welch, 1966b; Reali & Hall, 1970). If impulsive children have not acquired the cognitive skills that are necessary for effective hypothesis testing, then techniques which merely operate on response tempo cannot be expected to enhance performance. On the other hand, if impulsive children are taught more mature and efficient strategies for problem solving, then one should observe not only improved performance but also a more reflective style, as measured by response latency.

This hypothesis was tested directly in three studies reported in Chapter IV. These studies demonstrated a direct relationship between the type of strategy that was used and response latency during problem solving. Children who were taught a relatively simple strategy for avoiding errors on the Pattern Matching task emitted longer latencies than children who were untrained, and children who were taught an optimal focusing strategy emitted even longer latencies than those who were taught a simpler scanning strategy. Similarly, in Experiment III of this chapter it was found that style instruction which emphasized a careful, reflective approach with an enforced delay of responding was ineffective in increasing the performance and tempo of impulsive subjects on the Pattern Matching task. However, impulsive subjects who were taught a focusing strategy increased both their problem-solving efficiency and response tempo. Further, reflective children who received no training performed less efficiently and with shorter latencies than impulsive children who received strategy training. Thus, these results support those of previous studies in which impulsive behavior and error rate were modified on the MFF test by strategy instruction (Egeland, 1974; Meichenbaum & Goodman, 1971; Ridberg, Parke, & Hetherington, 1971), and extend them to other types of problem-solving tasks.

In addition to demonstrating a functional relationship between response tempo and strategy behavior, the studies in Chapter IV indicate that young elementary school children who process information in a random fashion are capable of acquiring and transfering complex strategies that are typically only observed in much older children. These results suggest that immature and/or impulsive problem solvers have the component skills that are necessary for more efficient performance, but often fail to combine them spontaneously and apply them to the problem at hand without suitable instruction. In conceptualizing this apparent deficiency in young problem solvers, White (cited in Reese & Lipsitt, 1970) described the period between 5 and 8 years as a transition from an associative level of functioning to a cognitive level, and noted that mediational deficiencies in young children are related to response latencies (Reese & Lipsitt, 1970, pp. 57-59). He pointed out that mediated responses require a longer latency than associative responses. In problem situations which elicit a mediating response as well as an associative response, the child must inhibit first-available associate responses in order for mediational responses to occur. Thus, in the present studies special instruction may have facilitated this shift from an associate to a cognitive level of functioning which necessarily involved more time to process task information.

In the final study, described in Chapter V, an attempt was made to relate reflection/impulsivity, as defined by the MFF test, to task-oriented and social behaviors in the classroom. Although reflective and impulsive children were found to differ in two of the categories that were examined, impressive evidence was not obtained to support the contention that reflection/impulsivity generalizes to classroom behavior. Rather, the data indicated that classroom environment and age were the major determinants of overt behavior patterns. Therefore, the findings of this study do not support the notion that performance on the MFF test represents a generalized response style or behavioral predisposition. Consequently, the concern expressed by Block, Block, & Harrington (1974) that too much surplus meaning has been attributed to the terms reflective and impulsive, as operationalized by accuracy and tempo on the MFF test, appears to be well founded.

Collectively, these studies provide rather strong support for the notion that cognitive style, as operationalized by response tempo in situations of response uncertainty, reflects individual differences in the development of essential problem-solving skills. One major implication of these results is that the generality of the reflection/impulsivity dimension may be limited to a rather narrow, but educationally important, set of tasks that require more time-consuming strategies for efficient performance. On the other hand, if reflective children, as identified by slow/accurate performance on the MFF test, are simply more competent problem solvers than impulsive children, then they may be better able to adapt their approach to the different requirements of different tasks, as was suggested in a recent study by Bush and Dweck (1975). In any event, it is clear that future research should concentrate on the manner in which children process task information, and those factors that account for competent strategy development, rather than the speed with which information is processed.

VII. References

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Appendix A: Means and Intercorrelations of Strategy Measures for Longitudinal Analysis

Table A

Mean Performance of Cohort A for Each Dependent Measure on Matrix Solution Task

Variable	7 years		8 years		9 years	
	R	I	R	I	R	I
Information Score	.69	.62	.82	.70	.89	.79
Type of Hypothesis						
% Attribute	47.20	32.20	67.60	51.40	77.70	61.90
% Spatial	4.20	1.70	3.70	0.00	5.10	0.00
% Specific Instance	27.70	5.34	21.10	39.60	6.10	24.60
% Noninformative	20.90	12.90	7.60	9.00	11.10	13.90
Type of Strategy						
# Focusing	1.43	.88	2.57	2.00	3.14	2.25
# Scanning	.07	.50	0.00	.06	0.00	.50
# Random	.50	1.19	.57	1.19	0.00	0.00
# Mixed	2.00	1.44	.86	.75	.86	1.25

Table B.

Mean Performance of Cohort B for Each Dependent Measure on Matrix Solution Task

Variable	9 years R	9 years I	10 years R	10 years I	11 years R	11 years I
Information Score	.81	.77	.97	.93	.91	.91
Type of Hypothesis						
% Attribute	69.10	60.40	85.10	83.60	87.70	86.40
% Spatial	4.20	3.20	5.30	5.70	1.60	3.50
% Specific Instance	12.[illegible]0	19.60	3.00	5.30	0.00	0.80
% Noninformative	14.10	17.10	1.90	4.46	10.60	9.30
Type of Strategy						
# Focusing	2.68	2.00	3.73	3.53	3.64	3.59
# Scanning	0.00	0.00	0.00	0.00	0.00	0.00
# Random	.18	.06	0.00	0.00	0.00	0.00
# Mixed	1.14	1.94	.27	.47	.36	.41

Table C

Mean Performance of Cohort C for Each Dependent Measure on Matrix Solution Task

Variable	11 years		12 years		13 years	
	R	I	R	I	R	I
Information Score	.87	.86	.99	.97	.96	.95
Type of Hypothesis						
% Attribute	81.20	79.10	95.30	95.10	93.30	92.60
% Spatial	3.80	4.50	2.90	0.00	1.40	.60
% Specific Instance	2.40	0.90	1.00	0.00	1.50	1.00
% Noninformative	12.70	15.90	0.80	4.90	3.90	5.80
Type of Strategy						
# Focusing	3.31	2.80	3.95	4.00	3.77	3.80
# Scanning	0.00	0.00	0.00	0.00	0.00	0.00
# Random	0.00	0.00	0.00	0.00	0.00	0.00
# Mixed	.69	1.20	.15	0.00	.23	.20

Table D

Percentage Constraint-seeking and Hypothesis-scanning Strategies on Twenty Questions Problems

Cohort A	7 years R	7 years I	8 years R	8 years I	9 years R	9 years I
Pictures Problems						
% Constraints	25.60	28.40	39.90	27.40	66.00	42.50
% Hypotheses	57.10	61.20	41.80	64.10	23.20	51.50
Verbal Problems						
% Constraints	25.00	16.40	38.80	26.10	33.80	26.60
% Hypotheses	71.90	75.70	56.50	64.30	65.80	69.10

Cohort B	9 years R	9 years I	10 years R	10 years I	11 years R	11 years I
Pictures Problems						
% Constraints	39.80	40.60	62.70	56.80	67.70	62.20
% Hypotheses	31.50	31.40	27.30	35.60	23.30	25.40
Verbal Problems						
% Constraints	29.80	26.60	44.50	40.70	50.90	37.50
% Hypotheses	64.40	69.80	51.60	53.40	48.70	59.80

Cohort C	11 years R	11 years I	12 years R	12 years I	13 years R	13 years I
Pictures Problems						
% Constraints	62.20	44.70	70.10	56.40	65.40	55.40
% Hypotheses	16.30	33.80	23.60	38.90	18.00	22.40
Verbal Problems						
% Constraints	31.90	26.80	58.20	47.60	47.00	38.00
% Hypotheses	65.50	70.80	41.50	47.00	53.00	61.30

Table E

Correlations Between MFF Measures and Performance on Matrix Solution Task

	Year	Information Score			Percent Attributes			Percent Specific Instances		
		7	8	9	7	8	9	7	8	9
Cohort A										
MFF Errors	7	-26*	-23	-20	-29*	-21	-22	07	-12	-16
	8		-17	-13		-12	-13		01	-01
	9			-29*			-35*			07
MFF Latency	7	04	13	10	10	12	15	-01	-01	-01
	8		27*	17		31*	26*		-17	-15
	9			09			17			-06
Cohort B										
		9	10	11	9	10	11	9	10	11
MFF Errors	9	-13	-27*	-20	-10	-09	-07	-08	-01	-04
	10		-30*	-14		-20	-02		00	-03
	11			-06			02			-07
MFF Latency	9	-07	07	10	06	09	09	-11	01	-05
	10		15	05		17	08		-11	-13
	11			-20			-06			-08
Cohort C										
		11	12	13	11	12	13	11	12	13
MFF Errors	11	-18	-11	-11	-20	08	09	04	-17	-05
	12		-17	-16		-12	21		09	-27
	13			-27			-38*			-16
MFF Latency	11	27	28	20	29*	18	06	-12	-09	-09
	12		00	26		02	30*		-03	-19
	13			20			31*			-09

*p .05

Table F

Correlations Between MFF Measures and Performance on Pattern Matching Task

	Year	Information Score			Noninformative Responses			Focusing Responses		
		7	8	9	7	8	9	7	8	9
Cohort A										
MFF Errors	7	-12	-37*	-36*	15	32*	39*	06	-27*	-26*
	8		-26*	-19		20	11		-13	-28*
	9			-34*			31*			-27*
MFF Latency	7	06	18	16	-05	-13	-19	03	14	10
	8		36*	32*		-32*	-28*		20	31*
	9			17			-11			22
Cohort B										
		9	10	11	9	10	11	9	10	11
MFF Errors	9	-24*	-29*	-27*	31*	24*	20	-05	-29*	-27*
	10		-23*	-20		23*	14		-16	-31*
	11			-07			-001			-15
MFF Latency	9	[illegible]	03	06	-14	-03	-06	08	-05	03
	10		-01	-02		-02	08		-03	09
	11			14			-07			20
Cohort C										
		11	12	13	11	12	13	11	12	13
MFF Errors	11	-55*	-42*	-36*	53*	36*	15	-47*	-35*	-57*
	12		-19	-20		18	14		-16	-23
	13			[illegible]			30*			-29
MFF Latency	11	29*	22	[illegible]	-28	-17	-10	28	22	37*
	12		15	17		-14	-07		[illegible]	28
	13			26			-16			36*

*p < .05.

Table G

Correlations Between MFF Measures and Twenty Questions - Pictures and Verbal Problems

	Year	Twenty Questions - Pictures						Twenty Questions - Verbal					
		% Constraints			% Hypotheses			% Constraints			% Hypotheses		
		7	8	9	7	8	9	7	8	9	7	8	9
Cohort A													
MFF Errors	7	04	-29	-29*	08	34*	27*	-17	-16	-20	07	04	12
	8		-10	-12		02	04		16	-02		-15	-02
	9			-25			27*			13			-23
MFF Latency	7	-21	08	13	12	-20	-18	07	12	35*	04	-07	-31*
	8		09	14		-15	-14		-08	02		12	06
	9			02			-05			-01			06
Cohort B													
		9	10	11	9	10	11	9	10	11	9	10	11
MFF Errors	9	-08	-23	-15	-03	18	-12	-09	-07	-15	19	01	12
	10		-24	01		29*	-19		02	-10		-08	08
	11			-04			-0[illegible]			-17			15
MFF Latency	9	-19	07	19	13	-14	-16	02	21	05	-11	-15	-02
	10		14	-05		-17	03		-05	09		13	-08
	11			-02			-07			25*			-23*
Cohort C													
		11	12	13	11	12	13	11	12	13	11	12	13
MFF Errors	11	-37*	-62*	-34*	21	60*	10	-31	-29	-22	25	13	21
	12		-17	-30*		14	33*		-42*	-10		48*	09
	13			-32*			30*			-11			09
MFF Latency	11	46*	32	39*	-35*	-37*	-27	24	20	05	-17	-10	-01
	12		17	38*		-31	-21		14	08		-15	-07
	13			35*			-24			12			-07

*p .05.

Table H

Intercorrelation of Strategy Measures Between Years 01 and 02

Cohort A	MS	PM	PICT	VERB
Matrix Solution (MS) Information Score	63*	56*	56*	22
Pattern Matching (PM) Information Score	60*	61*	50*	28
Twenty Questions - Pictures (PICT) % Constraints	56*	22	62*	13
Twenty Questions - Verbal (VERB) % Constraints	46*	51*	44*	27

Cohort B	MS	PM	PICT	VERB
Matrix Solution (MS) Information Score	13	19	11	08
Pattern Matching (PM) Information Score	-07	55*	26*	13
Twenty Questions - Pictures (PICT) % Constraints	31*	28*	11	15
Twenty Questions - Verbal (VERB) % Constraints	32*	28*	36*	57*

Cohort C	MS	PM	PICT	VERB
Matrix Solution (MS) Information Score	[illegible]*	05	0	-01
Pattern Matching (PM) Information Score	23	55*	50*	33*
Twenty Questions - Pictures (PICT) % Constraints	19	09	17	16
Twenty Questions - Verbal (VERB) % Constraints	24	32*	26	45*

*p < .05.

Table I

Intercorrelation of Strategy Measures Between Years 02 and 03

Cohort A	MS	PM	PICT	VERB
Matrix Solution (MS) Information Score	73*	44*	32*	24
Pattern Matching (PM) Information Score	63*	64*	55*	31*
Twenty Questions - Pictures (PICT) % Constraints	63*	58*	46*	31*
Twenty Questions - Verbal (VERB) % Constraints	23	22	17	22
Cohort B	**MS**	**PM**	**PICT**	**VERB**
Matrix Solution (MS) Information Score	06	22	-03	13
Pattern Matching (PM) Information Score	36*	60*	24	35*
Twenty Questions - Pictures (PICT) % Constraints	05	31*	50*	13
Twenty Questions - Verbal (VERB) % Constraints	13	27*	-04	47*
Cohort C	**MS**	**PM**	**PICT**	**VERB**
Matrix Solution (MS) Information Score	17	28	03	00
Pattern Matching (PM) Information Score	14	[illegible]*	43*	10
Twenty Questions - Pictures (PICT) % Constraints	[illegible]	30*	19	20
Twenty Questions - Verbal (VERB) % Constraints	-02	10	13	39*

* .05

Table J

Intercorrelation of Strategy Measures Between Years 01 and 03

Cohort A	MS	PM	PICT	VERB
Matrix Solution (MS) Information Score	55*	49*	38*	35*
Pattern Matching (PM) Information Score	57*	61*	32*	35*
Twenty Questions - Pictures (PICT) % Constraints	55*	40*	33*	30*
Twenty Questions - Verbal (VERB) % Constraints	35*	15	17	33*
Cohort B	**MS**	**PM**	**PICT**	**VERB**
Matrix Solution (MS) Information Score	10	49*	08	03
Pattern Matching (PM) Information Score	20	52*	40*	38*
Twenty Questions - Pictures (PICT) % Constraints	16	21	24	14
Twenty Questions - Verbal (VERB) % Constraints	22	23*	13	44*
Cohort C	**MS**	**PM**	**PICT**	**VERB**
Matrix Solution (MS) Information Score	10	17	04	18
Pattern Matching (PM) Information Score	15	33*	15	22
Twenty Questions - Pictures (PICT) % Constraints	45*	24	45*	51*
Twenty Questions - Verbal (VERB) % Constraints	25	15	05	35*

*$p < .05$.

Appendix B: Mean Frequency of Behavior in SCORBE Categories by MFF Classification, Age and Contextual Setting

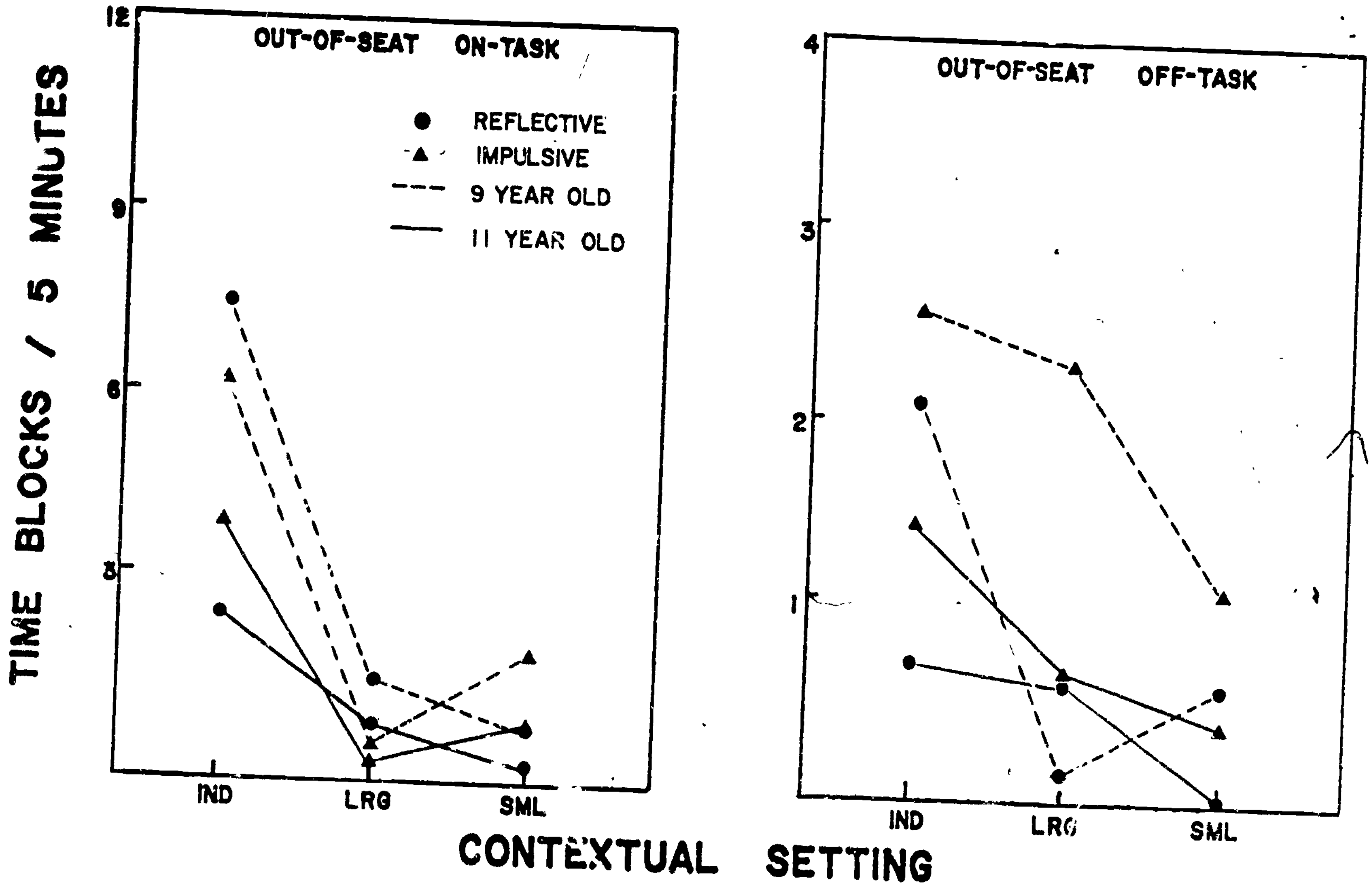

Figure A. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

163

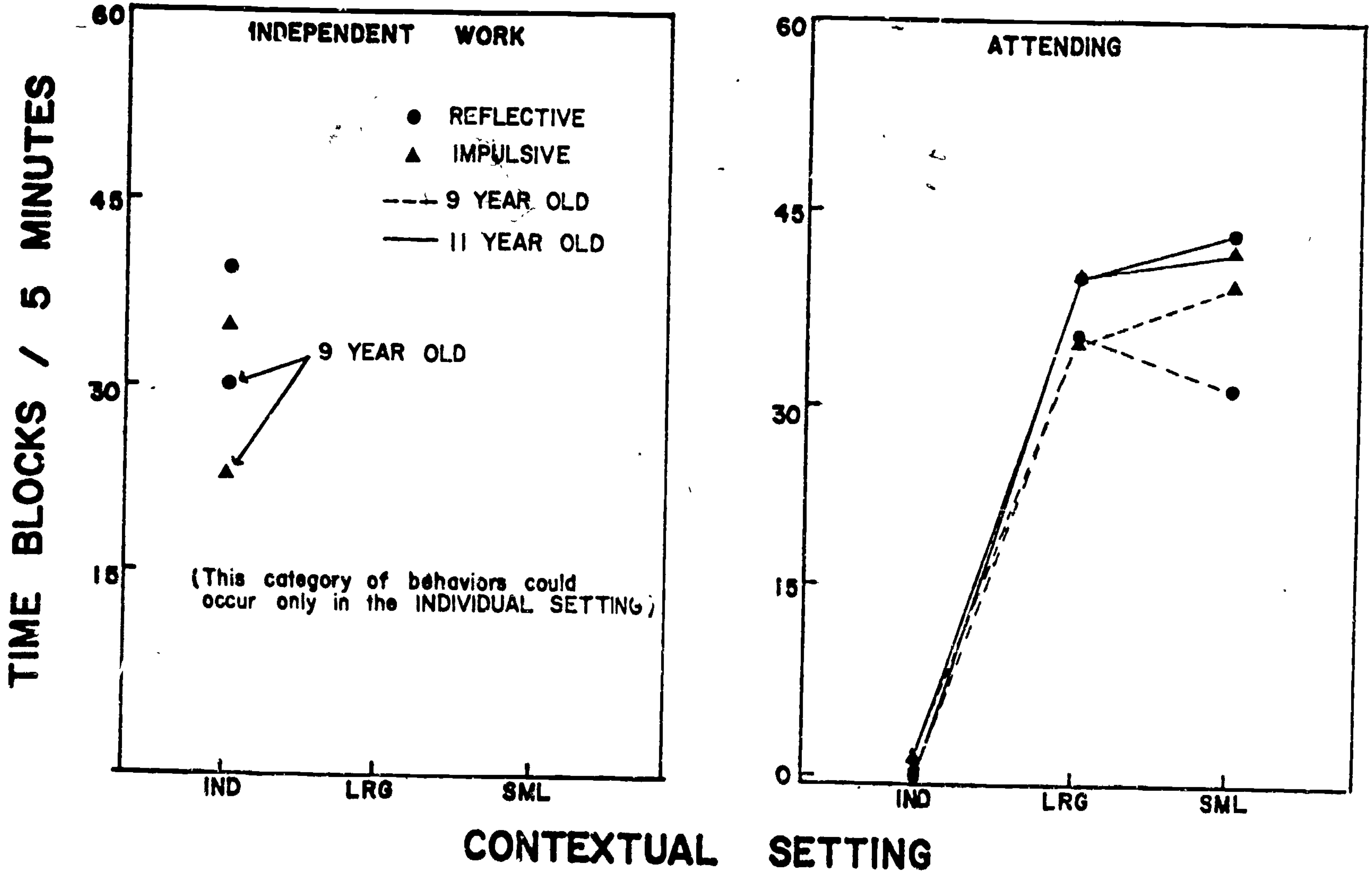

Figure 8. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

164

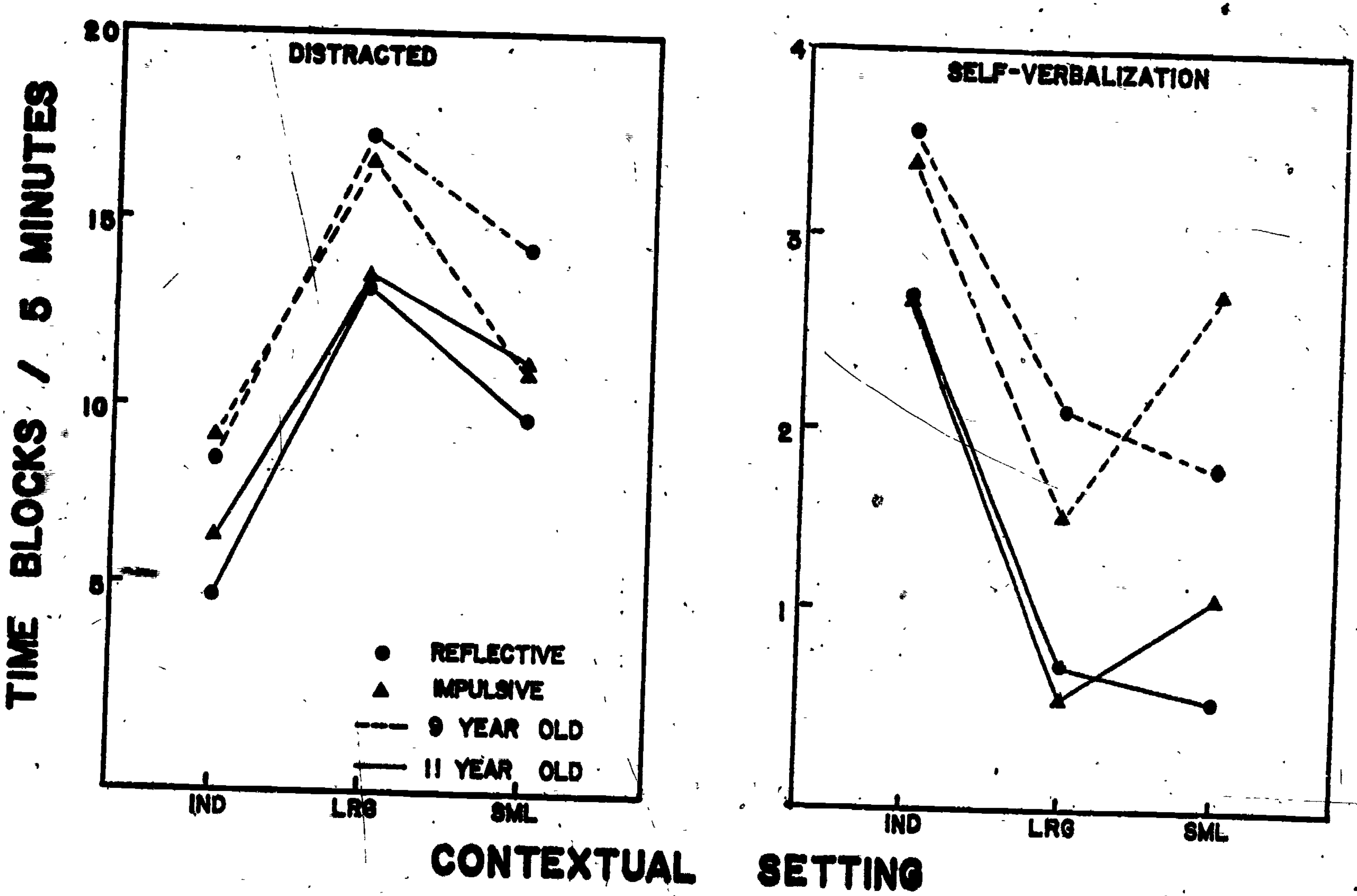

Figure C. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

165

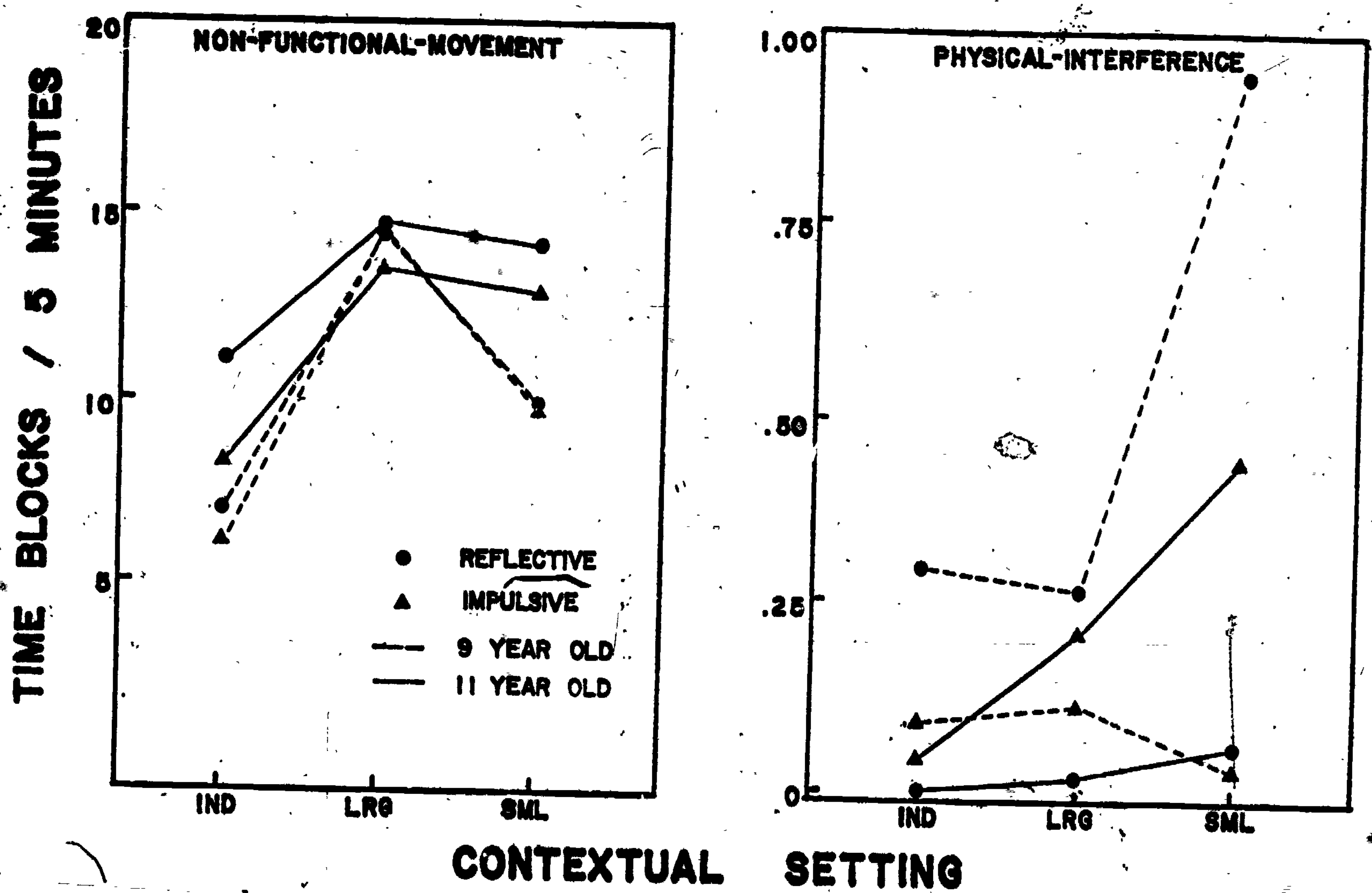

Figure D. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

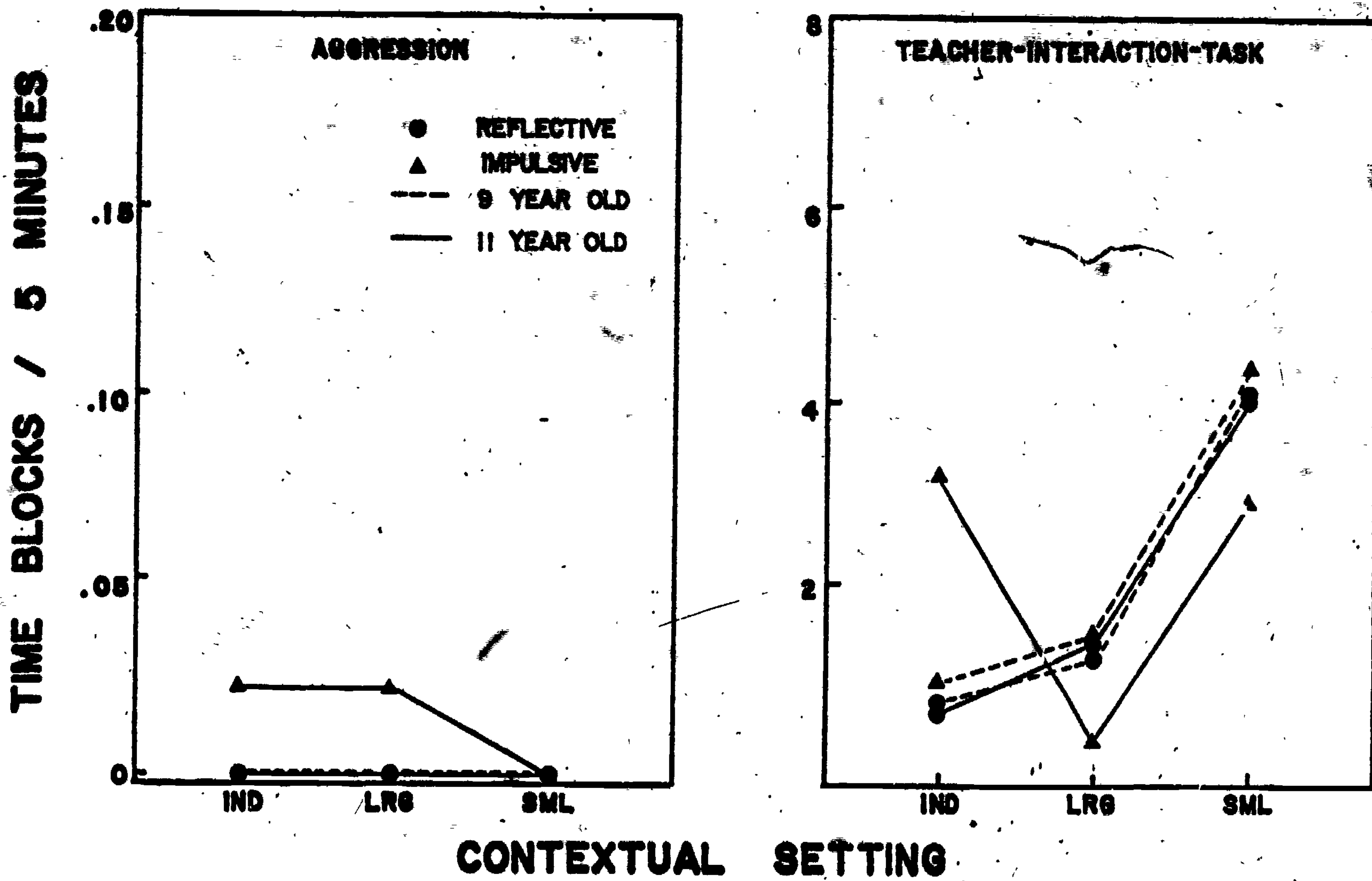

Figure E. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

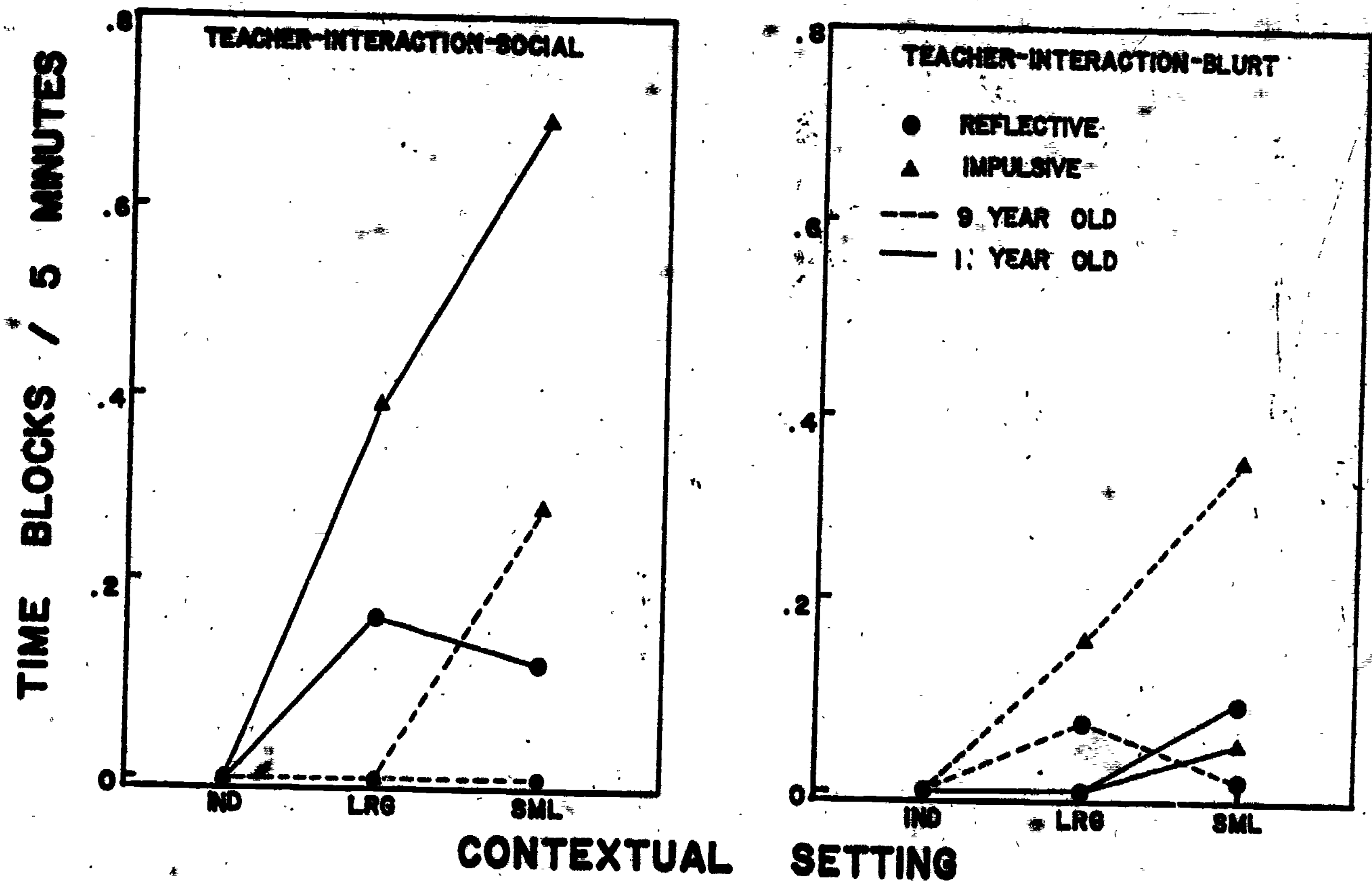

Figure F. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

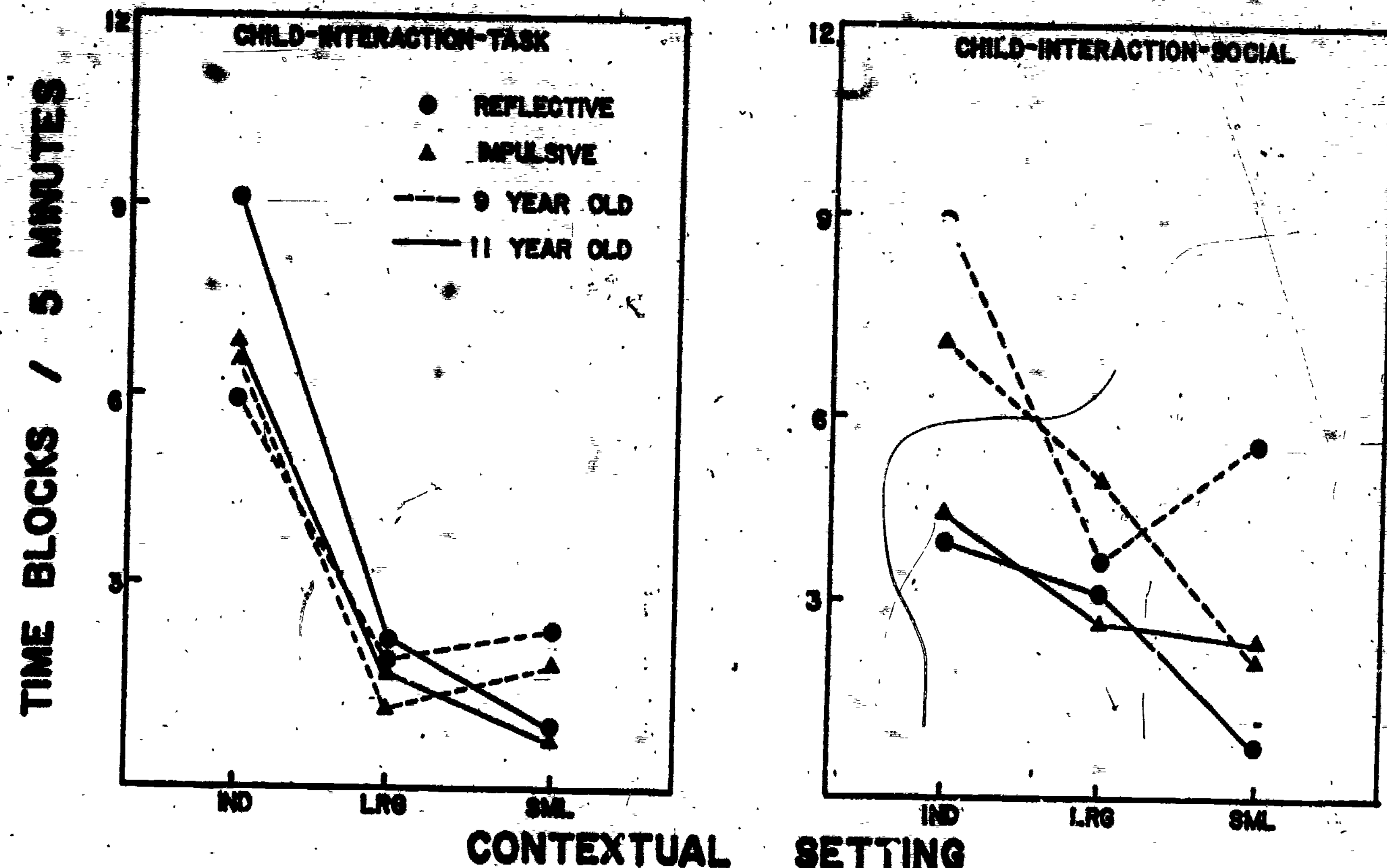

Figure G. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

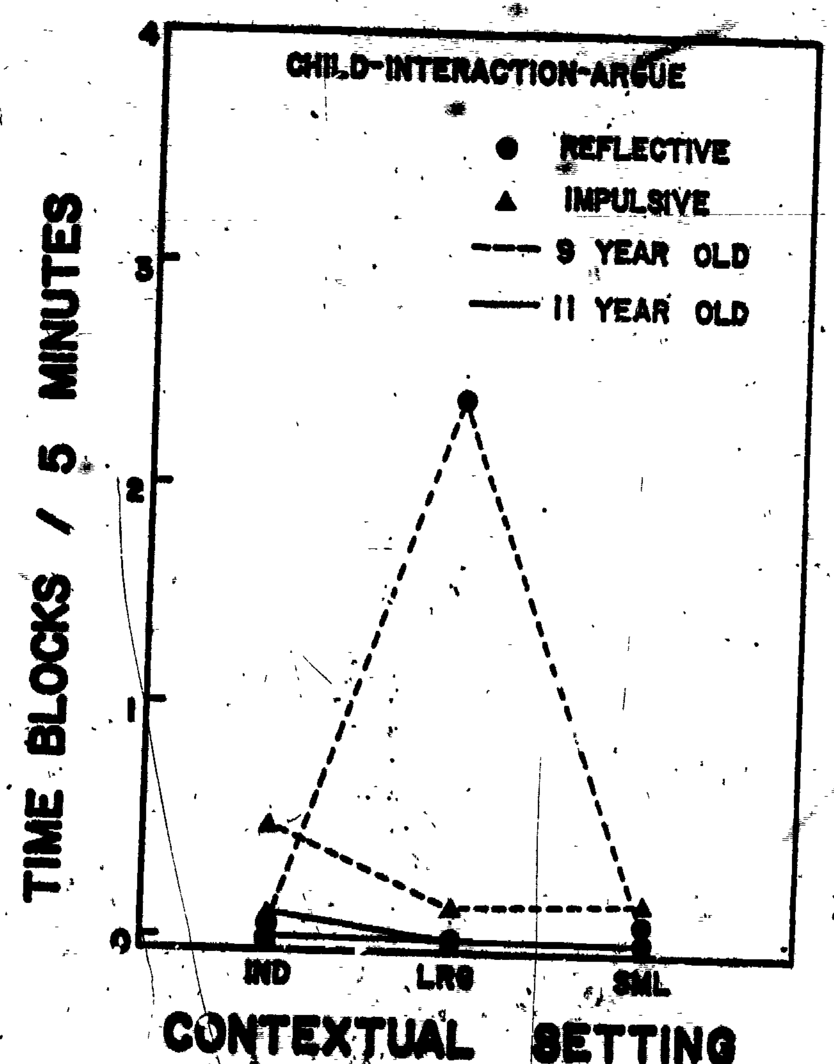

Figure H. Mean frequency of observation categories by MFF classification, by age group by contextual setting.

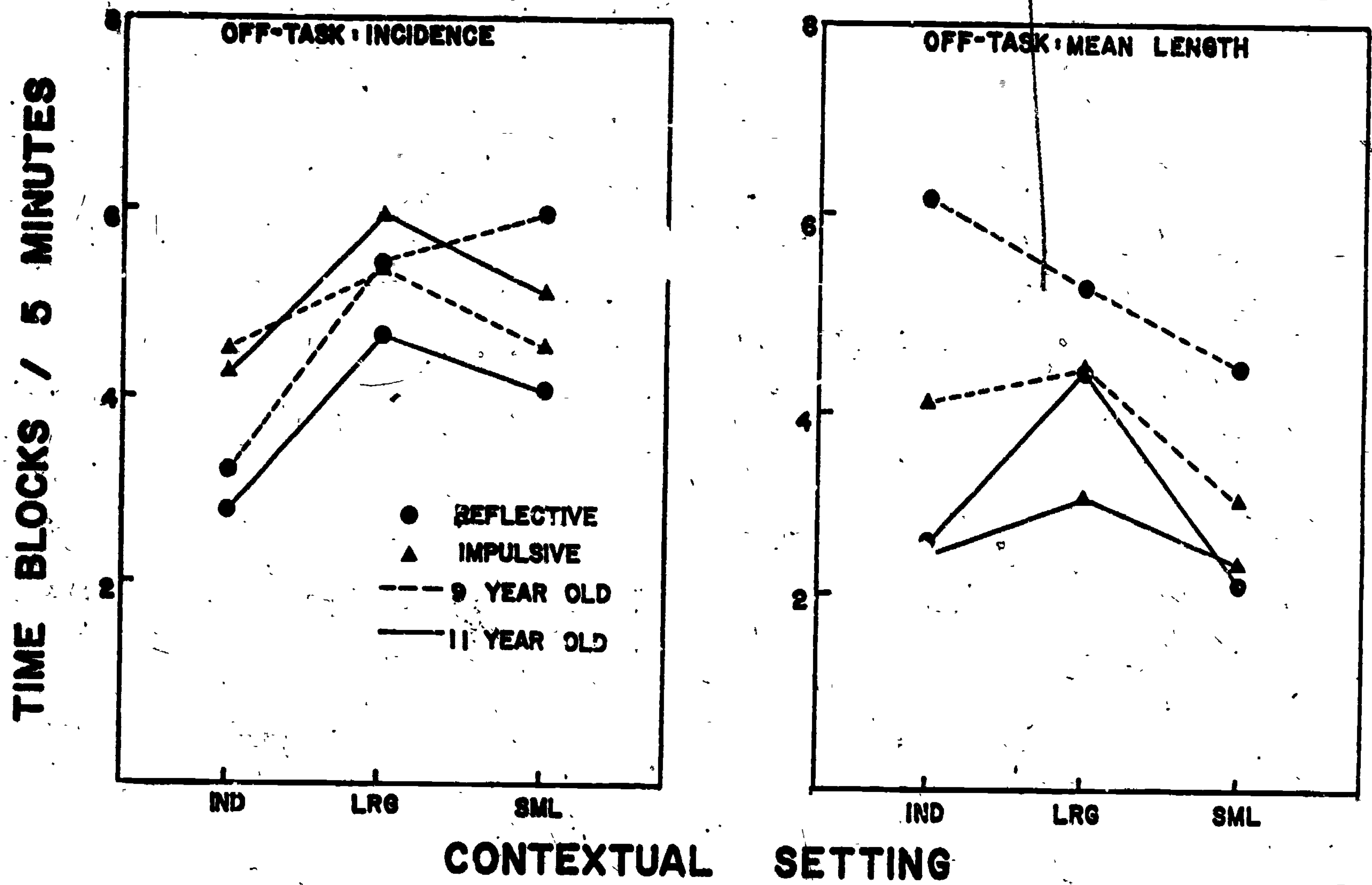

Figure I. Mean frequency of off-task composite categories by MFF classification, age group and contextual setting.

171