CHAPTER EIGHT

The Development of Reading Ability

This chapter addresses the important issue of the development of skill in reading. Our developmental scope is from elementary school reading beyond the first grade through adult reading. (*Beginning* reading is considered in Chapter 10.) The general questions are these: To what extent can the major sources of reading ability identified in verbal efficiency theory be extended to older readers? To what extent do ability differences among older readers require fundamentally different understanding?

THE SCOPE OF DEVELOPMENT

There is a wide range of reading talent even before a child learns how to read. This suggestion is a reflection of the central role that general cognitive and linguistic processes play in reading ability. Some general cognitive contributions to reading comprehension, as we have seen, are fundamental but not always illuminating. For example, specific knowledge is critical to reading but may play a limited role in explaining *generalized* reading ability. On the other hand, inference making is a fundamental cognitive ability that is generalized to the case of reading ability. Generally speaking, as basic cognitive abilities develop, they become more important for all cognitive activities, including reading. Nevertheless, we shall try to go as far as possible without paying too much attention to such abilities. We want to understand reading ability while assuming that other cognitive abilities are either equal or irrelevant for a particlar task.

A slightly different approach is needed for linguistic abilities. We do not need to assume that linguistic abilities are fundamentally different from other cognitive abilities. Rather, we assume that reading is patently a linguistic activity, no matter what other cognitive abilities are required by a particular reading task. The development of reading ability is partly included in the development of linguistic ability. This, unfortunately, does not mean that we will be able to explain the development of linguistic ability (let alone explain how it maps onto reading at each point). The point is that we will need to acknowledge the possible contribution of a range of linguistic abilities to the development of reading, even without a detailed understanding of these abilities.

The starting point is our understanding of the ability differences among elementary school children. These differences prominently include lexical access and verbal memory. The theoretical link between these ability differences is the efficiency of linguistic symbol activation and manipulation. There remains some question about how elementary this symbol activation process is. For example, there is some reason to believe that symbol *structure* (e.g., orthography) may be especially important, but it seems that simple symbol activation is also important. Is elementary symbol activation the fundamental factor? Similarly it seems that semantic processes are important ability factors, but it is possible that they can be accounted for, at a deeper level, by the same symbol activation process. The developmental perspective helps with such questions. It may be that the acquisition of skill in reading changes the relative contribution of these factors.

Development of Simple Verbal Processing Efficiency

In learning to read, a child develops an increasing ability to process printed linguistic symbols. As we have emphasized, this is not only the ability to recognize words but the ability to process them efficiently. We have also seen that decoding, letter recognition, lexical access, and semantic access are all important verbal processes in reading. These processes we group together under the category of *simple verbal processes. Decoding* is transforming a printed input into a speech form. *Letter recognition* is activating a printed letter symbol; it plays a role both in *decoding* and *lexical access.* One developmental issue, in part, is whether development in letter recognition accounts for development in decoding and lexical access. Another developmental question is whether any of these processes are accounted for by simple *symbol activation.* Symbol activation is simply the access and retrieval from memory of a symbol, regardless of its linguistic status. As a general processing constraint, the speed of *symbol activation* sets the limit on activation of particular symbol types, i.e., letters, higher level letter patterns, words, names, and word meanings.

Development in the Elementary School Years

A few studies have data on ability differences across several different age groups, although it has been typical to compare ability groups at two age levels. In one thorough, multitask experiment, Curtis (1980) tested second, third, and fifth graders and compared third- and fifth-grade readers of high and low ability. Tasks included word vocalization (naming), letter naming, word matching, and pseudoword matching. Within each grade level, high-ability readers performed better on these tasks. However, the best discriminators of high- and low-ability readers were word- and pseudoword-naming tasks, not letter tasks. These results agree with what we find generally for elementary school children in confirming the importance of decoding. Curtis examined the patterns of task correlations to assess whether the contributions of particular tasks to overall reading ability changed between the third and fifth grade. She found that a standardized listening comprehension test contributed unique variance to the reading comprehension measure. That is, its correlation with reading comprehension was significant even after its correlation with the symbol activation measures was accounted for.[1] The interesting age comparison is that listening comprehension accounted for more unique variance among fifth-grade readers than among third-grade readers. Correspondingly, decoding factors, especially word and pseudoword naming, accounted for less unique variance among fifth graders than among third graders. At the same time, there remained large differences in decoding between ability groups, even in the fifth grade.

The way to interpret such results is as follows: Decoding factors, not general symbol activation, are important ability factors throughout this period between second and fifth grade. In the second and third grades, however, ability differences in decoding may not be closely associated with differences in oral language processing. The two are correlated, but, for example, there are children who are weak only in decoding and not in listening comprehension, as well as children who are weak in both. As children get somewhat older, those whose earlier problem was only in decoding have become better at it. Those whose problem was both decoding and listening comprehension have not. Thus decoding still contributes high correlations with reading comprehension, but its *unique* independent contribution is less.[2]

The development of context-free decoding

According to verbal efficiency theory, context-free word recognition is the most salient characteristic of reading ability. An important development in reading ought to be a decrease in dependence on context. Stanovich, West, and Feeman (1981) provide a demonstration that such development can take place fairly early. Second-grade subjects practiced oral reading of isolated words over 15 consecutive days. Following this period of practice, subjects were given a word naming test in which the context was varied. Sentences were constructed to make the target more predictable and less predictable. One important result of this study is that the effect of practice on reading the target words was to reduce the effects of context. Furthermore, when subjects were tested some six months later, context effects were reduced even for unpracticed words. Thus, it is possible that during this six-month period the children were becoming more skilled at context-free word decoding in general. Whatever the underlying processes, there is an important skill development in which word identification gradually becomes independent of context. As we have seen, this development seems to come sooner for high-ability readers.

Symbol activation: What develops?

Of course, the developmental changes in the factors that contribute to differences in reading ability in part reflect what develops in reading processes generally. Generally, we assume that the simpler the process, the more quickly it reaches its maximum processing efficiency for an individual. That is, individuals will differ on their absolute performance rate for any symbol activation process, but each process may achieve its maximum development in the same order across individuals. Children will develop both letter- and word-recognition abilities.

A comprehensive study by Doehring (1976) provides some general developmental data on some of these processes. Doehring (1976) compared groups of children from kindergarten through high school on four different types of task: visual matching to sample, visual matching to oral sample, oral reading, and visual scanning. Within each task there were several variations in the materials. For example, numbers, three-letter words, four-letter words, three-letter (CVC) syllables, and three-letter consonant strings were among the materials for visual matching to sample. In this task, a visual target was displayed and the subject found a match in a three-item display set. Thus it is a visual search task. Doehring found that the overall response speed to all printed symbols decreased up to sixth grade (age 11). In visual scanning—essentially visual search through rows of symbols printed on paper—speed of search decreased beyond the age of 12, for all symbols. Searching for word targets never reached the rate of search for letter targets. A similar result for overall speed was obtained in the oral matching task, in which the subject heard a letter or word, etc., and had to find it in a three-item array. Response speed reached maximum by seventh grade (age 12). In naming, response speed continued to increase beyond the seventh grade, even for colors. However, by grade three, letter naming was as fast as color naming and word naming. Some of these naming data can be seen in Figure 8-1, which shows the increases in speed for four types of material—pictures, colors, letters, and words. Because these speeds were measured on oral reading from large chunks of material, their precision is not high and specific comparisons are not meaningful. However they show two things dramatically. One is how quickly word reading catches up with other kinds of symbol naming. The other is the very gradual increase in speed that continues for all tasks through grade 11. This implies that speed of symbol activation can continue to increase, but only very slowly, with increasing development.

One important point about word recognition is how easy it becomes relative to other processes that are superficially similar. In Figure 8-1, words are named more rapidly than pictures by the end of second grade. In a same-different task, Gibson, Barron, and Garber (described in Gibson and Levin, 1975) found word pairs judged more rapidly than picture pairs in grades four and six but not in grade two. In our study of third-grade children, low-ability readers were significantly *slower* naming single words relative to single pictures (Perfetti, et al., 1978). Even high-ability readers were faster for words than for pictures only for one-syllable names. (In contrast with Doehring's studies, the picture names were the same as the word names in the Perfetti et al. study [1978], assuring a meaningful comparison.) In general, adults and skilled readers read words more quickly than they name pictures. Exactly when children begin to activate word symbols more rapidly than corresponding pictures is not important. The point is that for high-ability readers this change does occur early in the elementary school years.

Some simple verbal processes, however, do continue to develop beyond elementary school. For example, in Doehring's (1976) study, speed continued to increase in naming and visual search beyond the seventh grade. In real reading situations, the demands of the reading task certainly increase for older readers. These elementary verbal processes involving symbol activation occur over and over again as the reader reads a text. However it appears likely that the low-ability reader in high school, like the low-ability reader in elementary school, is not efficient at all these symbol activation processes.

High School Readers

Research on high school readers of different ability has been carried out by Frederiksen (1978a; 1978b; 1981). This research confirms the assumption that symbol activation processes continue to be inefficient for low-ability readers who are slightly older. It also adds some additional insights into the processing factors in ability.

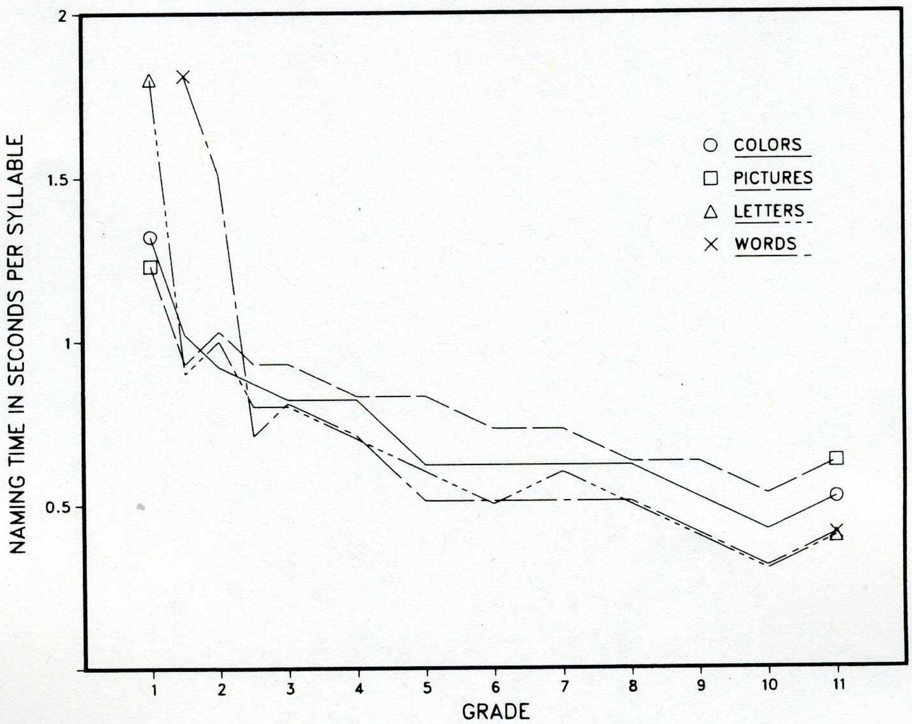

Figure 8-1. The development of naming speed for color names, pictures, letters, and words. Stimuli were presented as a series on a chart, not individually. The figure is constructed from data in Doehring (1976).

Frederiksen (1978a) designed tasks to tap three processing components of reading: perceptual, decoding, and lexical. The first two of these factors correspond to letter activation and word naming. The third, somewhat more complex, refers to activation and retrieval processes sensitive to specific lexical factors, including familiarity. The subjects for these studies were high school students with ability defined by the Nelson-Denny reading test. In earlier studies there were usually 20 subjects (Frederiksen, 1978a), and in later studies there were sometimes 44 subjects (Frederiksen, 1981). Subjects were grouped into quartiles of ability. The lowest quartile was below the 40th percentile; the other quartiles had percentile ranges of 41–85, 86–98, and 98–100. Thus only the lowest quartile would seem to be "low ability." Some of the results as summarized below.

Orthographic Structure. Subjects tried to recognize strings of four letters presented briefly under masking conditions. Recognition accuracy increased and decision latency decreased with the frequency of bigram patterns. Highly frequent bigrams, such as *TH*, were more accurate than low-frequency bigrams, such as *CK*. There was also a smaller effect of the positional frequency of the letters. The reading ability result is not quite what one might expect: Low-ability readers were more affected by bigram frequency than high-ability readers. This ability effect primarily separated the lowest group of five from the remaining subjects. The conclusion is that low-ability high school readers are relatively efficient at letter recognition in predictable (redundant) strings. High-ability readers are efficient in all letter strings.[3]

Decoding. Subjects vocalized single words and pseudowords. High-ability readers were faster than low-ability readers on both. Interestingly, the word latencies distinguished three ability groupings, with the top two quartiles indistinguishable. However the pseudoword latencies clearly distinguished four different reading levels. This is important evidence that, just as naming *accuracy* overestimates decoding ability of younger children, *word*-naming speed overestimates decoding ability of high school students (and probably adults). The low-ability readers were also more affected by words and pseudowords that began with longer initial consonant clusters, by two-syllable words (compared with one-syllable words), and by each additional letter to be identified.

Lexical Form. Subjects performed a lexical decision task in which letter strings were either all in capital letters (or all in lowercase) or they were in a mix of capital and lowercase (e.g., *WoRd*). The effects of case mixing were much greater for low-ability readers, especially for the two lower quartiles. The low-ability readers were also more affected by frequency. Frederiksen's (1978a) interpretation is that case mixing reduces visual access to familiar word forms and causes a greater reliance on decoding processes. This result at least suggests that low-ability readers depend more on visually familiar word forms.

Conclusions. The data summarized above were used to construct structural models of reading ability in Frederiksen (1978b).[4] One major processing factor contributing to general reading ability was multiple letter encoding. In our terms, this may refer to the rate of single-letter activation in the absence of any facilitation, e.g., the rate of encoding each letter in a poorly structured string such as *HTSR*. Interestingly, this factor seems to include a factor we have referred to as inactive memory. It includes, in Frederiksen's task, the difference in a name-level letter matching between *Aa* (same) and *Ad* (different). The different-name case takes longer. Different letter names cause a "mismatch" in activation, whereas same names are facilitated because the first letter primes the second. Thus a very general factor may be identified, roughly the speed of letter activation without facilitating context.

This does not mean that high-ability readers are less good at using orthographic structure. In another experiment Frederiksen and Adams (Frederiksen, 1981) varied the exposure duration of four-letter anagrams (e.g., *rtnu*) and pseudowords (e.g., *etma*). This is clearly a contrast between well structured and poorly structured letter strings. Here the critical measure was the increase in the number of letters a subject could report as the exposure duration was increased from 6 to 50 milliseconds. High-ability readers showed a larger advantage of structure than did low-ability readers. That is, as exposure duration increased, the rate of increased letter recognition was higher for pseudowords than for anagrams, showing the effect of structure. The highest ability group showed this effect more than the three other groups.

The best overall conclusion may be this: High-ability high school readers are superior in context-free letter activation rate; low-ability readers may be somewhat more dependent on orthographic context, but are not better at using it. At the very highest level of ability (above the 98th percentile) readers may take special advantage of structure, although they are not dependent on it.

Finally, there are also important decoding factors in the range of high school ability. The high-ability high school readers of Frederiksen's experiments were consistently faster at pseudoword naming than low-ability readers. This decoding factor is not completely dependent on the speed of letter activation from letter strings, although the two factors are correlated. Low-ability readers were especially affected by increases in pseudoword complexity, either by length or by vowel complexity. Thus there remain two distinct processing factors, interrelated but not reducible to a single process. One is rapid activation of letters, the other is the rapid activation of speech processes from pronounceable letter strings. That is, the two main ability factors among high school readers seem to be letter activation and decoding.

Adult Readers

It is not obvious that among adult readers the ability factors of childhood continue to be important. Adolescents and young adults have had increasing opportunity to master the simple verbal processes that are important in children's reading ability. However, there is reason to believe that simple verbal processes continue to be important in explaining ability.

There is one oddity concerning adult reading. Most of what we know about the simple processes of adult reading is based on research on college students. There have been important studies of adult reading in noncollege populations as well (see Sticht, 1977, 1979). For adult populations of low literacy levels the problems of ability are complex, although they undoubtedly include contributions of simple verbal processes. However, for what we know about adult abilities in these processes, we are largely dependent on college student samples. For such a population, we expect a selection process to have occurred, since children who demonstrated low ability in elementary school and high school are less likely to attend college.

The studies of Jackson and McClelland (1979) are informative for ability factors in adult reading. They defined reading ability by performance of college students on passages designed especially for the research. This performance measure was effective reading speed, which takes account of both accuracy and speed of reading: Effective reading speed = comprehension accuracy × reading speed. The comprehension measure is based on a short-answer test following the subject's reading of the passage. There was also a listening comprehension test based on this passage. The subjects of Jackson and McClelland (1979) were divided into groups of high vs. low ability relative to college freshmen and sophomores at the University of California, San Diego. High-ability readers were in the top quartile of effective reading speed, and low-ability readers were in the bottom quartile.

There were several tasks in the Jackson and McClelland (1979) study. One task that showed no ability difference was single-letter recognition threshold. Another no-difference task was thresholds for recognition of separated letter pairs. These results agree with earlier results by Jackson and McClelland (1975). Ability differences are not related to single-letter recognition accuracy.

Ability differences were found in matching tasks, which required the subject to decide whether pairs of visually presented stimuli were the same or different. The letter task required a "same" judgment to pairs of letters with the same name *(Aa)*; some pairs were also physically identical *(AA)*. The synonym task required decisions about whether two words had the same meaning. The homonym task required "same" responses to words that were homonyms *(doe, dough)*. The pattern task required judgments for pairs of nonlinguistic stimuli (□+, □□, ++, +□). The results for these tasks were that high-ability readers were faster than low-ability readers on all of them, including the pattern task. Ability differences tended to increase from the pattern task, which was fastest, to the homonym task, which was slowest.

There were two other tasks. One was a multiple-letter search task, with a display containing two, four, or six letters. (This task is similar to the one described in Chapter 7). The other was an auditory short-term memory task, in which the subject had to recall strings of consonants, as in a digit-span task. On the search task, high-ability readers had shorter times, but differences were in intercept not in slope. That is the *rate* of search was not different, but some component of general reaction time was. The auditory memory task produced very small but significant differences in mean number of items recalled, for example 5.64 versus 5.04 when strings were six items long.

Jackson and McClelland carried out further analysis based on intertask correlations, and the results of regression analysis support these conclusions: The best independent predictor of effective reading speed was listening comprehension measured on the same paragraphs. With listening comprehension controlled matching speed also predicted effective reading speed. The best matching task was letter matching. Jackson and McClelland interpret this as a name retrieval factor because all the matching stimuli were nameable and because a second experiment found no ability differences in speed of matching dot patterns. Thus this factor refers to a process of name activation in memory, not a simple perceptual process. Later experiments by Jackson (1980) suggest that this is a general visual access factor, however, one that depends on name codes in memory but *not* on alphabetic inputs. Jackson (1980) found that reading ability was related to the speed of matching categories of drawings as well as letter match. Thus, in terms of simple verbal processes, we conclude that there is a simple process of symbol activation that is important in college-level reading ability.

A decoding factor, independent of simple symbol activation, may be less important in this population. However, two results of Jackson and McClelland (1979) are interesting. First, high-ability readers were not only faster at the homonym task *(doe-dough)*, they were more accurate. Indeed, there was a significant correlation of accuracy with effective reading speed even after all other variables had been controlled. This may indicate specific word knowledge differences or underlying differences in knowledge of orthographic rules. In a second experiment, the speed difference in homonym decisions was found in pseudowords. Jackson and McClelland suggest that such differences could be accounted for by letter-encoding differences. Although their conclusion seems reasonable, with other, more demanding tasks of decoding it is conceivable that a different conclusion would be warranted. Recent research by Hammond (1984) suggests this is the case. Hammond's college subjects were comparable to Jackson and McClelland's, but unlike the latter, they performed pseudoword- and word-naming tasks in addition to letter matching. Vocalization latency in these tasks not only distinguished high-ability readers from low-ability readers; its correlation with ability remained significant even after controlling for the correlation between letter matching and ability. Thus, it appears that a lexical access factor may contribute to adult reading ability beyond simple symbol activation, provided a reasonably demanding access task is used. This vocalization latency measure is one of the most discriminating measures for children and adults.

Finally, it should be emphasized that the best predictor of reading effectiveness in Jackson and McClelland's study was listening comprehension. Listening comprehension was also a good predictor in Hammond's study. It is important to keep in mind that, whatever the contribution of lexical access or decoding skills beyond symbol activation, the contribution of a general language skill looms large—and at this point relatively unanalyzed.

Text reading

Much of the evidence on reading ability comes from tasks that do not require the actual reading of texts. In the long run, it is critical to learn whether the basic verbal processing factors that seem important in ability are observable when actual text reading is required.

A study by Graesser, Hoffman, and Clark (1980) illustrates one approach. They had college students read texts that varied in a number of ways. Some of the variables could be considered as higher text-level variables: (1) the extent to which the text was narrative (as rated by subjects), (2) the familiarity of the text, and (3) the relative number of new nouns (new arguments or new concepts). Others were more local text factors: (1) the number of words in a sentence, (2) the number of propositions in a sentence, and (3) the syntactic predictability of the sentence. Graesser et al. (1980) measured the reading times for a total of 275 sentences in 12 different texts. They found that the best predictor of reading times was the rated narrativity of a text. That is, sentences in texts that were more narrative-like were read more quickly than those in less narrative-like texts and this factor accounted for the major portion of systematic reading time variance.

However, a different picture emerged when Graesser et al. compared the faster readers with the slower readers. Only local text-processing factors differentiated the performance of fast and slow readers. Slower readers were more affected by the number of words and propositions and by syntactic predictability than were high-ability readers. Ability differences were unaffected by narrativity, the factor that was important for overall reading time.

These data thus confirm the importance of lower level processing components in adult reading ability for actual texts, provided that we can equate reading speed with reading ability. They also provide an important reminder for how general processing factors and individual differences can be related: It is not necessarily the case that those factors that contribute most to general processing are the same ones that produce the most important individual differences.

Reading Ability or Verbal Intelligence?

It is likely that at the college level what we have referred to as reading ability is not all that different from verbal intelligence. Nor should it be otherwise. The earnest effort to consider intelligence apart from reading ability has a practical purpose in the study of developmental dyslexia or of children's reading ability generally. The question with children is whether they should be expected to read better than they do read. But at the college level, even the "low-ability" readers of Jackson and McClelland are unskilled only relative to a college population; we should not be surprised if they score low on verbal tests of the Scholastic Aptitude Test (SAT). Nevertheless, even aside from matters of selection and other population characteristics, it is reasonable to assume that the verbal abilities that matter for verbal intelligence are some of the same ones that matter for reading, and vice versa.

In fact, studies of adult verbal intelligence suggest a shared view with adult reading. The studies of Hunt (1978; Hunt, Frost, & Lunneborg, 1973; Hunt, Lunneborg, & Lewis, 1975) have emphasized this same process that we have referred to as speed of symbol activation. The letter-matching task first described by Posner and Mitchell (1967) is the task that typically represents this process and it is the same task used in the Jackson and McClelland research. The ability measure on the letter-matching task is based on the difference in speed of two matching tasks. In a physical match, the physical identity (PI) of a pair of letters is the basis for a decision (e.g., *AA*). In a name-level match, the name identity (NI) of the letters is the basis for a decision regardless of their physical shapes (e.g. *Aa*). Hunt (1978) summarized several studies relating letter match times to the verbal ability of college students. There are consistent (but small) correlations between verbal ability and the difference between name matches and physical matches (NI − PI). The interpretation of the NI − PI difference is that it estimates the time to activate and compare single-symbol names while controlling for a visual matching component. It is a name retrieval measure. From the data summarized by Hunt (1978), it appears not only that NI − PI correlates with verbal intelligence of college students but also that the NI − PI difference may decrease with increasing absolute ability. For example, in a University of Washington study, non-University adults show NI − PI differences of 110 milliseconds compared with a difference of 64 milliseconds for high-verbal University students. ("High-verbal" means high on a test similar to a verbal SAT). At the other extreme mildly retarded children show an NI −

PI difference of 310 milliseconds. As Carroll (1980) points out, most studies also find small PI differences related to ability. However, the critical result is that some name-level activation and comparison process beyond shape comparisons is implicated in verbal ability. As we have seen, it is also implicated in college reading ability. Carroll (1980) actually estimated NI − PI from the Jackson and McClelland experiments described previously. Its correlation with verbal SAT scores was nearly as high as its correlation with effective reading speed ($r = .57$)[5] (It did not correlate with listening comprehension.) Conclusion: Reading ability and verbal ability at the college level are related to the same simple verbal process, the speed of symbol name activation and retrieval.

It is interesting to consider the implications of the assumption that verbal ability depends on symbol activation and retrieval. The symbols that are accessed are essentially overlearned codes. Reading is the principal means for acquiring overlearned codes. Even the lowest ability college readers must have overlearned letter names to their maximum. What is the difference in the amount of "practice" with a letter symbol between a 9-year-old third-grade student and a 19-year-old college student? Assuming a conservative estimate of 1,000 words per day, the 19-year-old has accessed 3.6 million more words than the 9-year-old—at least 13 million more letters. That should be enough practice to give even the low-ability college student an edge over even the high-ability third grader. In that light, it is surprising that activation of overlearned symbols has any variance among individuals, let alone any strong relation to general ability.

Another way of putting this is to note that differences among adults in such things as vocabulary are certainly more striking than differences in NI − PI. However, vocabulary differences continue to be accompanied by differences in simple verbal processes. For example, Butler and Haines (1979) found that college students of high vocabulary had faster decoding times than low-vocabulary students. Of course, this does not mean that decoding speed is more fundamental than vocabulary. Decoding itself may reflect speed of general symbol activation. Although cause and effect cannot be determined, it does seem safe to conclude that simple speed of symbol activation has reached its maximum efficiency by college age. Differences among individuals have had years to emerge in all areas of verbal processing, including word knowledge.

Finally, we consider speed of semantic access. This process may be part of the ability differences among children. But semantic access seems a less likely explanation for adult differences to the extent that simple symbol activation and retrieval can account for other aspects of verbal processing speed. An experiment by Goldberg, Schwartz, and Steward (1977) provides a comparison between decoding and semantic access. Subjects made matching decisions based on name identity *(Deer-dear)* and semantic category identity *(deer-elk)*, as well as on physical identity *(deer-deer)*. High-verbal subjects were faster than low-ability subjects on the name task (363 milliseconds) and the semantic category task (360 milliseconds). (The difference was only 136 milliseconds on the physical match task.) Thus, these data suggest that semantic access speed differences can be accounted for by decoding level differences.

The semantic access factor is also seen in a study in which subjects performed several picture- and word-matching tasks (Hunt, Davidson, & Lansman, 1981). For example in semantic categorization, subjects decided whether a picture or a word was an instance of a prespecified semantic category, a task earlier used by Hogaboam and Pellegrino (1978) in a study of verbal ability. Subjects also performed word-matching tasks *(DATE-date* vs. *DATE-gate)*, a semantic matching task *(ELK-DEER)*, a simple-choice reaction task, and some paper-and-pencil tasks. Performance was correlated with individual scores on the Nelson-Denny reading test, including its vocabulary test. The magnitude of the correlations was around .3 for all semantic categorization tasks, both for pictures and for words. The correlation between word and picture categorization was $r = .99$! Clearly we do not need a specific print-decoding component for these subjets. Hunt et al. (1981) also examined their processing tasks for a common component, one that they refer to as speed of memory access. The results of a factor analysis indicated that these various processing-speed tasks included a common factor that accounts for 75% of the task variance.[6] Since none of these tasks involved stimuli as simple as single letters or digits, this factor may not be simple symbol activation. However, the fact that the tasks included both name-level and semantic-level information (and pictures and words) makes it possible that such is the case. Furthermore the size of the correlations is consistent with other studies using letter name *(Aa)* matching (Hunt, 1978).

One other result of Hunt et al. (1981) is interesting. There was, in addition to the processing-speed tasks, one task that did not involve speed nor significant use of words in memory. It was a paper-and-pencil test in which subjects verified sentences describing visual symbol arrangement. The symbols were either ($\overset{*}{+}$) or ($\overset{+}{*}$). and subjects indicated *true* or *false* to sentences which varied in linguistic complexity, e.g., *Star isn't above plus* (Clark & Chase, 1972). Performance on this task seems to test syntactic processing and manipulation of symbols in memory more than speed of symbol access. High-ability subjects outperformed low-ability subjects, and the correlation with ability was independent of the matching-speed contribution to ability.

To summarize this semantic access issue: Although the experiments of Hunt et al. (1981) do not directly test whether there is a semantic access speed difference beyond general decoding or symbol activation, the fact that there was a very general factor in all the tasks indicates there is not. The results of Goldberg et al. (1977) are in agreement with this conclusion. Our conclusion is this: Younger children of low reading ability may have semantic information less tightly bound to a memory symbol, so that activation of the symbol is not always sufficient for the semantic information to become useful. However, with increasing verbal experience, common semantic category information becomes tightly bound to the symbol-name. That is, semantic information is specifically connected to the symbol-name rather than conditionally connected to the symbol-name. High-ability adults differ from low-ability adults in the basic speed of access and retrieval of this symbol-name but not in whether symbols are bound to their semantic values. One qualification: We do not cease to learn new words at any particular point in development. If a college student has a fragile knowledge of a particular word, e.g., *predicate* or *Renaissance*, the semantic information may not be bound to the name, but may be very context dependent.

Rate-limiting Processes in Development

The key features in development of reading ability can be summarized. First, there are simple verbal processes that affect the linguistic processes of reading: (1) general symbol activation and retrieval; (2) letter recognition; (3) word decoding; (4) semantic access. These processes are related to verbal ability (i.e., reading ability or verbal intelligence). Second, there are refinements to these processes that occur in individual development. There is reason to believe that ability differences among children include word decoding in addition to letter recognition and perhaps semantic access in addition to decoding. It is likely that for children above the second grade, letter recognition is not an additional ability factor beyond general symbol activation. After all, two years of reading instruction, even if partially unsuccessful, ought to bring simple letter codes into memory up to the level of any other symbol. (It is hard to imagine more overlearned symbolic codes—certainly not digits or pictures.) However, by the time readers become adults, things have changed. Semantic access and decoding have reached maximum efficiency independent of general symbol activation.

The developmental question here is what process sets overall processing rate limits. General symbol activation and retrieval set the overall limits. Nothing can occur faster than the access and retrieval of an over learned symbol name. However, until this limit is reached, there are opportunities for other processes to be rate limiting: first letters, then word names (decoding), and to some extent, semantic processes. Of these, according to the evidence, the most important is decoding. Throughout

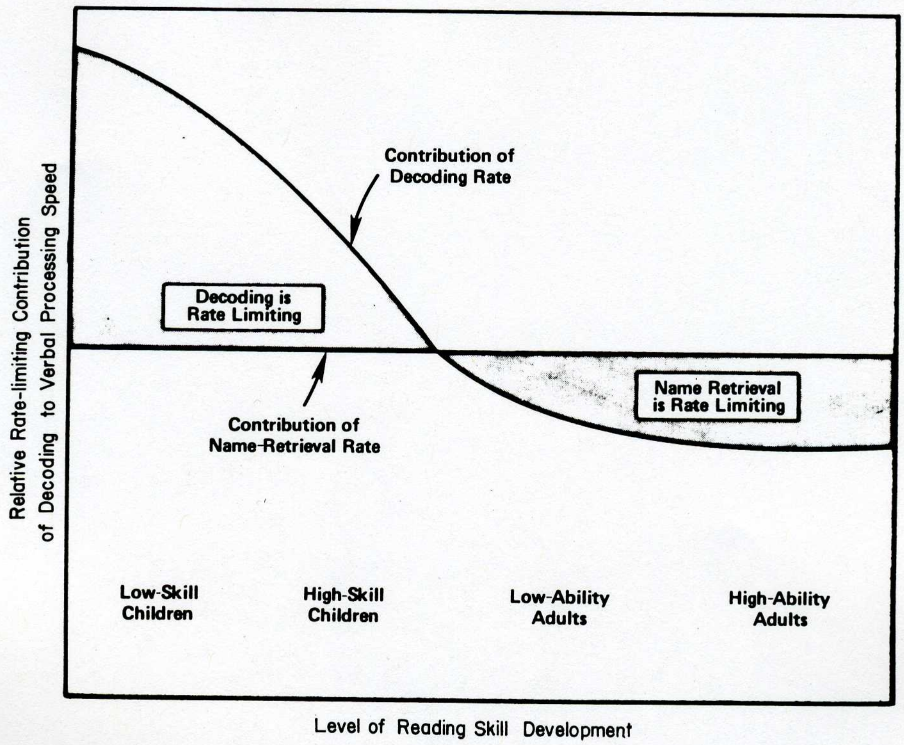

Figure 8-2. Schematic representation of the relative contribution of decoding and name-retrieval rates to verbal processing with increasing reading skill. At low levels of skill, decoding is rate limiting. At higher levels, name retrieval is rate limiting.

much of the elementary school period, decoding ability is rate limiting.

We can represent the general developmental pattern by considering just decoding and general symbol activation, as in Figure 8-2, which shows, hypothetically, the contribution of decoding to verbal processing speed, relative to general symbol-name access and retrieval. The latter is represented as making an invariant contribution. This does not mean that access and retrieval of symbol names does not increase in efficiency, only that these processes make a relatively constant contribution to overall ability differences in verbal processing speed. For young children and especially for low-ability readers, however, access-retrieval is not the rate-limiting process; decoding is. As decoding improves in efficiency, it is no longer rate limiting. Individual differences remain profound, but they derive increasingly from basic limits in symbol name access and retrieval—a process that operates on linguistic and nonlinguistic symbols in memory. While Figure 8-2 shows only decoding, similar representations are plausible for letter recognition and semantic access. At least letter recognition, however, would very quickly fall below the rate limit of general symbol name activation and retrieval.

Process-limited and Knowledge-limited Comprehension

It is one thing to point out that individual abilities in simple verbal processes are associated with individual abilities in reading and verbal intelligence. It is another thing to be certain that the abilities in simple verbal processes are causally connected to the general abilities. The general case for verbal efficiency has been made in earlier chapters. It is clear that efficiency differences in simple verbal memory processes can be causally related to comprehension. However, in the development of reading ability it is useful to distinguish two components to this relationship. One component is that simple verbal processes affect comprehension or other complex verbal performance because they are *process limiting*. The second is that simple verbal processes are *knowledge limiting*. The first component refers to the limitations on comprehension processes imposed at the time of processing. The second component has its effect in the history of the individual. The efficiency of simple verbal processes has directly or indirectly influenced the acquisition of knowledge, i.e., learning.

The development of reading ability thus includes two consequences of verbal efficiency: A given reading task is limited by the momentary efficiency of processing and by the previous learning of the individual. The amount of prior learning will have been partly influenced by simple verbal processes. But there is another important developmental principle in operation: The acquisition of knowledge is only weakly determined by verbal efficiency. For example, large differences in verbal efficiency should produce large differences in knowledge, other things equal. And small differences in verbal efficiency should produce small differences in knowledge, other things equal. However, there is no reason to assume that two individuals who differ by the slightest microsecond in symbol retrieval will differ in knowledge in one direction rather than another. *Beyond some theoretical limit in efficiency, knowledge acquisition is not limited by efficiency*. If anything, only the ease of acquiring knowledge is affected at the upper levels of efficiency. This is why correlations between name retrieval and college verbal ability are so modest. They would be much more profound among an unselected population, just as they are among children. The fact is that the acquisition of knowledge is subject to many other influences at the higher levels of efficiency.

Summary

The development of reading depends in part on acquisition of simple verbal processing ability. Since the processes may develop at different rates, ability differences among younger children may not be exactly the same as among adults. Nevertheless it is clear that certain verbal processes continue to be important through elementary school, high school, and adulthood. At all age levels, high-ability readers show more rapid access to symbol names in memory. In the elementary grades, decoding is a critical ability factor relatively independent of general symbol activation and retrieval. There is, however, an indication that decoding begins to make less of a unique contribution to overall ability as early as the fifth grade. Letter processes seem to reach a high level of skill as early as the second grade. By college age, the decoding process appears not to make a unique contribution to ability beyond its dependence on general symbol activation. Listening comprehension is an important factor throughout developmental levels.

THE DEVELOPMENT OF GENERAL LANGUAGE COMPREHENSION

There is much more to reading ability than efficiency at simple verbal processing. Indeed, as a general rule the more demanding the reading task, the more noticeable is the contribution of higher level language abilities. It is conceivable that higher level language abilities are partly dependent on lower level abilities, but even if they are it is important to understand their role in the development of reading ability.[7]

The important general language processes include those described in Chapters 3 and 5: the assembly and integration of propositions, inference processes, schema activation, and text modeling. In addition they include metacognitive skills and strategies. They also include explicit linguistic knowledge, which continues to develop. However, we have very little evidence about the development of differential abilities in these areas. Instead we have some interesting possibilities to consider.

Syntactic processes

It is quite likely that throughout the elementary school years and even beyond, there continues to be significant development of linguistic abilities. For example, syntactic processes that may be especially important for reading may require further development over the basic grammatical competence that young children have. Indeed, it is likely that reading places demands on syntactic abilities that are not placed by oral language processing. Oral language is so heavily dependent on context that it seldom places heavy demands on syntactic processes. Reading, much less contextualized, seems to require more syntactic processing.

As an example of a syntactic process, consider anaphora. The reader or listener, when an anaphora is encountered, must decide where in his model of the text the antecedent is to be found. A pronoun, *he* or *it*, must refer to something already mentioned. It is common in texts for there to be more than one possible referent. Frederiksen (1981), in his studies of high school readers described earlier, had subjects say what the referent was for certain pronouns encountered in short texts. For example:

(1) *Modern advertising does not, as a rule, seek to demonstrate the superior quality of the product.*
(2) *It plays up to the desire of Americans to conform, to be like the Joneses.*

In sentence (2) *it* refers to the first noun phrase of sentence (1), modern advertising. Low-ability readers and high-ability readers handle this easily. But suppose a different sentence appears as (1*a*):

(1*a*) *The superior quality of the product is not, as a rule, what modern advertising seeks to demonstrate.*

Now the antecedent of the pronoun of sentence (2) is the second noun phrase of the preceding sentence. That is, the antecedent is still *modern advertising*, but it is no longer at the beginning of the sentence. Frederiksen's (1981) low-ability readers had some problems with this second case, taking quite a bit longer to decide on the correct referent. High-ability readers had no problem with it. This suggests that low-ability readers had a topicalization strategy: When the pronoun begins a sentence (i.e., is the topic of the sentence), look for its antecedent as the topic of the preceding sentence. The high-ability reader, more flexible perhaps because of greater efficiency, has no need for such a strategy.

We probably do not want to conclude that low-ability readers have poor syntactic strategies. This is just one kind of evidence that syntactic processes in reading can become important, especially as the reader needs to integrate propositions. We have no reason to suppose that the ability to determine anaphoric reference has not developed well before this high school age. What may be important is whether the demands of textual syntax can be easily met by the reader. Meanwhile, some syntactic abilities continue to develop along with reading ability. The low-ability reader may not only be less able to apply his syntactic knowledge to written text, he will also acquire less syntactic knowledge through reading.

Inferences

If a reader encounters a sentence such as (1), (2), or (3), we might expect him to make some inferences:

(1) *Fred dug a hole in his backyard.*
(2) *Mary knew that it was raining in Youngstown.*
(3) *Molly walked to the store carrying her umbrella on her arm.*

For (1) the reader might infer that Fred used a shovel; for (2) he might—should—infer that it *was* raining in Youngstown; in (3) he might infer it was not raining at all. These examples, because they are very ordinary sentences, illustrate the pervasiveness of inferences in comprehension. Texts are never fully explicit. They also demonstrate the variety of inferences: the one in (2) is logically impelled; those in (1) and (3) are not. Apparently, everyone does not make inferences in such cases. More important, there are developmental differences. Younger children (age 7) are less likely to make inferences spontaneously for sentence (1) compared with older children (age 9) (Paris & Lindaur, 1976). There may be some circumstances in which even adults do not make such inferences when they read (Vonk & Noordman, 1982). Nevertheless, we have a clear candidate for an important development in reading ability. High-ability readers may make inferences at a younger age than low-ability readers. We should not be surprised if at any given age high-ability readers make more inferences. We know they have more processing resources for inferences because they have a higher level of verbal efficiency. In general, we can make the following assumption for development. The contribution of inference making to overall reading comprehension will increase with development. Its contribution to ability differences may be expected to be high for children as text reading becomes more demanding. For very young children and for adults general inference making may be less of a factor except as it is controlled by specific knowledge.

Listening and reading

The relationship between oral and written language is a very close one. And we know that reading ability and listening ability are closely associated throughout the age range (Berger & Perfetti, 1977: Curtis, 1980; Jackson & McClelland, 1979: Perfetti & Goldman, 1976). However there are some differences between oral and written language processes. One of the most important is that printed texts are more explicit. A second is that oral texts are more pragmatic. Olson (1977) has made a case for the idea that our propositional idea of language is made possible only by literacy. Speech contains utterances, written texts contain propositions. Utterances at an abstract level, of course, are also propositions. However, because they occur in rich communication settings, and because they usually refer to a shared field of experience between speaker and listener, their *propositional* content only loosely determines the *communication* content. By contrast, in print the propositional content becomes dominant. The writer seldom has one particular reader in mind as the receiver of his message (personal letters are an interesting exception). The result is a more explicit text, fewer gaps, less inferring, and more attention required by the reader to the language *in* the text.

It is possible, even likely, that the development of reading comprehension ability is not a straightforward transfer of listening processes to print. Of course, there are numerous differences between printed and spoken language. Spoken language is more contextualized, more transitory, and does not require the learning of a new code. Printed language is more propositional, more permanent, and does require some code learning. There are other differences that are important but essentially derivable from one of these differences (see Chapter 1). However, the differences between speech and print may change with development in a number of ways. At first, decoding is a salient difference between speech and print. Another difference becomes noticeable later, as the propositional content and explicit style of written texts becomes salient. Additionally, it is quite likely that reading fosters some significant linguistic growth for the child. This is a consequence of the fact that print is relatively decontextualized. Since the printed text cannot rely on the communication context that speech can, it must direct attention to sentences as the means for obtaining meaning. It is possible to comprehend oral language with only primitive syntactic abilities, but it is difficult to understand written texts without syntactic abilities because they depend on explicit propositions contained in sentences. In short, we can assume that significant developmental events occur as a child attempts to transfer oral language strategies to written texts. And we can wonder whether these events contribute to the development of reading ability.

Hildyard and Olson (1982) carried out an interesting experiment that tests the hypothesis that oral and written texts are different in their explicitness. They presented spoken and written stories to third- and fifth-grade subjects who were either high or low in reading ability. They were interested in whether readers recalled more explicit information than listeners and whether this depended on age or reading ability. A story example is shown below, along with four types of information that were tested: structural vs. incidental, and implicit vs. explicit. Structural information consisted of data important to the central story content. The implicit information was not given in the text but was inferable.

> Susan and Jonathan lived in a house in the middle of the city. At the end of their backyard there was a large maple tree. Susan and Jonathan often played under the maple tree in their sandbox. One morning they found something

in the sand. It was tiny and white. Susan went into the house to find a container to put it in. She went up to her bedroom and came back carrying a black and white box. It's too big, said Jonathan.

So Susan found a handkerchief and some Kleenex. They put the handkerchief on the bottom of the box and laid the tissues on top of the handkerchief. Jonathan carefully laid the strange thing on the tissues.

Next morning their teacher was interested in what they had found and gave the whole class a lesson on how birds' eggs hatch.

1. *Structural implicit:*
   Susan and Jonathan found a bird egg.
2. *Structural explicit:*
   What they found was small and white.
3. *Incidental implicit:*
   The sand box was at the end of the backyard.
4. *Incidental explicit:*
   They lived in the city.

Following listening or reading, subjects took a two-choice test asking questions that depended on one of these four types of information. For example, a test item for structural implicit information was a choice between *Susan and Jonathan found a bird egg* and *Susan and Jonathan found a stone*. Children actually answered two questions: Which choice was better? And did the story really say this? The important results are these: (1) High-ability readers performed better than low-ability readers on both listening and reading. (2) Listening and reading differed on incidental information, with written texts producing better memory for incidental information. For structural information, reading and listening were equal. (3) On the strict question of whether the information really occurred in the story (as opposed to merely fitting in appropriately), fifth-grade subjects were better than third-grade subjects and high-ability readers were better than low-bility readers. (4) Finally, and perhaps most interesting, children who read were able to discriminate explicit from implicit statements better than children who listened, when response bias was accounted for. Fifth graders and high-ability readers were also better at discriminating explicit from implicit statements than were third graders and low-ability readers.

This experiment seems to confirm the hypothesis that written texts produce more explicit processing than oral texts. Note that this effect does not depend on reading ability nor on age. There is no evidence that low-ability readers fail to adopt an appropriate explicit text strategy in reading. An interesting developmental question may be this: At an advanced stage of development might we expect the listening-reading difference to disappear? That is, does listening become more like reading under some conditions?

Story structures
Yet another type of higher level knowledge is the child's knowledge of the structure of stories. We have already noted that the evidence for ability differences in appreciation of structural importance is inconclusive (Chapter 5). The Hildyard and Olson study just described did not find an ability interaction with structural versus incidental information. Young children master the simple structural elements of stories at an early age (Stein & Glenn, 1979), and even low-ability readers, at least among 12- and 13-year-olds, reflect structural elements in their story recalls.

Linguistic memory
We know that working memory continues to differentiate high- and low-ability readers throughout the range of development (see Chapter 5). Adult verbal ability is also related to auditory memory span (Hunt et al., 1975; Lyon, 1977). However, we have suggested that linguistic memory and simple verbal processes are related: They both manifest the manipulation of symbols in a memory system. We do not know whether they are exactly the same things, but they do demand the same recurring symbol manipulation process. There is, however, an additional issue for development of reading ability. More complex texts tend to make greater absolute demands on memory as the reader gets older. Unless verbal efficiency keeps up with these demands, the reader will experience memory difficulty.

Summary

There are many contributors to reading ability development that go beyond simple verbal processes. We have described only a few of these to indicate that processes of linguistic inference may continue to develop and play a role in comprehension ability. However, we do not know much about other language and speech factors that seem to be related to reading comprehension. Important differences between oral language and reading processes seem to exist, but not differentially for high- and low-ability readers. Similarly, structural knowledge of stories develops too early to have much impact in later development. The one critical factor common to reading and general language processing is linguistic memory. It is not necessarily independent of other symbol-processing factors but it may appear to be when it is observed in complex texts. More is known about the development of simple processes related to reading than about more complex general linguistic processes.

The development of reading ability from the elementary school years depends on the development of two general components. One is the efficiency of simple verbal processes. Children develop efficiency in letter recognition, decoding, name retrieval, and semantic access as their reading fluency develops. A general symbol activation rate may set the general limit on efficiency throughout the development of fluency. However, for children of low ability, decoding, rather than general symbol activation, may be the rate-limiting factor. The second general component is the development of higher level language comprehension ability. This component is not independent of simple verbal processes, because acquisition of the latter may depend in part on effective reading.

NOTES

1. This unique variance concept is the residual correlation between two measures following the removal of all partial correlations with other variables entered into a multiple regression analysis. In the Curtis study, each independent variable's unique contribution was determined by entering it last into the multiple regression.
2. Other interpretations are possible and all must be taken with the critical acknowledgement that they are limited by measurement issues. Correlations among test scores reflect the difficulty of the tests, in part. If the decoding tests do not increase in difficulty while the listening test does—or, equivalently in this case, if the listening test has a built-in increasing performance standard—this variance affects the correlations. The interpretation offered is only consistent with the Curtis data, not compelled by them.
3. This result seems to contradict the effect of orthographic structure reported in Chapter 7 and in results of Massaro and Taylor (1980). In both cases, high-ability readers showed more benefit of orthographic structure. However, there are essential task differences. In the experiments of Chapter 7, the task was *backward* search, presumably a memory effect. In Massaro and Taylor, orthographic effects were found in forward visual search, but from their data it appears that most of the high-ability readers' advantage came from real words. Furthermore, in a later experiment Frederiksen (1981) found that high-ability readers could use orthographic structure more effectively than low-ability readers in pseudoword recognition.
4. Frederiksen's (1978b) procedure used the structural equations procedure of Joreskog and Sorbom (1978). Alternative rational models were based on hypotheses about what processing components were present in each task.
5. In fact, correlations between general ability test scores and NI − PI are usually smaller than this, typically around .30. As some have pointed out, these small correlations should make us realize that there is much more to intelligence than speed of verbal processing (see Sternberg, 1981). On the other hand, it should be kept in mind that NI − PI provides essentially a partial correlation.
6. Hunt et al. (1981) used the results of this principal-components factor analysis to compute canonical correlations, i.e., correlations between verbal ability measures and the factor loadings of the processing tasks on the memory access factor. This confirmed the contribution of a single

memory access factor to Nelson-Denny reading scores, r=.69. As Hunt et al. (1981) point out, this correlation is an estimation of the *maximum* relationship between reading ability (verbal ability) and speed of memory access because canonical correlations are sensitive to random error in the data.

7. In some of the studies there has been a statistical independece between some general measure of comprehension and specific processing-speed tasks (Curtis, 1980; Hunt et. al., 1981; Jackson & McClelland, 1979). This does not necessarily demonstrate that the comprehension processes underlying the general comprehension test are independent of the verbal processes measured by the speed tasks. The reason is that the measures of general comprehension are very similar to the reading comprehension tests which provide the dependent measures. For example, Curtis (1980) and Jackson and McClelland (1979) both used global listening comprehension tasks that were mirror images of the criterion reading comprehension tests, whereas the processing-speed tasks were quite different. An informative experiment would be to include batteries of listening and reading comprehension tests for comparable text units.