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A DEVELOPMENTAL STUDY OF STRATEGIES AND THE PROCESSING OF A TWO-COLOR MULTI-ELEMENT VISUAL ARRAY

by

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A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, the City University of New York.

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Date

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Abstract

A DEVELOPMENTAL STUDY OF STRATEGIES AND THE PROCESSING OF A TWO-COLOR MULTI-ELEMENT VISUAL ARRAY

by

Chih-mei Lin Chen

Advisor: Professor Joseph Glick

This study investigated the possibility that age differences in STM performance might be partly due to developmental differences in spontaneous use of organizational strategies -- encoding strategy and report strategy. Five-year-olds, eight-year-olds, and nineteen-year-olds were presented with visual arrays, each of which consisted of four red letters and four black letters arranged in a cross shape, and was exposed for 125 msec. The response measure was the number of letters correctly recalled from an array. Half of the subjects from each age group were experimentally provided with a sequential encoding strategy while the other half of the subjects were not. The sequential encoding strategy was manipulated by giving subjects a verbal instruction, just prior to each stimulus presentation, to "look at" red (black) letters first and then black (red) letters. The order of report was also controlled by giving subjects a variable report-order instruction immediately upon the termination of stimulus presentation. The report-order instruction allowed subjects to report letters in any order during some trials, but it imposed certain report strategies upon subjects during some other trials.

The results showed that when subjects were not provided with an encoding strategy nor with a report strategy, five-year-olds correctly recalled fewer items than eight-year-olds, and eight-year-olds recalled fewer items than nineteen-year-olds. However, with the experimental provision of a sequential encoding strategy, only the performance level of the five-year-old group was significantly increased (to the level of eight-year-olds). This suggests that five-year-olds' inferior performance can be partly attributed to their lack of spontaneous use of a sequential encoding strategy.

On the other hand, the experimental provision of a report strategy was not effective for any age group in increasing the total number of letters correctly recalled. Analyses of subjects' free report protocols suggest that subjects of all age levels had spontaneously organized their verbal report. The role of organizational strategies in information processing as well as the developmental differences in spontaneous use of encoding and reporting strategies are discussed.

This study also found that under the condition of a sequential encoding instruction, adults increased the number of correctly recalled letters with encoding precedence and decreased the number of correctly recalled letters without encoding precedence. The recall accuracies for letters with encoding precedence and letters without encoding precedence were more differentiated for adults than for children. This finding implies that the efficiency of employing a cognitive strategy increases with increasing age.

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CHAPTER I

INTRODUCTION

The Research Problem

Recently, an information processing approach has been adopted to study the development of perception and memory. Haith, Morrison, Sheingold, and Mindes (1970) found that after tachistoscopic presentation of a visual array five-year-olds were able to report only about 1.67 forms regardless of whether the array contained two, three, or four forms, while college-age adults could report an increasing number of forms as the array size increased. Possible sources of these age differences were investigated, and it was found that age differences in processing multi-element arrays could not be attributed to age changes in visual sensitivity (Haith, Morrison, and Sheingold, 1970; Holmes, cited in Haith, 1971), visual processing time for a single item (Liss and Haith, 1970), sensory storage capacity (Sheingold, 1973), or verbal labeling skills (Morrison, 1971, cited in Haith, 1971).

The problem of why pre-schoolers' STM performance for a multi-element visual array is inferior to those of older age groups is pursued further in this study. This investigation differs from other developmental studies of rapid information processing (Liss and Haith, 1970; Miller, 1972; Welsandt Jr., Zupnick Jr., and Meyer, 1973; Sheingold, 1973; Blake, 1974) by focusing on S's cognitive strategies and their effects on information processing, rather than by defining the limitation of the "hardware" of an information processor. It investigates the possibility that what appears to be an increase in processing capacity with age is in fact partly accounted for by a

general developmental trend of increasing use of organizational strategies.

Research studies involving visual scanning (Vurpillot, 1968; Mackworth and Bruner, 1970; Gibson and Yonas, 1966), central-incidental memory (Gibson, 1969; Hagen, 1972; Hagen and Hale, 1973; Doyle, 1973), and mnemonic processes (Flavell, 1970, 1971; Appel, Cooper, McCarrell, Sims-Knight, Yussen and Flavell, 1972; Belmont and Butterfield, 1971a, 1971b), seem to indicate that with an increase in age and cognitive development, Ss are more often observed engaging in strategic behavior in their encounters with stimulus information and to be more aware of the importance of strategies. Younger children, on the other hand, are less likely to devise and to utilize appropriate strategies to meet task demands and, therefore, their responses appeared to be haphazard, less systematic, less goal-directed, and often result in a performance score inferior to that of older children. Significant differences in the use of strategies have been reported not only between the performances of pre-schoolers and adults, but also between the performances of five-year-olds and eight-year-olds (Gholson, Levine and Philips, 1972; Hagen and Hale, 1973).

From the studies cited above, it is apparent that there is a growing consensus in this field that suggests that Ss employ cognitive strategies in many classes of problems (Flavell, 1971). It is unlikely that S's cognitive strategy will not also have some effects on the way information obtained in one fixation is processed and reported. As demonstrated in the aforementioned studies, pre-schoolers are less likely than elementary school children and college students to have the insight to plan ahead and to have the knowledge

for organizing information. So it is possible that pre-schooler do not spontaneously use certain organizational strategies in dealing with the information contained in a multi-element visual array, whereas older age groups do. Hence, it appears to be reasonable to investigate whether developmental differences in spontaneous use of organizational strategies extends as well to age differences in STM performance for a multi-element visual array.

Rationale for Research

When a subject does not spontaneously use strategies, it is probably due to his having either or both of two difficulties. First, there may be a difficulty in spontaneously generating a strategy due to a lack of insight about the value of planning ahead and/or the knowledge to contrive a strategy. Second, there may be a difficulty in applying a given strategy even when it is available to him. Flavell (1971) has made this distinction in his study of children's mediated memory. Flavell considers a young child as having production inefficiency if the first kind of difficulty is responsible for his inferior performance in a memory task. On the other hand, if the second kind of difficulty is responsible for his inferior performance, then this child is considered by Flavell as having mediational deficiency.

Flavell argued that if children were mediational deficient rather than production inefficient, then providing them with mnemonic aids, which they did not spontaneously produce, would still not improve their mediated memory. However, Flavell found from a series of studies that children's difficulties actually lie in their spontaneous production of mnemonic aids; because, when a mnemonic aid was

provided, they could make use of it and improve their performance. Analogously, in visual processing of a multi-element array, if subjects' STM performance can be improved by the experimental provision of strategies, then it can be inferred that their difficulty lies in the spontaneous production of strategies rather than in the employment of strategies. Therefore, this study will compare subjects' STM performances under conditions which differ in whether organizational strategies are provided or not.

The kinds of organizational strategies which will be focused on are encoding and report strategies. The following sections will be devoted to the discussion of each kind of strategy in terms of (1) whether such organizational strategy will affect STM performance and (2) whether developmental differences in initiating such strategy have been indicated in literature.

Encoding strategy. Haith (1971) has suggested that children's inferiority in processing a multi-element array is probably attributable to their lack of spontaneous use of serial encoding strategies for simultaneously presented items. Haith has stated that the five-year-old can efficiently process many of the stimuli if the strategy for dealing with these stimuli is imposed soon enough. "But leave him (i.e., the five-year-old) to his own devices or delay the instruction long enough so that he has to devise his own strategy for dealing with the information, and he has trouble." (Haith, 1971, p.257). Adults, on the other hand, (Holding, 1970, 1971) seem to be able to anticipate a to-be-delivered report cue and use their own selection strategy in information handling.

Before further discussing the possible age differences in using

the selection strategy for sequential encoding, some explanation about the strategy itself and the framework of information processing appears to be in order. A sequential encoding strategy is a notion pertinent to information processing models. An information processing approach considers that information from a stimulus undergoes a series of operations performed by an active processing system which has certain processing and storage limitations (Haber, 1969). It is generally accepted that visual information, following the termination of a brief exposure, is first preserved in an iconic memory (Neisser, 1967) and then serially transferred to short-term memory (Averbach and Sperling, 1961; Mackworth, 1963; Neisser, 1967; Sperling, 1963, 1967; Mewhort, Merikle, and Bryden, 1969). The iconic memory is a high capacity information store. The information preserved in iconic memory has not been analyzed or coded and it decays rapidly. Short-term memory is an information store of relatively limited capacity. The information preserved in short-term memory has been analyzed and coded in some form. It is more durable and provides the basis for verbal recall. Due to the rapid decay of iconic memory and the limited capacity of short-term memory, the order in which pieces of the information from a visual array are transferred from iconic memory to short-term memory becomes a critical factor in determining what information will be available to subjects beyond the life of the icon, which is approximately 250 msec.

The encoding sequence -- that is, the order in which pieces of information are transferred from iconic memory to short-term memory -- is considered not to be automatically determined, but to be subject to cognitive control. In Sperling's information processing model (1963,

1967), there is a "scan" component which determines the sequence of locations from which the encoded form of information in iconic memory will enter into short-term memory. In Neisser's (1967) two-stage model for information processing, the operation of focal attention (which is the second stage in the model) is spatially serial. Neisser stated that at a given time a subject can select part of the input information from the icon for further processing and encoding. In other words, it seems that Neisser believes that S has control over the sequential order in which pieces of information are transferred from iconic memory to short-term memory. Dick (1972) also stated that a self-induced or an experimentally-induced set can determine the order in which information from iconic memory is coded into short-term memory. There is evidence that adult Ss can follow instructions and change the processing and encoding order of discrete items (Scheerer, 1972; LaBerge and Brownstone, 1974).

In Scheerer's study (1972), a left-field superiority which is usually found in letter recognition, can be eliminated and changed into a right-field superiority if S was instructed, prior to stimulus exposure, to report in the order of right-to-left. However, when the same instruction was increasingly delayed and was given after the termination of stimulus exposure, the S seemed to have adopted a habitual left-to-right "scanning" strategy before the report cue arrived and therefore produced a left-field superiority in his letter recognition. In the LaBerge and Brownstone study (1974), S's detection of a target letter on a two-color array was more accurate in the condition where S was informed about the color of the target letter prior to stimulus exposure than in the condition where color

information was withheld.

However, as far as processing a multi-element visual array is concerned, it is not clearly understood from the theoretical viewpoints cited above or from others (Shiffrin and Atkinson, 1969; Kahneman, 1973; Norman and Bobrow, 1975) whether the mechanisms of cognitive control over the encoding sequence develops with age. In other words, it is still an open question as to whether young children can spontaneously devise any systematic sequential encoding strategies and whether the order of young children's encoding sequence can be varied by instructional sets. Nevertheless, given the important role of a sequential encoding strategy in the course of information processing, one can expect that if there are any developmental differences in exerting cognitive control over sequential encoding sequence, then there will be differences among various age groups in the kind and/or amount of information available to them beyond the life of the icon.

Although there is a lack of specific theoretical treatment on the problem of developmental differences in exerting cognitive control over the encoding sequence, the existence of such developmental changes has been implied in the empirical work of central-incidental learning. Hagen and his associates (Hagen, 1972; Hagen and Hale, 1973) have found that the recall of items in a central learning task increases with age and the recall of items in an incidental learning task decreases with age. Hagen and Hale (1973) consider that a two-stage sequence of information processing such as the model proposed by Neisser (1967) is involved in the central-incidental memory differences, and interpret their findings as primarily reflecting developmental changes in the second stage -- focal attention. In other

words, they appear to suggest that there is an increasing ability in subjects' control over which piece of information from the stimulus will further undergo analysis by synthesis and then be stored in STM.

Consequently, it is reasonable to hypothesize that younger children's difficulty in processing a multi-element visual array is partly due to their difficulties in generating a sequential encoding strategy. To confirm this relationship, it is expected that if subjects are provided with a sequential encoding strategy, five-year-olds will improve their performance and thus reduce the developmental difference in perfromance which is found in conditions when no strategy is provided and Ss have to devise their own strategies.

Report strategy. A report strategy refers to a systematic manner that a subject organizes the available information for verbal recall. Due to the nature of memory decay and response interference, a well-coded dimension or item in short-term memory has a better chance of being correctly reported if it is reported first rather than later in a report sequence. For adult subjects in tachistoscopic studies, it was found that an emphasized dimension or well-coded stimulus information was always chosen to be reported first by subjects (Haber, 1964; Lawrence and LaBerge, 1956). The recall accuracy of an item was clearly related to its ordinal position in a report sequence. On the other hand, it has been reported that four-year-olds did not always give their surest responses first (Blake, 1972, p.73). It is questionable whether younger children organize their report sequences in a systematic manner to maximize the accuracy of their recall. There is a possibility that younger children's cognitive deficits are also reflected in the way that report sequence is organized, and that this

in turn has contributed to the fact that their STM performance is inferior to those of other age groups.

An organization which is imposed on recall also serves as a strategy for retrieving information from memory storage. In list learning, it has been shown that providing subjects with category names during recall can dramatically increase the number of items correctly recalled (Tulving and Pearlstone, 1966). Apparently, additional words had been available to subjects but were accessible only when they were appropriately cued. This might lead one to question whether younger children have had as many items available to them as other age groups do, but those items are not accessible to children only because younger children in comparison to older children and adults have greater difficulty in using output organization.

In list learning, subjects' spontaneous organization of recall was found to be positively correlated with age (Bousfield, Esterson and Whitmarsh, 1958; Cole, Frankel and Sharp, 1971; Moely, Olson, Halwes and Flavell, 1969). Nursery school children in particular appear to have cognitive deficits in using output organization. When nursery school children were told about the organized nature of the lists they were required to memorize, category clustering was still not enhanced in their recall protocols (William and Goulet, 1975). Nevertheless, the above studies also show that when nursery school children are given constrained recall instructions to organize their recall, category clustering was increased and so was the number of correctly recalled items.

Consequently, it is hypothesized in this study that younger children in comparison to older subjects are more likely to have

deficit in using organizational strategies for retrieval and report; and this deficit in turn is partly responsible for the age differences in STM performance.

Summary of Purposes and Hypotheses

This study is designed to investigate the relationship between age differences in STM performance and developmental differences in the spontaneous use of organizational strategies.

First, it will attempt ot replicate the age differences found by Haith et al., (1970) that pre-schoolers' STM score is lower than those of older children's and adults', when there are no strategies provided experimentally.

Secondly, it will test the hypothesis that the age differences in STM performance are attributable, in part, to the developmental differences in spontaneous use of organizational strategies -- encoding strategy and report strategy. It is predicted that (1) pre-schoolers' performance will be improved when a sequential encoding strategy is experimentally provided, and (2) pre-schoolers' performance will be improved when a retrieval and report strategy is experimentally provided.

Thirdly, the study will examine the report strategies spontaneously adopted by different age groups. It is predicted that older subjects are more likely than younger subjects to voluntarily apply a systematic report strategy. More specifically, adults' report protocols are more likely than younger children's report protocols to reveal an organization which is consistent with the sequential encoding strategy experimentally provided. Under the condition when

an encoding strategy is not experimentally provided, adults' protocols are more likely than children's to reveal an organization which is consistent with the structure of a stimulus array.

Experimental Manipulations

To investigate the outcomes of providing subjects with a sequential encoding strategy, as well as a retrieval and report strategy, the two factors are experimentally manipulated in the following manner.

Encoding strategy. Encoding strategy is manipulated by giving different attentional instructions to different groups of subjects and also by withholding a variable order of report instruction until the time of reporting. This procedure has been found to be effective in studies of Harris and Haber (1963), and Haber (1964).

Haber and his associates variously instructed Ss about the importance of three separate dimensions of upcoming stimuli. The order in which the three dimensions of stimuli were to be reported, however, was not known to S until after each stimulus presentation. In those studies, the report-order was controlled by forcing Ss to report the stimulus dimensions in an order which did not always coincide with the order of original instructional set. They found that for Ss who used a dimensional code, a much higher number of errors were made on the unemphasized dimension than on the emphasized dimension even when each was reported first in the report sequence. This indicates that the main effect of instructional set was on the order of encoding and not just on the order of overt report (Neisser, 1967). The provision of an encoding strategy in this study is manipulated

in a similar fashion by instructing subjects how to attend to the stimulus array and by experimentally controlling the variable report-order.

However, the attentional instruction in this study differs from that in studies by Haber and his associates in two aspects. First, the instruction given in this study is more direct and explicit. Instead of telling Ss which part is more important, the instruction in this study directly tells subjects to "look at" one part of stimulus array before the other. Secondly, the encoding strategy in this study involves the order in which discrete items of an array are processed and coded, rather than different dimensions of the same stimulus. In spite of the differences, the instruction is also expected to be effective.

The sequence in which discrete items from different locations are coded is considered by Sperling (1963, 1967) to be determined by a "scan" component of an information processing model. This is somewhat similar to the operation of Neisser's focal attention (Neisser, 1967). Sperling as well as Neisser seems to believe that this order can be varied.

Report strategy. The variable order of report instruction which serves as a control for the manipulation of encoding strategy is, in fact, also a manipulation for retrieval and report strategy by itself. As shown in the study of William and Goulet (1975), a specific retrieval and report strategy can be provided to subjects by a constrained report instruction. In this study, subjects are given both free-report-order and constrained-report-order instructions. The free report instruction provides a basis for evaluating the effect of a

constrained report instruction, as well as a basis for examining subjects' free report strategies.

CHAPTER II

METHOD

Design

The independent variables of this study were age, encoding strategy, and order of report. Here, age and encoding strategy were between-subjects variables, and order of report was a within-subjects variable. The response measure was number of correct letters recalled from an array of eight letters arranged in a cross shape composed of one row of four red (black) inked letters and an intersecting column of four black (red) letters.

Pre-schoolers, elementary school children, and college students were the Ss of the study. Half of the Ss from each age group were randomly assigned to one of the encoding instruction conditions -- (a) free encoding strategy, and (b) sequential encoding strategy. Subjects in each condition were accordingly instructed, just prior to each stimulus presentation, as to how to "look at" the to-be-flashed stimulus array. Additionally, a report-order instruction was given immediately upon the termination of stimulus presentation. Each S was tested under all three kinds of report-order. Which report-order to use in a given trial was randomly determined by E and the report-order could vary from trial to trial. There were 24 test trials for each S -- (a) eight trials with free order of report, (b) eight trials with red items to be reported before the black items, and (c) eight trials with the black items to be reported before the red items. For subjects in a sequential-encoding-instruction condition, reporting items of one color before the other color was actually a

report strategy to report items in the same order as the encoding order or to report items in a reversed order to the encoding order.

The stimulus array consisted of eight letters. Upper-case English consonants were used, with no repetition of letters on the same array. The stimulus array for each test trial was different and therefore there were a total of 24 stimulus arrays. The duration of the stimulus presentation was 125 msec. After the stimulus presentation was terminated, S was asked to recall as many items as possible. In reporting, S had to indicate the color of the items before he named the item.

Subjects

There were sixty subjects, twenty kindergarteners, twenty eight-year-olds, and twenty college students. The kindergarten Ss ranged in age from 5:7 years to 5:11 years, with a mean age of 5:9 years. The eight-year-olds ranged in age from 8:5 years to 8:11 years, with a mean age of 8:8 years. The adult Ss were college students who ranged in age from 18:7 years to 22:2 years, with a mean of 19:10 years. All the eight-year-olds and most of the five-year-olds were recruited from an elementary school in Fairfax County of Northern Virginia. Other five-year-olds were recruited from a private day school in the same area. All the adults were recruited from George Mason University in Fairfax County of Northern Virginia. Each S was tested in his own school and was rewarded for his participation in the study. There were approximately equal numbers of male and female Ss in each group.

All sixty subjects had passed a pre-test and successfully

demonstrated their abilities in discriminating red and black colors, in naming all the letters in upper-case, and in understanding a verbal instruction concerning sequential order. In addition to the sixty subjects, there were thirteen subjects who were dropped due to the following reasons: (a) Six five-year-olds failed to name all the letters during the pre-test. (b) Three five-year-olds were reluctant to make verbal responses. (c) One eight-year-old claimed that he had some sort of eye problem. (d) A mistake was made by E in the experimental procedure during the testing of an eight-year-old. (e) Two college students were excluded since they were much older than the rest of the group.

Apparatus

A shutter-type tachistoscope was attached to the front of a projector lens for the purpose of stimulus presentation. The shutter (Lafayette Model 93015) was adjustable to permit unlimited viewing or an exposure of 1000 msec., 500 msec., 250 msec., 125 msec., 66.7 msec., 33.3 msec., 16.7 msec., 8 msec. A Wratten Gelatin Neutral Density Filter having a density of 0.9 was also placed in front of the opening of the shutter-type tachistoscope. This filter transmitted 12.59% of the luminance from a 300-watt projection lamp. The choice of using a filter having a density of 0.9 was based on pilot testing which determined optimal brightness for correct report of the stimulus. Both the shutter and the Kodak 800H projector were housed in a portable viewing box. The interior of the box was painted in flat black, except the screen, on which a stimulus array would be projected, was in flat white. In the center of the white screen, there was a black

dot to serve as a fixation point. This fixation point was directly at the subject's eye level and could be seen throughout the experiment since the interior of the viewing box was also illuminated by a 5-watt lamp.

Stimulus Materials

There were 24 slides for the main task, 30 slides for practice and warm-up, and one slide for pre-test. Each of the slides for test and practice consisted of eight letters, four red and four black, arranged in a cross configuration with a blank space in the center, and with the letters of one color located on the horizontal axis and the letters of the other color located on the vertical axis. The eight letters were upper-case English consonants, with no letter appearing twice in the same array. A, E, I, O, U, Y were excluded so that the array contained no words. C, D, F, J, M, N, Q, R were not used as well. This choice is primarily based on Gibson's (1969) report that there was relatively high confusion between the following pairs of letters: P and R; E and F; M and N; C and G; M and W. Therefore, the stimulus array was constructed by a random selection of eight consonants at a time from twelve consonants (B, G, H, K, L, P, S, T, V, W, X, Z) with the following restrictions. (1) No repetition: no letter appeared more than once in an array. (2) Equal use of letters: each of the twelve consonants appeared sixteen times among the total of twenty-four slides used in the test session. (3) Balancing colors: each of the twelve consonants appeared eight times in red and eight times in black among the total of 24 test slides. (4) Balancing the spatial dimensions of each color: among

the 24 test slides, the red (or black) letters were located on the vertical dimension in twelve slides and on the horizontal dimension in the other twelve slides. (5) Balancing the location of each letter : among the 24 test slides, each of the 12 consonants appeared twice in each of the eight locations of a cross. The above rules also applied to the construction of the 30 slides for practice and warm-up.

The size of each letter subtended a visual angle of 18', and the whole letter array subtended a visual angle of 2.5°(i.e., 150') on both vertical and horizontal dimensions, at a subject-screen distance of 48 inches. Thus, foveal viewing of all the eight letters simultaneously was possible.

The slide used in the pre-test consisted of two 5 X 5 matrices of letters. Each upper-case English letter (excluding "O") appeared once in each matrix, and was randomly placed in one of the 25 positions. The two matrices differed in the color as well as in the positions of the letters. One of the matrices was red and the other black. The size of each letter in the pre-test slide was the same as the size of each letter in a test slide or a practice slide.

Procedure

Each S was informed that the purpose of this study was to find out how fast people of different ages can see letters.

Pre-test. S was instructed to look through the viewing hole and to view all the letters projected on the screen for an unlimited amount of time. The following questions were asked. (1) "Can you see the two sets of letters ?" "Are those two sets of letters the same color or different colors ?" "What color are they ?" (2) "Now, I would like you to read those letters to me. Please read the red

(or black) letters first and then read the black (red) letters."

Any person who failed to give the correct answer in any part of this pre-test was not tested further. The Ss who passed the pre-test were randomly assigned to one of the two conditions -- (a) free-encoding-strategy condition and (b) sequential-encoding-strategy condition. Practice trials were administered to Ss of both conditions prior to the beginning of the test session. No further performance criteria were set beyond the pre-test.

Practice session. First, S was told, "Now, I am going to show you more letters." For five-year-olds and eight-year-olds, the following statements were also given. "Each time after I show you some letters, if you can tell me correctly about what those letters are, then, I will put a chip in front of you, like this." A chip was placed in front of the child by E. "After I show you letters many times and you tell me the letters correctly many times, you may get a large pile of chips." E put a few more chips, one at a time, in front of the child. Then, E, pointing to a separate pile of chips, said to the child: "Look, there is a pile of chips another child of your age has got. Let's see you get your own pile. When we finish this game, you can exchange your pile of chips for a ticket for free ice cream. So, please try to tell me correctly as many letters as you can, all right?"

S was then positioned with his eyes inside the viewing hole and his face against the viewing hood. S was told: "There is a black dot in the center of the screen. You should always look at the black dot first, so that you can get a good view of the letters. After you keep your eyes looking at the dot, tell me you are ready. Then, I

will say 'start' and show you the letters. You should remember not to blink your eyes after I say 'start'."

The first practice slide was shown to S for a prolonged period of time until S began his report. Then, the presentation of the letter array was immediately terminated, and S was encouraged to continue his reporting of what he had seen. After S claimed that he could not remember any more letters, he was shown the same slide again to check his answer. At this point, S was instructed that in reporting the items, both the color and the letter of each item should be reported, with the color preceeding the name. "When you tell me the letter, you should say the color of the letter before you tell me what the letter is." A few examples from the stimulus array were given to S. S was also assured that he would be able to report more letters after some practice.

After S understood the reporting procedure, the second practice trial was administered. This time, the letter array was presented for 1000 msec. S's verbal recall of what he had seen or what he might have seen from the letter array was requested by the E. Any mistake in not having reported the color of the letter before the letter itself was corrected. Next, S was given the third, the fourth, and the fifth practice trials, in which the exposure time was set to 500 msec., 250 msec., and 125 msec., respectively. Upon the completion of the fifth practice trial, additional instruction was given to the S to emphasize that he should "look at" the letter array in a certain way.

a) Encoding instructions. For Ss in the free-encoding-strategy condition, the instruction was as follows: "When you look at the

letters, I would like you to try very hard to look at all the letters. O.K.? Remember, I want you to look at all the letters. Do you know what I mean?" For Ss in the sequential-encoding-strategy condition, the instruction was as follows: "When you look at the letters, I would like you to try very hard to look at the red (black) letters first and then look at the black (red) letters. O.K.? Remember, I want you to look at the red (black) letters first and then the black (red) letters. Do you know what I mean?"

Ss were given more practice trials. Part of the encoding instruction (i.e., those underlined words) was restated before the start of each trial and was followed by the question: "Are you ready?" After S indicated that he or she was ready, E said "start" and pressed the key to start the stimulus presentation. The stimulus exposure time for the sixth and the seventh practice trials was 500 msec. and 250 msec., respectively. Beginning with the eighth practice trial and throughout the rest of the practice and test sessions, the exposure duration was set to 125 msec. The 125 msec. exposure time permitted only one fixation of the letter array, since the latency for saccadic eye movements to occur is about 250 msec. (Haith, et al., 1970). On the other hand, the time period of 125 msec. was far beyond the time required for pre-schoolers as well as adults to recognize one item (Blake, 1972; Haith, et al., 1970). Therefore, to limit information input to one fixation and to obtain optimal performance, the 125 msec. duration was assumed to be an appropriate exposure time for all age groups.

b) Report-order instructions. After the twelfth practice trial, the S was instructed about the report-order restrictions as follows:

"Now I want you to tell me the letters in a certain way. After the letters are gone, if I say to you 'red first' then you have to tell me all the red letters first and then tell me all the black letters. You will start by telling me as much as you can about the red letters you have seen. When you finish with all the red letters you know, then you will tell me as much as you can about all the black letters you have seen. So you will say something like red P, red G, or more red letters and then, you will say something like black B, black K, or more. Do you know what I mean? If I say to you 'black first,' then you must start with all the black letters you know before you tell me any red letter. You will tell me the black letters first: black B, black K, and as much as you can remember and then, you will tell me the red letters: red P, red G, or more. Do you understand? Sometimes, after the letters are gone I will say to you 'any way.' This means you can tell me all the letters in any way you want. You don't have to tell me all the red letters first or all the black letters first. You can do it in any way you want. Do you know what I mean? But, when you tell me each letter you still have to tell me its color, like red X or black X, O.K.? Let's practice."

Two consecutive trials for "black first," two consecutive trials for "red first," and two consecutive trials for "any way" were given to S to familiarize him or her with this report-order requirement. Any mistakes in regard to the way subjects reported the letters they could remember were corrected by E. Then, the S received a block of six additional practice trials. Within the block, the three report-orders were requested equally often and in a random sequence. Upon completion of the twenty-four practice trials, there was a short

break. Then the test session began.

Test session. Each S was first reminded of (a) the nature of a trial sequence, (b) the specific encoding instruction of his condition, and (c) the three kinds of report-order restriction. There were six warm-up trials and twenty-four test trials. The six warm-up trials were administered in a block, and the twenty-four test trials were administered in three blocks of eight trials. Within a block, the order of report required in each trial was randomly determined except that each S was requested to report in each report-order at least twice, and that within the twenty-four test trials each report-order was requested for a total of eight times.

A standard test trial sequence began with E's stating of the encoding instruction which is appropriate to the condition S was assigned to (see those underlined words in the encoding instructions appearing in the section on the practice session; p.21). Then S was asked "Are you ready?" After the S stated that s/he was ready, E said "start" and pressed the key to start the presentation of a letter array. The exposure time for a letter array was 125 msec. Upon the termination of stimulus presentation, E said one of the report-orders -- (a) any way, (b) red first, or (c) black first. Then, the S was required to give his verbal recall of what he had seen or what he might have seen from the letter array. In responding, the S had to say the color of the letter before he named the form identity of the letter. When S stopped reporting E said "go on" to encourage further effort. If S did not have any more items to report, the E said "all right" and started a new trial. If S was a five-year-old or an eight-year-old, a chip was placed in front of him at the end of each

trial, as long as he had made a verbal report. This kind of encouragement was given during the practice session as well.

CHAPTER III

RESULTS

Data analyses were carried out on the protocols of test trials only. An item was scored as correct only when both color and form identity of the letter were correctly named. As a result of this scoring method, three scores were obtained from each trial: (1) R-score -- the number of red items correctly recalled in a given stimulus array, (2) B-score -- the number of black items correctly recalled in a given stimulus array, (3) T-score -- the total number of items correctly recalled in a given stimulus array. The T-score of a given trial was equal to the sum of the R-score and the B-score of the same trial. The upper limit of both the R-scores and the B-scores was four items, since there were only four red items and four black items in an array. The upper limit of the T-scores was eight items.

Separate analyses of variance were carried out on the T-scores, and on the R-scores and B-scores. The results of the analyses on the T-scores provide answers for the questions in regard to whether the total number of correctly recalled items in an array was affected by age, encoding-strategy, and report-order variables. The analyses on the R-scores and the B-scores, on the other hand, examine the effects of age, encoding strategy, and report-order in terms of the number of correctly recalled items with or without encoding precedence, in terms of the number of correctly recalled items with or without reporting precedence, and in terms of the combination of both kinds of precedence.

An R-score obtained in a condition where subjects were given a sequential encoding instruction to "look at" red items first (i.e., in a sequential (red) encoding condition), is therefore actually the

number of correctly recalled items with encoding precedence. Similarly an R-score obtained in a red-first report-order is actually the number of correctly recalled items with reporting precedence. A B-score obtained in the conditions described above is actually the number of correctly recalled items without encoding precedence and the number of correctly recalled items without reporting precedence, respectively. In a sequential (black) encoding condition, or in a black-first report-order, the relationship between the color of the items and the priority of the items will be the opposite to what has been described above.

The findings to be presented in this chapter are organized in terms of the questions raised in the study. They can be classified into the following groups.

(1) Are there any age differences in STM performances, if subjects are not provided with any organizational strategies? Under this condition, what are the reporting strategies spontaneously adopted by subjects of different age levels?

(2) What are the effects of giving subjects a sequential encoding strategy? Are those effects different for different age groups? Will there be any age differences in STM performance after subjects are provided with a sequential encoding strategy?

(3) What are the effects of providing subjects with a retrieval and report strategy? Will those effects be different for different age groups? Will there be any age differences in STM performance after subjects are provided with such a strategy?

(4) What are the effects of providing subjects with both a sequential encoding strategy and a report strategy? What is the relationship between the effects of a sequential encoding strategy and the effects

of a report strategy? Are those effects different for different age groups?

The findings in regard to the first group of questions serve as the bases for evaluating the effects of a sequential encoding strategy, the effects of a report strategy, and the effects of both kinds of organizational strategies. Each group of effects is further divided into (a) the effects on the total amount of information correctly recalled in a stimulus array and (b) the effects on the amount of information correctly recalled for items with or without priority in encoding or reporting.

(1.A.) Age Differences in STM Performance Under a Condition Where Subjects Were Neither Given a Sequential Encoding Strategy Nor a Report Strategy

In order to evaluate the effects of giving subjects a sequential encoding strategy and/or a report strategy, it is necessary first to examine subjects' performance under the condition where those strategies were not provided. It has been reported (Haith, et al., 1970) that under this kind of condition, there are significant differences in the total number of items correctly recalled by five-year-olds, eight-year-olds and adults. The reported age differences in STM performance are replicated in this study.

A 3 x 2 analysis of variance was performed on the R-scores and the B-scores obtained in the condition where subjects received both a free encoding instruction and a free report-order instruction. The group means of the R-scores and the B-scores of this condition can be found in the top left area of Table 1 (free-free). The analysis

included age as a between-subjects variable, and the type of score as a within-subjects variable. The results, as summarized in Table 2, show that the effect of age is highly significant, F (2, 27) = 25.82, $p < .001$. This indicates that the three age groups performed at significantly different levels in terms of the overall number of items correctly recalled.

The results of the analysis also show that there is no overall difference between the number of red items correctly recalled and the number of black items correctly recalled. Those results indicate that none of the three age groups had any differential recall accuracy for red items and black items.

The overall age differences were investigated further by performing Scheffe' tests on the group means. It was found that five-year-olds had significantly fewer number of items correctly recalled than did eight-year-olds, $t = 4.82$, $p < .01$; and eight-year-olds had significantly fewer number of items correctly recalled than did nineteen-year-old college students, $t = 5.54$, $p < .01$. Therefore, it is clear than when subjects are not provided with any strategies for handling information coming from a multi-element visual array, age differences in STM are observed. Thus, previously reported age differences (Haith, et al., 1970) are replicated in this study.

(1.B.) Report Strategies Which Subjects Spontaneously Adopted Under the Condition of Free Encoding and Free Report-Order Instructions

The sequential organization of the protocols were analyzed to examine whether subjects had spontaneously used any kind of report strategy. The findings in this section will also provide a basis for

evaluating other results in determining whether the age differences in STM performance, as reported in 1A, are attributable to developmental differences in spontaneous use of encoding and/or reporting strategies.

From the inspection of subjects' protocols, it appears that younger subjects as well as older subjects did not report items in a completely random manner, nor in a simple alternation of red and black items. Instead, it was found that during 90% of the trials with free encoding and free report-order instructions, subjects reported items of one color before they reported items of the other color. In the other 10% of the trials, one or two additional items of the first color were reported after subjects had already begun reporting items of the second color. This kind of mixed sequence was relatively infrequent and occurred equally often in the three age groups. It seems that subjects of each age level adopted report strategies to report items of one color before the items of the other color.

The questions then arise as to the bases for subjects' choice of reporting items of a certain color first, and whether there are any age differences in the way a certain color was chosen to be reported first.

In a stimulus array, items of two different colors are separately arranged on an imaginary horizontal axis and on an imaginary vertical axis. The choice of reporting items of one certain color before reporting items of the other color could be made on the basis of color or on the basis of spatial coordinates. The relationship between subjects' first reported items and these two aspects of stimulus structure were examined.

Since each subject received eight free report-order trials, it is necessary first to index how consistent and reliable it was that each subject reported a particular color first over these eight trials. One way to index the various degrees of consistency is simply to record the total number of trials that a subject first reported a particular color, such as the red color or the color appeared on the vertical dimension. The distribution of subjects in regard to the various degrees of consistency in the first report is tabulated for the three age levels. Table 3 shows such a distribution in terms of the number of trials that the red color was reported first, and Table 4 shows such a distribution in terms of the number of trials that the color on the vertical dimension was reported first.

The frequency distribution at each age level was subjected to the Kolmogorov-Smirnov one-sample test (Siegel, 1956, p. 47) against a theoretical binomial distribution in order to determine (1) whether there was any group bias toward first reporting red items or black items, and (2) whether there was any group bias toward first reporting the vertical dimension or the horizontal dimension. The results of the statistical tests indicate that the five-year-olds group and the eight-year-olds group did not have any significant bias in choosing what to report first. The empirical distributions were not significantly different from the theoretical distributions derived from the assumption that subjects are as likely to start

their report with red items as to start with black items and the assumption that subjects are as likely to start their reports with the vertical dimension as to start with the horizontal dimension. On the other hand, the results of the statistical tests for the college-age adults suggest that adults were more likely first to report the color located on the horizontal dimension ($\underline{D} = 0.455$, $\underline{p} < 0.05$), although they also did not have any significant bias toward red or black color per se.

Next, the differences among the three age groups were examined by performing two one-way analyses of variance. Each of the scores on which an analysis of variance was performed was derived through an arcsin transformation of the proportion of trials that each subject reported a particular color first over the eight free-report-order trials. The results of the analyses indicate that there was significant age difference $\left[\underline{F} (2,27) = 4.05, \ \underline{p} < .05 \right]$ in the proportion of first reporting the red color, but that there was no significant age difference in the proportion of first reporting the vertical dimension. The significant age difference in the proportion of first reporting the red color reflects a shift over age from a tendency to start with red items to a tendency to start with black items. Nevertheless, it should also be noted that the previous analysis at each age level indicates that the tendency demonstrated by each age group was not strong enough to reach statistical significance.

The fact that none of the age groups had any color bias in organizing their reports seems to be perfectly related to the fact that none of the age groups showed any differential recall accuracy for red items and black items. It is less self-evident, however, as to how adults' spatial bias toward first reporting the horizontal dimension relates to the fact that adults had correctly recalled more items than those of other age groups. Since both the encoding variable and the report-order variable are left free in this condition, it is not clear as to whether the spatial bias demonstrated in adults' free reports merely reflects a bias in reporting or it also reflects a bias in encoding. Analyses on data obtained in the conditions where attempts are made to control the encoding and/or reporting strategy will help clarify this point.

(2.A.) The Effects of Giving Subjects Only a Sequential Encoding Strategy on the Total Number of Items Correctly Recalled

The findings to be presented under this heading are related to the questions as to (1) whether giving subjects a sequential encoding instruction, by itself, can increase their total number of items correctly recalled, (2) whether the younger subjects, in comparison to the older subjects, will show greater gains in their total scores from having been given a sequential encoding instruction instead of a free encoding instruction, and (3) whether there are still any age differences in STM performances when subjects are experimentally provided with a sequential encoding strategy.

A 3 x 2 analysis of variance was performed on the T-scores of the free- and the sequential-encoding conditions obtained in the free report-order. The group means are shown in the third column of Table 1. For the sequential-encoding condition, the group means being analyzed were derived from the scores of both the subjects who received a sequential (red) encoding instruction and the subjects who received a sequential (black) encoding instruction. The analysis included age and encoding-strategy as between-subjects variables. The results are summarized in Table 5. Age, encoding-strategy, and age X encoding-strategy are all significant, F (2, 54) = 56.06, $p < .001$; F (1, 54) = 12.08, $p < .005$; F (2, 50) = 4.52, $p < .05$, respectively.

The significant effect of encoding-strategy indicates that the subjects who received a sequential encoding instruction had an overall greater number of items correctly recalled than that of the subjects who received a free encoding instruction. Significant age X encoding-strategy interaction suggests that the increment is not uniform across the three age levels. It also suggests that the age differences in the sequential encoding condition are different from the age differences in the free encoding condition. Those relationships between age and encoding instruction are graphically represented in Figure 1.

Scheffe' tests were performed to determine the significance of the difference between the two encoding conditions at each age level, as well as to determine the significance of the differences among the three age groups in each encoding condition. In regard to the difference between the two encoding conditions, the results show that only

five-year-olds had significant increment due to the sequential encoding instruction, $t = 4.45$, $p < .01$. Thus, it appears that five-year-olds, in comparison to the two older age groups, had greater gains from the provision of a sequential encoding strategy. When five-year-olds were given a sequential encoding strategy, they could correctly recall more letters.

In regard to the age differences in the total number of items correctly recalled, the results of Scheffe' tests indicate that under the sequential encoding condition, there was no significant difference between the performance levels of five-year-olds and eight-year-olds. On the other hand, the Scheffe' test performed on the group means of the free encoding condition indicates that there was a significant difference between the number of items correctly recalled by five-year-olds and the number of items correctly recalled by eight-year-olds. This is true when the comparison between the performances of five-year-olds and eight-year-olds was made following the analysis described in the earlier section, as well as when the comparison was made following the analysis described in this section, $t = 4.23$, $p < .01$. When those results are considered together, they suggest that a sequential encoding instruction plays an important role in determining whether five-year-olds can perform well in a short-term memory task. When subjects are given a sequential encoding instruction instead of a free encoding instruction, five-year-olds can recall almost as many letters from a brief visual array as eight-year-olds do.

However, even when subjects were given a sequential encoding instruction, five-year-olds still cannot recall as many items as adults, and neither can eight-year-olds. The results of Scheffe'

tests show that under the sequential encoding condition, there were significant differences between the performance levels of five-year-olds and adults, $t = 5.57$, $p < .01$, and between the performance levels of eight-year-olds and adults, $t = 5.17$, $p < .01$. Those results seem to indicate that the age differences found in the condition of no provision of strategies cannot be totally removed by giving subjects a sequential encoding instruction. Other variables are responsible for the fact that adults outperformed both five-year-olds and eight-year-olds. Nevertheless, it is fairly clear that giving subjects a sequential encoding instruction can significantly increase the total number of items correctly recalled by five-year-olds, to such an extent that their performance level becomes not significantly different from that of eight-year-olds.

(2.B.) A Sequential Encoding Strategy and the Number of Correctly Recalled Items with Encoding Precedence and the Number of Correctly Recalled Items Without Encoding Precedence

The findings to be presented in this section are basically related to the same type of questions as those addressed in 2A. However, in this section, the number of correctly recalled items with encoding precedence and the number of correctly recalled items without encoding precedence are examined instead of the total number of items correctly recalled in an array. In other words, this section provides an opportunity to further investigate whether the age differences in the effects of experimental provision of a sequential encoding strategy is the same for items with encoding precedence and items without encoding precedence. In 2A, it was found that five-year-olds showed

greater gains in their total number of items correctly recalled. In 2B, it is asked: "Is this due to their remembering more items with encoding precedence and/or items without encoding precedence?" In section 2A, the total number of items correctly recalled by adults was not changed by giving subjects a sequential encoding strategy. This, however, does not preclude the possibility that their recall for items with encoding precedence was increased and their recall for items without encoding precedence was at the same time decreased by the sequential encoding instruction, or vice versa. Those possibilities are examined in this section.

Data obtained in the free report-order were reorganized for subsequent analyses. The R-scores of sequential (red) encoding condition and the B-scores of the sequential (black) encoding condition were classified as the scores for items with encoding precedence. The B-scores of sequential (red) encoding condition and the R-scores of sequential (black) encoding condition were classified as the scores for items without encoding precedence. The average of the R-scores and the B-scores of the free encoding condition was treated as the baseline performance for the purpose of two separate comparisons made with the scores for items with encoding precedence and with the scores for items without encoding precedence. The group means for those scores described above are presented in the first three columns of Table 6. Separate 3 (age) x 2 (encoding-strategy) analyses of variance were performed to determine the effects of encoding instructions on the recall of items with encoding precedence and on the recall of items without encoding precedence. Table 7 summarizes the results for the items with encoding precedence, and Table 8 summarizes

the results for items without encoding precedence.

In Table 7, the main effects as well as the interaction are significant. The significant age effect, F (2, 54) = 62.81, $p < .001$, indicates that the STM performance increased with the increase in age. In other words, the age trend observed in the recall for the entire stimulus array is also evident when the recall for items with encoding precedence was analyzed. The significant effect of encoding-strategy, F (1, 54) = 51.50, $p < .001$, indicates that the score for items with encoding precedence is generally higher than the average of the B- and R-scores of the free encoding condition. That is, with the sequential encoding instruction, the recall for items with encoding precedence is better than the average amount of recall made for the red items or black items during the condition without a sequential encoding instruction.

In Table 7, there is also a significant effect of age X encoding-strategy interaction, F (2, 54) = 3.98, $p < .05$. A graphic depiction of this interaction can be found in part of Figure 2. The significant effect of age X encoding-strategy interaction indicates that the influence produced by the sequential encoding instruction was not uniform across the three age levels. So, Scheffe' tests were performed on the group means of the three age levels under the free and the sequential encoding conditions (see the first and the second columns of Table 6). The results show that for both adults and five-year-olds, but not for eight-year-olds, the mean score for items with encoding precedence in the sequential encoding condition is significantly higher than the average of the R-scores and B-scores obtained in the free encoding condition (t = 5.76, $p < .01$; t = 4.38, $p < .01$,

respectively). Thus, it is clear that adults' STM performance is, in fact, changed by the sequential encoding instruction.

When the differences between the scores for items with encoding precedence and the baseline performances in the free encoding condition, in Figure 2, are inspected, it appears that adults actually have the largest amount of difference score among the three age groups. From the results of the aforementioned Scheffe' tests, the amount of the difference for adults is significantly greater than the amount of difference for eight-year-olds, $t = 2.70$, $p < .05$. On the other hand, the amount of difference for five-year-olds, which although is significant by itself, is not significantly greater than that of eight-year-olds. Those results suggest that among the three age groups adults rather than five-year-olds had more dramatic change in STM performance as a result of having a sequential encoding instruction. Scheffe' tests, however, indicate that the amount of increment for adults is not significantly greater than that of five-year-olds. Nevertheless, adults outperformed both five-year-olds and eight-year-olds in terms of the number of correctly recalled items with encoding precedence, $t = 8.19$, $p < .001$; $t = 7.64$, $p < .001$, respectively.

To summarize, the findings concerning items with encoding precedence are as follows: (1) A sequential encoding instruction increased the overall number of correctly recalled items with encoding precedence. (2) The increment is significant for both adults and five-year-olds. (3) Adults correctly recalled more items with encoding precedence than those of five-year-olds and eight-year-olds. The latter two age groups are not significantly different from each other in the recall accuracy for items with encoding precedence.

Those results concerning items with encoding precedence contrast with the following results concerning items without encoding precedence.

First of all, the effect of encoding-strategy in Table 8 is not significant. This indicates that a sequential encoding instruction did not produce an overall higher recall accuracy for items without encoding precedence than the baseline performance established in the free encoding condition. As illustrated by the two lower lines in Figure 2, the reason that encoding-strategy is not significant seems to be due to the recall accuracy for items without encoding precedence increasing for the group of five-year-olds, but decreasing for the groups of adults and eight-year-olds. As shown in Table 8, the age X encoding-strategy interaction is highly significant, F (2, 54) = 14.07, $p < .001$.

Secondly, it should be noted that the nature of the age X encoding-strategy interaction for items without encoding precedence is different from the age X encoding-strategy interaction for items with encoding precedence. For items with encoding precedence, the age X encoding-strategy interaction effect indicates that the three age groups had differential amount of gains from the provision of a sequential encoding strategy. For items without encoding precedence, the results of Scheffe' tests indicate that the age X encoding-strategy interaction is due to the adult group alone showing a significant decrement in their scores, $t = 4.89$, $p < .01$. For five-year-olds, as well as eight-year-olds, the number of correctly recalled items without encoding precedence was not significantly affected by the sequential encoding instruction. Thirdly, the results of Scheffe' tests also indicate that adults did not surpass

five-year-olds or eight-year-olds in the number of correctly recalled items without encoding precedence.

When the results concerning items without encoding precedence and the results concerning items with encoding precedence are considered together, it appears that giving subjects a sequential-encoding instruction has differential effects on the STM performance of five-year-olds and adults. For five-year-olds, the sequential-encoding instruction produced a greater number of correctly recalled items with encoding precedence without simultaneously decreasing the number of correctly recalled items without encoding precedence. For adults, the sequential-encoding instruction resulted in a significant increment in the number of correctly recalled items with encoding precedence and, at the same time, resulted in a significant decrement in the number of correctly recalled items without encoding precedence. Therefore, the total number of items correctly recalled by adults remained the same in the sequential- and the free-encoding conditions. It appears that adults, in comparison to younger subjects, had more differentiated recall accuracies for the items with encoding precedence and the items without encoding precedence.

In the following section, the sequential organization of protocols is examined. This is to investigate whether giving subjects a sequential encoding instruction has also changed subjects' report strategies, and whether such changes, if there are indeed any, are the same or different for the three age groups. If the changes occurring in subjects' free report strategies are different among the three age groups, the question arises as to whether those age differences in the free reporting strategies alone can explain the finding of the

age differences in the effects of a sequential encoding instruction on STM performance as described in Sections 2A and 2B. In other words, the following analyses will furnish additional information for determining whether what was found in this section about the age differences in the effect of giving subjects a sequential encoding instruction was indeed brought out through the experimental provision of sequential encoding strategies or was merely a result of some changes in reporting strategies.

(2.C.) Report Strategies Spontaneously Adopted by Subjects Under the Condition of Sequential Encoding and Free Report-order Instructions

The sequential organization of the protocols obtained under the condition of sequential encoding and free report-order instructions was examined. It was found that during almost all of the 240 trials, subjects reported items of one color before they reported items of the other color. There were only four trials during which eight-year-olds reported one or two items of the first color after they already started reporting items of the second color. Furthermore, the color of the first reported item was more often to be the color which had encoding precedence in a given sequential encoding instruction (see Table 9 and Table 10). The color bias was tested further by those procedures described in Section 1B.

When a sequential (red) encoding instruction was given, subjects had a tendency to start with red items rather than black items. From the results of the Kolmogorov-Smirnov one-sample test, it was found that the color bias toward starting with red items is statistically significant for five-year-olds, $D = .637$, $p < .01$; and for adults,

D = .965, $p < .01$; but not for eight-year-olds. The three age groups were significantly different in terms of the extent of having the color bias toward starting with red items, F (2, 12) = 6.31, $p < .05$. In other words, with the sequential (red) encoding instruction adults started their recall with red items more frequently than the other age groups did. On the other hand, when the sequential (black) encoding instruction was given, eight-year-olds and adults, but not five-year-olds, had a significant color bias toward reporting the black items first, D = .637, $p < .01$; D = .996, $p < .01$, respectively. Again, the three age groups are significantly different in regard to the degree of color bias, F (2, 12) = 21.81, $p < .01$, with the adults group's color bias being stronger than those of other younger age groups.

The first item in the subject's report protocol was also classified according to where its color was located on the spatial coordinates of a stimulus array. The distribution of subjects in regard to how consistent they reported the vertical dimension first over the eight trials was presented in Table 11 and Table 12 for the sequential (red) encoding condition and the sequential (black) encoding condition, respectively. In the sequential (red) encoding condition, only the eight-year-olds group showed a significant bias toward reporting the vertical dimension first, D = .455, $p < .05$, In the sequential (black) encoding condition, only the five-year-olds group showed a significant bias toward reporting the vertical dimension first, D = .637, $p < .01$. Thus, the report sequences of the two younger age groups sometimes still reflect an organization

dominated by the vertical dimension, rather than being completely determined by the sequential encoding instruction. In the sequential (black) encoding condition, the age differences in the proportion of first reporting the vertical dimension also reached statistical significance, $\underline{F}$ (2, 12) = 4.72, $\underline{p} < .05$.

In sum, both the analyses in color bias and spatial bias suggest that adults in comparison to children were more relaibly affected by the sequential encoding instruction and chose to report first those items for which the color is the same as the one defining the encoding precedence of items. The above statement is also supported by the results of the Kolmogorov - Smirnov two-sample tests, which were performed at each age level to determine the significance of the difference between the frequency distribution of the free encoding condition and the frequency distribution of the sequential encoding condition. We have found that only the difference for the adults group reached statistical significance. When the instruction was changed from free encoding to sequential (red) encoding, adults reported red items first, $\underline{\chi^2}$ (2) = 13.33, $\underline{p} < .01$. When the instruction changed from free encoding to sequential (black) encoding, adults reported black items first, $\underline{\chi^2}$ (2) = 13.33, $\underline{p} < .01$. If reporting items in an order consistent with the sequential encoding order is a more efficient reporting strategy, it appears that a sequential encoding instruction did not produce a more efficient reporting strategy for young children as it did for adults. Those findings concerning subjects' free reporting strategies will be taken into consideration with the findings of the age differences in the

effects of a sequential encoding instruction on STM performance.

Recall that in Section 2A it was found that five-year-olds alone had a significant increase in their total number of items correctly recalled, as a result of having a sequential encoding instruction instead of a free encoding instruction. Now, the result of the analyses on the organization of the protocols suggests that the possibility that a more efficient reporting strategy had been indirectly given to five-year-olds by the sequential encoding instruction, can be excluded as the reason that five-year-olds had greater gains from the sequential encoding instruction. When a sequential encoding instruction is given, adults rather than five-year-olds appear to have greater changes in their free reporting strategies and to have adopted a more efficient reporting strategy. Therefore, it seems reasonable to conclude that the greater increment in five-year-olds' recall accuracy for the entire stimulus array is due to a sequential encoding strategy being experimentally provided to five-year-olds under the sequential encoding condition, rather than due to the changes which were induced by an encoding strategy in the reporting strategy.

Additionally, recall that in Section 2B it was found that a sequential encoding instruction yielded more differential recall accuracy for adults in the items with encoding precedence and in the items without encoding precedence. For five-year-olds, the difference between their recall accuracy for items with encoding precedence and their recall accuracy for items without encoding precedence was smaller. Those findings appear to be related to the findings that adults almost always reported items in an order consistent with the encoding order

while five-year-olds did it less frequently. When the items with encoding precedence were almost always reported before the items without encoding precedence, the recall accuracy for those items with encoding precedence would be expected to be higher than the recall accuracy of the same items when they were sometimes reported after the items without encoding precedence. Therefore, the free reporting strategy adopted by adults under the sequential encoding condition seems to have contributed to the fact that adults had significant gains in the number of correctly recalled items with encoding precedence, although their total number of correctly recalled items was not increased by the sequential encoding instruction.

In the following section, the data obtained in the constrained report-orders as well as the data obtained in the free report-order will be analyzed, in order to demonstrate the relationship between report precedence and recall accuracy of items. The comparison of the constrained report-order and the free report-order, under the free encoding condition, also provides an answer to the question of whether the total number of items correctly recalled can be increased by imposing a report-order on the subject.

(3.) The Effect of Giving Subjects Only a Report Strategy (Via a Constrained Report-Order Instruction) on the Total Number of Items Correctly Recalled, and on the Recall Accuracy of Items with or without Reporting Precedence

In this section, the effects of the report strategies on STM performances are examined. In other words, this section attempts to determine whether giving subjects a constrained report-order instruction alone can produce a greater number of items correctly recalled than that obtained in the free report-order, and whether the recall accuracy of items with reporting precedence is higher than the recall accuracy of items without reporting precedence.

A 3 x 2 x 3 analysis of variance was performed on the R-scores and the B-scores of the free encoding condition (see Table 1). It included age as a between-subjects variable, and it included report-order and score-type as within-subjects variables. The results as summarized in Table 13 show that the effect of report-order is not significant, nor is the effect of age X report-order interaction. These indicate that the red-first, the black-first and the free report-order did not yield any differential amount of correct recall for any age group. In other words, making subjects report in a constrained report-order or providing subjects with a report strategy neither significantly increased nor decreased subject's total number of items correctly recalled.

The report-order X score-type interaction in Table 13 is highly significant, F (2, 54) = 35.72, $p < .001$. This indicates that forcing subjects to report items in a red-first or a black-first report-order produced differential amount of correctly recalled red items and

correctly recalled black items. As shown in Figure 3, the number of correctly recalled red items is greater than the number of correctly recalled black items, if items are reported in a red-first order. When items are reported in a black-first order, the number of correctly recalled black items is greater than the number of correctly recalled red items. On the other hand, the R-score and the B-score are about the same when the report-order is not constrained. These results suggest that when subjects consistently reported items in a specific order, the recall accuracy for items with reporting precedency is higher than the recall accuracy for items without reporting precedency.

In Sections 2 and 3, the effects of a sequential encoding instruction and the effects of a constrained report-order were evaluated separately. In the following sections, the data analyzed were those obtained under the condition where subjects received both a sequential encoding instruction and a constrained report-order instruction. In other words, subjects have received two sets of organizational rules instead of only one. Under these kinds of circumstances, what are the effects of having a sequential encoding instruction, and what are the effects of having a constrained report-order? Furthermore, what are the relationships between these two kinds of effects? What are the joint effects of a sequential encoding instruction and a constrained report-order on subjects' STM performances? These kinds of questions will be answered in the following sections.

(4.A.) The Effects of Giving Subjects a Sequential Encoding Instruction on the Total Number of Items Correctly Recalled in the Constrained Report-Orders

In Section 2A it is clear that a sequential encoding instruction by itself can increase the total number of items correctly recalled, especially for five-year-olds. However, the question still remains unanswered as to whether a sequential encoding instruction can increase the total number of items correctly recalled if subjects have to report items in a specified order as well. Although the findings in Section 3 indicate that the report-order instruction by itself is not effective in changing the total number of items correctly recalled, this does not necessarily lead to a conclusion that the effect of giving subjects a sequential encoding instruction is the same under the free report-order and the constrained report-order conditions. In the constrained report-order condition where subjects were also given a sequential encoding instruction, they must deal with two sets of organizational constraints. It seems reasonable to expect that the relationship between the two sets of organizational constraints will affect the extent to which subjects can benefit from the provision of organizational strategies.

For the sequential (red) and the sequential (black) encoding conditions, the data obtained in the red-first and the black-first report-orders were re-classified into a constrained-matched report-order and a constrained-mis-matched report-order, depending on the relationship between the specified encoding precedence and reporting precedence of items. In a constrained-matched report-order, the reporting precedence is consistent with the encoding precedence. In

a constrained-mis-matched report-order, the reporting precedence is opposite to the encoding precedence. The group means of the total number of items correctly recalled in constrained report-orders under the free- and sequential-encoding conditions are presented in Table 14. Two separate 3 (age) X 2 (encoding-strategy) analyses of variance were performed on the data. The results are summarized in Table 15 and Table 16, respectively.

As shown in Table 15, the effect of encoding-strategy is significant for the T-scores obtained in a constrained-matched report-order, F (1, 54) = 9.57, $p < .001$. However, unlike the data obtained in the free report-order (see Table 5), there is no significant effect of age X encoding-strategy interaction. In other words, when subjects were forced to report items in a specified order, five-year-olds no longer had significantly greater gains from the provision of a sequential encoding strategy than other age groups. This is also true when the T-scores obtained in a constrained-mis-matched report-order were examined. As shown in Table 16, the effect of age X encoding-strategy interaction is not significant. Additionally, Table 16 indicates that the effect of encoding -strategy did not reach statistical significance; F (1, 54) = 2.93, $.05 < p < .10$. When subjects were forced to report items in an order opposite to that of a given encoding strategy, the beneficial effect of having provided subjects with a sequential encoding strategy is clearly reduced.

In the analyses summarized in Tables 15 and 16, the constained report-order factor was treated as a constant, and only the effect of encoding-strategy was evaluated. What if the joint effects of having a sequential encoding strategy and a constrained report-order on STM performance are evaluated ? In order to answer this question, two additional analyses of variance were carried out in such a manner that the STM performances obtained in the condition where subjects received the sequential encoding and constrained report-order instructions were evaluated against the STM performances obtained in the condition where subjects received the free encoding and free report-order instructions. The results are shown in Table 17 and Table 18.

The significant effect of experimental condition in Table 17, $F(1,54) = 7.81$, $p < .01$, indicates that giving subjects a sequential encoding instruction and a constrained-matched report-order instruction can increase the total number of items correctly recalled. The effect of age X condition interaction is not significant. This result again indicates that the gains shown by the three age groups are not significantly different from one another. It appears that five-year-olds did not benefit more than other age groups from being provided with both a sequential encoding strategy and a report strategy even when the constrained report-order was consistent with the specified encoding order

Recall that with a free report-order instruction five-year-olds

showed a significantly greater amount of gains from having the sequential encoding instruction than any other group did. Note that with a constrained report-order instruction, five-year-olds no longer showed a significantly greater amount of gains. It appears that providing five-year-olds with a report-order, in addition to a sequential encoding strategy, did not really help their recall to a greater extent. Instead, it somewhat hindered their recall.

In Table 18, the effect of experimental condition is not significant. This indicates that providing subjects with a sequential encoding strategy but requiring them to report items in an order opposite to the encoding order cannot produce better recall overall. However, there is a significant age X condition interaction in Table 18, F (2, 54) = 3.42, $p < .05$. As depicted in Figure 4, the combined effect of having the instructions of sequential encoding and constrained-mis-matched report-order is different for different age groups. The age X condition interaction appears to be attributable to five-year-olds still showing some increment in performance when they were provided with the sequential encoding strategy and were forced to report items in an order opposite to the sequential encoding order, whereas adults' performance declined slightly under this condition. It appears that younger children's STM performance is more affected by whether or not they are provided with a sequential encoding strategy, and is less affected by whether or not a constrained

report-order is consistent with or opposite to the sequential encoding order.

The five-year-olds group stands out in showing improvement over STM performance as long as a sequential encoding strategy was experimentally provided to them, even though the gain in performance was somewhat smaller when items were required to be reported in a constrained order. For adults in the sequential encoding condition, the unique phenomenon of having an apparent decrement in their performance when the report-order was constrained to an order opposite to the sequence of encoding is quite consistent with the previous findings in Section 2C that adults under the free report-order condition were more likely than any other age group spontaneously to report items in an order which is consistent with the given sequential encoding instruction. The hindrance of the constrained-mismatched report-order instruction could be expected if it contradicts with the report-order that subjects were just about to use for their recalls. Recall that the frequency of spontaneously adopting a report strategy which is consistent with a given encoding strategy is greater for adults than for five-year-olds. Thus, it seems natural that STM of adults rather than five-year-olds' suffered more from a constrained-mis-matched report-order.

(4.B.) The Effects of Requiring Subjects of the Sequential Encoding Condition to Report Items in Specified Orders

In the previous section (4A), two kinds of analyses were made : One was made to compare the effects of free- and sequential-encoding instructions when subjects had to report items in a constrained order. The other analysis was made to compare the STM performance under the condition where subjects had both sequential-encoding and constrained-report-order instructions and the STM performance under the condition where subjects had both free encoding and free report-order instructions. In this section, different report-order instructions will be evaluated for those subjects who had the sequential encoding instruction. In other words, the encoding factor will be held as a constant.

Two separate analyses of variance were performed on the R- and B-scores of the sequential (red)- and the sequential (black)-encoding conditions. Each analysis included age as a between-subjects variable, and included report-order and score-type as within-subjects variables. The results, as shown in Table 19 and Table 20, indicate that the report-order factor did not produce any significant changes in the overall scores . The non-significant effect of report-order is consistent with what was found for the free encoding condition. However, in the sequential encoding condition the three report-orders produced differential effects on the scores for items with encoding precedence and the scores for items without encoding precedence. This is indicated by the significant report-order X score-type interaction in the sequential (red) encoding condition and in the sequential (black) encoding condition, F (2, 24) = 15.31 , $p < .001$; and F (2, 24) = 22.69 , $p < .001$, respectively. When items were reported in free order , the R-score

is higher than the B-score in the sequential (red) encoding condition, and the B-score is higher than the R-score in the sequential (black) encoding condition. In other words, the recall for items with encoding precedence is superior to the recall for items without encoding precedence. From careful inspection of the group means of the sequential encoding condition in Table 1, it appears that the significant report-order X score-type interaction in Table 19 and Table 20 is due to the superiority of recall for items with encoding precedence being somewhat enhanced by reporting items in a constrained-matched order; yet, it was reduced or wiped out by forcing subjects to report items in a constrained-mis-matched report-order. Those trends can also be observed in Figure 5 and Figure 6.

In Table 19 and Table 20, there are also significant age X report-order X score-type interactions, F (4, 24) = 3.27, $p < .05$; F (4, 24) = 2.87, $p < .05$, respectively. This higher order interaction indicates that the effect of the report-order on the scores for items with encoding precedence and on the scores for items without encoding precedence is not uniform across the three age levels. As suggested by the group means graphically presented in Figure 5 and Figure 6, five-year-olds, in comparison to other age groups, are least affected by the report-order factor. For five-year-olds, the difference between the score for items with encoding precedence and the score for items without encoding precedence did not vary a great deal with the three kinds of report-orders. There is no significant effect of interaction between items' encoding precedency and the report-order instruction for five-year-olds (see Table 21). For adults, the difference score in a constrained-matched report-order is very large

and it is considerably reduced in a constrained-mis-matched report-order. The interaction between encoding-precedency and report-order instruction is highly significant, F (2, 16) = 18.47, $p < .001$. For eight-year-olds, the effect of report-order X score-type interaction is also highly significant, F (2, 16) = 38.35, $p < .001$. Furthermore, the group of eight-year-olds alone was affected by the report-order factor to such an extent that the score for items without encoding precedence became higher than the score for items with encoding precedence when subjects were required to report items in a constrained-mis-matched order. In other words, for eight-year-olds, the order of report surpassed the order of encoding in determining which one of the two colors will yield relatively higher recall accuracy.

In the next section, the developmental differences in the relationships between the encoding precedence and reporting precedence will be examined further by looking into the joint effects of the sequential encoding instruction and the constrained report-order instruction on (1) the scores for items with both encoding and reporting precedence, (2) the scores for items without both encoding and reporting precedence, (3) the scores for items with encoding precedence but without reporting precedence, and (4) the scores for items with reporting precedence but without encoding precedence.

(4.C.) The Effects of a Sequential Encoding Instruction and a Constrained Report-Order Instruction on the Recall of Items with or without Encoding and/or Reporting Precedence

In this section, subjects' STM performance under the condition where subjects received both sequential encoding instruction and a

constrained report-order instruction was classified into four different kinds of scores, depending on both encoding precedence and reporting precedence of the items (see the last four columns in the far right side of Table 6). Each kind of score is then compared with the baseline performance obtained in the condition where subjects received free encoding and free reporting instructions. The main question being asked in this section is as follows : "If subjects are given both a sequential encoding strategy and a report strategy, will subjects of the three age groups show differential amount of gains in their recall for (1) those items with both encoding and reporting precedence, (2) those items without both encoding and reporting precedence , and (3) those items with either encoding precedence or reporting precedence but not both ? "

Four separate 3 (age) X 2 (experimental condition) analyses of variance were performed on the number of items correctly recalled. The average of the R-scores and the B-scores obtained in the condition of free encoding and free report-order instructions was treated as the baseline performance in the four analyses. The results are summarized in Tables 24, 25, 26, and 27. The significant effect of experimental condition in Table 24, $F\ (1,54) = 72.42$, $p < .001$, indicates that the recall for those items with both encoding precedence and reporting precedence is better than the baseline performance. However, age X condition interaction is not significant. This indicates that the three age groups had no differential amount of gains from the provision of different strategies, as far as the recall of items with both encoding and reporting precedence is concerned.

As for the items with encoding precedence but without reporting

precedence, the data in Table 25 show that giving subjects both a sequential encoding strategy and a report strategy did not result in better recall overall. As indicated above, the recall for items with encoding precedence and reporting precedence was better than the baseline performance. Also recall that under the free report-order condition, the number of correctly recalled items with encoding precedence was higher than the average of the R-score and the B-score of the free encoding condition. When those results are considered together with the findings stated in this paragraph, it appears that when the reporting of those items with encoding precedence was consistently delayed, the positive effect of experimental provision of encoding strategy on the recall accuracy of those items was clearly reduced.

For eight-year-olds, the number of correctly recalled items with encoding precedence and without reporting precedence was even lower than their baseline performances (see Figure 7) . The decrement shown by eight-year-olds, however, was not statistically significant in Scheffe' tests. For five-year-olds, the number of correctly recalled items with encoding precedence but without reporting precedence was still significantly higher than their baseline performance, $t = 3.44$, $p < .05$. In other words, in terms of the number of correctly recalled items with encoding precedence but without reporting precedence, only five-year-olds showed significant gains from the provision of both a sequential encoding strategy and a report strategy. Thus, the experimental effects are clearly different for different age groups. As shown in Table 25, this age X condition interaction is highly significant, $F\ (2, 54) = 8.27$, $p < .001$. Recall that when subjects were not

given any strategies, there were significant differences among the number of items correctly recalled by the three age groups. Now, with the experimental provision of encoding and reporting strategies, five-year-olds and eight-year-olds became not significantly different in the number of correctly recalled items with encoding precedence but without reporting precedence.

As for the items without encoding precedence but with reporting precedence, the results of analyses of variance indicate that the experimental effect for the three age groups combined is not significant. However, age X condition interaction is significant in Table 26, F (2, 54) = 5.51, $p < .01$. This shows that the experimental effect is not the same for the three age groups. From Figure 7, it appears that for five-year-olds and eight-year-olds, the recall for items without encoding precedence but with reporting precedence was better than their baseline performances. For adults, on the other hand, the recall for items without encoding precedence but with reporting precedence was poorer than the baseline performance. Those difference scores themselves, however, did not reach statistical significance. As for the differences among age groups, the results of Scheffe' tests show that adults and eight-year-olds are not different in the number of correctly recalled items without encoding precedence but with reporting precedence. The difference between eight-year-olds and five-year-olds is significant, $t = 3.85$, $p < .05$.

Remember that when subjects were allowed to report items in any order, adults had poor recall accuracy for items without encoding precedence. It was also found that they had adopted a strategy to report items with encoding precedence before items without encoding

precedence. It was suggested, at that point, that the lower recall accuracy for items without encoding precedence may be related to the fact that those items were not reported sooner. Now, the results in this section indicate that when adults were forced to report items without encoding precedence before items with encoding precedence, the recall accuracy for items without encoding precedence is still not on a par with the baseline performance, and it is clearly not greater than the baseline performance. It seems that adults have a tendency to process and retain less information from those items designated to be encoded later, while they have more information from items designated to have encoding precedence available for report.

For the items without both encoding and reporting precedence, the overall recall accuracy is significantly lower than the baseline performance, F (1, 54) = 9.27, $p < .001$, (see Table 27). However, as indicated by the Scheffe' test, only the adults group had a significant decrement in their STM performance, t = 5.06, $p < .005$. Age X condition interaction was also significant in Table 27 , F (2, 54) = 10.10 , $p < .001$. Those results can be interpreted as follows: When subjects are given both encoding and reporting strategies, the recall accuracy for those items without both encoding and reporting precedence was not better than the average recall accuracy in the condition where strategies were not given; adults in particular had even recalled fewer items if those items were designated to be encoded later and to be reported later.

When all the results described in Section 4C are considered together, it seems that giving subjects both a sequential encoding strategy and a report strategy produced effects similar to those of

giving subjects a sequential encoding strategy only, if subjects are five-year-olds and adults. For five-year-olds and adults, the reporting precedence prescribed in the constrained report-order instruction did not change the relationships among the scores for items with encoding precedence, the scores for items without encoding precedence, and the average score of the free encoding condition. In other words, the score for items with encoding precedence is always higher than the score for items without encoding precedence, regardless of whether the items had reporting precedence or not. On the contrary, whether eight-year-olds' recall for items with encoding precedence will be better than their recall for items without encoding precedence is dependent upon whether or not the items with encoding precedence also had reporting precedence. For eight-year-olds, reporting precedence rather than encoding precedence of items determines whether or not the number of correctly recalled items will be higher than the baseline performance in the free encoding condition.

It should be also noted that while five-year-olds, as well as adults, responded to the sequential encoding instruction in a similar fashion during both kinds of report-order trials -- free and constrained, the response pattern of five-year-olds is different from that of adults. When five-year-olds were given a sequential encoding instruction, both the number of correctly recalled items with encoding precedence and the number of correctly recalled items without encoding precedence became higher than the average number of correctly recalled red items and black items obtained in the free encoding condition. When adults were given a sequential encoding instruction, the number of correctly recalled items with encoding precedence became higher

than the average number of correctly recalled red items and black items in the free encoding condition, but the number of correctly recalled items without encoding precedence became lower than the average number of items correctly recalled in the free encoding condition. For items with encoding precedence as well as for items without encoding precedence, the recall accuracy is higher if those items also had reporting precedence. This is true for five-year-olds and adults. However, the recall accuracy for items differing in reporting precedence is more differentiated in adults than in five-year-olds. In other words, adults are more affected by the report-order variable than five-year-olds.

Summary of Findings

1. Age differences in STM performance. When subjects were given free encoding and free report instructions, five-year-olds correctly recalled fewer items than eight-year-olds, and eight-year-olds correctly recalled fewer items than adults from viewing a two-color, eight-letter array for 125 msec.

2. Effects of a sequential encoding instruction on STM performance (A). When the report-order was left free, giving subjects a sequential encoding instruction produced an overall increase in the amount of items correctly recalled. However, only the increment for the group of five-year-olds reached statistical significance. The increment produced by the sequential encoding instruction was signifi-

cantly greater for five-year-olds than for other age groups. With a sequential encoding instruction and a free report-order instruction, five-year-olds correctly recalled as many items as eight-year-olds, although adults still outperformed both five-year-olds and eight-year-olds.

3. Effects of a sequential encoding instruction on STM performance (B) . When the effect of a sequential encoding instruction (under the free report-order condition) was evaluated separately for items with encoding precedence and items without encoding precedence, it was found that the instruction had produced a significant overall increase only for the items with encoding precedence. The increment in the number of correctly recalled items with encoding precedence was significant for both adults and five-year-olds, so that adults as well as five-year-olds were in fact affected by the sequential encoding instruction. For adults, the sequential encoding instruction also significantly decreased the number of correctly recalled items without encoding precedence. Thus, the difference between the number of correctly recalled items with encoding precedence and the number of correctly recalled items without encoding precedence appeared to be more pronounced for adults. As a result of the sequential encoding instruction, there were no age differences in STM performances in terms of the number of correctly recalled items without encoding precedence. As for the number of correctly recalled items with encoding precedence, adults still outperformed both five-year-olds and eight-year-olds,

whereas the two age groups were not significantly different from each other.

4. Free report strategies. All the subjects spontaneously organized their report protocols, during almost all of the trials, with items of the same color being clustered together and reported before items of the other color in a report sequence. Under the condition with free encoding instruction, there was no bias in terms of whether red or black color was consistently chosen to be reported first; however, the adults group showed a significant bias in first reporting the color presented on the horizontal dimension of a stimulus array. The report strategy which subjects spontaneously adopted was affected by the encoding instruction. Under the condition of a sequential encoding instruction, the adults group showed a significant bias in first reporting the color designated to be encoded first. For five-year-olds and eight-year-olds, however, their report sequences also reflected an organization of starting from the color on the vertical dimension.

5. Effects of report-order instruction. Giving subjects a report strategy through constrained report-order instruction did not increase the total number of items correctly recalled. However, a constrained report-order instruction, such as red-first or black-first, resulted in differential scores for red items and black items in such a way that recall accuracy was higher for those items with reporting precedence than those without reporting precedence.

6. Encoding precedence, reporting precedence and recall accuracy. When subjects were given both a sequential encoding instruction and a constrained report-order instruction, the overall recall for items with encoding precedence was better than that of the items without encoding precedence; and the overall recall for items with reporting precedence was better than that of the items without reporting precedence. The three age groups had a similar amount of gains in the number of items correctly recalled when the items with both encoding and reporting precedence were examined. However, the instruction of sequential encoding and constrained report-order produced differential effects for the three age groups on those items which did not have encoding and/or reporting precedence. When encoding precedence conflicted with reporting precedence, the recall accuracy of eight-year-olds was more affected by the reporting precedence of items so that items without encoding precedence were recalled relatively better than items with encoding precedence, if items without encoding precedence were reported first. For five-year-olds and adults, encoding precedence overrulled reporting precedence in determining the recall accuracy of items so that items with encoding precedence were always recalled relatively better than items without encoding precedence even when items with encoding precedence were reported later. When the amount of correct recall for items without both encoding and reporting precedence was evaluated against the baseline performance in the condition with free encoding and free report-order instruction, only the group of adults showed a significant decrement in performance

CHAPTER IV

DISCUSSION

This study investigated whether the inferior performance of younger children, especially the pre-schoolers on an information processing task, is attibutable, in part, to their lack of spontaneous use of organizational strategies, such as (a) a sequential encoding strategy for dealing with the flow of information into short-term memory store, and (b) a report strategy for dealing with the flow of information out of short-term memory store. The results suggest that the major deficiencies of pre-schoolers are more likely to reside in encoding processes than in retrieval and reporting processes.

This study replicated the reported age differences in STM performance (Haith, et al., 1970) through tachistoscopic presentation of two-color, eight-letter arrays. It clearly demonstrated that when subjects were not provided with any strategies, the amount of information being processed and retained by subject increases with increasing age.

With a simple instruction however, it is possible to provide five-year-olds with a sequential encoding strategy such that the total number of items correctly recalled by five-year-olds can be significantly increased to the level of eight-year-olds. This finding supports the hypothesis proposed by Haith (1971) that five-year-olds' difficulty in processing a multi-element visual array is attributable, in part, to their lack of spontaneous use of a sequential encoding strategy rather than their incapability of using a sequential encoding strategy. Thus, five-year-olds' processing and memory capacity is clearly not

limited to 1.67 items as previously found.

The importance of organizational strategies, especially a sequential encoding strategy, in information processing is indicated by this study. The findings also substantiate the contention that developmental differences in memory performance are partly accounted for by general developmental trends of increasing use of cognitive strategies. However, developmental differences in the spontaneous use of a sequential encoding strategy alone cannot account for all the age differences in STM performance. Other factors, such as rehearsal strategies, processing speed or storage capacity, need to be studied.

As stated before, this study indicated that there is a tendency toward increasing use of cognitive strategies with increasing age. In addition, the data suggest that adults, in comparison to children, are more efficient in applying a given sequential encoding strategy. Those findings have significant implications for developmental theories and also provide a developmental perspective for information processing theories.

Those conclusions and implications will be further discussed in the following sections.

Organizational Strategies and the Amount of Information Correctly Recalled

In this study, five-year-olds correctly recalled more items from an eight-letter array if a sequential encoding strategy was experimentally provided. This result indicates that an organizational strategy for transferring visual information into STM store is helpful to a subject's performance, not only in terms of which pieces

of information will be saved but also in terms of the total amount of information being processed and retained. Lacking this kind of organizational strategy may result in fewer number of items correctly recalled.

In studies involving verbal recall of words non-tachistoscopically presented, the importance of organization for memory is well recognized (Mandler, 1966). In the developmental literature, there is also a growing body of evidence which suggests that the presence of organization in lists of words enhances recall for those words. When subjects were given specific instruction on how to use categories, their pre-recall clustering activity increased and so did their recall scores (Moely, et al., 1969). Blocking of stimuli by category in list presentation was also found to enhance recall (Cole et al., 1971; Kobasigawa and Middleton, 1972; Kobasigawa and Orr, 1973). This study is generally compatible with the above findings in pointing out the importance of organization. This study, however, extends the role of organization further to situations where stimulus information is accessible in only one fixation. Considering that the stimulus information is only available for very limited amount of time, the effect of organizational strategy in this kind of situation, thus, appears to be even more dramatic and more significant than that of list memory, in which words are each exposed for one second or longer. On the other hand, considering that information undergoes a series of transformations which are performed by an active information processor (Haber, 1969), it is not surprising to find that the nature of the operation determines the fate of information, even when the stimulus information is available for a limited time.

The question then arises as to what is the specific operations involved in the use of organizational strategies are and how they act to increase the amount of information that can be processed and retained. A few possibilities will be examined in the following paragraphs with reference to the temporal course of information flow, from stimulus presentation to the completion of verbal recall.

Taking the position that information is sought after by an active perceiver rather than stamped into a passive organism, it appears that the very act of fixation is a selective process, that it can be affected by a sequential encoding instruction which was given prior to stimulus exposure and which requested subjects to process and encode one part of stimulus array before the other part. However, in this study subjects were also instructed to maintain their focus on a dot which was located at the center of the array, and the stimulus array was exposed for only 125 msec., which is shorter than the latency of eye movement. Therefore, the choice of the point of fixation and the path of visual scanning seems unlikely as the possible locus of these effects.

According to information processing theories, information contained in a briefly exposed stimulus array is first maintained in a post retinal internal representation called iconic memory (Neisser, 1967). The iconic memory decays rapidly (Sperling, 1960), and it seldom lasts for more than 250 msec. under most conditions (Averbach and Sperling, 1961). Unless a partial report cue is given soon enough, S cannot make verbal recall or visual recognition of the stimulus array on the basis of iconic memory.

In this study, a subject's verbal report of the stimulus array was withheld until the subject received a report-order instruction from the experimenter. Due to the reaction time of E, there was an approximately 400 msec. lapse of time from the offset of the stimulus array until the issuance of a report-order instruction, although E attempted to give the report-order instruction immediately after the stimulus offset. Upon receiving the instruction the subjects must have spent a few hundred milliseconds in processing the information about report-order before they actually started making verbal recall. therefore, it does not seem to be likely that the iconic memory was still available to the subjects by the time s/he made verbal recall. Instead, it is assumed that the verbal report was based on the short-term memory store, which contains the analyzed and coded forms of information (Neisser, 1967). Due to the fact that iconic memory decays rapidly, information which is not encoded (from iconic memory) into STM is virtually lost and is not available for verbal report. Therefore, how efficiently a subject can transfer information into STM during the limited processing time (i.e., the duration of icon) must bear a close relationship to the amount of information which a subject will be able to report accurately.

There are two possible changes which may take place in dealing with the flow of information in STM, if subjects are given a sequential encoding strategy which they do not spontaneously produce.

(1) The encoding process becomes a systematic operation and processing time is more efficiently used. When subjects are given a sequential encoding strategy, they are provided with a plan to encode stimulus information in a systematic manner. For subjects who

are not given a sequential encoding strategy, their encoding processes may have been carried out in a random and haphazard fashion if they do not spontaneously generate a plan for encoding. Without the guidance of an encoding plan, subject may have encoded fewer pieces of information because some of the limited processing time is wasted rather than being actively engaged in encoding pieces of information one after another. Having an organizational plan, on the other hand, may lead to an efficient utlization of the limited time during which iconic mamory is available and thus, although the processing resources are limited, may result in transferring more information into STM.

(2) Information can be grouped into larger chunks. Short-term memory has been conceived as being composed of a limited number of slots (Atkinson and Shiffrin, 1968; Newell & Simon, 1972). Grouping information into larger units will make it possible to store a larger amount of information into that limited number of slots (Miller, 1956). In this study, the sequential encoding instruction to "look at" red (or black) letters first and then black (or red) letters may have provided subjects with color categories by which the whole array of eight letters can be grouped into two units of four letters. Thus, the problem of stimulus overload is less likely to occur. If younger children can only remember two items (Haith, et al., 1970), they will be able to remember more information in a total, if each of the two items is informationally rich (Miller, 1956) and contains four letters instead of one letter.

Additionally, there is a possibility that the sequential encoding instruction, through providing subjects with categories for grouping

information, may facilitate rehearsal, retrieval, and report. Rehearsal is considered to be an iterative process by which materials in STM are continuously attended to in a serial fashion at about the rate of 250 msec. per item (Chi, 1976). Since response latency was not measured in this study, it is not clear whether subjects who received the sequential-encoding instruction (in comparison to subjects who received the free encoding instruction) were more likely to have spent time in rehearsing or have rehearsed at a higher rate. However, based on the other research findings (Flavell, beach and Chinsky, 1966), it seems implausible that five-year-olds could have spontaneously used a rehearsal strategy in this study.

In this study, the analyses performed on the report protocols reveal that a sequential encoding instruction can provide subjects with an organization for retrieving and reporting the available information. However, from the separate evaluation of the effects of report-order instruction we know that the changes in the organization of report sequence was not accompanied by an improvement in STM performance. This evidence suggests that the effect which a sequential encoding instruction produced on the total amount of information correctly recalled could be mainly attributed to the provision of an organizational strategy for dealing with the flow of information into STM store -- i.e., the provision of a sequential encoding strategy.

The important role of an encoding strategy in rapid information processing has been emphasized in terms of determining which part of

input information will be rescued before the icon fades away (Sperling, 1963, 1967; Neisser, 1967). Additionally, Haith (1971), by suggesting that pre-schoolers' inferior STM performance for a multi-element visual array is attributable to their lack of a sequential encoding strategy, has first implied a relation between the use of a sequential encoding strategy and the total amount of information which can be correctly recalled. The relation, however, has not been examined clearly.

Haith (1971) has considered the arrival of a partial report indicator in Sheingold's study (1973) as a provision of an encoding strategy for subjects, and interpreted the age differences in STM found under conditions where the partial report indicator was delayed for more than 50 msec. as younger children's lacking of spontaneous use of an encoding strategy. However, where the partial report cue was used for studying the retention of information, we cannot exclude the possibility that the smaller amount of correct recall which is associated with a long delay of the indicator is due to subjects having lost the information about where an item is located in relation to the position of the indicator (Townsend, 1973). In other words, even when identity information of an item is available to a subject, a subject may make an incorrect recall when he is cued by a partial report indicator. On the other hand, our study, by giving subjects an explicit instruction to "look at" some part of stimulus information before the other, can provide subjects with a sequential encoding strategy without the above problem. The finding that the five-year-olds group had recalled a greater amount of items when a sequential encoding strategy was given experimentally, provides better evidence for illustrating the relation between the use of encoding strategy

and the amount of information correctly recalled. It appears that the statement made for long-term memory that organization is a necessary condition for memory (Mandler, 1966) also holds for short-term memory performance in a tachistoscopic situation. This study specifically demonstrated the importance of input organization in the processing and retention of information.

The instruction of a constrained report-order was not effective in producing a greater amount of correct recall for any age group tested in this study. This result, however, does not necessarily imply that an organizational plan for retrieving and reporting information is totally unrelated to the amount of information correctly recalled. What does not seem to be important is the specific order in which red items and black items have to be reported. All of our subjects already spontaneously organized their report sequence by reporting items of one color before items of the other color even in the free encoding condition. This study is therefore unable to assess the experimental effect of giving a retrieval and reporting plan to subjects who do not yet have their own output organizational strategies.

There is also a possibility that recall by color is not an optimal strategy for organizing recall in our task. Based on the fact that adults had a tendency to start their report from the color presented on the horizontal dimension of a stimulus array, it seems that an organization of recall by spatial dimension might have produced a better recall. In other studies involving free recall of words non-tachistoscopically presented, imposing organization in recall was found to improve recall for adults (Tulving and Pearlstone,

1966) as well as for children (William and Goulet, 1975; Scribner and Cole, 1972; Kobasigawa, 1974).

To reiterate, our findings imply that organization is important in rapid information processing and memory, and the use of a sequential encoding strategy, for example, can lead to a greater amount of information correctly recalled.

Developmental Differences in the Spontaneous use of Organizational Strategies

The multi-element visual array used in this study has certain instrinsic structural characteristics. The eight letters always form into two distinctive groups which differ both in the color of letters and the spatial coordinates that letters are located. Additionally, each subject was required to report the information sometimes in any order, but sometimes in a red-first or a black-first order. Our data imply that under these kinds of circumstances there are developmental differences in the spontaneous use of a sequential encoding strategy organized on the basis of color. On the other hand, all of the three age groups were capable of organizing their report sequences spontaneously. However, there are developmental differences in the consistency of using a report strategy appropriate to the task.

Encoding strategy. If subjects spontaneously use a certain strategy in a given task, then their performance would not be expected to differ in conditions where such a strategy is experimentally provided or not. On the contrary, our five-year-olds had significantly greater amount of items correctly recalled when a sequential encoding

strategy was experimentally provided, and their difference score between the two conditions was significantly greater than those of the other two age groups. Those findings suggest that five-year-olds in comparison to other age groups were deficient in spontaneously using a sequential encoding strategy organized in terms of color.

An interesting question arises as to why younger children did not spontaneously use a sequential encoding strategy. Could it be that five-year-olds were unable to discover the structure of the stimulus array (Gibson, 1969) so that a red-first or a black-first sequential encoding strategy as the one given in experimental condition could not be spontaneously produced? This explanation appears to be implausible since all of the five-year-olds tested had also passed a pre-test and successfully demonstrated their ability in discriminating red colored items and black colored items. Additionally, from their experience during the practice session in learning how to report items in a constrained report-order, subjects were made aware of the fact that there are two types of colored letters -- red letters and black letters. Apparently, pre-schoolers' awareness of the color category of letters was not sufficient for their spontaneous production and use of a color-based sequential encoding strategy.

In this respect, this study is consistent with findings in other memory tasks where stimuli were not tachistoscopically presented. For example, Kobasigawa and Middleton (1972) found that naming the categories of a list of familiar objects did not facilitate the correct recall for kindergarten children, although it facilitated the performance for the fifth grade children. It appears that the lack of

spontaneous use of strategies is due to younger children being often unaware of the planning required in a task (Flavell, 1971; Flavell and Wellman, 1977) and being unaware that the structure present in stimuli can be used as organizational scheme to facilitate performance (Tenney, 1975). Rarely do they introduce appropriate activities in response to explicit instruction to learn, to remember, or to comprehend (Flavell, 1971; Appel, et al., 1972: Mackworth and Bruner, 1970). Only when they are forced to undertake the appropriate activity is their performance improved (Scribner and Cole, 1972; Kobasigawa, 1974; William and Goulet, 1975). The presence of stimulus structure in our study did not facilitate five-year-olds' spontaneous use of a sequential encoding strategy. Their STM performance improved only when they were explicitly told to "look at red letters first, then black letters" or vice versa.

In regard to our eight-year-olds and adults, the total number of items correctly recalled by either group was not changed by the provision of a sequential encoding strategy. This suggests that they probably have produced and used the sequential encoding strategy spontaneously, and hence, E's intervention was superfluous. This conclusion, however, needs to be qualified.

First of all, in spite of the possibility that eight-year-olds and adults may have spontaneously used a sequential encoding strategy in the free encoding condition, this strategy may not be exactly the same as the one given in the sequential encoding condition. Under the free encoding condition where subjects were instructed to "look at" all the letters, the number of correctly recalled red items and

the number of correctly recalled black items are about the same. On the other hand, subjects in the sequential encoding condition correctly recalled more items with encoding precedence than items without encoding precedence. It seems that only under the sequential encoding condition a strategy which was intended consistently to process and encode items of one particular color before items of the other color was employed. Under the free encoding condition, a strategy might have been used to encode the red letters first during some trials and to encode the black letters first during some other trials. Such a strategy could be a strategy organized in terms of the spatial coordinates of letter array or a strategy organized in terms of color but with a variable order for the two colors.

The analyses of subjects' free report in the free encoding condition reveal that adults had a systematic bias in reporting the horizontal dimension first. As indicated in the results section, it is possible that this bias reflects an encoding strategy instead of merely a report strategy, since both the encoding order and the report order are left free in this condition. Therefore, it appears plausible that adults had spontaneously used a spatially orgranized strategy to encode the horizontal dimension first and then the vertical dimension.

Secondly, there is a possibility that the performance of eight-year-olds and adults could not be improved by the experimental provision of a sequential encoding strategy due to a ceiling effect. It has been reported that adult subjects can correctly report only about four or five letters in a whole report procedure (Sperling, 1960;

Averbach and Coriell, 1961). This limitation is considered to be attributable to factors such as storage capacity of STM, rapid decaying of icon, the speed of encoding, output interference, among other things. In this study, subjects were required to report both color and identity information of the letters presented. The output interference could have been greater than where recall for only identity information was required. Since adults correctly reported about 3.5 items in the free encoding condition, their performance may be already close to a ceiling with little room for improvement. We do not know whether the processing and memory system of eight-year-olds is even more limited. If the 2.4 items reported by the eight-year-olds is close to the maximum amount set for eight-year-olds, then they may not be able to show any significant improvement either.

In a word, we can be less conclusive in regard to whether eight-year-olds and adults had spontaneously employed a sequential encoding strategy; whereas it is more apparent that five-year-olds did not spontaneously use an encoding strategy which is as effective as the one given in the experimental condition, insofar as the processing and retaining information from a multi-element visual array is concerned.

Retrieving and reporting strategy. The report protocols under the free report-order condition provide a basis for investigating subjects' spontaneous use of retrieving and reporting strategies. Even in the free encoding condition where subjects were instructed to "look at" all the letters, the three age levels had equally often reported items in color clustering during at least ninety percent of the trials. Thus, they appeared to have spontaneously produced and used strategies

in retrieving and reporting the information which is available to them. That all of the three age groups had spontaneously used report strategies was also supported by the fact that the constrained (or prompted) report-order instruction did not significantly change the number of items correctly recalled by any age group.

In other studies involving free recall, pre-schoolers were found to be incapable of organizing their recall spontaneously (Moely, et al., 1969; William and Goulet, 1975). It appears that our procedure has facilitated the spontaneous use of a report strategy. The report-order factor is a within-subjects variable in that all of our subjects were required to report items sometimes in constrained orders and sometimes in a free order. All subjects had some practice with these variable report-order instructions before the test session. Thus, the organization which subjects were forced to adopt during constrained report-order trials was spontaneously maintained during free report-order trials. Scribner and Cole (1972) have also found that the facilitation effect of constrained recall was maintained when the constraints were removed and children were free to recall list items in any order.

Although all of the subjects appeared to introduce organization to their free recall by reporting items of the same color before items of the other color, the three age groups differed in whether a certain color was more often chosen to be reported first. The adults group alone showed a bias toward first reporting the color which appeared on the horizontal dimension of the stimulus array. Perhaps, this strategy to start from the horizontal dimension is related to the many years of experience our adult subjects have in reading English letters. On

the other hand, all of the three age groups had reported red color as often as black color in the free report-order condition. This appears to be related to the fact that subjects received the constrained report-order instruction in a red first order as often as in a black-first order.

The three age groups were different in their capabilities of taking into account of the task demand in tailoring their free report strategies. With the sequential encoding instructions to encode one color before the other color, only our adults group showed significant changes in the report strategy and consistently reported items in an order which matches the specified encoding order. The incorporation of a given encoding organization into an organizational strategy for reporting items was carried out more reliably by adults in both kinds of sequential encoding conditions. A tendency toward reporting items according to the specified order of encoding was also shown by five-year-olds and eight-year-olds. But this tendency was less stable in the two younger age groups that it was observed in only one kind but not both kinds of sequential encoding conditions.

When both the spontaneous use of encoding strategy and the spontaneous use of report strategy are considered together, a developmental trend emerges that with the increase in subjects's age, there is increasing use of strategies by subjects themselves. Additionally,five-year-olds appear to have more problems with the spontaneous use of an encoding strategy than with the spontaneous use of a report strategy. As discussed before, the specific research

procedure used in this study could have contributed to these results. However, it is also likely that it is indeed easier for pre-schoolers to organize a report sequence than to organize an encoding sequence. In a tachistoscopic viewing condition, Haith, et al. (1970), also found that children as well as adults organized visual information before reporting. Those findings in regard to developmental differences in the spontaneous use of strategies converge with those of others (Blake and Vingilis, 1977) in suggesting that age differences in STM performance are primarily due to age differences in encoding processes rather than in retrieval or reporting processes.

One possible additional explanation of aspects of these results invokes the notion of a rehearsal strategy being used by Ss. It could be that only our adults group rehearsed spontaneously before a report-order instruction was issued, and they rehearsed according to the specification of encoding instruction and put more emphasis on the items designated to be encoded first. Eight-year-olds, on the other hand, did not rehearse until the report-order instruction was issued, and they rehearsed those items which were designated to be reported first. Five-year-olds probably did not rehearse even after the report-order instruction was issued.

The above speculation about developmental differences in the spontaneous use of rehearsal strategy would be able to explain why the report accuracy of the eight-year-olds groups alone was affected more by reporting precedence of items, when reporting precedence and encoding precedence conflicted with each other; whereas the report accuracy of five-year-olds and adults was more affected by encoding precedence

of items. Our data show that adults' free reporting strategy under the sequential encoding condition matched closely with the encoding order given in the sequential encoding instruction. Adults clearly have their own plan to organize the available information for report. Consequently, it seems unlikely that they would not at least try to rehearse those items with encoding precedence before they received a report-order instruction for them to start reporting. Haith (1971), based on Sheingold's data and Morrison's data, had similarly suspected that the adults group alone might have visually rehearsed the items after they sequentially encoded the items. Both Sheingold (1973) and Morrison (in Haith,1971) found that for adults group only, the report accuracy had a curious upturn after a 450-500 msec. delay interval. If adults of our study had rehearsed the items with encoding precedence, the chance would be slim for the recall accuracy for items without encoding precedence to become greater than the recall accuracy for items with encoding precedence, even when the items without encoding precedence were reported first. For adults, the recall accuracy for items without encoding precedence was indeed found to be never greater than the recall accuracy for items with encoding precedence.

Our five-year-olds and eight-year-olds had organized their free report by color clustering, but they did not always report the two colors in the order specified in the sequential encoding instruction. It seem implausible that they would rehearse those items with encoding precedence right after they have encoded the items. If subjects nevertheless started rehearsing after the issuance of a

report-order instruction and rehearsed those items being specified to be reported first, then they might have correctly recalled more of the items with reporting precedence. The data of eight-year-olds fit into this pattern. Those are the bases of the speculation about developmental differences in spontaneous use of a rehearsal strategy. This speculation is consistent with other memory tasks in that there are developmental changes in the probability of spontaneous rehearsal (Flavell, et al., 1966).

In sum, our data suggest that with increase in age, subjects are more likely to introduce strategies to maximize their performance to the specification of the task demand. Developmental differences in spontaneous use of strategy are implied for the encoding, rehearsal, retrieval and reporting processes.

Developmental Differences in Employing a Given Sequential Encoding Strategy

The experimental manipulation of providing subjects with a sequential encoding strategy through the verbal instruction to "look at" the items of one particular color first and then the items of the other color, was successful in this study. All the three age groups produced significantly better recall for the red letters than for the black letters when they were instructed to "look at" the red letters first, and produced significantly better recall for the black letters than for the red letters when they were instructed to "look at" the black letters first. The fact that more information was correctly recalled from items with encoding precedence than from items without

encoding precedence suggests that subjects were able to follow instructions and to employ a given sequential encoding strategy to encode a specified subset of stimulus information with higher priority. Thus, it lends support for the converging viewpoint from different theoretical frameworks that the order in which pieces of information are transferred to STM is under S's cognitive control and can be altered by experimental instruction (Sperling, 1967; Dick, 1972; Neisser, 1967). It also indicates, as other studies did (Von Wright, 1968, 1972), that color information can be used as a basis for determining the encoding priority among items. Of particular importance in the findings is the indication of pre-schooler's ability in controlling encoding priority among items. Interestingly, pre-schoolers' ability in exerting considreable control over the allocation of resources during encoding was also reported in a recent study involving the memory of different dimensions of a stimulus non-tachistoscopically presented (Howard and Goldin, Note 1). Thus, it indicates that the assertion which information processing theorists made about adults concerning the use of processes of cognitive control generally holds for younger subjects as well.

But, can subjects have complete control over the encoding sequence? Can younger children control their encoding order to the same extent as adults do? When subjects are given a particular sequential encoding strategy, can children and adults apply this strategy equally well? The findings of this study suggest a negative answer for all of these questions.

In the test array, there are four red items and four black items. If a subject has complete control over the order in which pieces of

information are transferred into STM, then, when they were given the sequential (red) encoding instruction, they would not have any black letter available for report unless they have already coded the four red letters. Similarly, when subjects were given the sequential (black) encoding instruction, subjects would not be able to report any red letter correctly unless they already had all the four black letters available for report. However, the data show that all the three age groups had correctly recalled some items without encoding precedence, while they had not correctly recalled all the four items with encoding precedence. Although it is possible that even when the subject had encoded all the four items designated to be encoded first, their correct recall for those items may be still less than perfect due to some problems like output interference and memory decay; it is plausible that the control process is incomplete for both adults and children.

The lack of perfect cognitive control is also evident in other studies which used selective attention research paradigms. All of the findings imply that when subjects were required to focus their attention on the target item(s) only, they also processed some information from extraneous items (Eriksen and Hoffman, 1973; Eriksen and Eriksen, 1974; Blake, 1974; Holmgren, 1974; LaBerge and Brownstone, 1974; Shiffrin and Schneider, 1977). It appears that our conscious intentions only have some control but not full control over the way information is processed. In other words, the extent to which subjects can employ a given cognitive strategy during the course of his information handling, is limited. This gives support for the contention that performance is determined by the interplay of conscious strategies

and automatic activation processes (Posner and Snyder, 1975) or the interplay of controlled processes and automatic processes (Shiffrin and Schneider, 1977).

Furthermore, our data suggest that there are age differences in the extent to which a given congitive strategy can be employed in information processing. Our five-year-olds, in comparison to adults, had less differentiated scores for items with encoding precedence and items without encoding precedence. Even when the possible age differences due to order of report was minimized by only examining the performance under a constrained-matched report-order condition, the proportion of the recall accuracy for items with encoding precedence to the total amount correctly recalled was sixty percent for five-year-olds, sixty-seven percent for eight-year-olds, and seventy-four percent for adults. Thus, it appears that the efficiency of employing a given sequential encoding strategy under task demand increases with increasing age.

Since the task demand was clearly specified and understood by subjects of all ages, the above data implies that there are developmental differences in the efficiency of exerting cognitive control over the encoding of items. This study thus provides developmental perspective for those theoretical viewpoints (Sperling, 1967; Dick, 1972; Neisser, 1967) which consider that the order in which subsets of stimulus information received further processing or encoding, and being transferred to STM store, is under subjects' cognitive control. Additionally, our findings can be interpreted from the viewpoints of capacity theories of attention, including those proposed by Kahneman (1973), and by Norman and Bobrow (1975), and suggest that the control

over the allocation of processing capacity or resources becomes more efficient with an increase in age.

Recently, a conception of a control mechanism which has broader scope and includes possible operations on coding as well as on rehearsal, retrieval and other processes, has been advanced by Shiffrin and Schneider (1977). With this conception of control processes, our findings can be interpreted as implying that there are developmental differences in the efficiency of utilizing control processes which apply at any level of information processing. It is useful to interpret our findings of the increasing efficiency in employing a given sequential encoding strategy in such broader terms. Recall that in previous sections, a possibility was suggested that there may be age differences in the use of a rehearsal strategy instigated by the sequential encoding instruction or a constrained-report-order instruction. If there were indeed age differences in the spontaneous use of rehearsal strategy, this could have contributed to the increasing differentiation of scores for items with and items without encoding precedence. Therefore, what appears to be an increasing efficiency in employing a given encoding strategy, may not merely reflect an increasing ability to control the encoding priority among items.

From the conclusion that there are developmental differences in utilizing control processes, a couple of questions arise. First, does more efficient control basically reflect an increasing ability in facilitating the processing and retention of the items designated to have encoding priority, or does it basically reflect an increasing ability in inhibiting the processing and retention of the items

designated to be without encoding priority so that the processing and better retention of the items with encoding priority can be accomplished first? Secondly, what are the developing processes underlying the age trends toward a more efficient control? Issues comparable to those stated above have been addressed in studies of selective attention. Differential viewpoints in regard to the efficiency of selective attention will be discussed in the following paragraphs, since the research paradigm of this study is similar to the research paradigm of selective attention in that subjects were required at some point during the available processing time to focus on one particular subset of information rather than the other subset of information which is also contained in the visual array.

In the Broadbent-Triesman approach of attention, the important role of selectivity is placed on inhibition and attenuation of the processing of certain unwanted inputs. Similarly, Posner and Snyder (1975) have stated that the main importance of a strategy that turns the subject's attention to a particular input channel or memory pathway is not so much to facilitate the selected items as it is to reduce the likelihood of interruption from outside the selected domain. On the surface, this view has an interesting counterpart in the findings of a different research area. Patterson and Mischel (1976), in studying the effects of temptation-inhibition and task-facilitating plans on self-control, have suggested that the crucial cognitive activity underlying the child's ability to sustain goal-oriented work in the face of tempting distraction is not the direction of attention to the task per se, but rather the active suppression of attention to the temptation. Following these trends of thought, an

efficient control in employing a given strategy in our study would lie in the subject's better success in restraining himself from processing the items without encoding precedence, at least during the early phase of the available processing time.

On the contrary, Neisser (1976) considers that we selectively attend to certain information by actively engaging ourselves with it, not by shutting out its competitors. He has emphasized that selectivity is a positive process by which organisms do something and leave something undone. He gave an example by stating: "To pick one apple from a tree you need not filter out all the others, you just don't pick them." (Neisser, 1976, p. 85). Therefore, it appears that effective accentuation of the wanted stimulus information is the basis of efficient selective attention. Shiffrin and Schneider (1977) also share this view, except that they are more willing to admit that distracting stimuli are capable of initiating automatic-attention responses.

In fact, the theoretical issue of facilitation versus inhibition is a complex one. It also involves the problem of why the distracting stimuli initiate automatic processing, and whether the processing capacity is limited at a given time. With the assumption of a limited processing and storage capacity, and a condition of stimulus overload, the processing and retention of the relevant information will be at the expense of the processing and retention of the irrelevant information; and the inhibition of the processing and retention of the irrelevant information will benefit the deployment of resources on the relevant or wanted information. Either way, there will be a trade-off relationship between recall of relevant and irrelevant information.

For our adult subjects who had received a sequential encoding instruction, the number of correctly recalled items with encoding precedence was significantly higher than the baseline performance established in a free encoding condition, while the number of correctly recalled items without encoding precedence was significantly lower than the baseline performance. The trade-off relationship suggests that a ceiling effect may be involved. It is impossible to discern whether facilitation for the items with encoding precedence or inhibition for the items without encoding precedence is solely responsible for this result.

For our five-year-olds, the sequential encoding instruction resulted in a significantly greater number of correctly recalled items with encoding precedence than the baseline performance in the free encoding condition. The number of correctly recalled items without encoding precedence was also increased considerably, although the increment did not reach statistical significance. Apparently, no ceiling effect is involved. Paradoxically, the result suggests that five-year-olds enhanced the processing and retention of information which came from those items to-be-encoded first, but did not inhibit the processing and retention of information which came from those items not-to-be-encoded first. Thus, one is left to ponder whether an increase in five-year-olds' ability to prohibit or delay the processing of the items designated not-to-be-encoded first would have increased their efficiency in using the sequential encoding strategy.

According to Gibson (1969), the developmental trend in optimization of attention includes both the tendency for attention to become more exclusive and the tendency for attention to become more selective.

In other words, both the ability to ignore irrelevant information and the ability to focus on the wanted information increase with increasing age. It appears plausible that the interplay of an increase in both kinds of abilities contributed to the efficiency in applying a given sequential encoding strategy.

Conclusion

In investigating the problem of why pre-schoolers' STM performance for a multi-element visual array is inferior to those of older age groups, this study found that five-year-olds probably had a production deficiency in encoding processes. This study also indicates that five-year-olds were inefficient in carrying out a given sequential encoding strategy.

In spite of the fact that five-year-olds were not very efficient in employing a given sequential encoding strategy and that the items designated to be encoded first were not recalled much better than the items designated to be encoded later, five-year-olds had significant gains in the total number of items correctly recalled through the experimental provision of a sequential encoding strategy. This suggests that the effect which a given sequential encoding strategy had on five-year-olds' STM is not so much tied to the specific content of the encoding plan being provided, but rather tied to the provision of an encoding plan in general. This study supports Haith's contention that five-year-olds' deficit in the processing and memory of a multi-element array can be attributed, in part, to their lack of spontaneous production of a plan for sequential encoding.

A sequential encoding strategy plays an important role in rapid

information processing and memory. STM performance suffers when subjects lack cognitive ability to spontaneously produce such a strategy. The finding of this study is consistent with Flavell's (1971) contention that memory development is largely applied cognitive development. Flavell stated that ". . . what we call 'memory processes' seem largely to be just the same old, familiar, cognitive processes, but as they are applied to a particular class of problem." (Flavell, 1971, p. 273).

In memory development, the use of cognitive strategies other than those studied here needs to be studied. The one suggested by this study is the rehearsal strategies spontaneously used by different age groups. Additionally, while this study has forcused on the relationship between age differences in STM performance and the developmental differences in the use of cognitive strategies, it does not rule out the possibility that age differences in encoding speed, storage capacity and/or other factors may have contributed to the age differences in STM performance. By providing the sequential encoding strategy to subjects, the age differences in STM performance were only somewhat reduced.

Table 1

Group means of the R-scores, the B-scores, and the T-scores obtained in the three report orders.

Encoding Strategy	Age	Report-Order								
		Free			Red-First			Black-First		
		R	B	T	R	B	T	R	B	T
Free Encoding [a]	5	.75	.70	1.45	1.04	.49	1.53	.63	1.04	1.67
	8	1.24	1.17	2.40	1.44	.83	2.27	.93	1.48	2.47
	19	1.72	1.78	3.49	2.02	1.40	3.42	1.15	2.10	3.25
Sequential Encoding (Red-First) [b]	5	1.40	1.15	2.55	1.48	1.05	2.53	1.30	1.05	2.35
	8	1.48	1.08	2.55	1.73	.98	2.70	.93	1.58	2.50
	19	2.58	1.35	3.93	2.58	1.28	3.85	1.93	1.88	3.80
(Black-First) [b]	5	.95	1.40	2.35	1.03	1.03	2.05	.80	1.25	2.05
	8	1.05	1.48	2.53	1.63	.88	2.50	.90	2.15	3.05
	19	.90	2.58	3.48	1.15	1.70	2.85	.63	2.58	3.20
(Two sub-groups combined) [a]	5	1.17	1.27	2.45	1.25	1.04	2.29	1.05	1.15	2.20
	8	1.26	1.28	2.54	1.68	.93	2.60	.91	1.86	2.78
	19	1.74	1.96	3.70	1.86	1.49	3.35	1.28	2.23	3.50

Note. Due to rounding error, the group mean of the T-scores may not be exactly equal to the sum of the group mean of the R-scores and the group mean of the B-scores.

[a] n = 10 at each age level.

[b] n = 5 at each age level.

Table 2

Summary of ANOVA on the R-scores and the B-scores in the free encoding and free report-order condition.

Source of Variation	SS	df	MS	F
Between Subjects				
A (Age)	10.1545	2	5.0772	25.82 ***
Sub. within groups	5.2345	27	0.1939	
Within Subjects				
B (Score-type)	0.0069	1	0.0069	<1
A x B	0.2874	2	0.1437	1.36
B x Sub. within groups	2.8464	27	0.1054	

*** $p < .001$

Table 3

Number of subjects with various degrees of consistency in first reporting the red color, in the free encoding condition.

Age of subjects [a]	Number of trials starting with the red								
	0	1	2	3	4	5	6	7	8
5	0	0	0	2	2	4	1	0	1
8	0	0	1	3	2	2	1	1	0
19	0	0	3	3	4	0	0	0	0

Note. [a] $n = 10$ at each age level

Table 4

Number of subjects with various degrees of consistency in first reporting the color on the vertical dimension, in the free encoding condition.

Age of subjects [a]	Number of trials starting with the vertical dimension								
	0	1	2	3	4	5	6	7	8
5	0	0	0	2	1	2	3	1	1
8	1	0	2	1	1	1	2	1	1
19	0	1	5	0	1	1	1	1	0

Note. [a] $n = 10$ at each age level

Table 5

Summary of ANOVA on the T-scores obtained in the free report-order.

Source of Variation	SS	df	MS	F	
A (Age)	28.2659	2	14.1329	56.06	***
B (Encoding-Strategy)	3.0465	1	3.0465	12.08	**
A x B	2.2770	2	1.1385	4.52	*
Within cell (Error)	13.6150	54	0.2521		

* $p < .05$

** $p < .005$

*** $p < .001$

Table 6

The mean number of correctly recalled items defined in terms of the encoding and reporting precedency specified in the instructions.

Age	Free Encoding + Free Reporting	With Enc. Pre. + Free Reporting	Without Enc. Pre. + Free Reporting	Free Encoding + With Rep. Pre.	Free Encoding + Without Rep. Pre.	With Enc. Pre. + With Rep. Pre.	With Enc. Pre. + Without Rep. Pre.	Without Enc. Pre. + With Rep. Pre.	Without Enc. Pre. + Without Rep. Pre.
5	0.72	1.40	1.05	1.04	0.56	1.35	1.16	1.04	0.94
8	1.20	1.48	1.06	1.46	0.90	1.94	0.90	1.60	0.94
19	1.75	2.58	1.12	2.06	1.28	2.58	1.81	1.52	0.95

Table 7

Summary of ANOVA on the scores for the number of items recalled with encoding precedency, obtained in the free report-order.

Source of Variation	SS	df	MS	F	
A (Age)	13.0260	2	6.5130	62.81	***
B (Encoding-Strategy)	5.3402	1	5.3402	51.50	***
A x B	0.8264	2	0.4132	3.98	*
Error	5.6014	54	0.1037		

* $p < .05$

*** $p < .001$

Table 8

Summary of ANOVA on the scores for the number of items recalled without encoding precedence, obtained in the free report-order.

Source of Variation	SS	df	MS	F	
A (Age)	2.9984	2	1.4992	18.08	***
B (Encoding-Strategy)	0.2912	1	0.2912	3.51	
A x B	2.2329	2	1.1164	14.07	***
Error	4.4790	54	0.0829		

*** $p < .001$

Table 9

Number of subjects with various degrees of consistency in first reporting the red color, in the sequential (red) encoding condition.

Age of subjects [a]	Number of trials starting with the red								
	0	1	2	3	4	5	6	7	8
5	0	0	0	0	0	2	3	0	0
8	0	0	0	0	2	1	1	0	1
19	0	0	0	0	0	0	0	3	2

Note. [a] $n = 5$ at each age level

Table 10

Number of subjects with various degrees of consistency in first reporting the red color, in the sequential (black) encoding condition.

Age of subjects [a]	Number of trials starting with the red								
	0	1	2	3	4	5	6	7	8
5	0	1	0	2	2	0	0	0	0
8	0	0	2	3	0	0	0	0	0
19	5	0	0	0	0	0	0	0	0

Note. [a] $n = 5$ at each age level

Table 11

Number of subjects with various degrees of consistency in first reporting the vertical dimension, in the sequential (red) encoding condition.

Age of subjects [a]	Number of trials starting with the vertical dimension								
	0	1	2	3	4	5	6	7	8
5	0	0	1	0	1	1	1	1	0
8	0	0	0	0	1	1	1	0	2
19	0	0	0	2	2	1	0	0	0

Note. [a] $n = 5$ at each age level

Table 12

Number of subjects with various degrees of consistency in first reporting the vertical dimension, in the sequential (black) encoding condition.

Age of subjects [a]	Number of trials starting with the vertical dimension								
	0	1	2	3	4	5	6	7	8
5	0	0	0	0	0	2	0	1	2
8	0	1	0	0	2	1	1	0	0
19	0	0	0	0	5	0	0	0	0

Note. [a] $n = 5$ at each age level

Table 13

Summary of ANOVA on the R-scores and the B-scores in the free encoding condition.

Source of Variation	SS	df	MS	F	
Between Subjects					
A (Age)	25.4033	2	12.7017	37.37	***
Subj. W. Groups	9.1784	27	0.3399		
Within Subjects					
B (Report-order)	0.0283	2	0.0142	<1	
A x B	0.3399	4	0.0850	1.46	
B x Subj. W. G.	3.1474	54	0.0583		
C (Score-type)	0.0008	1	0.0008	<1	
B x C	11.1161	2	5.5581	35.72	***
A x B x C	0.5083	4	0.1271	<1	
B x C x Subj. W. G.	8.4016	54	0.1556		

*** $p < .001$

Table 14

Group means of the T-scores obtained in the constrained report-orders.

Group[a]	Report-order	
	Constrained-matched	Constrained-mis-matched
Five-year-olds		
Free encoding[b]	1.60	1.60
Sequential encoding	2.29	2.20
Eight-year-olds		
Free encoding[b]	2.37	2.37
Sequential encoding	2.88	2.50
Nineteen-year-olds		
Free encoding[b]	3.34	3.34
Sequential encoding	3.53	3.33

[a] $n = 10$

[b] For the free encoding condition, the red-first report-order and the black-first report-order cannot be classified in terms of constrained-matched or constrained-mis-matched report-order. Therefore, the average score of the red-first report-order and the black-first report-order was computed for each S. Then, the mean of those scores was derived and reported here as the mean score for both constrained-matched and the constrained mis-matched report-orders.

Table 15

Summary of ANOVA on the T-scores obtained in the constrained-matched report-order.

Source of Variation	SS	df	MS	F
A (age)	22.0933	2	11.0467	32.97 ***
B (Encoding-strategy	3.2063	1	3.2063	9.57 ***
A x B	0.6282	2	0.3141	< 1
Within cell (Error)	18.0968	54	0.3351	

*** $p < .001$

Table 16

Summary of ANOVA on the T-scores obtained in the constrained-mis-matched report-order.

Source of Variation	SS	df	MS	F
A (Age)	14.4697	2	7.2348	9.13 ***
B (Encoding-Strategy)	2.3207	1	2.3207	2.93
A x B	0.5637	2	0.2819	< 1
Within cell (Error)	42.7976	54	0.7925	

*** $p < .001$

Table 17

Summary of ANOVA on the T-scores in the free encoding and free reporting condition and the T-scores in the sequential encoding and constrained-matched report-order condition.

Source of Variation	SS	df	MS	F
A (Age)	26.8471	2	13.4236	34.47 ***
B (Condition)	3.0420	1	3.0420	7.81 **
A x B	1.6089	2	0.8045	2.07
Within cell (Error)	21.0254	54	0.3894	

** $p < .01$

*** $p < .001$

Table 18

Summary of ANOVA on the T-scores in the free encoding and free reporting condition and the T-scores in the sequential encoding and constrained-mis-matched report-order condition.

Source of Variation	SS	df	MS	F	
A (Age)	25.3902	2	12.6951	39.47	***
B (Condition)	0.7866	1	0.7866	2.45	
A x B	2.2023	2	1.1012	3.42	*
Within cell (Error)	17.3659	54	0.3216		

* $p < .05$

*** $p < .001$

Table 19

Summary of ANOVA on the R-scores and the B-scores in the sequential (red) encoding condition.

Source of Variation	SS	df	MS	F	
Between Subjects					
A (Age)	8.8774	2	4.4389	20.27	***
Subj. w. groups	2.6262	12	0.2188		
Within Subjects					
B (Report-order)	0.0899	2	0.0450	< 1	
A x B	0.0434	4	0.0109	< 1	
B x Subj. w. groups	2.1896	24	0.0912		
C (Score-Type)	4.3340	1	4.3340	40.17	***
C x A	2.0378	2	1.0189	9.44	**
C x Subj. w. groups	1.2948	12	0.1079		
B x C	3.5983	2	1.7992	15.31	***
A x B x C	1.5392	4	0.3848	3.27	*
B x C x Subj. w. groups	2.8208	24	0.1175		

* $p < .05$

** $p < .005$

*** $p < .001$

Table 20

Summary of ANOVA on the R-scores and the B-scores in the sequential (black) encoding condition.

Source of Variation	SS	df	MS	F	
Between Subjects					
A (Age)	3.9441	2	1.9721	9.86	**
Subj. w. groups	2.3990	12	0.1999		
Within Subjects					
B (Report-order)	0.4764	2	0.2382	2.48	
A x B	0.6465	4	0.1616	1.68	
B x Subj. w. groups	2.3042	24	0.0960		
C (Score-Type)	10.0000	1	10.0000	73.26	***
C x A	5.9135	2	2.9568	21.66	***
C x Subj. w. groups	1.6385	12	0.1365		
B x C	6.5542	2	3.2771	22.69	***
A x B x C	1.6604	4	0.4151	2.87	*
B x C x Subj. w. groups	3.4646	24	0.1444		

* $p < .05$

** $p < .005$

*** $p < .001$

Table 21

Summary of ANOVA on the number of items correctly recalled by the five-year-olds of the sequential encoding condition.

Source of Variation	SS	df	MS	F
Between Subjects				
A (Color of the items with encoding precedence)	0.3961	1	0.3961	1.90
Subj. w. groups	1.6606	8	0.2087	
Within Subjects				
B (Report-order)	0.1609	2	0.0805	< 1
A x B	0.0484	2	0.0242	< 1
B x Subj. w. groups	1.6292	16	0.1018	
C (Encoding-precedency of items)	1.3128	1	1.3128	35.10 ***
A x C	0.0003	1	0.0003	< 1
C x Subj. w. groups	0.2990	8	0.0374	
B x C	0.2286	2	0.1143	< 1
A x B x C	0.1349	2	0.0675	< 1
B x C x Subj. w. groups	2.4854	16	0.1553	

*** $p < .001$

Table 22

Summary of ANOVA on the number of items correctly recalled by the eight-year-olds of the sequential encoding condition.

Source of Variation	SS	df	MS	F	
Between Subjects					
A (Color of the items with encoding precedence)	0.0440	1	0.0440	<1	
Subj. w. groups	2.2792	8	0.2849		
Within Subjects					
B (Report-order)	0.4266	2	0.2133	2.36	
A x B	0.1099	2	0.0550	<1	
B x Subj. w. groups	1.4427	16	0.0902		
C (Encoding-precedency of items)	0.8461	1	0.8461	11.43	*
A x C	0.0753	1	0.0753	1.02	
C x Subj. w. groups	0.5917	8	0.0740		
B x C	7.4547	2	3.7274	38.35	***
A x B x C	0.2505	2	0.1253	1.29	
B x C x Subj. w. groups	1.5552	16	0.0972		

* $p < .05$

*** $p < .001$

Table 23

Summary of ANOVA on the number of items correctly recalled by adults of the sequential encoding condition.

Source of Variation	SS	df	MS	F	
Between Subjects					
A (Color of the items with encoding precedence)	1.7510	1	1.7510	12.99	**
Subj. w. groups	1.0781	8	0.1348		
Within Subjects					
B (Report-order)	0.3521	2	0.1761	1.98	
A x B	0.1538	2	0.0792	< 1	
B x Subj. w. groups	1.4219	16	0.0889		
C (Encoding-precedency of items)	18.9844	1	18.9844	74.36	***
A x C	1.0667	2	1.0667	4.18	
C x Subj. w. groups	2.0427	8	0.2553		
B x C	5.1813	2	2.5907	18.47	***
A x B x C	0.0271	2	0.0316	< 1	
B x C x Subj. w. groups	2.2448	16	0.1403		

** $p < .01$

*** $p < .001$

Table 24

Summary of ANOVA on the number of correctly recalled items with encoding precedence and reporting precedence.

Source of Variation	SS	df	MS	F
A (Age)	12.5898	2	6.2949	56.20 ***
B (Condition)	8.1107	1	8.1107	72.42 ***
A x B	0.1054	2	0.0527	<1
Within cell (Error)	6.0467	54	0.1120	

***$p < .001$

Table 25

Summary of ANOVA on the number of correctly recalled items with encoding precedence but without reporting precedence.

Source of Variation	SS	df	MS	F
A (Age)	8.2473	2	4.1236	50.35 ***
B (Condition)	0.0770	1	0.0070	< 1
A x B	1.3543	2	0.6771	8.27 ***
Within cell (Error)	4.4244	54	0.0819	

*** $p < .001$

Table 26

Summary of ANOVA on the number of correctly recalled items without encoding precedence but with reporting precedence.

Source of Variation	SS	df	MS	F	
A (Age)	5.8689	2	2.9344	27.68	***
B (Condition)	0.4051	1	0.4051	3.82	
A x B	1.1679	2	0.5839	5.51	**
Within cell (Error)	5.7252	54	0.1060		

** $p < .01$

*** $p < .001$

Table 27

Summary of ANOVA on the number of correctly recalled items without encoding precedence and without reporting precedence.

Source of Variation	SS	df	MS	F	
A (Age)	2.6732	2	1.3366	10.68	***
B (Condition)	1.1593	1	1.1593	9.27	***
A x B	2.5278	2	1.2639	10.10	***
Within cell (Error)	6.7544	54	0.1251		

*** $p < .001$

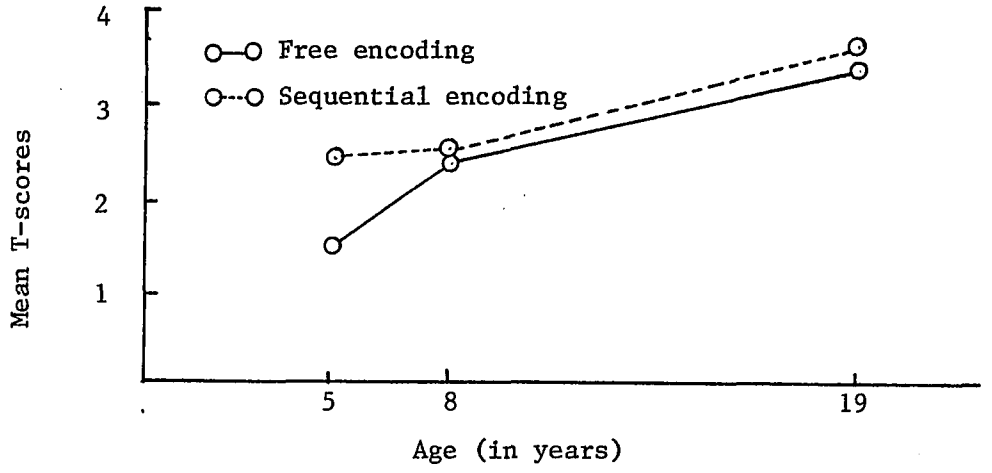

Figure 1. Age X encoding-strategy interaction in the T-scores obtained in the free report-order.

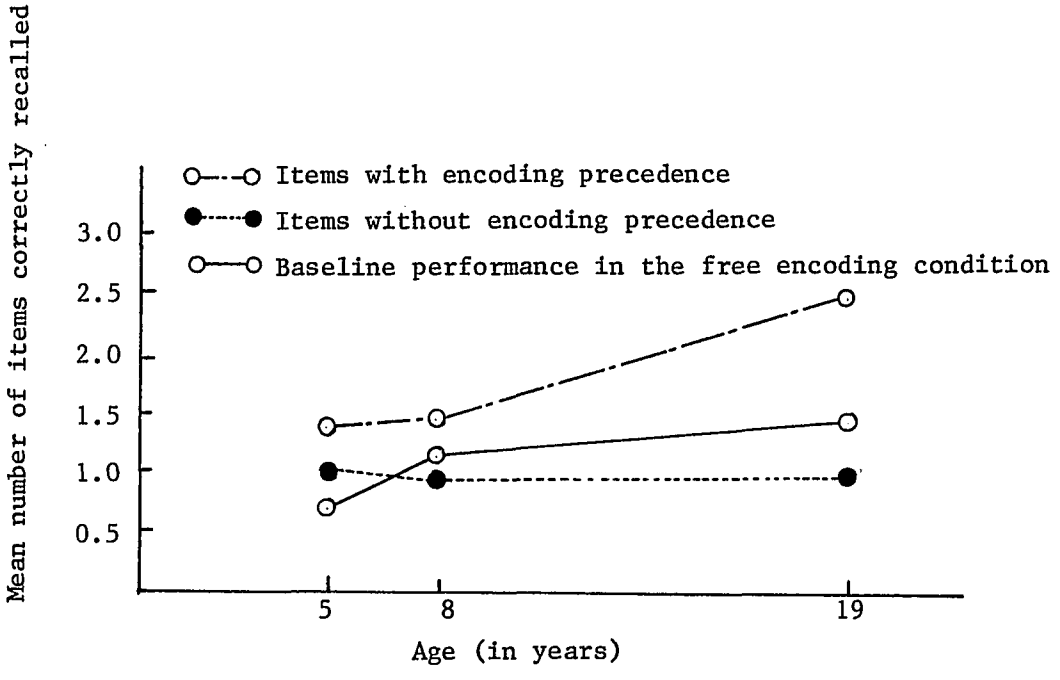

Figure 2. Age X encoding-strategy interaction in the scores for items with encoding precedence and in the scores for items without encoding precedence.

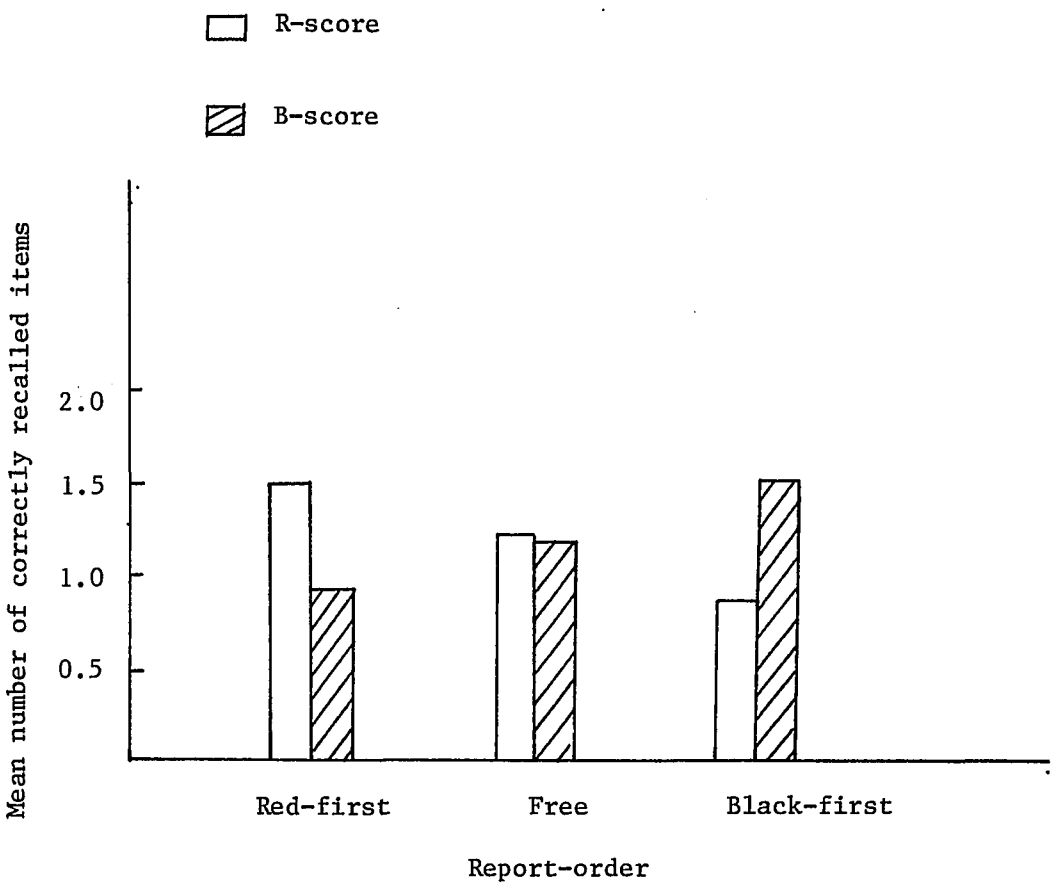

Figure 3. Report-order X Score-type interaction, in the free encoding condition.

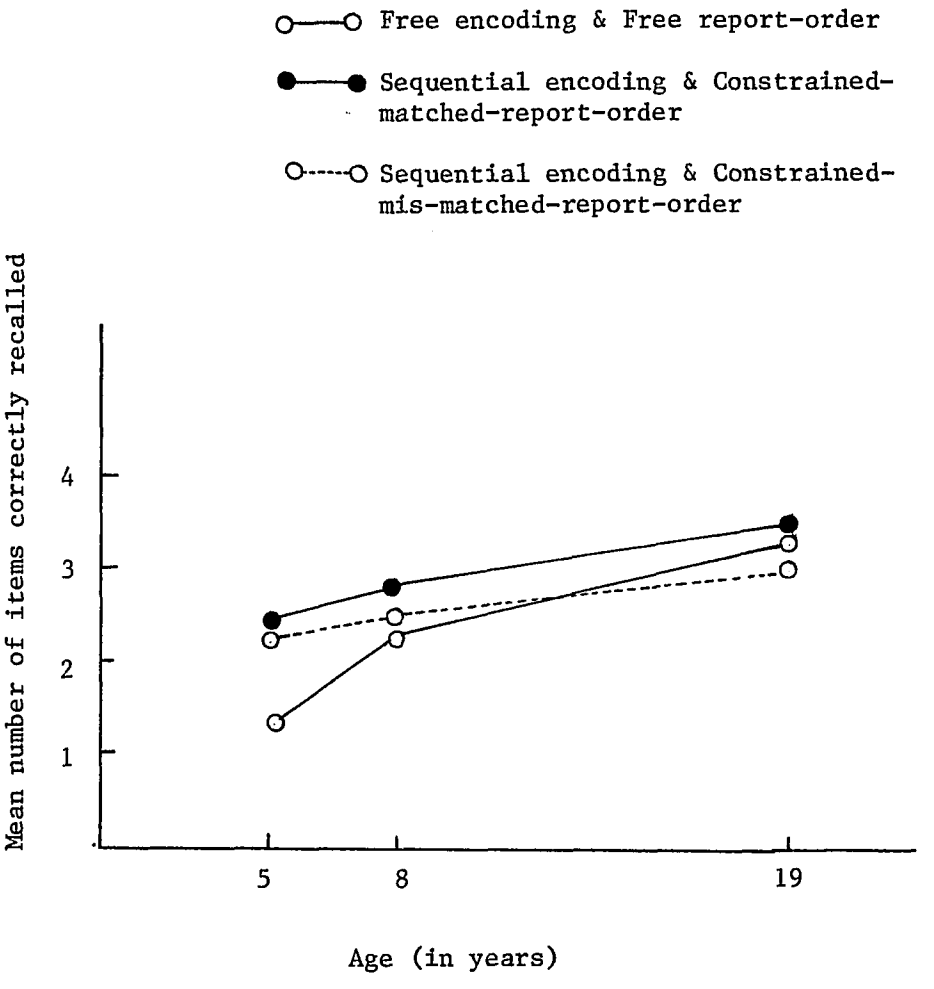

Figure 4. The joint effect of sequential encoding and constrained report-order instructions on the T-score.

Note: This figure illustrates two separate age x condition interactions reported in Table 17 and Table 18, respectively.

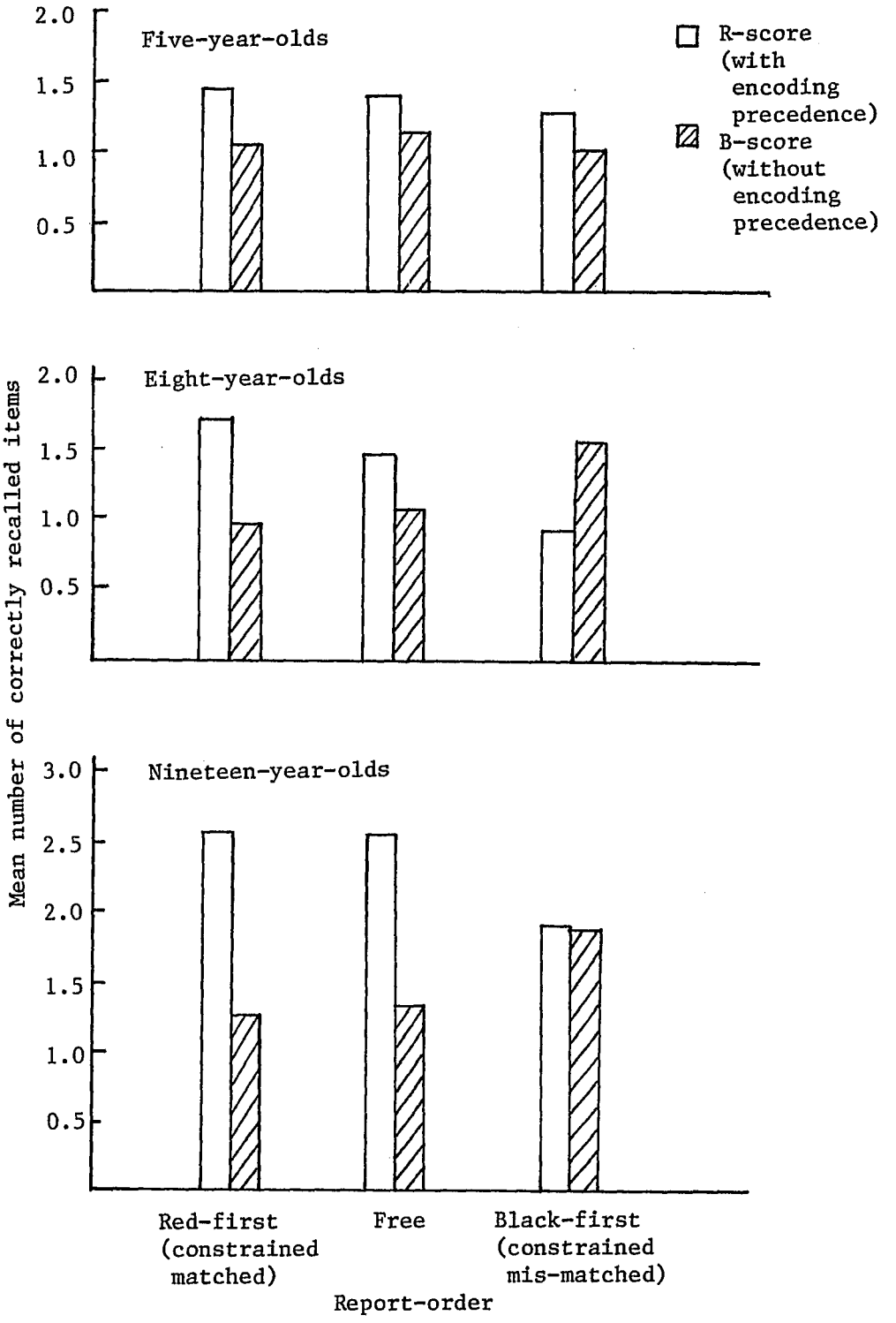

Figure 5. Age X report-order X score-type interaction, in the sequential (red) encoding condition.

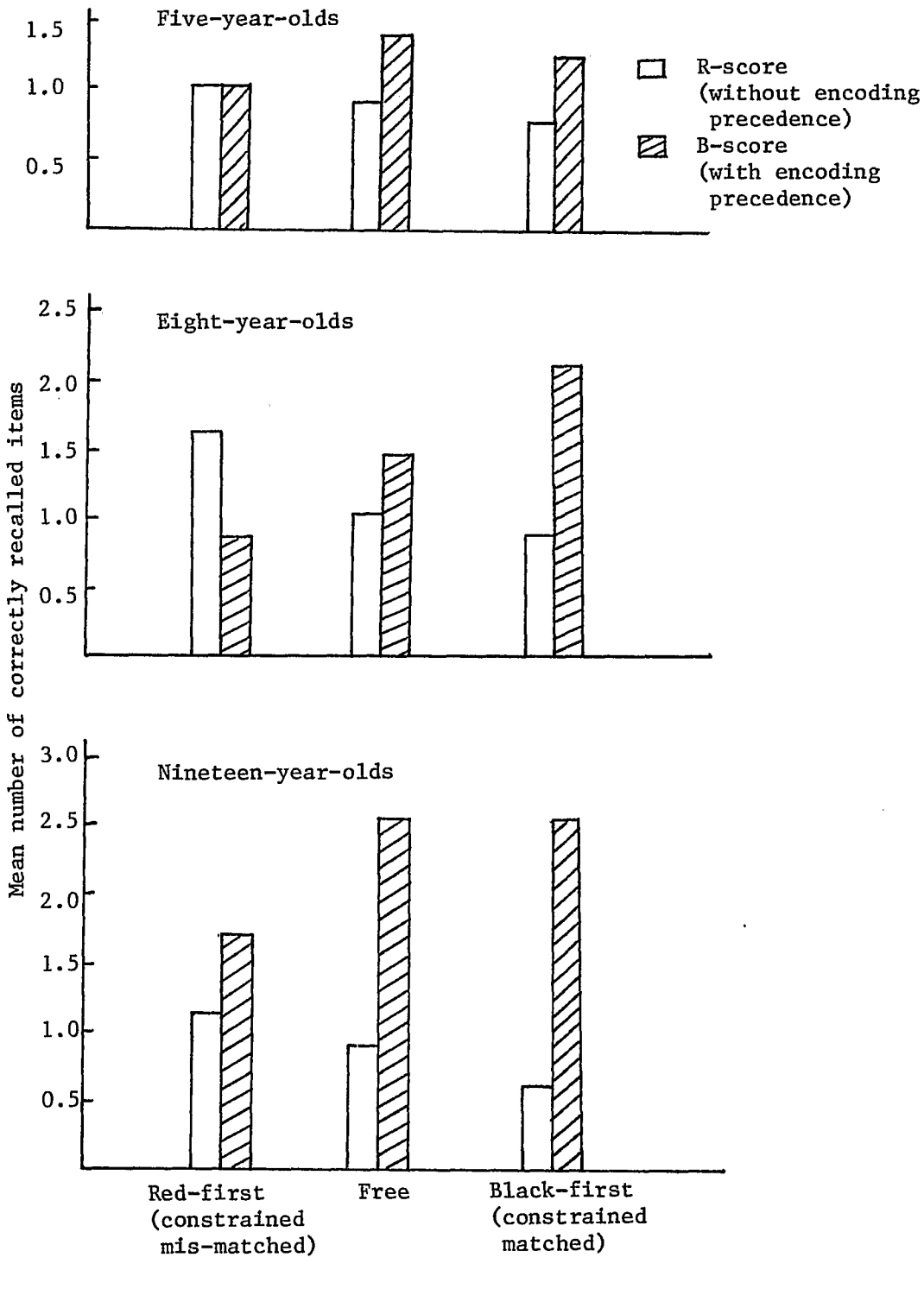

Figure 6. Age X report-order X score-type interaction in the sequential (black) encoding condition.

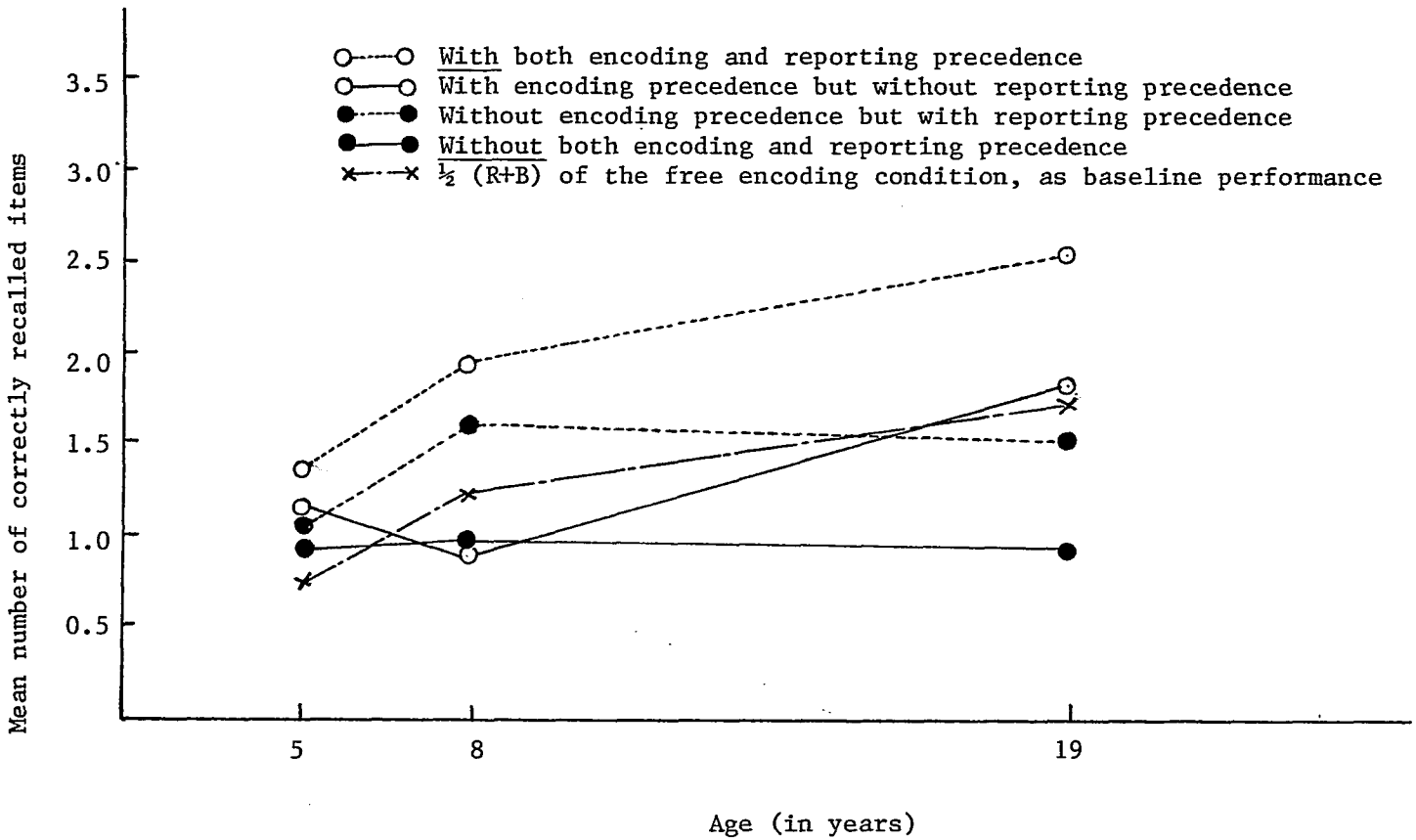

Figure 7. The joint effects of having given a sequential encoding strategy and a report strategy on subjects' STM performance, in terms of the various scores for items differing in encoding and reporting precedence.

Reference Note

1. Howard, D. V., & Goldin, S. E. Selective processing in encoding and memory of kindergarten children. Paper presented at the meetings of the Eastern Psychological Association. Washington, D. C., March, 1978.

References

Appel, L. F., Cooper, R. G., McCarrell, N., Sims-Knight, J., Yussen, S. R., & Flavell, J. H. The development of the distinction between perceiving and memorizing. Child Development, 1972, 43, 1365-1381.

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. Spence & J. Spence (Eds.), The psychology of learning and motivation (Vol. 2). New York: Academic Press, 1968.

Averbach, E., & Coriell, A. S. Short-term memory in vision. Bell System Technical Journal, 1961, 40, 309-328.

Averbach, E., & Sperling, G. Short-term storage of information in vision. In C. Cherry (Ed.), Symposium on information theory. London: Butterworth, 1961.

Belmont, J. M., & Butterfield, E. C. Learning strategies as determinants of memory deficiencies. Cognitive Psychology, 1971, 2, 411-420. (a)

Belmont, J. M., & Butterfield, E. C. What the development of short-term memory is. Human Development, 1971, 14, 236-248. (b)

Blake, J. A. A developmental study of speed and strategy in visual information processing, using backward masking. Unpublished Doctoral Dissertation, City University of New York, 1972.

Blake, J. A. Developmental change in visual information processing under backward masking. Journal of Experimental Child Psychology, 1974, 17, 133-146.

Blake, J. A., & Vingilis, E., Developmental change in the temporal course of tachistoscopic recognition. Developmental Psychology, 1977, 13 (1), 39-46.

Bousfield, W. A., Esterson, J., & Whitmarsh, G. A. A study of developmental changes in conceptual and perceptual associative clustering. Journal of Genetic Psychology, 1958, 92, 95-102.

Chi, M. T. H. Short-term memory limitations in children: Capacity or processing deficits? Memory and Cognition, 1976, 4 (5), 559-572.

Cole, M., Frankel, F., & Sharp, D. Development of free recall learning in children. Developmental Psychology, 1971, 4, 109-123.

Dick, A. A. Parallel and serial processing in tachistoscopic recognition: Two mechanisms. Journal of Experimental Psychology, 1972, 96, 60-66.

Doyle, A. Listening to distraction: A developmental study of selective attention. Journal of Experimental Child Psychology, 1973, 15, 100-115.

Eriksen, B. A., & Eriksen, C. W. Effects of noise letters upon the identification of a target letter in a nonsearch task. Perception & Psychophysics, 1974, 16, 143-149.

Eriksen, B. A., & Hoffman, J. E. The extent of processing noise elements during selective encoding from visual displays. Perception & Psychophysics, 1973, 155-160.

Flavell, J. H. Developmental studies of mediated memory. In H. W. Reese & L. P. Lipsitt (Eds.), Advances in child development and behavior, 1970, Vol. 5, 181-211.

Flavell, J. H. First discussant's comments: What is memory development the development of? Human Development, 1971, 14. 272-278.

Flavell, J. H., Beach, D. R., & Chinsky, J. M. Spontaneous verbal rehearsal in a memory task as a function of age. Child Development, 1966, 37, 283-299.

Flavell, J. H., & Wellman, H. M. Metamemory. In R. Kail, & J. Hagen (Eds.), Perspectives on the development of memory and cognition. Hillsdale, New Jersey: Erlbaum, 1977.

Gibson, E. J. Principles of perceptual learning and development. New York: Appleton-Century-Crofts, 1969.

Gibson, E. J., & Yonas, A. A developmental study of visual search behavior. Perception & Psychophysics, 1966, 16, 169-171.

Gholson, B., Levine, M. & Philips, S. Hypotheses, strategies, and stereotypes in discrimination learning. Journal of Experimental Child Psychology, 1972, 13, 423-446.

Haber, R. N. A replication of selective attention and coding in visual perception. Journal of Experimental Psychology, 1964, 67, 402-404.

Haber, R. N. Introduction. In R. N. Haber (Ed.), Information-processing approaches to visual perception. New York: Holt, Rinehart, and Winston, 1969.

Hagen, J. W. Strategies for remembering. In S. Farnham-Diggory (Ed.), Information processing in children. New York: Academic Press, 1972, 65-79.

Hagen, J. W., & Hale, G. H. The development of attention in children. In A. D. Pick (Ed.), Minnesota Symposia on Child Psychology (Vol.7). Minneapolis : The University of Minnesota Press, 1963.

Haith, M. M., Morrison, F. J., Sheingold, K., & Mindes, P. Short-term memory for visual information in children and adults. Journal of Experimental Children Psychology, 1970, 9, 454-469.

Haith, M. M., Morrison, F. J., & Sheingold, K. Tachistoscopic recognition of geometric forms by children and adults. Psychonomic Science, 1970, 19, 345-347.

Haith, M. M. Developmental changes in visual information processing and short-term memory. Human Development, 1971, 14, 249-261.

Harris, C. S., & Haber, R. N. Selective attention and coding in visual perception. Journal of Experimental Psychology, 1963, 65, 328-333.

Holding, D. H. Gussing behavior and Sperling store. Quarterly Journal of Experimental Psychology, 1970, 22, 248-256.

Holding, D. H. Amount seen in brief exposures. Quarterly Journal of Experimental Psychology, 1971, 23, 72-81.

Holmgren, J. H. The effect of a visual indicator on rate of visual search : Evidence for processing control. Perception & Psychophysics, 1974, 15 (3), 544-555.

Kahneman, D. Attention and effort. Englewood Cliffs, New Jersey : Prentice-Hall, Inc., 1973.

Kobasigawa, A. Utilization of retrieval cues by children in recall. Child Development, 1974, 45, 127-134.

Kobasigawa, A., & Middleton, D. Free recall of categorized items by children at three grade levels. Children Development, 1972, 43, 1067-1072.

Kobasigawa, A., & Orr, R. R. Free recall and retrieval speed of categorized items by kindergarten children. Journal of Experimental Child Psychology, 1973, 15, 187-192.

LaBerge, D., & Brownstone, L. S. Control of visual processing by color cueing. Bulletin of the Psychonomic Society, 1974, 2, (4B), 417-418.

Liss, P., & Haith, M. M. The speed of visual processing in children and adults : Effect of backward and forward masking. Perception & Psychophysics, 1970, 8(6), 396-398.

Mackworth, N.H., & Bruner, J. S. How adults and children search and recognize pictures. Human Development, 1970, 13 , 149-177.

Mandler, G. Organization and memory. In K. W. Spence & J. T. Spence (Eds.), The psychology of learning and motivation. New York : Academic Press, 1966.

Mewhort, D.J. K., Merikle, P. M., & Bryden, M. P. On the transfer from iconic to short-term memory. Journal of Experimental Psychology, 1969, 81, 181-189.

Miller, G.A. The magical number seven, plus or minus two : Some limits on our capacity for processing information. Psychological Review, 1956, 63, 81-97.

Miller, L. K. Visual masking and development differences in information processing. Child Development, 1972, 43, 704-709.

Moely, B. E., Olson, F. A., Halwes, T. G., Flavell, J. H. Production deficiency in young children's clustered recall. Developmental Psychology, 1969, 1, 26-34.

Neisser, U. Cognitive psychology. New York : Appleton-Century-Crofts, 1967.

Neisser, U. Cognitive and reality : principles and implications of cognitive psychology. San Francisco : W. H. Freeman and Company, 1976.

Newell, A., & Simon, H. A. Human problem solving. New Jersey : Prentice-Hall, 1972.

Norman, D. A., & Bobrow, D. G. On data-limited and resource-limited processes. Cognitive Psychology, 1975, 7, 44-64.

Patterson, C. J., & Mischel, W. Effects of tempation-inhibiting and task-facilitating plans on self-control. Journal of Personality and Social Psychology, 1976, 33(2), 209-217.

Posner, M. I., and Snyder, C. R. Attention and cognitive control. In R. L. Solo (Ed.), Information processing and cognition, The Loyola Symposium. New Jersey : Lawrence Erlbaum Associates, Publishers, 1975.

Scheerer, E. Order of report and order of scanning in tachistoscopic recognition. Canadian Journal of Psychology, 1972, 26 (4), 382-390.

Scribner, S., & Cole, M. Effects of constrained recall training on children's performance in a verbal memory task. Child Development, 1972, 43, 845-857.

Shiffrin, R. M., & Schneider, W. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychological Review, 1977, 84, (2), 127-190

Siegel, S. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill, 1956.

Sperling, G. The information available in brief visual presentations. Psychological Mongraphs, 1960, 74 (11, whole No. 498).

Sperling, G. A model for visual memory tasks. Human Factors, 1963, 5, 15-31.

Sperling, G. Successive approximation to a model for short-term memory. Acta Psychologica, 1967, 27, 285-292.

Tenney, Y. J. The child's concept of organization and recall. Journal of Experimental Child Psychology, 1975, 19, 100-114.

Townsend, V. M. Loss of spatial and identity information following a tachistoscopic exposure. Journal of Experimental Psychology, 1973, 98 (1), 113-118.

Tulving, E., & Pearlstone, Z. Availability versus accessibility of information in memory for words. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 381-391.

Von Wright, J. M. Selection in visual immediate memory. Quarterly Journal of Experimental Psychology, 1968, 20, 62-68.

Von Wright, J. M. On the problem of selection in iconic memory. Scandinavian Journal of Psychology, 1972, 13, 159-171.

Vurpillot, E. The development of scanning strategies and their relation to visual differentiation. Journal of Experimental Child Psychology, 1968, 6, 632-650.

Welsandt, R. F. Jr., Zupnick, J. Jr., & Meyer, P. Age effects in backward visual masking (Crawford paradigm). Journal of Experimental Child Psychology, 1973, 15, 454-461.

William, K.G., & Goulet, L.R. The effects of cueing and constraint instructions on children's free recall performance. Journal of Experimental Child Psychology, 1975, 19, 464-475.