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ABSTRACT

The research described in this report is the first part of an attempt to study the development of both overall reading ability and verbal encoding efficiency in an effort to see how the two are related. The report proposes a theory of prerequisite or hierarchical relationships and suggests that there may be differences between performance of a skill and learning a skill. It then uses this theory of prerequisite skills as a basis for describing the nature of observed correlation between phonological or articulatory proficiency and reading achievement. It notes that clear evidence exists that poor readers in both elementary school and high school are slower at tasks that involve retrieving a verbal/phonological code in response to a visual stimulus. A longitudinal study of beginning reading in process is described in which children were tested as they completed various portions of a reading curriculum. One preliminary result noted is that oral reading speed during the first year of reading instruction was shown to be predictive of later reading achievement. (MKM)

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Introduction

Recent contributions to the instructional psychology of reading have tended toward a consensus that poor readers are deficient in some portion of the processing involved in accessing phonological codes from memory (Frederiksen, 1978a; Jackson & McClelland, 1979; Jorm, 1979; Perfetti & Lesgold, 1977; Vellutino, 1977; and others). This deficiency is increasingly well documented, but there has yet to emerge a clear picture of what it means. Perfetti and Lesgold (1977; Lesgold & Perfetti, 1978) have proposed that the efficiency of the reading process depends critically on the efficiency of phonological code access, but this is only one of the possibilities. The work to be described in this paper is the first part of an attempt to study the development of both overall reading ability and verbal encoding efficiency in an effort to see how the two are related.

The structure of this chapter is as follows: First, we present some foundations for a theory of the types of prerequisite relationships that can exist between cognitive competences. Second, we use this theory as a basis for understanding the nature of the observed correlation between phonological or articulatory proficiency and reading achievement, and show how this concern motivated the longitudinal study of beginning reading now in progress. Finally, we present a considerable amount of preliminary data and discuss their implications for the issues raised earlier.

Notes Toward a Theory of Prerequisites

The notion of prerequisites for instruction is as old as formal instruction itself. Today, it is taken for granted that there are certain components of a curriculum that must precede others. As each new approach to education or to the psychology of education has developed, there has been implicit or explicit reinterpretations of the meaning of prerequisite relationships within that new approach. However, there has not been such a reinterpretation to correspond to the full emergence of the use of cognitive process models as a major tool of cognitive psychology.

Current views of prerequisite relationships between skills tend to derive from the work on learning hierarchies (Gagne, 1962; 1965). This work is based upon a combination of an expansion of verbal learning into the cognitive realm (Gagne, 1965) and rational task analysis (cf. Resnick, 1973). The basic idea that has evolved is that if one wishes to teach a complex skill, one should analyze that skill into component subskills, which should be taught first. This "working backwards" approach is applied recursively to build an overall map of the dependency relations between progressively more complex subskills (see, as an example, Resnick, Wang, & Kaplan, 1973).

Empirical approaches have been suggested for the validation of hierarchies. Most of them call for verifying that if a particular sequence of skills has the property that each skill in the sequence is a prerequisite for the next, then test items that measure performance on this sequence should form a Guttman scale (i.e., no one should correctly answer an item that measures Skill B but fail to pass an item that measures Skill A if Skill A is prerequisite to Skill B). While there have been attempts to specify the nature of prerequisite relationships with greater rigor (e.g., Gagne, 1968), a common weakness of these approaches is that they use rational analyses of final performance to order the course of instruction. This point leads us to consider two sets of candidate definitions for prerequisite relationships: one set which is based upon the extent to which a prerequisite skill is necessary for performance of a target skill, and a corresponding set which is based upon the necessity of a skill that is necessary for the learning of a target skill. Listed below are several types of prerequisites.

Prerequisite Relationships in Skill Performance

1. Performance of the target skill always includes performance of the prerequisite skill. For example, adding three-digit numbers requires adding one digit numbers.

2. Performance of the target skill usually, but not necessarily, includes performance of the prerequisite skill. An example

of such a prerequisite skill would be use of a foot pedal as a prerequisite for driving. Performance of the target skill of driving includes the use of foot pedals as control devices. However, here the relationship is not one of necessity, since it is possible to drive by using an alternative control device, as amputees, in fact, do.

3. Efficiency of the prerequisite skill is a limiting factor on performance of the target skill. That is, efficiency of the prerequisite skill is not _required_ for performance of the target skill, but will represent an _advantage_ in target skill performance. For example, being a poor reader limits one's ability to be a chef (it would be handy to be able to read cookbooks), so we can think of reading as an efficiency prerequisite to chef duties.

Prerequisite Relationships in Skill Learning

4. Skill A is prerequisite to Skill B if the performances involved in learning the target skill, _B_, necessarily include performances of the prerequisite skill, _A_. For example, if it is impossible to learn how to add without being able to count, then counting would be a necessary prerequisite to _learning_ to add, even though it would not be a _performance_ prerequisite.

5. The prerequisite skill is usually required in order for learning of the target skill to take place. For example, knowledge of decimal arithmetic is usually required in learning statistics, but one could imagine teaching statistics to people who knew the arithmetic operations with fractions but not with decimals. Once they knew statistics, they could use computer programs to do their computations. Here, then, is a case where one skill can be substituted for another during learning without necessarily detracting from final performance.

6. Finally, one might speak of one skill being prerequisite to another if efficiency of the prerequisite skill affects the rate at which the target skill is learned. For example, reading fluency is prerequisite to learning a number of skills in the sense that those skills are learned more efficiently if one can easily read certain instructional material. The performances of the target skills, though, may involve no reading.

Given the above ways of characterizing prerequisite skills, we can now specify the task of this paper as exploring the nature and extent of the prerequisite relationship between efficient phonological-articulatory skills and the learning and performance of reading skills. Next, we will examine the merits of each type of prerequisite relationship in explaining the correlation between phonological-articulatory coding and reading achievement.

The first relationship is clearly ruled out, since we know that skilled reading sometimes proceeds without access to phonological codes (e.g., Bradshaw, 1975). Similarly, the fourth type must be eliminated, since it is not the case that less-skilled readers are unable to access and use phonological information (Barron, this volume). The second and fifth types are more plausible, particularly since words can be recognized via both access to phonological codes and direct access of visual representations (Wernicke, 1874;1966). Furthermore, it appears that skilled readers tend to use a phonological strategy in word identification while less-skilled readers rely more on their visual memories for words (Barron, 1978). In terms of our theory of prerequisites, the correlation between phonological coding and a reading skill could be due to either: (a) failure of less-skilled readers to fully compensate for slow phonological access by increased use of the visual route (Relationship 2), or (b) failure of reading instruction to teach poor phonological coders to rely more on "direct access" in reading (Relationship 5). There is, however, evidence which causes us to question whether these relationships are the appropriate description of the data on differences between skilled and less-skilled readers. There is considerable doubt that (a) visual and phonological access are independent processes (Barron, this volume), and (b) all reading can proceed without access to phonological codes (Lesgold & Perfetti, 1978; Perfetti & Lesgold, 1979). Thus, we question the possibility that visual access can always be substituted for phonological access without detracting from final performance.

This leaves us with relationships 3 and 6, which suggest that differences in phonological coding are the cause of either less effective reading or less effective learning of reading skills. Ignoring time constraints and motivational issues, if Relationship 3 holds between phonological coding and reading performance, then improving encoding should improve overall reading. Of course, this assumes that poor readers can in fact be brought to a high enough level of phonological encoding efficiency. As it turns out, there has been considerable research in recent years that purports to show that verbal processing deficiencies are enduring qualities of at least some less-skilled readers. In the next sections, we briefly review two threads of this work--one showing that poor readers have some differences in visual evoked potentials over the parietal lobes and the other showing that verbal memory access and processing speeds are slower in poor readers at all age levels.

Electroencephalographic evidence. In a recent paper, Jorm (1979) argues that poor readers have a "genetically-based dysfunction of the inferior parietal lobule" (page 19), and suggests that such children should be taught by methods that assume that they will never have the level of verbal processing efficiency and capacity that normal readers have. To buttress this theory, Jorm points out that the structures of the inferior parietal lobe of the brain play a role in the kinds of tasks that less-skilled readers are unable to do well. The critical evidence is that which purports to show that less-skilled readers have a dysfunction of the inferior parietal lobe. Here, Jorm cites four studies (Connors, 1970; Preston, Guthrie, & Childs, 1974; Preston, Guthrie, Kirsch, Gertman, & Childs, 1977; and Symann-Louett, Gascon, Matsumiya, & Lombroso, 1977) which show lower levels of evoked response from the parietal lobes, particularly the left, in response to word stimuli, and perhaps also to light-flash stimuli.

The question is whether these studies provide adequate evidence for Jorm's claim that evoked response differences are direct manifestations of structural differences that cause low reading achievement. While the inferior parietal lobe of the left hemisphere is an important locus of verbal processing, including some of the processing less-skilled readers are less able to perform, the evoked potential differences may simply be an indication that the processing we know to be different in effect is also different in the electrical phenomena it produces near the parietal lobe. Or, if not merely an epiphenomenon of verbal processing differences, the evoked response differences may be the result of verbal processing experience differences.

That is, a control group equivalent in reading achievement to a dyslexic group may have had more learning experience with simple word processing tasks--and we are dealing here with evoked responses to single words!! Also, the dyslexic groups in these studies were drawn from special classrooms and may have more substantial problems than one would find, say, in an urban public school classroom. Thus, while there seems to be some evidence here that at least some of the differences between normal readers and poor readers are quite enduring and pervasive, there is no evidence that this difference is either the major cause of reading problems in more normal children or that it is the same as the more specific speed-of-vocalization difference upon which we are concentrating.

Does phonological coding speed distinguish normal from poor readers at all age levels? Differences in verbal processing efficiency have been observed in less skilled readers at several age levels, leading to the conclusion that at least some of the slower access to verbal codes that less skilled readers show may be unaffected by practice. In children, there have been clear demonstrations that elementary school poor readers are slower in saying words and pseudowords than good readers, especially when the word to be vocalized is low in frequency or multisyllabic (Hogaboam & Perfetti, 1978; Perfetti & Hogaboam, 1975). Frederiksen (1978b) looked at a number of performances in high school children who were split into four groups on the basis of their scores on the Nelson-Denney reading test. Children in the lowest quartiles (based upon national norms) were slower in vocalization of low frequency words and pseudowords and also required more time per syllable than better readers to make a lexicality judgment on a multisyllable letter string.

To summarize, clear evidence exists that poor readers, in both elementary school and high school, are slower at tasks that involve retrieving a verbal/phonological code in response to a visual stimulus. Some evidence exists that this difference persists into adulthood, but this evidence involves above average vs. average readers and different tasks. This may mean that phonological coding speed is necessary for efficient reading performance, (Relationship

3). However, it may also mean that phonological coding speed is needed to learn how to read and for that reason only stays correlated with subsequent reading performance (Relationship 6). There is one extensive study that can be interpreted as offering evidence for the latter claim that the verbal processing speed differences that are pervasive over age are correlationally, but not causally, related to overall reading ability differences. This is a study by Curtis (in press), in which poor readers in third and fifth grades were compared to children of equivalent age but average reading ability and to an ability-matched group of younger children of average reading ability for their age.

Using high frequency words and pseudowords, Curtis found the expected phonological coding deficits for the poorer readers at both age levels, but she also found that the predictive power of phonological coding speed tended to decrease with increasing reading ability—relative to the predictive power of listening comprehension. This result is not inconsistent with the claim that verbal memory access remains slow in poor readers over age, but it may also suggest that verbal memory access speed is a less critical need in higher levels of reading.

This may indeed be the case, but there are at least two alternative possibilities. First, tests of listening comprehension may themselves involve more verbal memory retrieval in later grades. More generally, different performances were required in the listening comprehension tests at different grade levels (at least in the sense that subject variability involved different items), while the same words were used at all levels of the vocalization latency measurement. Presumably, if progressively harder words were used for the vocalization task at higher grade levels, that task might have retained its relative predictive power. This issue will be discussed again near the end of this paper. Another possibility is that, to some extent, poor readers come to use alternative strategies to get around their verbal memory access problems, permitting a partial approximation to good performance. If this is the case, the direct deleterious effect of slow code access would decrease over grade levels.

To conclude, it would be useful to have data on the changes in children's verbal memory access speed and in their reading speed and overall reading ability as they progress through school. This would permit at least some further precision in understanding whether phonological coding abilities are needed to learn to read, but are not, in fact, necessary in skilled reading per se.[1] In the next two sections, we describe the methodology and initial results of a longitudinal study designed to provide this additional information.

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[1] We cannot, thus far, separate this theory from an alternative that the phonological processing efficiency correlation with reading is due to a general limit on memory function that shows itself most strongly in phonological processing. For example, a slowness in retrieving any verbal code (the name of something) would show up most when the input is weak. Bouma and Legein (1977) have shown reader differences in accuracy of perception of letters from parafoveal, laterally masked displays. However, we have yet to formulate a test to distinguish the general memory access speed hypothesis from the specific phonological deficiency hypothesis. Some of the data presented below partially disentangle these two hypotheses.

Method

The mastery-referenced developmental design. Ordinarily, developmental studies produce data in which various dependent measures are plotted as a function of age. In the present study, we have chosen a somewhat different strategy. We test children when they complete various portions of the reading curriculum. This means that our basic data consist of plots of the dependent measures against level of progress or mastery through the reading curriculum. Of course, it is also possible to plot the data against age or number of days of schooling, just as might be done in a more traditional study. However, the approach we have taken allows us to easily separate three kinds of developmental effects: (a)skills which are not directly affected by the reading instruction, (b)skills affected by the instruction but which are equal over different children at points o equal mastery, and (c)skills which the curriculum does not teac equally to all children.

The second type of skill would be one which, throug individualization of rate of progress through the curriculum, i successfully taught to all children. For such a skill, performanc data plotted against progress through the curriculum would show n differences between children scoring high on annual readin achievement tests and those scoring lower, even though the slowe children took longer to get to each test point. The third type o skill would be one for which even our mastery-referenced data plot show differences between high and low achievement children. Here too, though, there are several possibilities. For example, both hig and low ability groups may be moving toward the same performance asymptotes. In this case, we would feel that the curriculum is doing the right kind of instruction but that its mastery tests do not capture mastery of the particular performances we are studying. A more interesting alternative would be the finding that children of different achievement levels are moving to different performance asymptotes. This would suggest that current practices (and perhaps any possible teaching approach) cannot bring all children to the same levels of efficiency in that particular skill.

Design details. We have been testing several groups, or cohorts, of children in this study. We present, in this report, data from Cohort A, begun in 1976, and Cohort B, begun in 1977.

The children in both cohorts were from a racially balanced urban school which used the New Reading System (NRS) beginning reading curriculum (see Beck & Mitroff, 1972 for more information about NRS). Cohort A began with 49 children and Cohort B with 53 children. By June of 1979, 19 of the students in Cohort A and 17 of those in B had moved or changed schools and were lost from the sample. Means of the standardized test scores available for the remaining children are shown in Table 1.

NRS is an individualized reading program which emphasizes both phonics and comprehension skills. The program is organized into fourteen major units of more or less equal size called levels. An average child takes about 2.5 years to get through all 14 levels. Each child was tested as soon as possible (ordinarily within a few weeks) after finishing each even-numbered unit. The numbers of

Table 1

Sample Size and Mean Achievements Scores: Cohorts A and B

	Level							Test Scores			
	2	4	6	8	10	12	14	Letters	Phonemes	Vocabulary	Comprehension
Cohort A											
Grade 1 ('76-'77)	38	38	16	--	--	--	--	42[a]	37[a]	1.7[b]	1.5[b]
Grade 2 ('77-'78)	32	32	32	28	21	17	9	--	--	2.1[b]	2.2[b]
Grade 3 ('78-'79)	30	30	30	30	28	26	21	--	--	3.0[c]	3.3[c]
Cohort B											
Grade 1 ('77-'78)	49	30	12	--	--	--	--	1.6[d]	--	--	--
Grade 2 ('78-'79)	36	36	31	23	15	9	1	--	--	2.0[b]	2.1[b]

[a] Raw score means on Murphy Durrell Test.

[b] Grade equivalent means on Stanford Achievement Test, Primary 1.

[c] Grade equivalent means on Stanford Achievement Test, Primary 2.

[d] Grade equivalent mean on Stanford Early School Achievement Test.

children that had been tested at each level by the end of each year are also shown in Table 1.

We have used two basic categories of tasks: oral reading and speed of verbal processing. The oral reading material for each level of Cohort A is of two types. First, there are familiar passages, adapted 'th minimal change from the children's workbooks and other NRS materials. Second, there are transfer passages, written using words for which the child had just learned decoding rules or that he had just learned as sightwords in the portion of the curriculum just finished.

In Cohort B, a subset of the familiar and transfer passages from Cohort A are used again. In addition, Cohort B children also read one familiar test passage from the next test point. Using passages which contain words to which the children have not yet been exposed in the curriculum provides measures of both the degree of reading skill acquisition outside NRS and the degree of improvement on the same passage between levels of NRS. The passages are of differing lengths over levels, reflecting the children's increasing skills. The numbers of words in each level are shown in Table 2.

Both oral reading speed and number of reading errors are recorded. In addition, the reading errors are qualitatively analyzed, following the procedure of Hood (1975-76). When possible, errors are also classified according to their graphemic similarity and their contextual appropriateness to the passage words. (In order for an error to be scored on these measures, it has to be an error of commission that can vary on the dimension being measured. Thus, for

Table 2

Mean Oral Reading Selection Lengths

(Words)

	Cohort A		Cohort B		
	Familiar	Transfer	Familiar	Transfer	Next Level
Level 2	14(n=4)	20(n=4)	13(n=2)	19(n=2)	19(n=1)
4	28(n=4)	24(n=4)	29(n=2)	27(n=2)	59(n=1)
6	65(n=4)	32(n=4)	58(n=1)	62(n=1)	150(n=1)
8	75(n=2)	86(n=2)	150(n=1)	90(n=1)	145(n=1)
10	145(n=1)	106(n=1)	145(n=1)	106(n=1)	115(n=1)
12	115(n=1)	132(n=1)	115(n=1)	132(n=1)	106(n=1)
14	106(n=1)	142(n=1)	106(n=1)	142(n=1)	--

example, the error of skipping a word cannot be classified for graphemic similarity or contextual appropriateness, and a nonsense error would not be scored for contextual appropriateness but would be scored for graphemic similarity.) These qualitative scoring categories are shown in more detail in Table 3.

In addition to oral reading, testing at each level in Cohort A also includes three types of verbal processing tasks: visual, word, and category matching. In visual matching, two letter strings are displayed simultaneously. The upper left corner of the display always contains a word from the vocabulary of the last two levels that the child had completed; the lower right corner displays a string which is either the same or contains two changed letters. When these changes are made, they involve substitution of letters with the same basic shape as the ones being replaced to form a nonword.

In the word matching task, the experimenter first pronounces a word. The child is then shown a word. The child's task is to decide whether the two words are the same or not. The category matching task is similar except that the child has to decide whether a visually presented word (e.g., "horse") is an instance of a category (e.g., "animal") spoken by the experimenter. The words for both these tasks were chosen from the vocabulary of the last two levels the child had completed.

Each of the matching tasks has 28 trials. Fourteen words are used in each task, each word appearing once in the yes and once in the no conditions. The same words, in different orders, are used in the word and category tasks; a different set is used for the visual task.

Table 3

Scoring Categories in Oral Reading Error Analysis

Error Type

0: Stop - Child makes no response to word in 5 seconds.
1: Order - Child changes word order ("that man" for man that)
2: Reversal - Change of letters with a word ("was" for saw)
3: Stem - Correct stem, wrong ending ("bats" for batting)
4: Affix - Correct ending, wrong stem ("hitting" for batting)
5: Substitution - Word substituted for another ("hit" for bat)
6: Insertion - Insertion of extra word
7: Omit - Word omitted unintentionally
8: Skip - Word skipped intentionally
9: Nonsense - Nonword said instead of word

Graphemic Similarity (Applies if error type is 3, 4, 5, or 9)

0: No letters the same between error and word
1: One letter overlap
2: More than one letter but less than 50%
3: 50% or more letters overlap

Contextual Appropriateness (Applies if error type is 2, 3, 4, or 5)

0: Error word is totally inappropriate to context
1: Error word appropriate only in preceding context
2: Error word appropriate in current sentence only
3: Error word preserves meaning of text

Six practice trials precede each task. A summary of the verbal processing tasks used in this cohort is shown in Table 4.

There are four measures of verbal processing speed in Cohort B: simple reaction time (RT), scanning RT, vocalization latency, and category matching RT. In the simple RT task, either the word "yes" or the word "no" appears on the screen, and the child's task is to push the appropriate button as quickly as possible.

In the scanning RT task, a letter appears on the screen and the experimenter names it. Following this, a word replaces the letter on the screen, and the child's task is to decide whether the letter was contained in that word or not. On yes trials, the position of the letter in the word is varied. In the voacalization task, a word appears on the screen and the child's task is to say that word out loud as quickly as possible. The category matching RT task is the same as that described for Cohort A. Table 4 contains a summary of the verbal processing tasks used in this cohort.

The simple, scanning, and category matching RT tasks each have 30 trials, 15 yes and 15 no, while the vocalization task has 15 trials. Six practice trials precede each task. The same 15 words are used in the word RT tasks, each word appearing once each in the yes and no conditions in scanning and category matching. There are three types of words used: five from the last two levels of NRS that the child had just completed (familiar words); five that the child has either learned decoding rules for or learned as sightwords (transfer words); and five from the next two levels in NRS that the child would be starting (next level words). The next level words at each test

Table 4

Summary of Verbal Processing Speed Tasks

	Yes	No	Cohort
Visual Matching	action-action	action-acfuon	A
Word Matching	"square"-square	"square"-thread	A
Category Matching	"Is this an animal?" horse	"Would you see this in the sky?" horse	A,B
Scanning	n-barn	h-barn	B
Vocalization			B
Simple RT			B

session are always the familiar words at the next test point.

Procedure. Testing is conducted in two sessions on different days except for Levels 8-14 in Cohort A, for which all tasks can usually be given the same day. The oral reading passages are typed in the same type style as had been used in the readers for the levels being tested.[2] In the reaction time tasks, the stimuli are photographed for slides and projected on a rear projection screen, appearing black against a white background. The opening of the projector's shutter starts a digital clock which stops when the child presses either a yes or no button. Timing is measured to the nearest millisecond with estimated overall precision of ±5 msec. The children are instructed to respond as quickly and as accurately as they can.

Results

Changes in Basic Measures across Levels

The means of the oral reading and verbal processing measures at each level of testing are shown in Table 5 (Cohort A) and Table 6 (Cohort B).

Oral reading speed and error rate. As indicated in these tables, both oral reading speed and error rate change as the child advances through the curriculum. Since the level of difficulty of the passages is held relatively constant across test sessions (i.e., the passages contain information that has been introduced only in the latest portion of the curriculum that has been completed), these decreases in

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[2] NRS starts with large, "primary grades types" and switches to gradually smaller fonts.

Table 5

Means of Basic Measures at Each Level in Cohort A

	Level						
	2	4	6	8	10	12	14
n	30	30	29	26	24	24	20
Familiar Passages							
WPM	34	56	73	92	75	96	96
% errors	12%	6%	7%	4%	8%	6%	4%
Transfer Passages							
WPM	24	27	48	49	56	53	76
% errors	18%	18%	13%	10%	9%	10%	9%
Visual Match							
RT	3.23	3.77	2.88	2.52	2.63	2.23	2.09
% errors	6%	9%	6%	3%	6%	2%	9%
Word Match							
RT	2.86	2.57	1.88	1.74	1.83	1.65	1.51
% errors	5%	7%	4%	4%	8%	4%	4%
Category Match							
RT	3.91	3.30	2.68	2.43	2.50	2.13	2.09
% errors	13%	11%	6%	8%	11%	8%	17%

Table 6

Means of Basic Measures at Each Level in Cohort B

	Level					
	2	4	6	8	10	12
n	36	34	28	20	15	9
<u>Familiar Passages</u>						
WPM	32	65	84	104	84	111
% errors	17%	6%	6%	4%	9%	5%
<u>Transfer Passages</u>						
WPM	29	27	54	66	65	65
% errors	17%	18%	13%	9%	10%	11%
<u>Next Level Passages</u>						
WPM	30	43	62	60	81	89
% errors	28%	22%	7%	12%	5%	10%
<u>Scanning</u>						
RT	2.24	2.20	2.16	2.01	2.31	2.14
% errors	12%	10%	10%	5%	5%	3%
<u>Category Match</u>						
RT	4.26	3.58	2.96	2.42	2.48	2.52
% errors	24%	24%	22%	16%	21%	26%
<u>Simple</u>						
RT	1.16	.96	.92	.79	.88	.86
% errors	6%	3%	1%	1%	0%	1%
<u>Vocalization</u>						
RT	3.60	2.88	2.63	1.96	2.25	2.28
% errors	23%	32%	38%	18%	23%	32%

reading time and error rate reflect the child's increasing skill in reading.

Within a given level of testing, the type of passage read also affects both oral reading measures. Passages which include words which have been taught as sightwords or for which the child knows only decoding rules (transfer passages) are read with more difficulty than passages containing words from the curriculum. It is interesting to note that the next level passages--those which contain words which have not yet been introduced at the time of testing--are not any more difficult than the transfer passages. This may be a function of the design of the NRS curriculum, i.e., rules of decoding which will be necessary for learning words at the next level may be stressed more than those which are not. In any case, a comparison of more interest to the goals of the present study is between the next level passages at a given level with the familiar passages at the next level (see Table 6). Since these materials are the same (e.g., the next level passage at level 8 become the familiar passage at level 10), the observed decrease in both reading time and error rate is a good indication of the rapid changes that are occurring in reading skill during the first few years of instruction.

<u>Verbal processing speed measures</u>. Tables 5 and 6 indicate that while accuracy on most of these tasks is quite high, category matching and vocalization in Cohort B are more difficult than the other tasks. Further analyses of these two tasks, breaking them down by the different types of words used (i.e., familiar, transfer, and next level), are being conducted. So far, these analyses show no major

pattern differences for different word types, though transfer words are generally harder (i.e., slower RTs and lower accuracy) than familiar and next-level words.

The mean reaction times in Tables 5 and 6 are for correct responses only, and are averaged across yes and no trials. Inspection of these means indicates that processing speed increases across levels on all tasks but two: simple reaction time and scanning. That differences are not found on these tasks is important for several reasons. First, it confirms that changes across levels on the other tasks are not due to global changes in speed of responding. Second, it reassures us that the pattern across levels is not due to the particular words tested, since the same words are used in scanning, category matching, and vocalization within a level in Cohort B, but different words are used in each level. Finally, it indicates that changes in speed of word processing that occur as skill in reading develops are not related to changes in speed of letter processing, since the scanning task would have been sensitive to this factor. This last finding has implications that we will consider near the end of this paper.

Oral Reading Error Analysis. In addition to reading times and error rate, the oral reading task allows us to classify reading errors according to their type and their similarity to the correct word in the passage. This qualitative error classification has been highly reliable: trained independent scorers agree on error type for 95% of the errors in a sample, on graphemic similarity for 99%, and on contextual appropriateness for 85%.

The mean proportions of errors classified as each type at each level for Cohort A are shown in Table 7. In spite of the fact that error rate decreases as children progress through the curriculum, the distributions of the types of errors occurring at each level remains quite constant in both cohorts. Substitution of a word that differs from the one in the passage accounts for approximately 50% of the errors made at each level. Order, reversal, and intentional skip errors occur very rarely. The high frequency of substitution errors may be inflated somewhat by the fact that we make no attempt to judge whether the child actually knows the word that is substituted--if the child's utterance is known to be an English word, it is scored as a substitution rather than a nonsense error.

The proportion of errors falling within each category of graphemic similarity seems also to be invariant with test level in both cohorts. The majority of errors made are, from the beginning, very similar visually to the word that appeared in the text. In terms of contextual appropriateness, only one category seems to be affected by level in the curriculum: the proportion of errors that are totally inappropriate to the meaning of the passage decreases as skill in reading increases.

Achievement-Related Differences in Basic Measures across Levels

While discussion of the results up to this point has focussed on changes that take place in children's oral reading and verbal processing skills as they learn to read, we have also been concerned with finding out whether there are any differences on these measures

Table 7

Mean Proportion of Oral Reading Error Types at Each Level in Cohort A

	Level						
	2	4	6	8	10	12	14
<u>Error Type</u>:							
Stop	.17	.14	.02	.09	.02	.06	.07
Order	.02	.00	.00	.00	.01	.00	.01
Reversal	.00	.00	.00	.02	.02	.00	.01
Stem	.11	.09	.12	.11	.21	.27	.07
Affix	.04	.03	.04	.07	.04	.02	.02
Substitution	.47	.61	.54	.47	.46	.41	.49
Insertion	.04	.02	.05	.05	.05	.06	.06
Omit	.07	.03	.10	.09	.06	.10	.09
Skip	.01	.01	.01	.01	.00	.01	.01
Nonsense	.08	.07	.13	.09	.13	.07	.18
<u>Graphemic Similarities</u>:							
None	.07	.13	.20	.14	.17	.08	.10
One Letter	.18	.14	.18	.13	.08	.08	.17
Less than 50%	.04	.09	.13	.15	.07	.06	.04
50% or more	.71	.64	.49	.59	.68	.77	.68
<u>Contextual Appropriateness</u>:							
None	.27	.21	.19	.13	.10	.13	.11
Preceding only	.31	.25	.43	.47	.48	.35	.38
Sentence	.14	.13	.09	.13	.14	.17	.19
Meaning preserved	.28	.41	.30	.27	.28	.36	.33

among children who vary in their later achievement in reading. As a preliminary attempt at addressing this question, we have used the children's most recent reading achievement scores as a basis for classification into three groups: low, medium, and high achievers, and we have looked at the performance of these groups across levels. The achievement scores for Cohort A are from the beginning of third grade, with the following group mean grade levels in reading: low = 2.2 (n=11); medium = 3.2 (n=9); high = 4.0 (n=8). Scores from the beginning of second grade were used in Cohort B, since these children have not yet had their third-grade tests and the groups' mean grade levels were: low = 1.5 (n=11); medium = 2.2 (n=12); high = 3.4 (n=11).

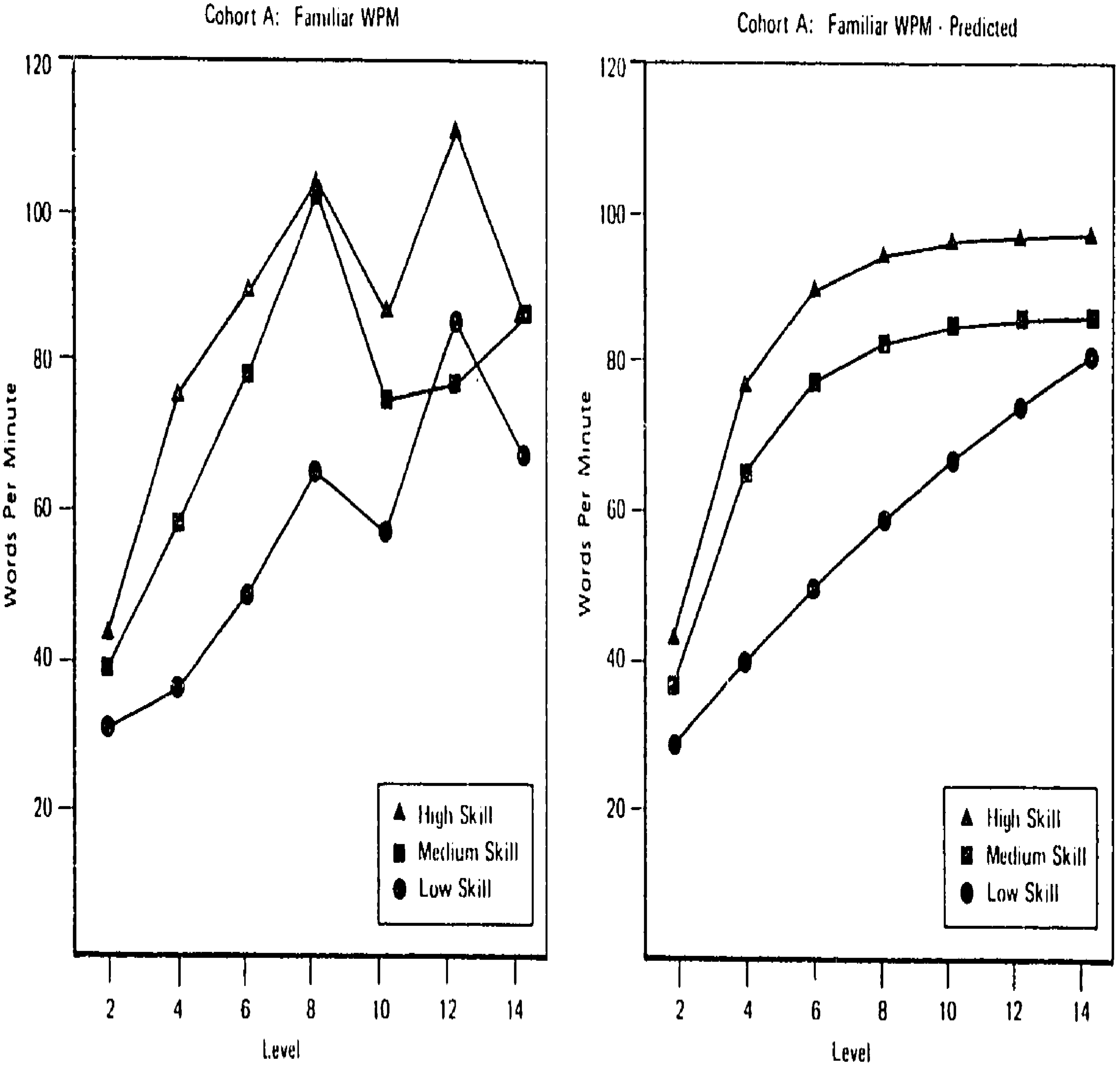
Oral reading speed and error rate. The means of familiar, transfer, and next level reading speed across levels for the three ability groups are shown in the left panels of Figures 1-5. As these figures indicate, reading speed differs widely among the three groups in both cohorts. Also, since error rate in reading and reading speed are not orthogonal factors, similar ability group differences are found in the proportion of oral reading errors made across levels on each type of passage.

In order to get a better understanding of what these differences in oral reading speed among the ability groups mean, we performed asymptotic regression analyses which predicted each group's reading speed (y) at each level (x) by estimating the parameters a, b, and k for the equation $y = a + bk x$ (see Suppes, Macken, & Zanotti, 1978, for a related application of this model). The least-squares fits of the regression functions are significant in all cases (ps < .03), and the plots of the predicted means at each level for each ability group are shown in the right panels of Figures 1-5.

The patterns for predicted means on familiar reading speed are strikingly similar in the two cohorts: for low readers, speed increases linearly as the children move through the curriculum (.9 < k < 1.0), while in the medium and high groups, asymptote is reached by the last few levels of testing (.3 < k < .4). For transfer passages, low readers in both cohorts continue to make greater gains at each successive level (1.2 < k < 1.5), while the medium readers show a more linear increase (.8 < k < 1.0), and the high readers may be showing decreasing gains at later levels (.6 < k < .7). Finally, on the next level passages, both the medium and high readers appear to increase their reading speed in a linear fashion (.9 < k < 1.1), while the low readers are beginning to show decreasing gains between later levels (k = .6).

In general, these analyses reveal several interesting differences among the groups. In quantitative terms, oral reading speed during the first year of reading instruction has been shown to be predictive of later reading achievement. High ability readers are faster than medium and low readers initially, and they remain faster throughout their period of primary reading instruction. In fact, this difference in initial rate of processing rather than rate of increase in processing speed seems to be the major difference between medium and high skill groups.

In qualitative terms, differences are found between the low


Cohort A: Familiar WPM

Cohort A: Familiar WPM - Predicted

Figure 1. Actual and predicted means on familiar reading speed by levels and ability groups in Cohort A.

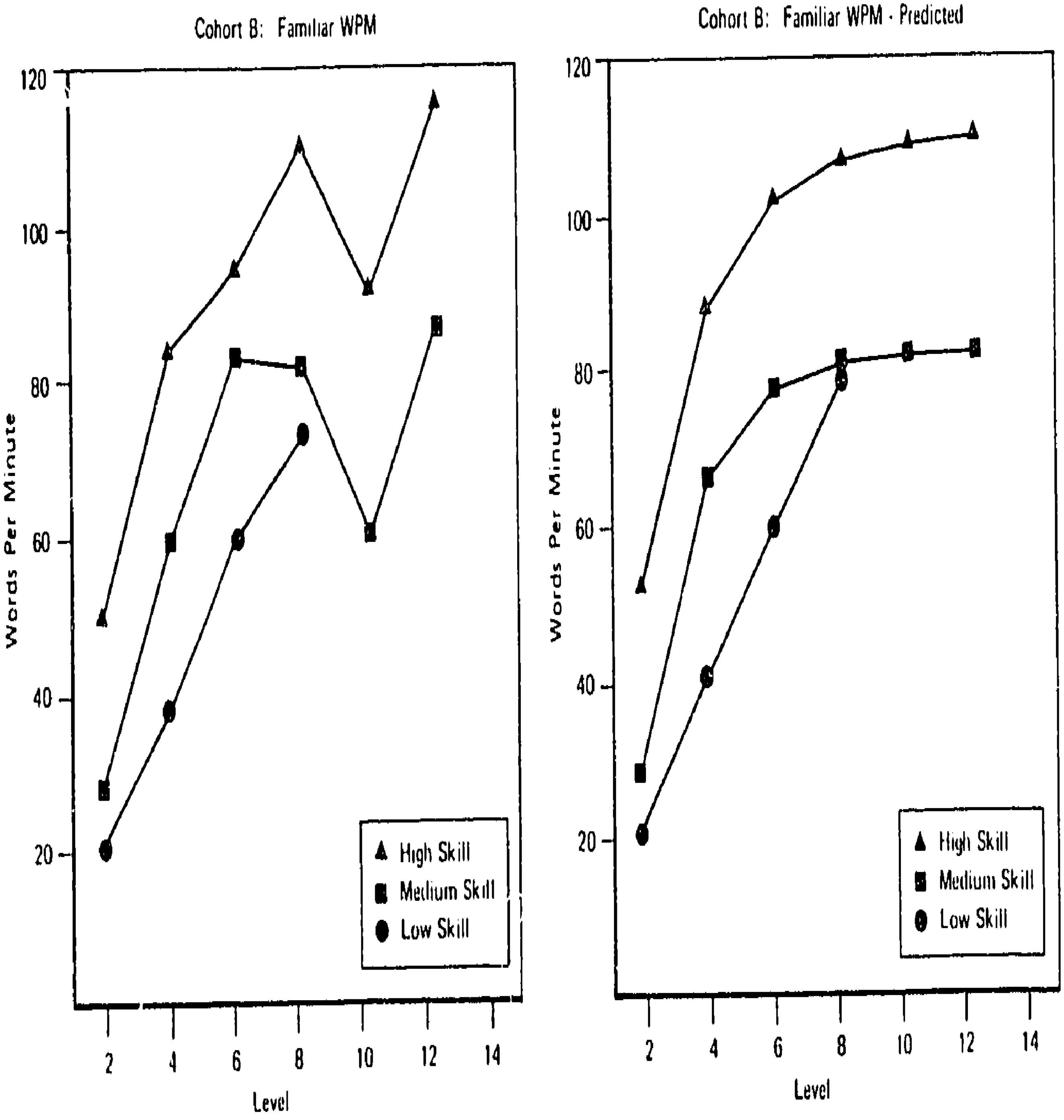


Figure 2. Actual and predicted means on familiar reading speed by levels and ability groups in Cohort B.

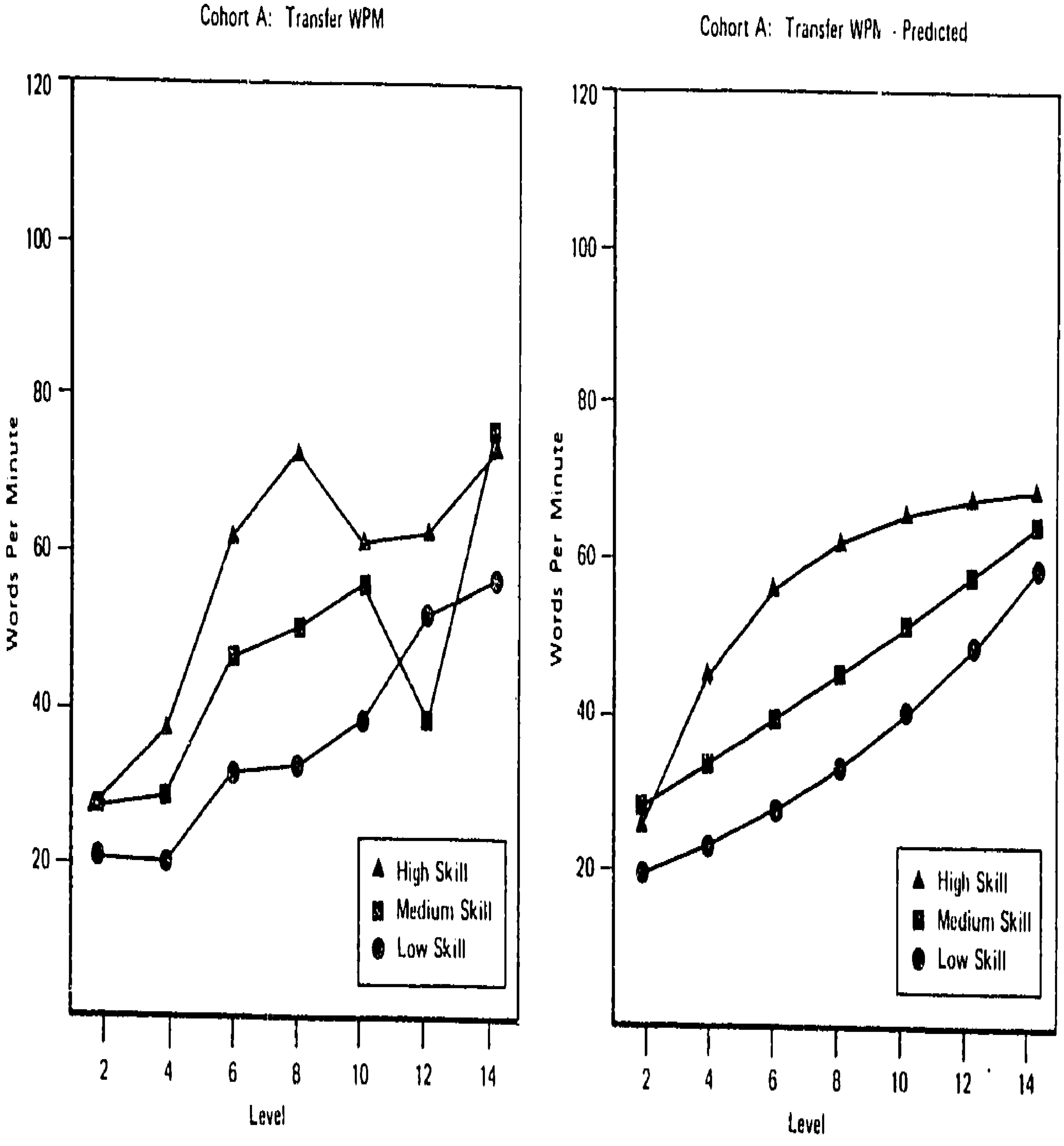


Figure 3. Actual and predicted means on transfer reading speed by levels and ability groups in Cohort A.

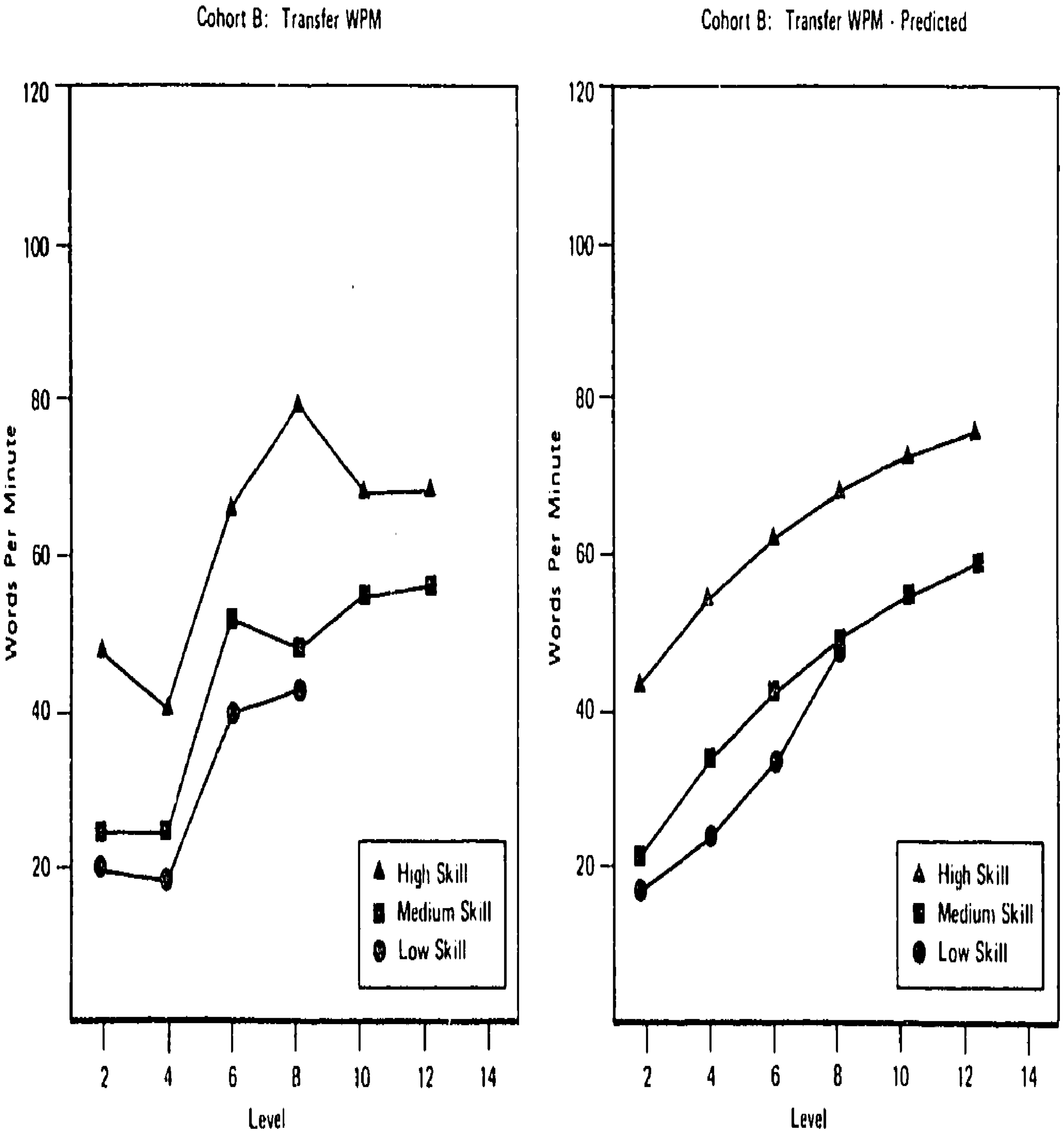


Figure 4. Actual and predicted means on transfer reading speed by levels and ability groups in Cohort B.

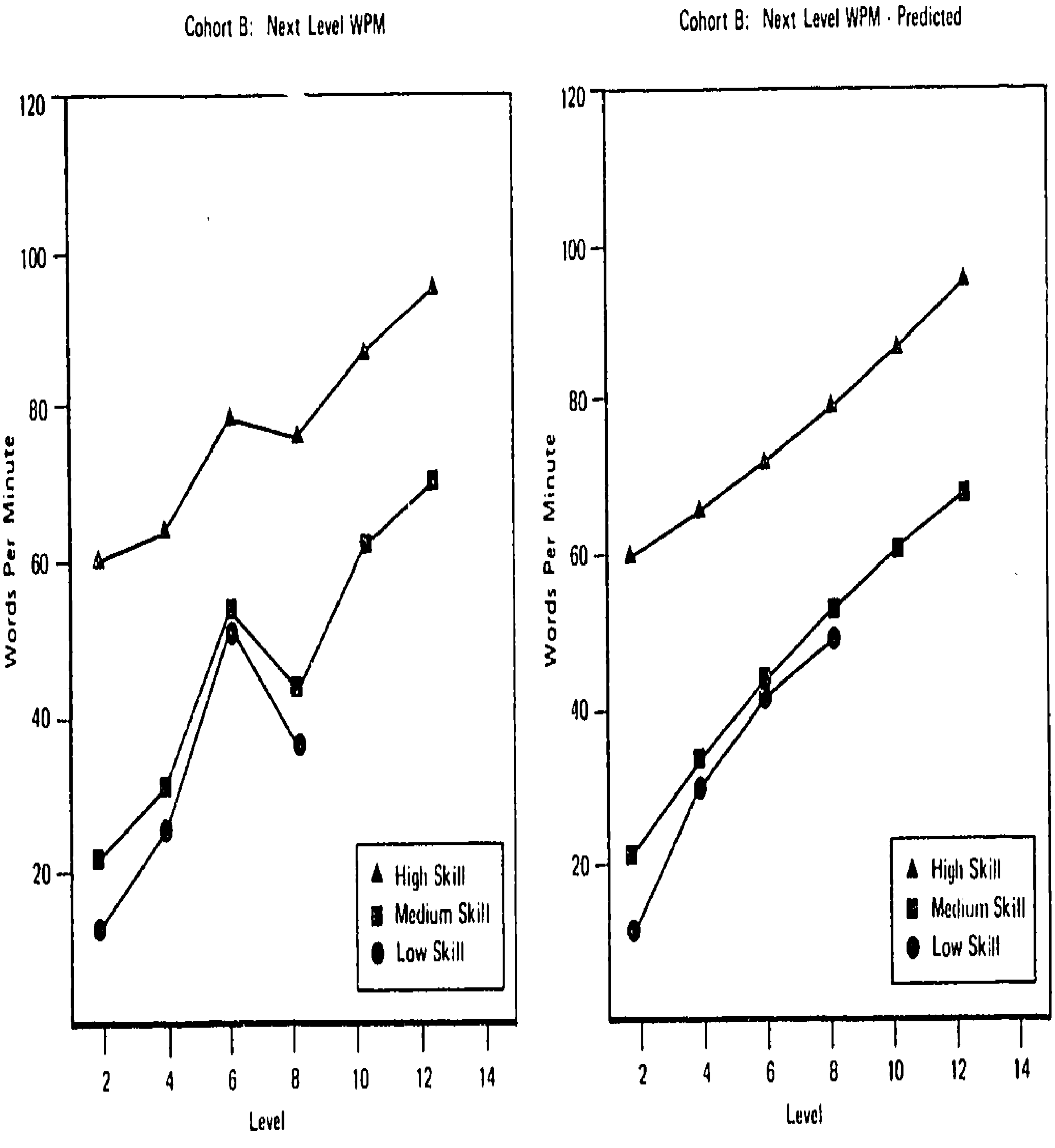


Figure 5. Actual and predicted means on next level reading speed by levels and ability groups in Cohort B.

ability group and the medium and high readers. On familiar and transfer passages, although the low group remains slower than the other two, low skill readers make greater gains in reading speed at later levels of the curriculum than medium and high readers. This is in contrast to the next level of passages, where the gains in reading speed are more similar among the three groups though the high-ability children are faster at all levels. This suggests that instruction in reading may be having a differential effect upon the three groups: while it raises oral reading speed to its asymptotic level for medium and high readers at each level, it maintains the rate of gain in reading speed for the low readers, who do not reach asymptote during the period for which we have data.

Verbal processing speed measures. The means for the reaction time tasks across levels for the three ability groups are shown in Figures 6-9. In contrast to the oral reading measures, there is only one task on which processing speed is related to later achievement differences among the groups: vocalization latency. Looking across the various measures, we see all three developmental patterns mentioned in the beginning of the Method section. The simple RT and scanning RT tasks (both in Cohort B) show no change over levels. Presumably, these tasks measure performance abilities unaffected by the reading instruction these children received. The visual RT task of Cohort A falls in between this pattern and a second pattern, shown by the word RT task of Cohort A and the category RT task (both Cohorts), which show improvement over the course of instruction but no achievement-related differences once level in the curriculum is held

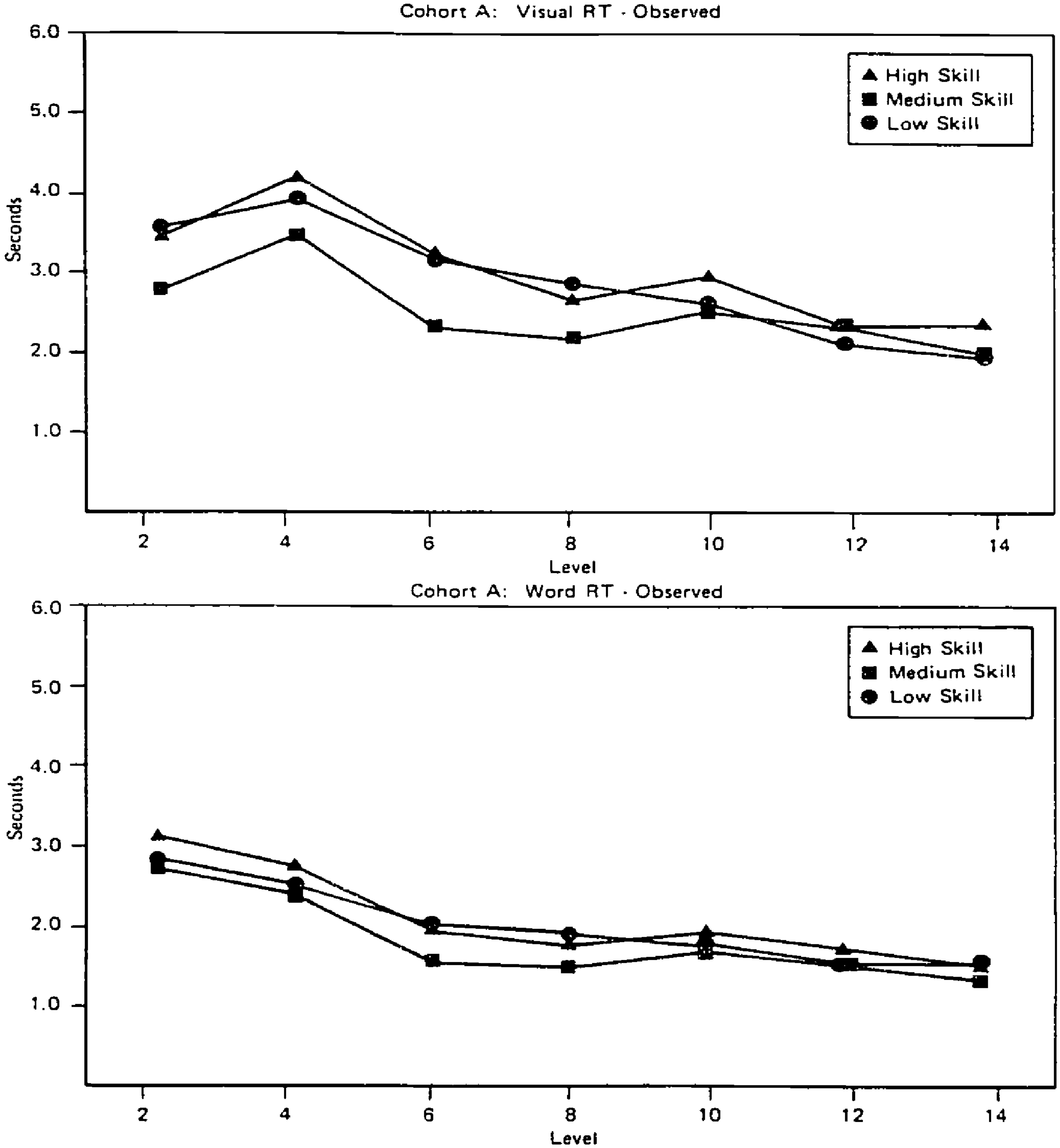
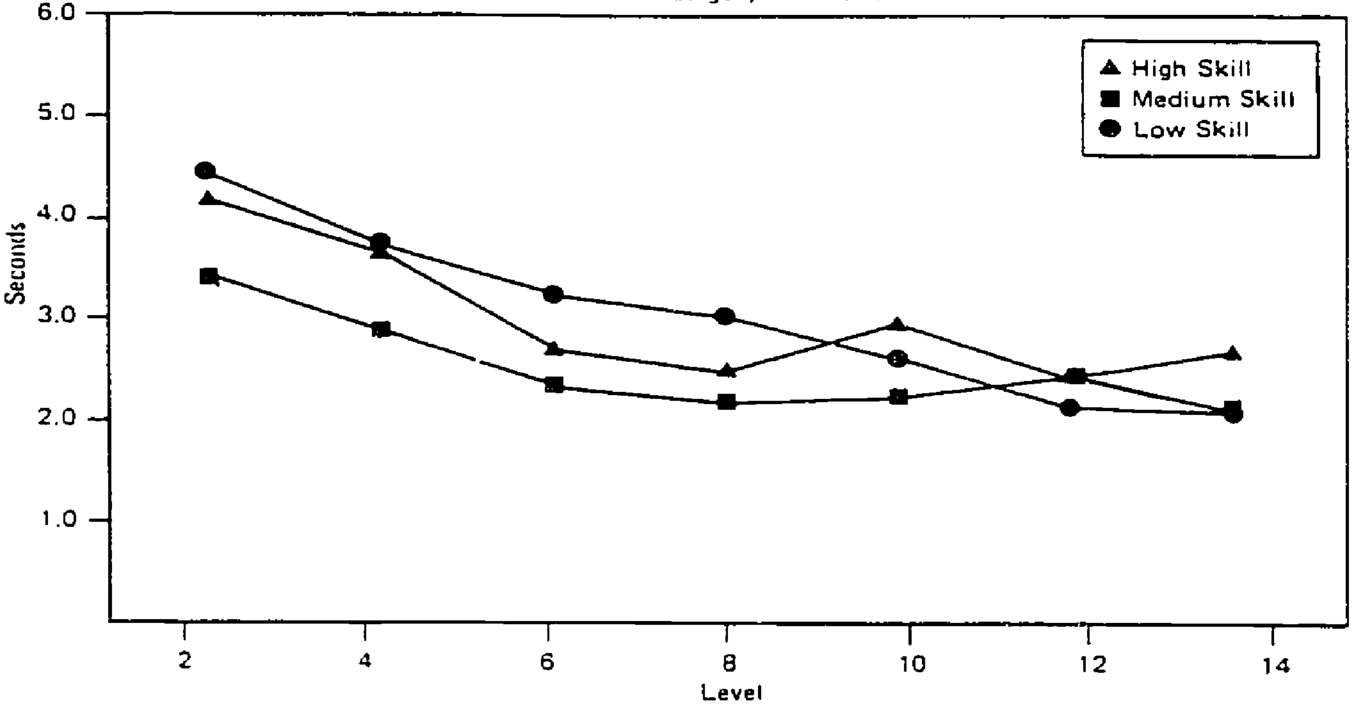


Figure 6. Means on visual and word matching RTs by levels and ability groups in Cohort A.


Cohort A: Category RT - Observed

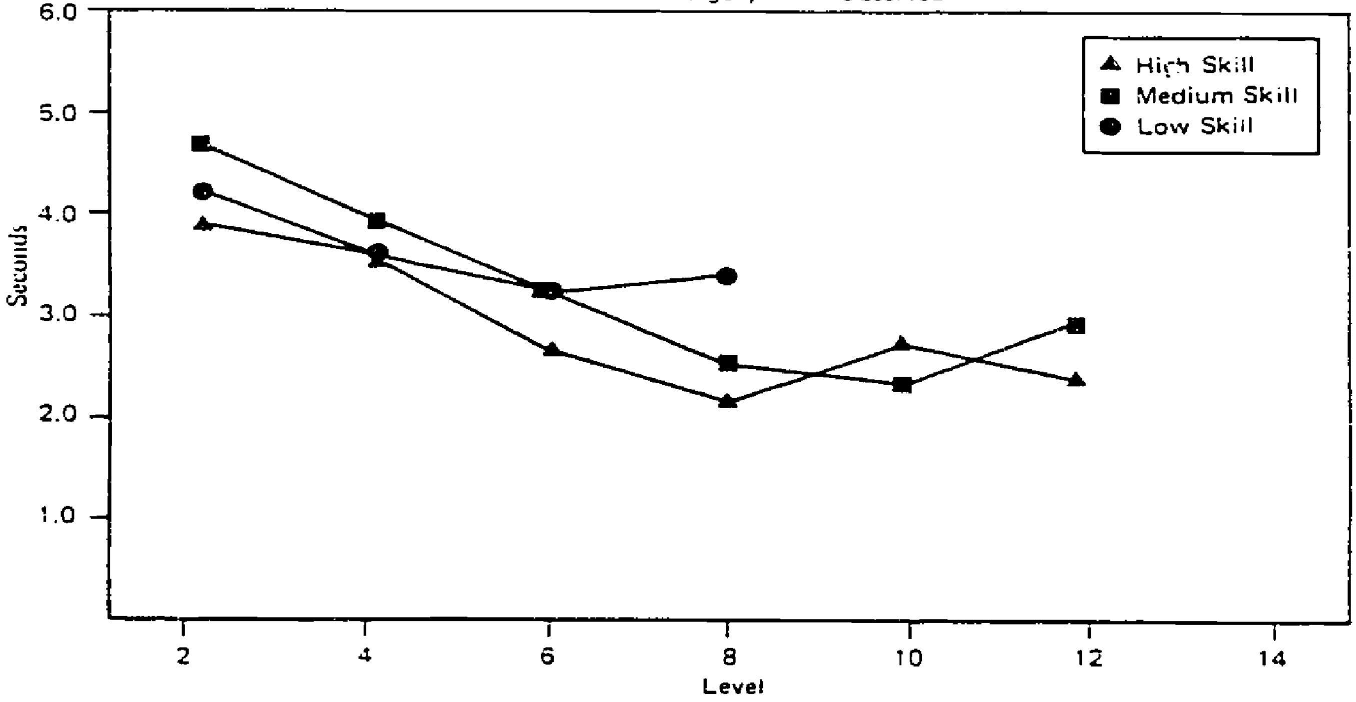

Cohort B: Category RT - Observed

Figure 7. Means on category matching RT by levels and ability groups in Cohorts A and B.

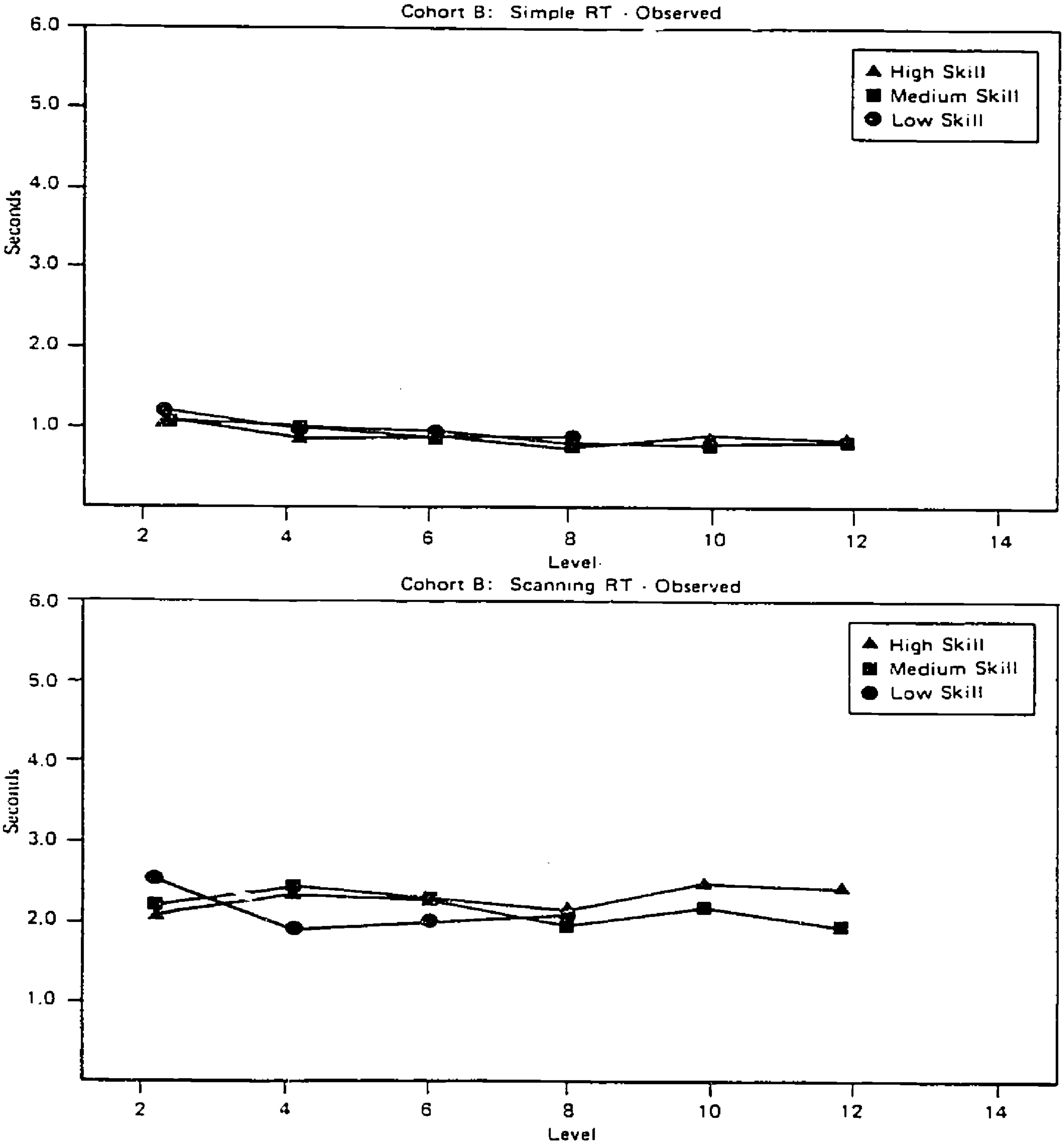


Figure 8. Means on simple and scanning RTs by levels and ability groups in Cohort B.

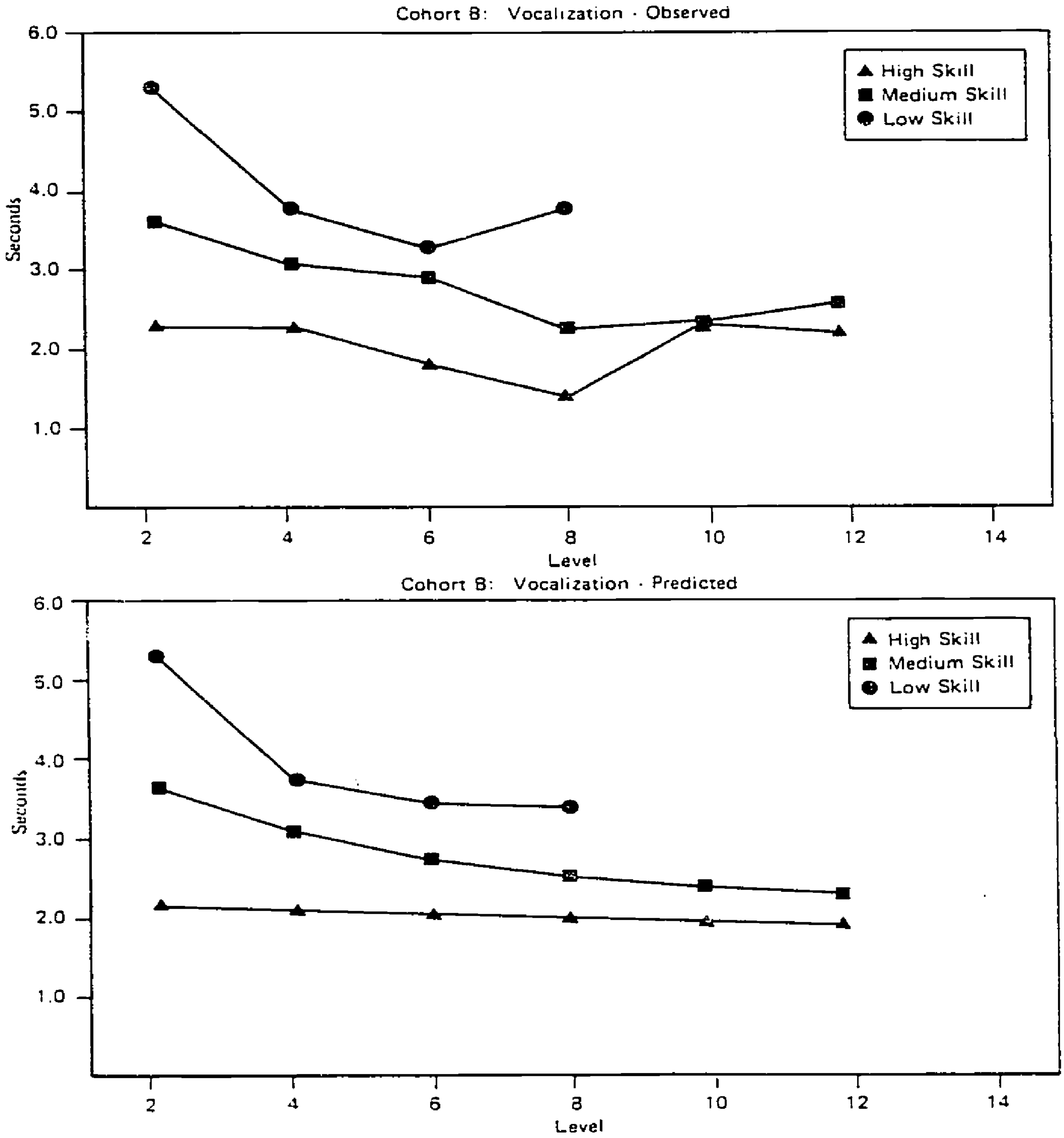


Figure 9. Actual and predicted means on vocalization latency by levels and ability groups in Cohort B.

constant. Finally, vocalization latency (Cohort B) shows differences that remain even after we allow for differences in rate of progress through the reading curriculum.

Asymptotic regression was used again to predict each group's vocalization latency at each level, and the predicted means are shown in Figure 9. While both initial processing speed and the rate of increase in this speed discriminates among the groups, a more interesting aspect of this data is the fact that all the groups appear to be approaching asymptote by Level 4. The role that instruction plays in the components of reading measured by this task seems confined to maintaining (over progressively larger reading vocabularies) rather than increasing rate of processing.

Oral reading error analysis. The mean proportions of oral reading error types for each ability group are shown in Table 8. The pattern of errors across skill groups is similar to that found across levels: substitution errors are the most frequently occurring errors in all skill groups, and the majority of errors are graphemically similar to the words in the passage. As with successive levels in the curriculum, however, there is a difference among the groups in terms of the categories of contextual appropriateness: as reading level increases, the proportion of errors which preserve the meaning of the text increases and the proportion of errors which are totally inappropriate to the meaning decreases.

Table 8

Mean Proportions of Oral Reading Error Types by Ability Groups

	Cohort A[a]			Cohort B[b]		
	Low	Medium	High	Low	Medium	High
Error Type:						
Stop	.08	.05	.09	.09	.11	.10
Order	.00	.00	.01	.00	.01	.00
Reversal	.01	.00	.01	.01	.01	.01
Stem	.11	.16	.12	.07	.09	.10
Affix	.05	.05	.05	.04	.05	.08
Substitution	.52	.53	.46	.48	.50	.53
Insertion	.03	.05	.05	.01	.02	.02
Omit	.04	.07	.16	.03	.02	.04
Skip	.02	.01	.00	.14	.08	.05
Nonsense	.14	.07	.06	.13	.11	.06
Graphemic Similarities:						
None	.13	.12	.16	.09	.08	.12
One Letter	.15	.12	.14	.17	.14	.10
Less than 50%	.11	.09	.04	.06	.05	.01
50% or more	.61	.67	.66	.68	.73	.78
Contextual Appropriateness:						
None	.24	.17	.03	.27	.20	.12
Preceding only	.39	.36	.41	.42	.41	.42
Sentence	.13	.11	.13	.20	.21	.19
Meaning preserved	.24	.36	.43	.11	.18	.27

[a] Collapsed across Levels 2-10

[b] Collapsed across Levels 2-6

Discussion

In this section, we address a number of issues to which the data just presented are relevant. First, we consider whether the data clarify the nature of the skill(s) which poor readers lack. Then, we attempt to specify the specific prerequisite relationship we have observed between those skills and overall reading achievement. Third, we examine the effects of practice for higher and lower skilled individuals on word decoding. Fourth, we consider the extent to which there are differences in top-down aspects of processing between higher and lower reading ability children. Finally, we discuss our future plans for the study and some of the developmental issues it raises.

What differentiates less-skilled readers?

A review of the data we just presented shows that less-skilled readers are not distinguished from their more skilled fellows by simple choice reaction time or performance on the scanning RT task. On the word RT, category RT and perhaps the visual RT tasks, the differences between different reading achievement groups are accommodated by their different rates of progress through the reading curriculum. That is, a slower learner shows the same performance on these tasks at a given level as was shown by his faster colleague on that level (some time earlier). In contrast, there are substantial differences on the vocalization latency measure and on measures of oral reading speed. There are also differences in the extent to which the oral reading errors of less-skilled readers give evidence of contextual constraint on word identification.

Oral reading speed. The oral reading speed analyses merit more detailed consideration. Basically, there is a difference in the shape of the learning curves for the different ability groups. The high and middle groups show the classical learning curve. They experience negatively accelerated growth in reading speed, with major gains from the beginning. The low group shows a much more constant, incremental improvement. One interpretation of the strongly negatively accelerated curve is that there is only a specific, easily-learned skill separating the (expected-to-be) average and above-average children from reading facility. When they are taught this skill--specific word recognition rules--they integrate it with other language skills which they already have, and they are then reading with facility.

The poorer readers, in this explanation, show less transfer between learning to read one word and learning to read another. Thus, their progress in acquiring the enabling skill of word recognition is slow and incremental. They do not seem to get a "critical (apperceptive) mass" of word recognitions that could allow them to burst into reading expertise. This viewpoint is consistent with soft data on the use of the NRS curriculum with learning-disabled samples (Beck, personal communication). There it was found that LD children progress nicely through the individualized program, achieving the specific skills taught and tested by NRS, at a slower but reasonable pace. However, these children do not show the same level of transfer to non-NRS words and sentence forms which normal children would show at the same points in the curriculum.

There is an alternative to the hypothesis that the low group learns much more slowly and with less transfer. This alternative is brought to mind by the classic study of learning in retardates, by Zeaman and House (1963). They found that while group data showed a lower-than-normal learning rate for the retardates, each individual retardate showed a pattern closer to no learning for a variable number of trials followed by normal learning thereafter. Zeaman and House suggested that the retardates took much longer to notice relevant dimensions of the stimuli, but once they learned where to focus their attention, they learned at a normal rate. In the same way, it is possible that all of our children show equally rapid reading progress, *once they have achieved certain prerequisite skills*. Prior to that point, there would be the appearance of little or no progress in such measures as oral reading speed. Assuming different points in different children for passing the critical hurdle, the slower children, viewed through averaged data would show about the pattern we have seen. The question is whether the averaging obscures a Zeaman-House type of individual pattern in some or all of the children.

We have examined the individual subject data from Cohort A, where we have three years worth of data. The patterns are mixed. Some children show long periods of no progress, followed by normal learning. Others show continual slow learning. Once we have adequate data from Cohort B (where we have the vocalization latency measure), we can examine that data for individual patterns and even see if the point of departure for children with the Zeaman-House pattern is predicted by reaching a particular level of vocalization latency performance.

Vocalization latency. Another issue we must consider is the nature of the differences between the more and less successful reading students in the shapes of their "learning curves" for vocalization latency. Comparing the fitted asymptotic curves of Figure 9, it appears that the high-skill subgroup starts out at a fast (i.e., short RT) asymptote, or at least gets there very quickly. The middle group also reaches asymptote after a few levels. The low group, however, appears to be heading toward a much different asymptote, not nearly as fast. This result is particularly striking when one realizes that the horizontal axis of the figure is in units of "levels completed," not time. When the data are plotted against "days in school," the effect is to stretch out the low curve relative to the others, i.e., the less-skilled readers show not only the apparently less proficient asymptotic performance but also move more slowly toward that asymptote. We will consider this result in more detail in the section on practice below.

How is word recognition prerequisite to reading?

The results for vocalization latency and its relationship with reading achievement help to clarify the nature of word recognition as a prerequisite for reading. As discussed earlier, we are not dealing with word recognition as a prerequisite in the sense of needing to be able to recognize words at all. Rather, we need to ask the question: What aspects of reading or of learning how to read work better when access to phonological codes is rapid and efficient?[3]

This leaves us with two basic alternatives to consider. One is that some portion of the word vocalization performance is slow, will make reading difficult. The other is that this performance inefficiency retards the process of *learning to read* but does not render reading itself that difficult, once it is learned. The data, at this point, are not yet complete enough to make a final decision about which interpretation is most reasonable. If it should continue to appear that the low-skill children asymptote at a slower vocalization speed but do eventually develop normal reading speed for some materials (e.g., the familiar set), then we would have to say that slow phonological access/processing retards the *acquisition* but not necessarily the *performance* of oral reading of text. On the other hand, by definition, the low-skill group is subnormal *after instruction* on whatever it takes to do well on a standard reading achievement test. Consequently, we might argue that children with slow phonological processes are less expert in *performance* of some of the skills reading achievement tests tap.

Even this statement requires some hedging. This is because reading achievement tests often include, in their primary grades versions, a number of items that do not measure reading per se, but rather a set of component or prerequisite skills (according to the

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3. As there were a significant number of errors by less-skilled readers (inter alia) on the word vocalization task, it may seem unreasonable for us to claim that even the less-skilled readers can do word recognition but just can't do it quickly. However, few of the errors, if any, after Level 2, were associated with *not knowing* a word. Rather, they were produced by the speeded nature of the task.

implicit reading theory of the test designer). We have not yet ruled out the possibility that our low-reading-achievement-score group is low because of specific failures on more artificial phonological code access tasks. However, none of the items in the tests we used were prima facie phonological code access tasks, and we do not, on the basis of anecdotal data, believe that low scorers are low primarily because they are too slow to get to all the items. Ultimate removal of this hedge, though, will depend upon finding, as we accumulate more years of data on the present cohorts, that vocalization latency predicts reading achievement even on levels of the test that include only reading comprehension items.

Issues of Practice

In our study, the words used for RT tasks at each testing point are selected to be in one of three categories (for Cohort A, no "next" words were used). Some are words which are introduced specifically in the last two levels ("familiar" words), some are words which contain symbol-sound correspondences taught in the last two levels ("transfer words"), and some are words that will be introduced in the next level the child enters ("next words"). Significantly, none are words that have been known to the child (assuming he learns his words at school), as reading vocabulary, for very long. Thus, we are testing, at every level, words the child has not yet practiced to any great extent.

This creates two plausible situations. One is that we are really giving a variety of transfer task when we give the vocalization latency task. That is, a significant amount of the speed of performance we see in a child may be determined by how much transfer that child experienced from earlier words to the learning of the relatively new words in the test set. The other possibility is that the better readers have amassed more practice on the words being tested and that this is why they are more familiar. This second possibility is depreciated somewhat by the fact that the groups do not differ on the other word processing RT tasks that use the same words: scanning, visual matching, audio-visual matching, and category matching. Thus, we tentatively conclude that part of the differences we see between higher and lower reading ability children on vocalization latency may reflect transfer of training on earlier words.

It would be interesting to also have data in which a common word set were used at each test occasion, so that scores were *relatively* uninfluenced by transfer effects. We have something of this sort in the data reported by Curtis (in press). The same words were used at the second, third, and fifth grade levels. Here, then, we have nonlongitudinal data, at mostly higher grade levels, but that speak to the issue at hand, in part. Table 9 shows the correlations found between various vocalization measures and standardized reading comprehension test scores (Spache Diagnostic Reading Scales) for different subsets of the Curtis sample.

The most striking finding in the Table is that, across age levels, word and pseudoword vocalization latencies correlate best with reading comprehension achievement for children whose reading achievement is normal for their grade level while vocalization speeds

Table 9

Correlations of Reading Comprehension Achievement Test Scores with Vocalization Latency

(from Curtis, 1979)

Subsample	Correlation of Reading Comprehension with: Letter Vocalization	Word Vocalization	Pseudoword Vocalization
2nd graders (average ability)	.51**	.78**	.54**
3rd graders (average and below-average)	.20	.53**	.44**
5th graders (average and below-average)	.26*	.45**	.47**
Average (2nd and 3rd grades)	.39**	.71**	.56**
Average (3rd and 5th grades)	.26*	.37**	.52**
Below average (3rd and 5th grades)	.66**	.50**	.19

Notes: *p<.05.
**p<.01.

for real words and even for letters are the best correlates of the three for below-average readers. Here we see some evidence of the nature of the "transfer" effects for better readers. They have acquired word pronunciation knowledge that can be applied even to meaningless letter strings. Presumably, this knowledge facilitates acquisition of new reading vocabulary as well. For the below-average readers, these generative subword pronunciation skills appear not to develop to significant levels. We take the high correlations of letter and real-word vocalization with reading to indicate that the below average reader needs to practice and overlearn recognition of all words he is likely to read. The faster he gets on familiar material, presumably, the better he will do.

Another finding in the Curtis (in press) data helps us address again the issue of the nature of prerequisites to reading achievement. She performed commonality analyses on the correlations of her various measures with reading comprehension. For both average and below-average readers, the various measures could account for about 2/3 of the variance in the reading scores. However, the patterns of correlation varied. For the below average readers, word matching speed, letter vocalization, and listening comprehension uniquely accounted for 0% to 3% each of the reading comprehension variance. Sixty percent was accounted for by variance common to all of the tasks. For the third and fifth grade average readers, listening comprehension and pseudoword vocalization uniquely accounted for 28% and 7% respectively, and commonly accounted for another 33%.

The appearance is of a diffuse general factor underlying the performance of the less successful readers, with general comprehension skills (measured in the listening task) and generative decoding/phonological access skills (measured by pseudoword vocalization latency) making very little independent contribution. All of these findings, of course, will benefit from additional data, such as a three or four year pattern, in individual children, on the growth of efficient word-access skills.

Are good readers playing a better guessing game?

We turn now to the data on oral reading error patterns. Turning again to Table 8, we see that children in our three ability groups did not differ in the extent to which their oral reading errors betrayed sensitivity to the letter patterns in the words they were reading. On the other hand, they did differ in the extent to which their error words fit the context in which they were inserted. It is part of the lore of reading instruction that poor readers, in phonics curricula, have too much of their attention drawn to the graphemic nature of words and consequently ignore meaning. The present results are only partly consistent with that claim and suggest an alternative viewpoint.

If the less-skilled readers were paying excessive attention to the specific visual input at the cost of context information, we would expect to see them being more sensitive than skilled readers to graphemic content. That is, they would err by missing one or two graphemes of a word, perhaps even ending up with a nonsense utterance. However, when we look at Table 8, we do not find this happening. The poor readers do not show significantly more sensitivity to graphemic information. Nor are there ability group differences in nonsense errors after Level 2. Also, the children are showing sensitivity to context in three-fourths of their errors. This means that after the first half of first grade, there is no evidence to substantiate any strong claim that children having trouble learning to read will, if taught in a phonics-loaded program, become "word callers." If the less-skilled children were paying excessive attention to graphemics at the expense of semantics, they would, presumably, be more likely to call out nonsense syllables while decoding--but they are not, after the first months of school, and they never have nonsense rates of even 20%. The data, as a whole, are much more supportive of the claim that slow decoding means that more cognitive capacity is required for words to be recognized, not that poor readers choose to allocate more capacity to this task (Perfetti & Roth, this volume).

Future Plans for this Study

We have recently added two more cohorts to this study in hopes of further clarifying the tradeoff between inefficient decoding and sensitivity to context. In one cohort, we are testing children in a curriculum with less phonics emphasis, i.e., a standard basal series. They are receiving the same type of testing as Cohort B, though they started first grade a year later. We have matched a new set of test materials to their curriculum so that both cohorts have equivalence in the frequency and recency of test words in the child's in-school reading experience. Thus, in another year, we will be able to answer the comparative question: Does a less phonics-oriented curriculum produce less naive word calling and/or greater sensitivity to context in the less able children?

More important, the cross-curricular comparisons allow us to better understand the data relating phonological access speed to reading ability. The vocalization task, after all, is pretty similar to some of the activities one might observe in a phonics classroom. It could be that the ability differences reflect differences in a skill that is prerequisite only to learning how to read in such a curriculum. On the other hand, if effects of similar pattern and magnitude are found in a very different curriculum, we will have greater reason to believe that phonological processing speed is not a curriculum-specific prerequisite for becoming a good reader.

Our other new cohort contains NRS children who, in addition to being tested on the same tasks as in Cohort B, are tested on sentence and paragraph comprehension tasks. In the sentence task the child has to read and decide whether a sentence answered a question which has just been asked by the experimenter. The paragraph task is similar except that the child has to read a three sentence paragraph and decide whether it answers the question.

The sentences and paragraphs contain words from the levels which are being tested, and their structure is derived from Kintsch's (1974) propositional system (see Turner & Greene, 1977). In particular, each sentence in both tasks consists of a single proposition which expressed a case, quality, or locative relation. The questions are similarly structured, except that an interrogative is used in place of one of the concepts. On "yes" trials in both tasks, the concepts in both the question and a sentence are the same, and the interrogative can be replaced by the extra concept in the sentence. On "no" trials, the concepts in the questions and sentence(s) are not the same. If, as Perfetti and Lesgold (1978) claim, inefficient attention-demanding decoding skills destroy part of the top-down aspects of reading, performance on these tasks should be highly correlated with performance on the vocalization task.

<u>Developmental issues</u>. There are two major developmental issues that still need further study -- and further data. First, there is the question of the exact nature of the developmental trajectories at which the present data hint. We will need to see how completely the curriculum continues to produce equal performance, at different rates, on all but the vocalization latency word processing task. More important, we will need to verify that the apparent asymptote difference in vocalization latency between high and low reading achievers is sustained when children are classified on higher-grade reading tests (with a larger comprehension component) and when more data is available for the later levels of the curriculum.

The second issue to be undertaken in the future is the extent to which our stratified group data accurately reflects the progress and prospects of the individual children in the various ability groups. We have hinted at one sort of individual variability. Another that appears to be present on very cursory examination involves visual tasks (scanning and visual matching) in comparison to verbal tasks (category and word matching). There is a subgroup of children for whom the general pattern of similar RTs on the two task types does not hold. These children start out with slow visual processing, which approaches the verbal processing rate in later testings. We have yet to verify the extent or meaning of these findings. More generally, we have yet to examine, on a child by child basis, the relationship between time at which facility on speeded tasks is reached and the shape of the oral reading trajectories. Thus, we have a substantial task left before the results hinted at in this chapter are complete and verified.

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