THE EFFECT OF PHONETIC SIMILARITY ON PRESCHOOL CHILDREN'S MEMORY: EVIDENCE FOR PHONETIC CODING ABILITY

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Abstract

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Recent studies have shown that good readers' performance on visual and auditory short-term memory tasks falls to the level of poor readers' performance when the stimulus material is phonetically similar. These findings have been interpreted as support for the hypothesis that poor readers are less affected by phonetic similarity because they are less able than good readers to use phonetically based coding in short-term memory. The question has been raised as to whether or not the poor reader's failure to code phonetically reflects a developmental delay or a constitutional deficiency in information processing abilities. The present study tested the development of phonetic coding over the preschool period in an attempt to clarify this issue. Eighty preschool children, 40 aged 42 to 58 months and 40 aged 60 to 68 months were presented with sets of rhyming (phonetically similar) and nonrhyming (phonetically dissimilar) letters. Recall for the letters was begun either immediately or after a short delay. Memory for the letters was measured by either a serial reconstruction task or by an oral free recall task. The results provide significant evidence that preschool children's recall of letters is adversely affected by phonetic similarity. This finding held true for memory for both item and order information, regardless of whether recall was measured across sets presented or within sets. It therefore appears that preschoolers do use a phonetic code as a memory strategy for recalling visually presented

letters, even when use of such a code penalizes recall. In general, both age groups were equally affected by phonetic similarity. The results showed that phonetic coding is advanced enough by the preschool age to be used as a memory strategy, and thus suggest that phonetic coding is a skill acquired at an early stage, perhaps with speech. By implication, then, its absence in poor readers may reflect a constitutional deficiency in information processing abilities.

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There has been a great deal of research on the nature of the abilities required in reading. One ability that is thought to play a role in reading is that of holding the information gained from the printed letters in memory long enough to abstract it into phonemes, words, or idea units. Recent research has suggested that this holding ability is achieved by transferring the visual information on the printed page to a phonetically-based form so that it can be held in a short-term memory system which is assumed to have a phonetic format (Conrad, 1972).

Baddeley (1978; 1979) attempted to explain this transfer of printed information and its role in reading by developing a model of a two-part short-term memory system entitled "working memory". According to Baddeley, working memory utilizes a verbal code, is time based and can hold up to two seconds of information. The first part, called the "central executive", is concerned with control processes and possibly with selective attention. The second part, called the "secondary articulatory loop", is a slave-like system that enables any material that can be verbalized to be stored in a way that makes minimal demands on the central executive (Baddeley, 1978).

Baddeley (1979) suggested that the secondary articulatory loop is important in learning to read. He theorized that the beginning reader uses the central executive to translate the letters in the words being read into individual speech sounds, and then progresses from the sequence of unrelated sounds to the understanding of a read English word. The central executive can also be used to hold the decoded speech sounds during this process; however, the processing space in the central executive is limited and decreases with each new speech sound it encounters. The secondary articulatory loop serves as a supplementary way of storing sequences of sounds (or phonemes). As each phoneme is decoded by the central executive, it is stored in the secondary articulatory loop, thereby leaving the central executive free to decode the next phoneme and perhaps hypothesize about what the final target word may be. When two or three phonemes have been loaded into the loop, they can be blended into a syllable. This syllable is then returned to the loop, and is held there until further phonemes are decoded, which are then in turn blended with the initial syllable. The process continues until sufficient information has been processed for the beginning reader to decode the meaning of the word, phrase or clause. On the basis of this model, Baddeley hypothesized that a child who has difficulty with or is unable to use the loop may experience difficulty in learning to read.

Earlier studies with normal readers had consistently found greater confusion in recall when the items presented were phonetically similar than when the items presented were visually or semantically similar (Baddeley, 1978). This finding, referred to as the phonetic similarity effect, suggested that perceivers have so strong a tendency to store information phonetically that they persist in using a phonetic recoding strategy even when it penalized recall. According to Baddeley's (1979) working memory model, the phonetic similarity effect results from an overload on the secondary articulatory loop. This overload prevents the working memory from holding on to the sequences of phonemes.

The role of working memory in reading is the focus of the research activity of a group at Haskins Speech and Hearing Laboratories. These researchers consider that the secondary articulatory loop is involved in both reading and the phonetic similarity effect. In their experiments, the group at Haskins have hypothesized that poor readers would have difficulty with the use of the secondary articulatory loop as an aid for phonetic recoding in working memory. In other words, they have predicted that good readers would rely more on a phonetic code in working memory, whereas poor readers would not (Shankweiler, Liberman, Mark, Fowler & Fischer, 1979; Mann, Note 1).

The hypothesis that poor readers make less use of a phonetic code than good readers was first tested by Shankweiler et al. (1979). Superior, marginal and inferior Grade 2 readers, matched on IQ and age, were tested to determine the role of phonetic representation in memory for letter strings. Sixteen strings of five letters were presented. Eight strings were composed of five rhyming consonants (phonetically confusable) and eight strings were composed of five nonrhyming consonants (phonetically nonconfusable). In three different experiments the strings were presented visually simultaneously, visually successively and auditorily. Recall of the letters was begun either immediately after presentation, or after a 15-second delay. Memory was measured by having the children write the letters that they had seen or heard in the order in which the letters had been presented.

Shankweiler et al. (1979) expected that rhyming letters would generate more phonetic confusions, i.e., a larger phonetic similarity effect in good readers than in poor ones, since good readers were supposed to rely on a phonetic representation of letter names as a means of retaining the letters in working memory, while poor readers were supposed to have difficulty with phonetic representation. The results of the experiments bore out their expectations. Superior readers were generally better at recall of the letter strings, but this advantage was nearly eliminated when the letter strings were phonetically confusable. In other words, phonetic confusability penalized the superior readers' performance more than it penalized the marginal or inferior readers' performance. Since good readers showed a phonetic similarity effect and poor readers did not, Shankweiler et al. concluded that this finding supported the idea that good readers rely more on phonetic representation in working memory than poor readers do.

The interaction between reading ability and the effect of phonetic confusability on working memory was also found with stimulus materials that more closely resembled actual text and therefore were presumably more ecologically valid for the study of reading. Mann, Liberman, and Shankweiler (1980) asked good and poor readers in Grade 2 to repeat word strings and sentences that varied on phonetic similarity and meaningfulness. While the good readers generally surpassed poor readers in recall of both words and sentences, the performance of the good readers did not differ significantly from that of the poor readers when the word strings rhymed and the sentences contained a high density of rhyming words.

In summary, the Haskins group have found that good readers' performance on both visual and auditory short-term memory tasks falls to the level of poor readers' performance when the stimulus material consists of phonetically confusable letter strings, word strings and sentences. The researchers at Haskins have interpreted these findings as support for the hypothesis that poor readers are less affected by phonetic similarity because they are less able than good readers to use phonetic representation in working memory.

Recent research at Haskins, as yet unpublished, has provided further support for the hypothesized relationship between phonetic coding abilities and reading. Mann (Note 1) found that the use of phonetic representation not only is correlated with good reading abilities, but may be a necessary prerequisite for reading. In a longitudinal study, kindergarten children were given a test for memory for nonverbal stimuli, a test for syllabic awareness and a test for memory for spoken rhyming and nonrhyming word strings. These same children were retested in Grade 1 on the word string task. They were also grouped according to performance on several reading tests, although Mann does not mention if the children were matched for IQ. The nonverbal memory test did not differentiate between children in good, average and poor reading groups. Success at learning to read, however, was strongly related to performance on the verbal tasks. Children who excelled at realizing syllabic structure in kindergarten became good readers in Grade 1. Similarly, both in kindergarten and in Grade 1, children classed as good readers were strongly penalized by the phonetic confusability of rhyming word strings, average readers less so, and poor readers hardly at all. The important finding here is that the children who became good readers in Grade 1 showed prior evidence of phonetic recoding ability in kindergarten. Children who became poor readers did not show evidence of phonetic recoding ability in kindergarten. It thus appears that phonetic recoding ability is present as early as kindergarten age and is predictive of later reading achievement.

In summing up the work at Haskins and discussing new directions for research, Liberman and Mann (Note 2) state that more information is needed about the developmental progression of the phonetic and nonphonetic strategies available for storing information in working memory. They cite one developmental study of phonetic coding (Conrad, 1971) that apparently explains the poor readers' use of nonphonetic strategies in the Haskins experiments. Conrad showed that nonphonetic strategies appear to be typical of younger children at a prereading stage, and that the frequency of use of phonetic strategies increases as children mature.

Conrad (1971) differentiated three age groups of children according to their phonetic recoding abilities by measuring their susceptibility to phonetic interference in a short-term memory task. In the first group (children under about five years of age), he found that phonetic similarity did not interfere with recall at all. These children did not appear to be using a phonetic recoding strategy to aid recall. The second group (children five to six years of age) appeared to make some use of a phonetic strategy, since their recall of phonetically similar stimuli was somewhat worse than their recall of phonetically dissimilar stimuli. Conrad pointed out that this finding is consistent with the fact that this is the age when children typically begin to master reading. The third group (children six to eleven years of age) preferred the phonetic strategy, showing a systematically increasing disadvantage in recall of phonetically similar stimuli as age increased. Conrad concluded that preschool children typically employ a nonphonetic strategy to hold information in their working memory, and suggested that phonetic coding may not be available as a memory strategy for children until they master reading.

The researchers at Haskins utilized Conrad's (1971) results and interpretation in explaining their good and poor readers' differential performance on phonetic coding tasks. Liberman and Mann (Note 2) stated that the phonetic strategy used by the good readers in their studies is a more mature strategy, akin to that used by adults, and that the strategy used by poor readers is regressive, or at least less mature. Given this interpretation, Liberman and Mann then raised the question as to whether poor readers are constitutionally deficient in the abilities needed to recode information phonetically, or whether they are simply more immature and slower in developing these abilities. Because of the similarity between their findings with poor readers and Conrad's findings with preschoolers, Liberman and Mann favored the second interpretation, that is, developmental delay.

The soundness of comparing poor readers with preschoolers depends on the validity and interpretation of Conrad's data. In Conrad's experiment children were shown pictures of objects which had phonetically similar and dissimilar labels (for example, cat, rat, bat; girl, bus, spoon). The pictures were presented simultaneously in a horizontal array and memory for the stimuli was measured by a matching method of item recall. Most models of reading stress the relation between phonetic recoding and the necessity of retaining the temporal sequence of verbal items in order to make sense of them. For example, in Baddeley's (1978; 1979) conceptualization of working memory, the secondary articulatory loop stores phonetic information on a temporal and sequential basis. Conrad, however, was essentially testing for memory for item information and spatial location. Therefore, it is questionable whether or not Conrad's choice of stimulus presentation and recall method is a valid way of tapping the phonetic recoding processes which may be underlying the abilities needed for reading.

Furthermore, Conrad's choice of stimuli may not have been the best one for tapping the phonetic aspects of working memory. Baddeley (1978) mentioned that working memory uses a verbal code, and Conrad used pictures of common objects as stimuli. Such pictorial stimuli may provide more visual or semantic coding options than do written words and hence reduce the necessity for recoding in phonetic form. In any case, it is simply not clear from Conrad's data whether his preschoolers cannot recode or whether they do not recode because he used pictures instead of words or other verbally-based stimuli.

Recently, two studies with preschoolers presented results contrary to Conrad's in that evidence of phonetic recoding was found. In the first study, Alegria and Pignot (1979) gave four-year-olds simultaneously presented pictures and asked for item recall. They found that the children remembered pictures of nonrhyming items better than rhyming ones even when the authors controlled for the intrinsic difficulty of the items. In the second study, Brown (1977) presented children four to five years of age with rhyming and nonrhyming letters as stimuli. Brown reasoned that the use of letters as opposed to pictorial stimuli would more likely predispose preschoolers who knew their letters to code them phonetically. He presented the letters in a horizontal array, and tested for memory for spatial location. Brown found that letters of high phonetic similarity exerted a detrimental effect on verbally-probed recall and concluded that four- and five-year-old children can code visual items phonetically during input in a verbally based memory task.

Despite these contradictory findings in the developmental literature, Liberman and Mann (Note 2) have found that poor readers seem similar to Conrad's (1971) preschool sample, and have inferred that poor readers may be simply less mature in terms of their ability to recode visual information into phonetic form. However, the methodological flaws inherent in Conrad's study and the recent evidence suggesting that preschoolers do code phonetically (Brown, 1977; Alegria & Pignot, 1979) calls into question the replicability of Conrad's findings and hence the validity of Liberman and Mann's inference. The issue is an important one because it has implications for the "cause" and hence for the treatment of reading disability. If the ability to code phonetically does develop over the preschool period, then it would be reasonable to suggest that the absence of such coding in poor readers reflects a developmental lag. In contrast, if preschoolers at all ages show the ability to recode phonetically, then the absence of such an ability among poor readers would seem to be more consistent with the idea of a constitutional deficiency.

The present experiment attempted to address the issue by examining developmental changes in the use of phonetic codes over the preschool period. Both because of the methodological problems with Conrad's (1971) paradigm and because of the desirability of using a paradigm similar to that used in the Haskins studies, this experiment was a partial replication of one of Shankweiler at al.'s (1979) experiments with a few modifications designed to maximize the likelihood of tapping the working memory of preschoolers.

Baddeley (1979) conceptualized working memory as holding on to both the units of information (be it letters, phonemes or syllables) and the sequence that the units were presented in. In essence, there are two aspects to what is being "held" in memory. One is the units of information (the items) and the other is the manner in which these units are held (in this case, the temporal order). In the Shankweiler et al. (1979) experiment, the units of information were letters and they were held sequentially. Shankweiler and his colleagues used serial recall (items were to be recalled in the order given) to tap these two aspects. With serial recall, memory for order is confounded with memory for items, since subjects are asked to recall both at the same time. The present experiment attempted to avoid this confounding by using two different recall tasks, one for recall of order and one for recall of items. In both tasks, visual stimuli were presented sequentially. Memory for order was measured by a serial reconstruction task where subjects were given the items and were asked to place them in the correct temporal sequence. Item memory was measured by an oral free recall task where items could be recalled in any order.

In keeping with Shankweiler et al.'s (1979) paradigm, letters were used as stimuli. Brown's (1977) work has shown that preschoolers are capable of working with letter stimuli and furthermore, the use of letters, as opposed to Conrad's (1971) pictorial stimuli, reduced the number of coding options available. The number of letters in each set and the number of sets presented were decreased from the number used in the Shankweiler et al. experiment, since pilot studies showed that the original numbers made the task too difficult for children of preschool age. Stimuli within a given set were either all rhyming letters or all non-rhyming letters. For one group of children, recall was measured immediately; for the other group it was measured after a 15-second delay. It was expected that a delay would force greater reliance on the use of the secondary articulatory loop and thereby would tend to increase the phonetic similarity effect if it does exist in preschoolers.

In the Shankweiler et al. (1979) paradigm the subjects learned and recalled several sets of letters. Underwood (1957) has stated that the greater the number of previous lists learned the greater the proactive interference (a decrease in memory as a function of previous learning). Wickens (1972) stated that proactive interference is greater when items are being repeatedly encoded on the same dimension and that one dimension which generates proactive interference is rhyme. Therefore, if a phonological code is being repeatedly used by the children in the present study, one would expect the decline in recall across sets to be greater for rhyming letters than for nonrhyming letters. Shankweiler et al. did not report any analysis of the effects of prior sets on recall for subsequent sets, but in the present study, recall was measured as a function of position of sets within a stimulus series to detect any differential build up of proactive interference across rhyming and nonrhyming sets.

The present findings were also analyzed as a function of serial position of letters within each set. This analysis enabled the effects of the experimental manipulations on both short- and long-term memory to be examined. Shankweiler et al. (1979) used this measure and found that the results of all their reading groups followed the typical serial position curve for free recall. Thus recall was highest for items in the terminal positions, it was slightly lower for items in the initial positions, and lowest for items in the middle positions. The first portion of the bow-shaped curve showing enhanced recall for initial items is known as the primacy effect. According to theorists (e.g., Waugh & Norman, 1965), the primacy effect is attributable to recall for items already in the long-term memory. The last portion of the curve, showing enhanced recall for items at the end of the list, is called the recency effect. According to Waugh and Norman, the recency effect is attributable to items that are still in the short-term memory. Since the presentation of phonetically similar stimuli in this study was designed to overload working memory (that is, short-term memory), it was expected that the recency or short-term memory portion of the serial position curve would be markedly affected by phonetic similarity. In other words, the recall advantage of phonetically dissimilar letter strings over phonetically similar ones would be greater for items at the end of the string than for those at the beginning.

The principal hypothesis to be explored in the present study is concerned with the interaction of age with stimulus type. To test for developmental changes in any phonetic coding abilities that may be present in preschoolers, two age groups of subjects were tested. Half of the subjects were over 60 months of age (the age where Conrad's subjects began to show evidence of phonetic coding), and half were under 60 months of age (where according to Conrad subjects are not yet able to code phonetically). The performance of the two groups of preschoolers on recall of rhyming versus nonrhyming letters in the present experiment was expected to aid in answering Liberman and Mann's (Note 2) question of whether the absence of phonetic coding in poor readers reflects a developmental delay or a constitutional deficiency.

If poor readers' performance on working memory tasks reflects a developmental delay, the preschoolers in this study would be expected to show either no significant difference between recall of rhyming and non-rhyming letters, i.e., neither group has yet developed this skill, or a developmental interaction, i.e., the children over 60 months of age have begun to develop the skill and hence are more affected by the manipulation of phonetic similarity. In the latter case, the recall advantage for nonrhyming over rhyming letters would be greater for the older children. If, however, phonetic coding is a skill that is acquired with speech or is "built in" then poor readers' absence of phonetic coding would reflect a constitutional deficiency. Under these circumstances and assuming that the vast majority of the children sampled in this study will become "normal readers", children in both age groups should be adversely affected to approximately the same degree by phonetic similarity, i.e., rhyming letters should not be recalled as well as nonrhyming letters by either age group.

Method

Subjects

Eighty preschool children were selected from four day care centres and nurseries in the Greater Montreal area. All children were English speaking and came from middle to upper class families. Only children who were able to identify correctly all the stimulus letters when presented visually were selected. The older group of 40 children ranged in age from 60 months to 68 months, with a mean age of 63.1 months. The younger group ranged in age from 42 months to 58 months, with a mean age of 52.1 months.

Stimuli

The stimuli used in the experimental trials consisted of 12 sets of 7.6 by 12.7 cm cards showing various upper case letters of the English alphabet hand printed in black ink. There was one letter measuring 5.5 cm in height on each card and four cards per set. Six sets were composed of rhyming letters (drawn from the letters B, C, D, E, G, P, T, V) and the remaining six sets were composed of non-rhyming letters (drawn from the letters H, K, L, M, O, R, S, Y). In the sets, each letter was allowed to appear only once. Across sets, all letters appeared equally often in each serial position. Within these restrictions, assignments of letters to sets and to serial position was random. The rhyming and nonrhyming sets were intermixed, but did not alternate. The order of the 12 sets, as presented to the children, was randomized. The particular letters used were, with three exceptions, the same as those used in the Shankweiler et al. (1979) study. The exceptions were E instead of Z, O instead of Q and M instead of W. Stimuli used in the practice trial consisted of four 7.6 by 12.7 cm cards with hand drawn pictures of common objects on them. The objects pictured were a horse, a ball, a tree and a bird. Pictorial practice stimuli were employed to minimize potential interference with the subsequent presentation of the experimental letter stimuli.

Design

Recall for the letters was measured by two tasks. Half of the children within each age group were randomly assigned to a Serial Reconstruction task which measured order recall. The remaining half of the children within each age group were randomly assigned to an Oral Free Recall task, which measured item recall. The data from both of these tasks were scored in two different ways. The first way involved scoring the children's recall with respect to position of the sets. The second way involved scoring the children's recall with respect to serial position of letters. Thus, two four-way analyses were conducted for each recall task, one using position of sets as the dependent variable, the other using serial position of letters. There were four factors in each of the analyses. The two between-subjects factors were age (children 60 months of age and older; children under 60 months of age) and timing of response (immediate; delayed). The two within-subjects factors were stimulus type (rhyming letters; nonrhyming letters) and position. The position factor had six levels when recall was scored as a function of position of sets within each stimulus type. The position factor had four levels when recall was scored as a function of serial position of letters within sets.

Procedure

All children were tested individually. In a previous session, each child had been individually screened by a task where they had to correctly identify all the letters used in the experiment. In the experimental session, each child was brought into a quiet area for testing. The child either sat at a child-sized table and chair set up or was seated on the floor in front of a flat area. The experimenter then chatted with the child to establish rapport and put the child at ease. A practice trial utilizing the picture stimuli was given that was identical in the procedure to the following experimental trials.

Once the experimenter was sure that the child understood the procedure, the experiment continued. The first card of the first set was presented face up on a table or the floor for three seconds duration, then the card was turned over. Each of the remaining three cards in the set were presented, one at a time, in the same manner, and then were turned over and placed on top of the preceding card. After the four cards were presented, those children assigned to the immediate response condition were tested for memory for the stimuli presented. Those children assigned to the delayed response condition waited for a 15-second interval during which time the experimenter said to the child "Now we are going to wait for a little while before we go on, O.K.? We'll just sit here and wait just like this, and now we will start with the next part".

Children for whom recall was measured by Serial Reconstruction were then given the cards that they had just seen after the cards had been randomly shuffled. The children were told to look through the cards and asked to pick out which card came first and place it on the flat surface. Then the children were asked which card came next after the first one, and so on, until they placed the remaining card in the last position. Children for whom recall was measured by Oral Free Recall were asked to tell the experimenter which letters they had seen. With both recall measures, recall was measured after each set was presented. Each child was presented with 12 separate sets of cards. The sets were presented to half of the children within each condition of age, task and delay interval in the prearranged order (Set 1 to Set 12); the other half of the children had the sets presented to them in the reverse order (Set 12 to Set 1). After the last set was presented all children were praised for their attention and good work and thanked for their participation.

Scoring

In the analysis involving set position, the scores were arrived at by adding the number of correct responses across the four letters in each set, resulting in a score out of four. Each child received six scores reflecting the number of rhyming letters remembered correctly for the six rhyming sets and six scores reflecting the number of nonrhyming letters remembered correctly for the six nonrhyming sets. In the Serial Reconstruction task, measuring order recall, a letter was counted correctly only when it was placed in the correct serial position within each set. In the Oral Free Recall task, a response was counted if it was a correct letter, thus measuring item recall.

In the analysis involving serial position within sets, the scores for each serial position were arrived at by adding the number of correct responses across the number of sets presented, resulting in a score out of six. Each child received four scores reflecting the number of rhyming letters remembered correctly for the six rhyming sets and four scores reflecting the number of nonrhyming letters remembered correctly for the six nonrhyming sets. In the Serial Reconstruction task, a letter was counted as correct if it was placed in the correct serial position. In the Oral Free Recall task, the number of times that items in a given serial position were recalled was counted.

Results

The finding of primary interest in this study was the highly significant detrimental effect that phonetically similar stimuli had on memory. Recall for rhyming letters was generally poorer than recall for nonrhyming letters, regardless of age of subjects, task performed, delay interval and serial position within and across sets. The magnitude of this phonetic similarity effect, however, differed markedly with respect to recall tasks and analyses when the other factors were brought into the analysis. Therefore, each of the analyses and recall tasks will be dealt with separately.

Analysis with Set Position within Stimulus Series

In this scoring method, a 2 x 2 x 2 x 6 analysis of variance was performed on each of the two recall tasks.

Serial Reconstruction Task. The ANOVA summary table for this analysis appears in Appendix A. The means and standard deviations for the Serial Reconstruction task are given in Table 1. The four-factor analysis of variance performed on the data revealed that the overall effect of stimulus type was significant, $F(1,36) = 51.1$, $p < .01$, in the expected direction. Recall of letter order was greater for nonrhyming letters than for rhyming letters. The magnitude of this effect depended on how many rhyming or nonrhyming sets had been presented to the children, as evidenced by a significant stimulus type by set position within stimulus series interaction, $F(5,180) = 3.72$, $p < 01$. As can be seen in Figure 1, recall for order of rhyming letters decreased as a function of set position within stimulus series, whereas recall for order of nonrhyming

Table 1

Mean number of letters placed in correct serial position in the Serial Reconstruction Task, summed across sets and serial positions within sets

Age	Timing of Response	Stimulus Type: Rhyming	Stimulus Type: Non-rhyming
Young (42-58 months)	Immediate	10.5[a] (4.33)[b]	16.6 (3.6)
	Delay	9.9 (4.12)	15.7 (3.71)
	Mean	10.2	16.2
Old (60-68 months)	Immediate	13.1 (4.01)	17.6 (4.14)
	Delay	11.9 (4.61)	16.6 (5.48)
	Mean	12.5	17.1

[a]Maximum = 24

[b]Standard deviations given in parentheses.

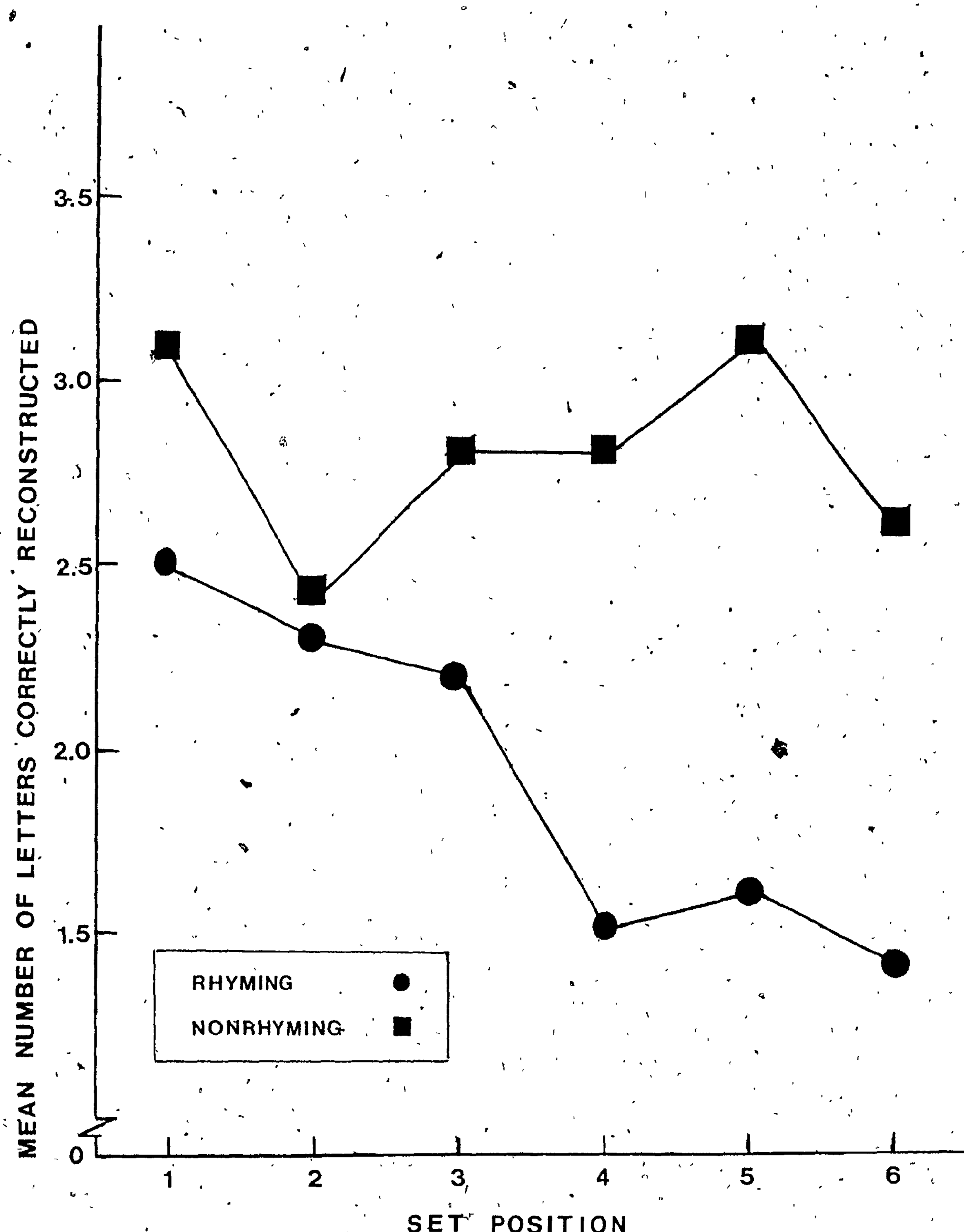

Figure 1. Serial Reconstruction Task: Mean number of correct reconstructions in relation to position of sets for each stimulus type.

letters was consistent over set position within stimulus series. *Post hoc* comparisons (Tukey's) showed the differences in recall of rhyming and nonrhyming stimuli were significant at the first, fourth, fifth and sixth set positions within stimulus series ($p < .01$). Recall of order of rhyming and nonrhyming letters did not differ significantly at the second and third set positions.

The factors of age and timing of response taken alone did not have an effect on the children's recall for order of letters. When the factors of stimulus type and set position within stimulus series were taken into consideration, the three-way interactions were significant. In the figures for each interaction, adjacent pairs of set positions were averaged to clarify the effects. Figure 2 graphically represents the interaction between age, stimulus type and set position within stimulus series, $F(5,180) = 2.30$, $p < .05$. Recall for the order of rhyming letters decreased as a function of set position within stimulus series, and recall for order of rhyming letters was greater for the older children than for the younger children. Both of these effects were eliminated for recall for order of nonrhyming letters. The same pattern of results (shown in Figure 3) occurred in the triple interaction of timing of response by stimulus type by set position within stimulus series, $F(5,180) = 2.36$, $p < .05$. Delay of response and later position of a set in the series had a detrimental effect on recall for order of rhyming letters, while the factors of timing of response and position of the sets did not affect recall for order of nonrhyming letters.

In summary, recall for order of nonrhyming letters was generally greater than recall for order of rhyming letters. Recall for order of rhyming letters was adversely affected in interaction with the factors of

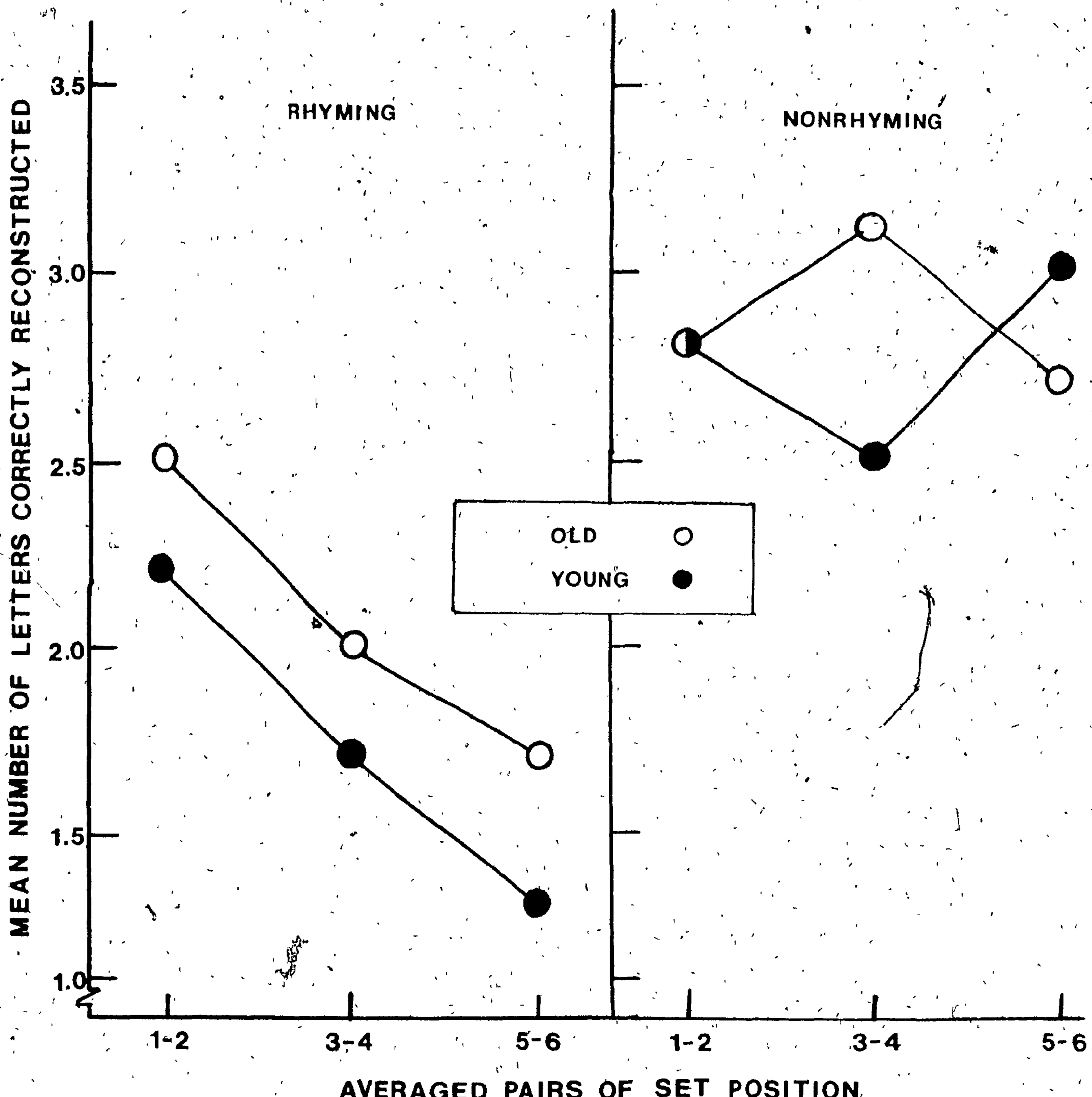

Figure 2. Serial Reconstruction Task: Mean number of correct reconstructions in relation to age and averaged pairs of positions of sets for each stimulus type.

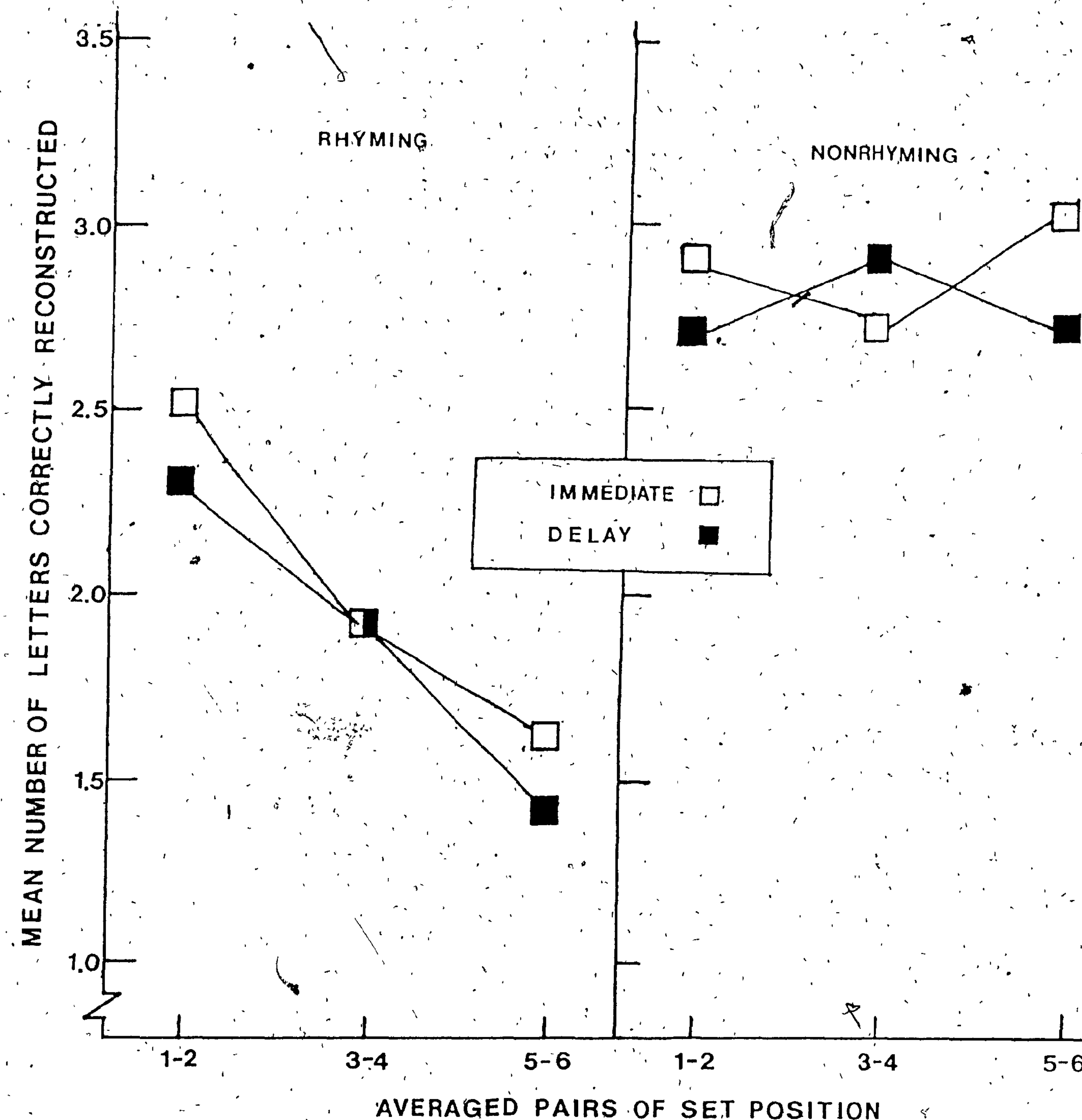

Figure 3. Serial Reconstruction Task: Mean number of correct reconstructions in relation to timing of response and averaged pairs of positions of sets for each stimulus type.

timing of response, age and set position within stimulus series. Recall for order of nonrhyming letters was not affected by any of these factors.

<u>Oral Free Recall Task</u>. The ANOVA summary table for this analysis appears in Appendix B. Table 2 shows the means and standard deviations for the Oral Free Recall task. The four-factor analysis of variance revealed three main effects with no interactions. First, children recalled more nonrhyming letters than rhyming letters, $F(1,36) = 72.44$, $p < .01$. Second, older children recalled more letters than younger children, $F(1,36) = 6.52$, $p < .05$. Third, children for whom response was delayed recalled fewer letters than children who responded immediately, $F(1,36) = 5.37$, $p < .05$.

To summarize these results it is apparent that there were different patterns of recall for order and item measures. In the Serial Reconstruction task, which measured order memory, the detrimental effect of rhyming stimuli varied as a function of set position within stimulus series, timing of response and age of children. These factors did not affect recall for order of nonrhyming stimuli. In the Oral Free Recall task, which measured item memory, set position within stimulus series did not affect recall at all, while stimulus type, timing of response and age of children each affected recall separately and independently with no interactions.

<u>Analysis with Serial Position of Letters within Sets</u>.

In this scoring method, a 2 x 2 x 2 x 4 analysis of variance was performed on each of the two recall tasks. In all figures, relative frequency of recall was measured in order to differentiate the measures from the first analysis.

<u>Serial Reconstruction Task</u>. The ANOVA summary table for this

Table 2

Mean number of letters correct in Oral Free Recall Task, summed across sets and serial position within sets.

Age	Timing of Response	Stimulus Type	
		Rhyming	Non-rhyming
Young (42-58 months)	Immediate	10.8[a] (3.29)[b]	15.2 (3.12)
	Delay	7.9 (4.18)	12.4 (2.17)
	Mean	9.35	13.8
Old (60-68 months)	Immediate	13.3 (4.97)	17.4 (2.99)
	Delay	10.4 (4.48)	16.1 (4.12)
	Mean	11.85	16.75

[a]Maximum = 24

[b]Standard deviations given in parentheses.

analysis appears in Appendix C. The four-factor analysis of variance performed on the data revealed that the overall effect of stimulus type was again significant, $F(1,36) = 53.18$, $p < .01$, in the expected direction. Recall of letter order at each correct serial position was greater for nonrhyming letters than for rhyming letters. There was also a main effect of serial position of letters within sets, $F(3,108) = 18.96$, $p < .01$. These two effects are graphically represented in Figure 4. The figure shows typical serial position curves for both types of letters, with the recall of nonrhyming letters generally exceeding that for rhyming letters. The interaction suggested in Figure 4 was not statistically significant ($.10 > p > .05$). In contrast to the analysis of the Serial Reconstruction Task with set position, there were no effects of delay or age, either alone or in interaction.

Oral Free Recall Task. The ANOVA summary table for this analysis appears in Appendix D. The data from the four-factor analysis of variance scored the number of letters recalled for each serial position. The frequency of times that a letter in a given serial position was recalled was affected by all four factors. Older children recalled significantly more letters than younger children, $F(1,36) = 6.48$, $p < .05$. Delay of response exerted a detrimental effect on recall, $F(1,36) = 5.35$, $p < .05$. Nonrhyming letters were recalled better than rhyming letters, $F(1,36) = 63.91$, $p < .01$, and the pattern of recall approximated a typical serial position curve, with recall highest for letters in the last positions (the recency portion), lower for letters in the initial positions (the primacy portion), and lowest for letters in the middle positions, $F(3,108) = 28.76$, $p < .01$. These results, however, are modified by a higher order interaction. Figure 5 shows the significant interaction between age and

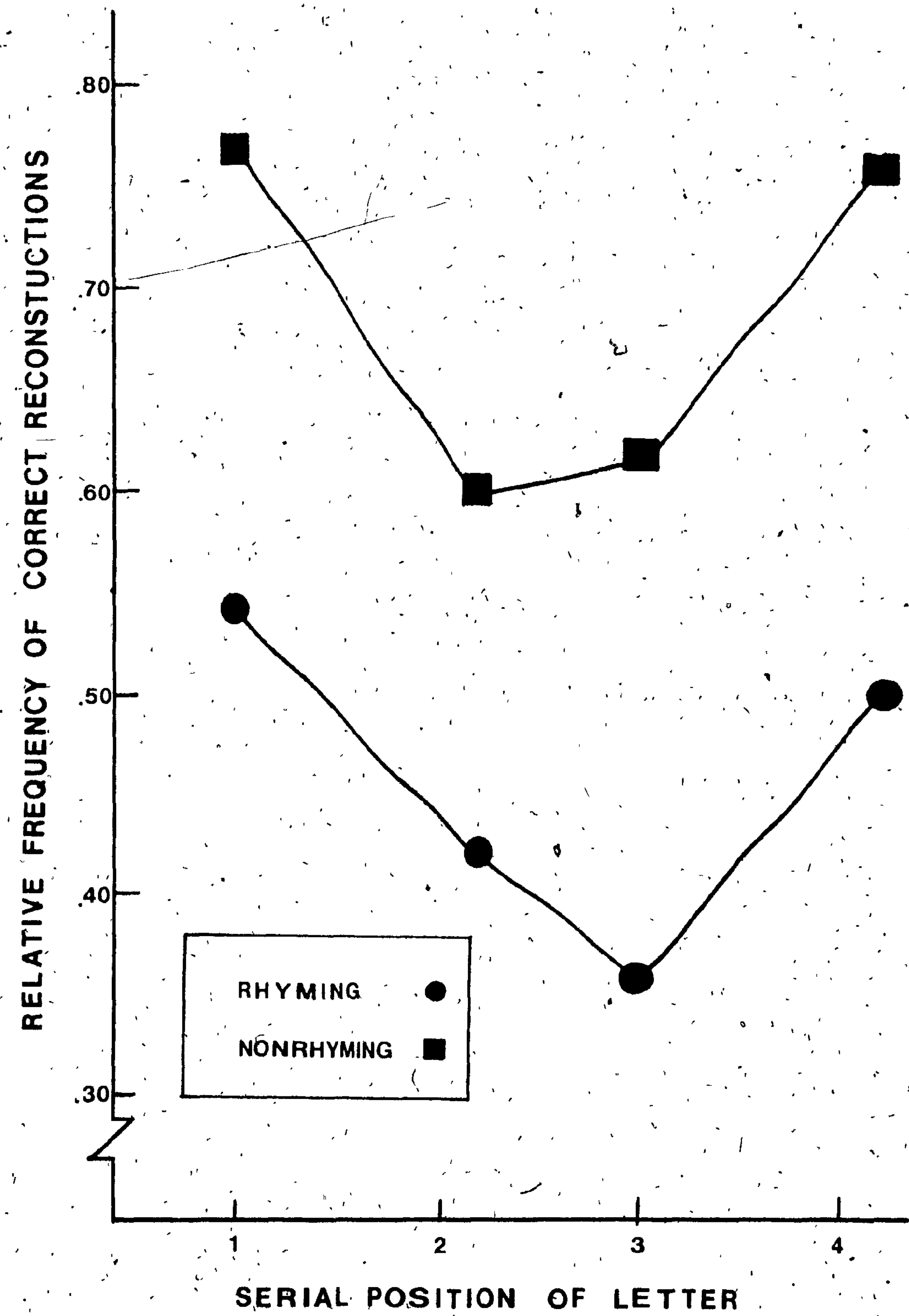

Figure 4. Serial Reconstruction Task: Relative frequency of correct reconstruction in relation to stimulus type and serial position of letters.

serial position, $F(3,108) = 2.77$, $p < .05$. As can be seen in Figure 5, older children recalled more letters than younger children, but only at the primacy portion of the serial position curve. Figure 6 graphically represents the significant interaction between timing of response and serial position, $F(3,108) = 3.06$, $p < .05$. In this case, children whose recall was delayed did worse than those who responded immediately, but only for letters in the last two serial positions, or the recency portion of the curve. These interactions, however, are still influenced greatly by stimulus type. The four-way interaction between age, timing of response, stimulus type and serial position was significant, $F(3,108) = 3.75$, $p < .01$, and is graphically represented in Figure 7. As can be seen in Figure 7, the number of times nonrhyming letters were recalled basically followed a typical serial position curve. There was a general flattening of the serial position curve for rhyming letters. The deviation from the normal serial position curve was most obvious in the last serial position, where rhyming letters were not recalled as often as nonrhyming letters. The only group that showed a pattern of recall approximating the typical serial position curve was younger children tested immediately for recall of rhyming letters. Their frequency of recall, however, was still lower than their corresponding recall for nonrhyming letters. Therefore, rhyming stimuli had a detrimental effect on recall, but, when the frequency of letters recalled for each serial position was examined, the recency portion of the serial position curve was affected the most.

In summary, the analyses with serial position of letters within sets showed that in Serial Reconstruction, results approximated the typical serial position curve, with a slight advantage in the primacy portion.

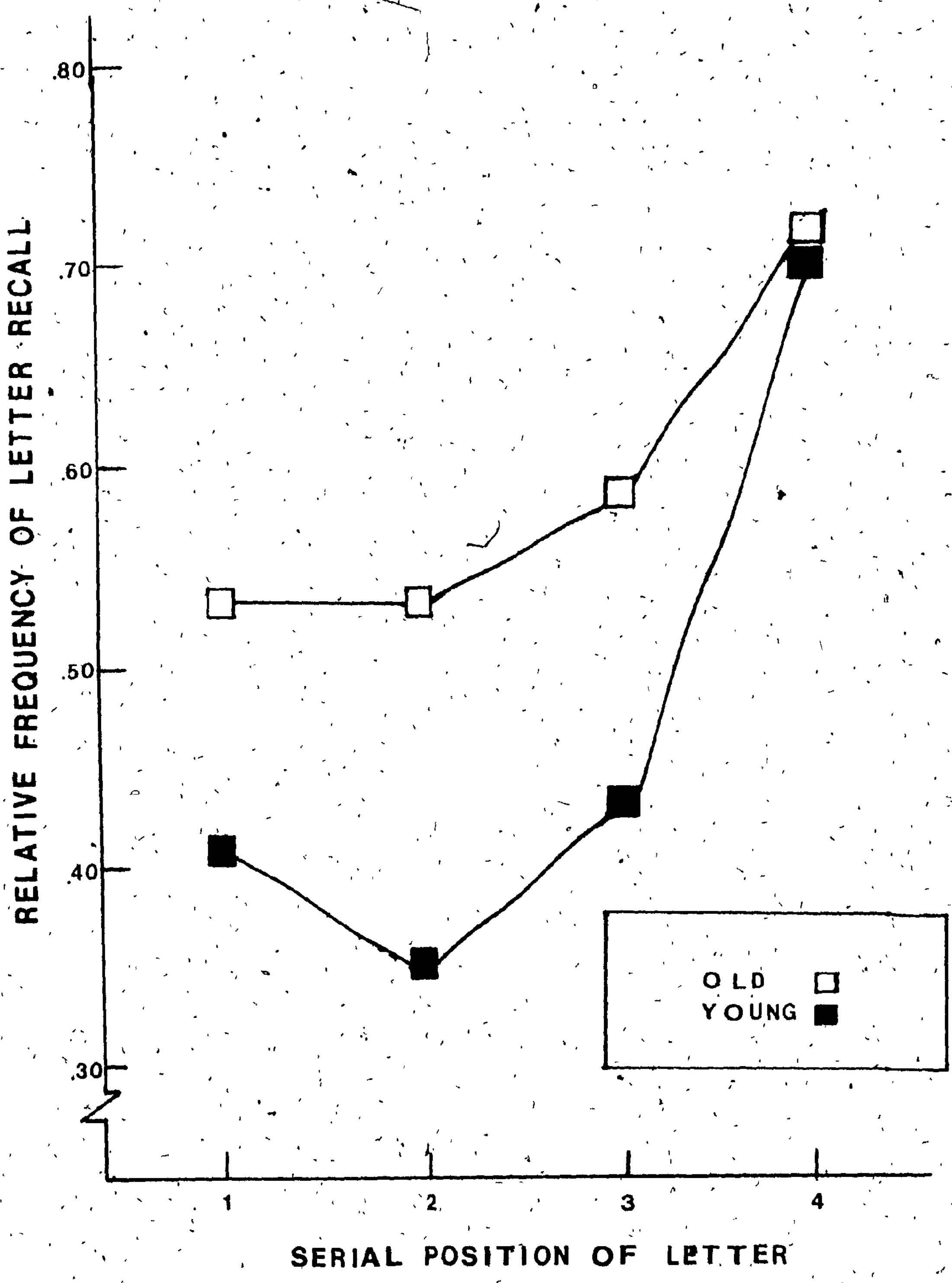

Figure 5: Oral Free Recall Task: Relative frequency of letter recall for each serial position in relation to age.

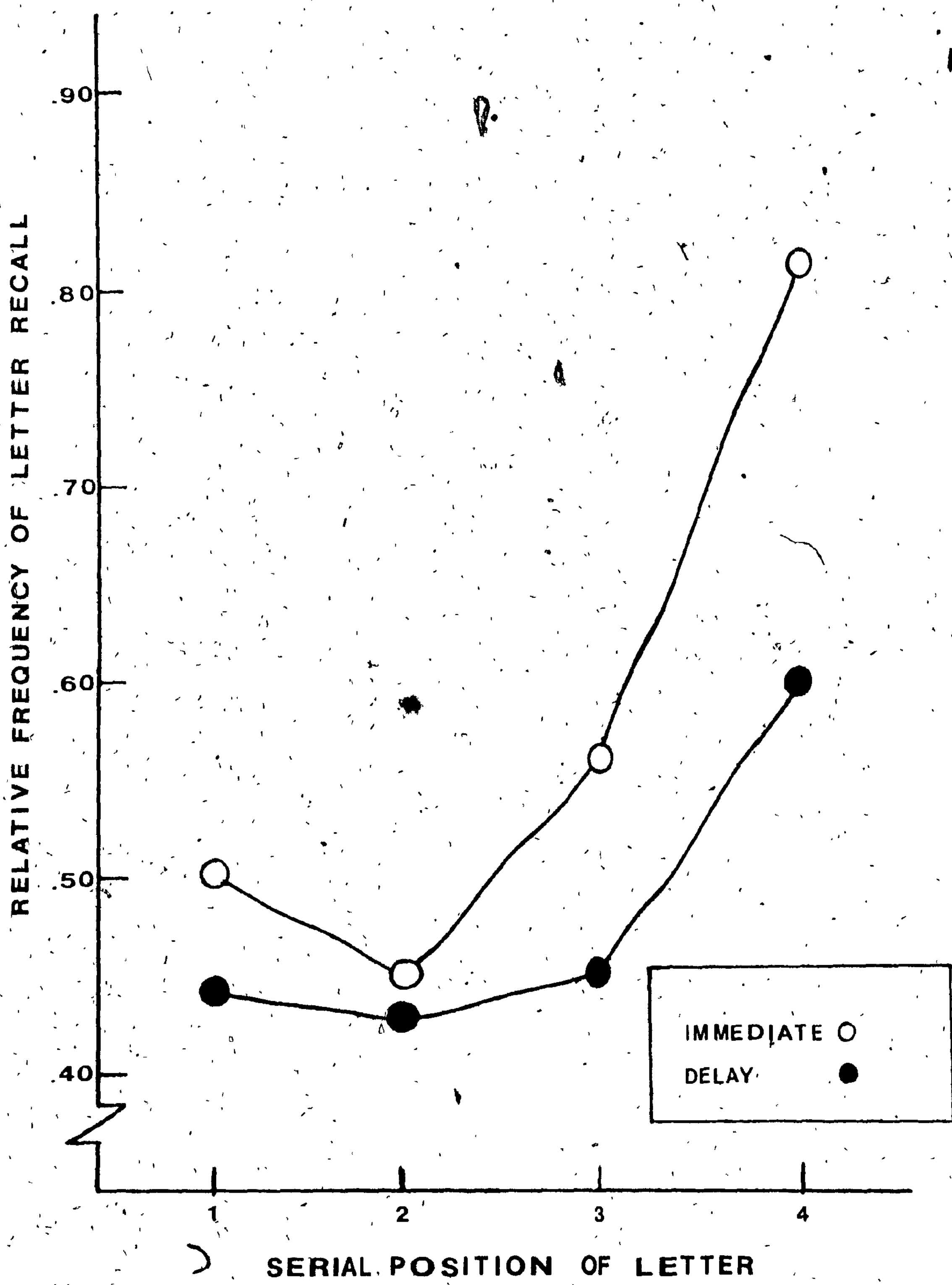

Figure 6. Oral Free Recall Task: Relative frequency of letter recall for each serial position in relation to timing of response.

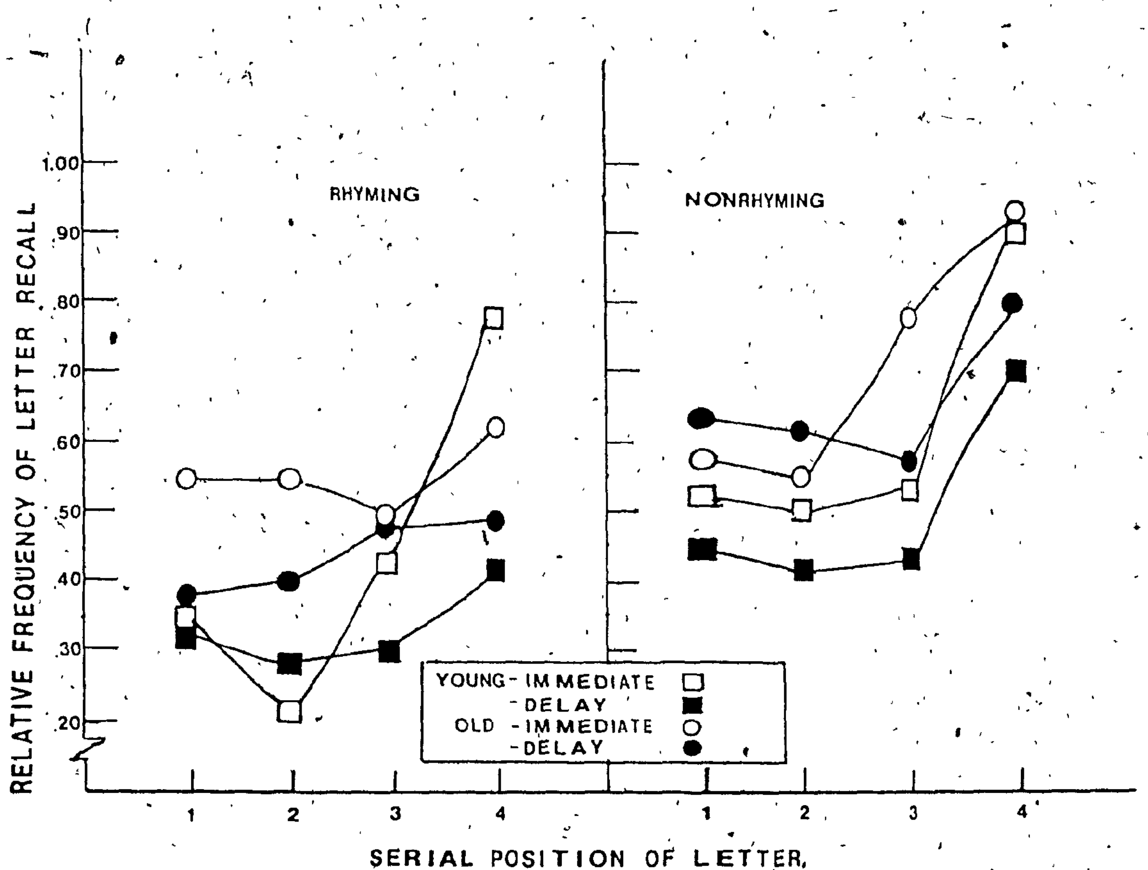

Figure 7. Oral Free Recall Task: Relative frequency of letter recall for each serial position in relation to stimulus type, age and timing of response.

Recall for nonrhyming letters was better than recall for rhyming letters for all serial positions. When the Oral Free Recall data was scored for frequency of letters recalled for each serial position, rhyming stimuli generated a flattening of the serial position curve, whereas recall for nonrhyming stimuli was greater and consistently approximated a typical serial position curve.

Discussion

The results confirm the major expectation of this study. The data reported provide significant evidence that preschool children's recall of letters is adversely affected by phonetic similarity. This finding held true for memory for both item and order information, regardless of whether recall was measured across sets presented or within sets. It therefore appears that preschoolers do use a phonetic code as a memory strategy for recalling visually presented letters, even when use of such a code penalizes recall.

The results reported may help to clarify whether the Haskins group's poor readers' failure to use a phonetic code reflects a constitutional deficiency or a developmental delay (Liberman & Mann, Note 2). In general, both age groups in the present study were equally affected by phonetic similarity. The results showed that phonetic coding is advanced enough by the preschool age to be used as a memory strategy and thus suggest that phonetic coding is a skill acquired at an early stage, perhaps with speech. By implication, then, its absence in poor readers may reflect a constitutional deficiency.

The phonetic similarity effect differed with respect to types of recall tasks and analysis used. Nevertheless, the pattern of results for each analysis and task supported the hypothesis that phonetically similar stimuli exerted more of an overload on working memory than phonetically dissimilar ones did. Consequently, there was more interference and poorer recall for rhyming letters, confirming the contention that children were using a phonetic coding strategy to aid working memory.

When recall was measured by Serial Reconstruction as a function of set position within stimulus series, only rhyming stimuli were subject to proactive interference. This is clearly evident in Figure 1, where there is a decrement in recall for order of rhyming letters which increased as more rhyming sets were presented. The proactive interference built up with additional phonetically confusable stimuli but did not with additional phonetically nonconfusable stimuli. As Wickens (1972) showed, proactive interference increases when items are being recoded on the same dimension. One of these dimensions was shown to be rhyming stimuli. Therefore, the decrease in recall seen for rhyming letters supports the contention that the children were recoding by rhyme, or, in other words, were using a phonetic code to aid working memory.

The finding that the differences in recall for rhyming and nonrhyming letters was not significant at the second and third set positions (as seen in Figure 1) may shed light on why previous studies have failed to find evidence of phonetic coding in preschoolers. In the present study, the greatest amount of proactive interference for rhyming letters occurred after the first three sets were presented, and the largest phonetic similarity effect occurred after four sets of each stimulus type had been presented. Therefore it is possible that studies failing to find a phonetic similarity effect in preschoolers did not utilize a sufficient number of trials (or sets) in their procedure to enable proactive interference for rhyming stimuli to build up to an amount that made the phonetic similarity effect clear. Previous studies have typically not examined their data for proactive interference across sets. In Conrad's (1971) study, where preschoolers did not show evidence of phonetic coding, 16 trials were given. Conrad states that young children completed the test in two sessions on different days, while for older children a single session was used. Conrad neglects to mention what age groups of children were considered young. If by "young" he meant preschool children, then the reason he found no evidence of phonetic coding within that group may have been because they were not given sufficient sets in a session for interference to build up.

Figures 2 and 3 show that age of children and timing of response affected recall of order, but only for order of rhyming letters. The absence of proactive interference for nonrhyming letters, even when coupled with the effects of age and timing of response, reinforces the contention that working memory was overloaded by phonetic similarity and that the children were using a phonetic code to hold on to order information in working memory. The major conclusion to be drawn here is that even younger children are capable of holding on to order information. Furthermore, all children appeared to be using a phonetically based strategy, since the experimental manipulations designed to overload working memory (e.g., delayed response, proactive interference) only affected phonetically confusable (rhyming) stimuli.

The information from the data from the Oral Free Recall task, as seen in Table 2, was consistent with the expectations. Younger children and those children whose response was measured after a delay recalled fewer letters and all children recalled fewer rhyming letters than nonrhyming letters. The order recall interactions combining stimulus type and set position within stimulus series with age and timing of response provide evidence that rhyming stimuli generated a sizeable overload on working memory. Therefore, it can be concluded that preschool children have difficulty holding on to both the rhyming stimuli and the order they are presented in. Since both aspects of working memory were adversely affected by phonetic confusability, it can be assumed that the children were using a phonetic code to aid working memory.

The information gained from analyzing the data with respect to serial position curves further reinforces the evidence that preschoolers were coding phonetically. In the Serial Reconstruction task, Figure 4 shows that the serial position curve was similar to the one that Shankweiler et al (1979) found with their data, except that letters were recalled equally well for both the primacy and recency portions of the curve. This may be due to the fact that the present experiment utilized a shorter set length (that is, four letters as compared to five), and that some of the letters from the primacy portion may have still been in short-term memory at the time of recall.

The data obtained from scoring the Oral Free Recall task with respect to serial position curves approximated the typical results for serial position scoring. As seen in Figure 5, younger children had more difficulty remembering the initially presented letters than older children. This finding shows that younger children had greater difficulty than older children in retrieving items that were no longer present in short-term memory. This finding is consistent with the developmental literature which shows that the amount of verbal material that can be remembered after one presentation has been shown to increase with age throughout the preschool period (e.g., Arbuckle, 1981). As seen in Figure 6, delay of response affected recall for the recency portion of the list presumably because the extra time placed between the presentation of the last letter and recall prevented the child from reporting items directly from short-term memory. When age and timing of response and serial position factors are looked at in terms of whether stimuli were rhyming and nonrhyming, it is clear that phonetic similarity exerted a sizeable overload on working memory. Figure 7 shows a typical serial position curve for nonrhyming stimuli. With rhyming stimuli, however, the serial position curve was relatively flat with the effect being most evident at the recency portion which supposedly reflects primarily output from short-term or working memory. This flattening of the recency portion supports the hypothesis that working memory is phonetically based and is overloaded when phonetically similar stimuli are entered into it. The only condition (seen in Figure 7) in recall of rhyming stimuli that showed a curve similar to the typical serial position curve seen for nonrhyming stimuli was that of younger children tested immediately after presentation.

The fact that the younger children who were tested immediately showed a recency effect in their recall of rhyming items and the older children did not is the only finding in the whole study which could possibly be interpreted as support for the idea that phonetic coding ability develops over the preschool period. It is difficult, however, to make such an interpretation since for both age groups the relative frequency of recall of rhyming letters was still lower than the relative frequency of recall of nonrhyming letters and there was no evidence of any age by stimulus type interaction. Given these findings the most reasonable interpretation is that both age groups were similarly affected by the manipulation of phonetic similarity.

Therefore, the preschoolers in the present study were essentially behaving like the good readers in Shankweiler et al.'s (1979) study. By separating recall for items and order, the present study showed that children of preschool age can retain both item and order information by coding such information phonetically. Like the good readers in the Haskins studies, these preschoolers persisted in coding phonetically even when it penalized recall.

The present study found a phonetic similarity effect for visually presented letters. To determine whether or not this effect generalizes to other modalities and stimuli, it should be extended to recall of phonetically similar auditorily presented word strings and sentences. The Haskins group (Mann, Liberman & Shankweiler, 1980) extended their findings in a similar way. They only found a phonetic similarity effect in good readers, whereas poor readers failed to use phonetic coding as a memory aid for auditorily presented word strings and sentences. One of the major rationales for this extension was to better approximate reading material. If the phonetic similarity effect found in the present study is also extended to the auditory modality and stimulus material that more closely resembles reading material, then it may be possible to assume that the poor readers in the Haskins studies are suffering from a constitutional deficiency in phonetic coding. If a child does not have a phonetic coding ability at the preschool stage, this may be an indication of a future reading disability. Mann and her colleagues (Note 1) have found that children who failed to code phonetically during kindergarten also did poorly on reading tests in Grade 1. If the same type of longitudinal study could be started at the earliest preschool age tested in the present study (three and one-half years), then the hypothesis that poor readers have a constitutional deficiency in phonetic coding could be tested. If this hypothesis is confirmed, the results would have an important bearing on present methods of diagnosis and treatment of those reading disabilities which involve problems with phonetic coding. If we are dealing with a constitutional deficiency in coding, then a series of tasks which overload working memory, similar to the one used in the present study, may be able to identify children with such coding problems at a prereading stage. Therapeutic intervention could be started before the child finds that he or she has a problem with reading. If intervention at an early stage could teach the required coding strategy, the child would be equipped with it when he begins to read. Thus the child may be able to avoid the failure experience of having reading difficulties.

Reference Notes

1. Mann, V.A. <u>Reading skill and language skill.</u> Paper presented at the meeting of the Society for Research in Child Development, Boston, April, 1981.

2. Liberman, I.Y. and Mann, V.A. <u>Should reading instruction and remediation vary with sex of the child?</u> Paper presented at a symposium on The Significance of Sex Differences in Dyslexia, Boston, November, 1980.

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APPENDICES

Appendix A

ANOVA Summary Table for Analysis with Set Position Within Stimulus Series for Serial Reconstruction Task.

Source	Sum of Square	df	Mean Square	F
Between-Subjects				
Age	6.53	1	6.53	1.53
Timing of Response	1.63	1	1.63	.39
Age x Timing of Response	.53	1	.53	.12
Subjects Within Groups	1.53	36	4.26	
Within-Subjects				
Stimulus Type	97.20	1	97.20	51.11*
Age x Stimulus Type	2.13	1	2.13	1.12
Timing of Response x Stimulus Type	.33	1	.33	.18
Age x Timing of Response x Stimulus Type	.36	1	.36	.19
Stimulus Type x Subjects Within Groups	68.47	36	1.90	
Set Position	29.50	5	5.90	3.39*
Age x Set Position	15.77	5	3.15	1.81
Timing of Response x Set Position	6.52	5	1.30	.75
Age x Timing of Response x Set Position	10.12	5	2.02	1.16
Set Position x Subjects Within Groups	313.27	180	1.74	
Stimulus Type x Set Position	27.30	5	5.46	3.72*
Age x Stimulus Type x Set Position	16.87	5	3.37	2.30**
Timing of Response x Stimulus Type x Set Position	17.32	5	3.46	2.36**
Age x Timing of Response x Stimulus Type x Set Position	4.15	5	.83	.56
Stimulus Type x Set Position x Subjects Within Groups	264.53	180	1.47	

*$p < .01$
**$p < .05$

Appendix B

ANOVA Summary Table for Analysis with Set Position Within Stimulus Series for Oral Free Recall Task

Source	Sum of Squares	df	Mean Square	F
Between-Subjects				
Age	24.30	1	24.30	6.52**
Timing of Response	20.00	1	20.00	5.37**
Age x Timing of Response	.41	1	.41	.11
Subjects Within Groups	134.01	36	3.72	
Within-Subjects				
Stimulus Type	72.08	1	72.08	72.44*
Age x Stimulus Type	.21	1	.21	.65
Timing of Response x Stimulus Type	.53	1	.53	.54
Age x Timing of Response x Stimulus Type	.53	1	.53	.54
Stimulus Type x Subjects Within Groups	35.82	36	.99	
Set Position	5.74	5	1.15	1.62
Age x Set Position	3.18	5	.64	.90
Timing of Response x Set Position	3.67	5	.73	1.04
Age x Timing of Response x Set Position	3.07	5	.61	.87
Set Position x Subject Within Groups	127.52	180	.71	
Stimulus Type x Set Position	6.00	5	1.20	1.35
Age x Stimulus Type x Set Position	7.47	5	1.49	1.68
Timing of Response x Stimulus Type x Set Position	1.84	5	.37	.41
Age x Timing of Response x Stimulus Type x Set Position	1.14	5	.23	.26
Stimulus Type x Set Position x Subjects Within Groups	160.38	180	.89	

*$p < .01$
**$p < .05$

Appendix C

ANOVA Summary Table for Analysis with Serial Position of Letters Within Sets for Serial Reconstruction Task

Source	Sum of Squares	df	Mean Square	F
Between-Subjects				
Age	12.40	1	12.40	2.08
Timing of Response	3.40	1	3.40	.57
Age x Timing of Response	.25	1	.25	.42
Subjects Within Group	214.66	36	5.96	
Within-Subjects				
Stimulus Type	152.63	1	152.63	53.18*
Age x Stimulus Type	3.00	1	3.00	1.05
Timing of Response X Stimulus Type	.15	1	.15	.53
Age x Timing of Response x Stimulus Type	.28	1	.28	.98
Stimulus Type x Subjects Within Groups	103.31	36	2.87	
Serial Position	65.93	[illegible]	21.98	18.96*
Age x Serial Position	1.78	3	.59	.51
Timing of Response x Serial Position	4.48	3	1.49	1.29
Age x Timing of Response x Serial Position	5.48	3	1.83	1.58
Serial Position x Subjects Within Groups	125.19	108	1.16	
Stimulus Type x Serial Position	2.86	3	.95	1.42
Age x Stimulus Type x Serial Position	5.33	3	1.78	2.64
Timing of Response x Stimulus Type x Serial Position	1.08	3	.36	.54
Age x Timing of Response x Stimulus Type x Serial Position	2.36	3	.79	1.17
Stimulus Type x Serial Position x Subjects Within Groups	72.74	108	.67	

*$p < .01$

Appendix D

ANOVA Summary Table for Analysis with Serial Position of Letters Within Sets for Oral Free Recall Task

Source	Sum of Squares	df	Mean Square	F
Between-Subjects				
Age	37.81	1	37.81	6.48**
Timing of Response	31.25	1	31.25	5.35**
Age x Timing of Response	.45	1	.45	.77
Subjects Within Groups	210.23	36	5.84	
Within-Subjects				
Stimulus Type	92.45	1	92.45	63.91*
Age x Stimulus Type	.20	1	.20	.14
Timing of Response x Stimulus Type	1.01	1	1.01	.70
Age x Timing of Response x Stimulus Type	1.01	1	1.01	.70
Stimulus Type x Subjects Within Groups	52.08	36	1.45	
Serial Position	127.46	3	42.49	28.76*
Age x Serial Position	12.26	3	4.09	2.77**
Timing of Response x Serial Position	13.58	3	4.53	3.06**
Age x Timing of Response x Serial Position	2.88	3	.96	.65
Serial Position x Subjects Within Groups	159.56	108	1.48	
Stimulus Type x Serial Position	4.88	3	1.63	1.59
Age x Stimulus Type x Serial Position	5.43	3	1.81	1.77
Timing of Response x Stimulus Type x Serial Position	3.36	3	1.12	1.10
Age x Timing of Response x Stimulus Type x Serial Position	11.46	3	3.82	3.75**
Stimulus Type x Serial Position x Subjects Within Groups	110.13	108	1.02	

*$p < .01$
**$p < .05$