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The Development of Verbal Efficiency, Metacognitive Strategies, and Their Interplay

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This article explores the interplay between low-level reading subcomponents, metacognitive aspects of reading, and how this relation changes developmentally. First, theories relevant to the question of how subcomponent efficiencies, available resources, and metacognitive aspects of reading interrelate are reviewed. Second, research documenting increases in a reader's subcomponent efficiencies is briefly surveyed. Next, research revealing the child's developing metacognitive competencies is explored. To conclude, compensatory-encoding theory (Walczyk, 1993) is used to propose a model of the development of the interplay between resources, subcomponent efficiencies, and metacognitive aspects of reading. Diagnostic and intervention implications are considered.

KEY WORDS: metacognition; reading development; cognitive development.

INTRODUCTION

The articles in this special edition of *Educational Psychology Review* focus on the implications of cognitive psychology for reading diagnostics. This paper is primarily concerned with metacognitive (strategic) aspects of reading, or the control a reader exerts over his/her own reading activities. What are the implications of increasing metacognitive competencies for the diagnosis of reading problems? I argue that, with gains in subcomponent efficiencies and metacognitive knowledge, the nature of the interplay be-

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tween low-and high-level aspects of reading changes with age. A model of this interplay and metacognitive diagnostic implications are proposed.

Preliminary Definitions

I divide the complex activity of reading into three aspects.

1. *Subcomponent processes* are activities capable of becoming highly efficient and automatic. Among them, lexical processes are concerned with identifying letters, recognizing words, and recoding words from a visual to a phonological form. Lexical access typically becomes highly efficient early on during reading development (Stanovich, 1990). Post-lexical subcomponents involve putting word meanings together to form propositions, syntactically parsing a sentence, combining propositions across sentences, and resolving anaphors (e.g., deciding to whom "she" refers) (Perfetti, 1985).

2. There exist *limited pools of resources* used in the comprehension of text (LaBerge and Samuels, 1974; Perfetti, 1985). These resources, usually called attention and working memory, can be allocated by the executive component (discussed below) to many tasks (e.g., to help resolve anaphors or to assist in the decoding of words).

3. The final aspect of reading is its *metacognitive* (executive or strategic) component. Metacognitive strategies involve setting appropriate reading goals, choosing a strategy to attain a goal, checking to see if a goal is being met, and taking remedial action if it is not. Cognitive strategies are specific steps which, if followed, are likely to result in achieving a cognitive goal. Each of these three aspects will be important to the following discussion.

IMPORTANCE OF UNDERSTANDING THE INTERPLAY AMONG THESE ASPECTS

Understanding how reading subcomponent processes, resource availabilities, and metacognitive strategies interact is fundamental to understanding the nature of reading as it occurs in real life. Understanding this interaction in successful readers can suggest how it may break down in the cases of less successful readers. Interventions designed to correct reading problems necessarily depend on accurate diagnosis of the source of the problems. Just as the human body can become ill due to many causes, so reading problems arise from many sources. Verbal working memory span for a particular reader may be too small, making it hard to connect ideas across sentences (Perfetti, 1988). A child may have such inefficient decoding skills that attention must be shifted from comprehension-fostering activities to accessing word meanings such that comprehension suffers (Stanovich, 1980). On the other hand, a child with a large working memory and with efficient subcomponent processes may still have comprehension problems due to metacognitive deficits (Palincsar and Brown, 1984; Paris, Cross, and Lipson, 1986). A reader, for example, may be unaware of the need to connect conceptually the ideas contained in disparate sentences to have an internally coherent model of a text's meaning. The reader lacking this awareness needs to learn to make inferences.

A lot of research points to the importance of each of the three aspects in isolation (see Baker and Brown, 1984; Perfetti, 1985 for reviews). Because successful reading depends on blending all three to produce comprehension, it is *crucial* to understand how they interact and how the interaction changes developmentally. Consider these possibilities. Sometimes the optimal reading intervention may not be where there is a clear deficit. Children can be taught metacognitive strategies for overcoming poorly automated word-recognition skills. Over time, better word-recognition skills can develop. In this case, metacognitive training is a makeshift cure. In another situation, a child with a small verbal working-memory span can functionally achieve a larger span with metacognitive strategies. Perhaps the individual does not chunk ideas into larger semantic units but can be encouraged to do so. The point is that one aspect of reading may compensate for a deficiency elsewhere. If a diagnostic system reveals comprehension problems, inefficient subcomponents, and metacognitive deficits, then perhaps metacognitive training is called for. Successful diagnosis, however, depends on an understanding of how the three aspects of reading interact in normal reading.

REVIEW OF THEORIES RELEVANT TO THIS QUESTION

One approach that pertains to how the three aspects of reading interrelate has been referred to as resource theory. Although resource notions have fallen out of favor among reading theorists (Stanovich, 1990), I believe that they still afford insights on the interrelations among the three aspects.

Resource accounts, first suggested by LaBerge and Samuels (1974), have been refined and embodied in Perfetti's (1985) verbal efficiency theory. Implicit in resource accounts is the distinction between effortful (*control*) processes that require the allocation of resources (e.g., attention and working memory) and *automatic* processes. Control processing resources (attention) are capacity-limited but can flexibly be assigned to novel processing tasks. A reader may encounter an unusual word. Attention is required as s/he tries to sound it out. The second form of processing, *automatic*, is effortless, highly efficient, and makes minimal demands on attention. Automatic subcomponents of any skill, such as driving, usually have been practiced for many years (Schneider, Dumais, and Shiffrin, 1984).

However, the concept of automaticity in reading has come under attack (Stanovich, 1990). This vague construct has been defined in various ways. I choose to equate the concept of subcomponent automaticity with a subcomponent being encapsulated. A subcomponent, for instance, lexical access, is encapsulated if its processing is uninfluenced by the execution of higher level processes. As an example, if decoding is truly encapsulated then knowing the context in which a word appears (what the passage is about) should provide little facilitation (will not make it faster) of word recognition.

An implication of resource theory is that there will be a correlation between subcomponent efficiencies and comprehension. If, for instance, a child has difficulty resolving anaphors, which typically occurs automatically (McKoon and Ratcliff, 1980), attention (resources) will have to be shunted from comprehension activities to the resolution of anaphors. In short, inefficient subcomponents require attention reallocation that, in general, will impair comprehension. The reader may forget where s/he was in the course of reading. S/he also may forget the main idea, especially if the reader must reallocate attention often.

A second theoretical approach, labeled *interactive theory*, is currently popular (Perfetti, 1988; Stanovich, 1980). Interactive accounts are not incompatible with resource accounts. They underscore the ways in which automatic and control processes interact in reading. According to these accounts, such interactions routinely occur. Reading often proceeds on "autopilot." That is, automatic, highly efficient reading subcomponents process text while making minimal demands on capacity-limited attentional and working-memory resources. These resources can then be allocated to text comprehension. However, attention is often shunted between high- and low-level activities. Stanovich (1980), for instance, has argued that less efficient readers use attentional processes to assist in activating context-appropriate word meanings. Even if a reader's subcomponent processes are highly efficient, s/he will, on occasion, have to divert attention to low-level subcomponents to assist in decoding, and so forth.

Having to divert attention from comprehension-fostering activities clearly may hamper comprehension. There are two ways in which comprehension can be impaired. First, the speed of comprehension may be slowed. This impairs reading in the sense that a reader will not be able to comprehend as quickly as her/his peers. Second, the quality of comprehension can be impaired. This will be the case if information is lost from working memory while an anaphor is resolved, a word is sounded out, and so forth, making it more challenging to integrate text. Also, comprehension will be impaired if the reallocation of resources is simply inadequate to fix the problem. As an example, readers may lack background information necessary to understand text. No amount of attention reallocation will help.

I now briefly review research documenting developmental improvement in subcomponent and resource aspects of reading. A description of normal reading subcomponent development is relevant to the identification of reading problems. Problems can arise anytime normal development goes awry.

INCREASES IN VERBAL EFFICIENCIES AND AVAILABLE RESOURCES WITH AGE

For a detailed discussion of subcomponent development, I refer you to the other articles in this special edition. Briefly, as the reader grows older, the efficiency of a variety of subcomponent processes increases. For instance, letter and word identification quickly become automatic so that their execution makes minimal demands on attention. Of course, the processing of unfamiliar words at any age will demand the reallocation of attention (Perfetti, 1988; Rayner and Pollatsek, 1989). Other subcomponents that show efficiency gains are lexical access, acoustic recoding (changing a visual code to an acoustic one), semantic-memory access, syntactic analysis, the resolution of anaphors, and proposition integration (Chabot, Petros, and McCord, 1983; McKoon and Ratcliff, 1980; Perfetti, 1985).

Even though some subcomponent processes become highly efficient early on, such as letter and word identification (see Greene and Royer, 1994; Walczyk and Raska, 1992), different children may reach different early threshold levels. One child may reach an upper limit of lexical access of 400 ms while a second child may achieve only 500 ms. How do such interindividual differences affect reading outcomes? This important question is beyond the scope of this paper.

Other subcomponents such as semantic-memory access may exhibit constantly increasing efficiencies over the course of reading skill development. These gains may improve comprehension or reading speed at any age. Upon reading a word, those with more efficient access to semantic information, can resolve anaphors more quickly, make inferences, and so forth before information is lost from working memory. Which reading subcomponents reach an early threshold beyond which efficiency gains do *not* entail comprehension benefits? Which subcomponents show steady gains that are comprehension enhancing throughout the course of reading skill development? Letter and word identification, as noted above, seem to reach an early asymptote (Perfetti, 1985). Again, consult the other articles of this special edition for discussion of the threshold reached by different subcomponents.

More resources are made available as a reader matures. Case (1985) argues that working-memory capacity increases with age as does the ability to focus and sustain attention. Older children have been observed to have larger verbal working -memory spans (Perfetti and Goldman, 1976; Walczyk and Raska, 1992). Consequently, they are better able to keep information active in memory.

INCREASES IN METACOGNITIVE COMPETENCIES: CAN METACOGNITION BE TRAINED?

I now note gains in metacognitive (executive or strategic) competencies over time. As mentioned in the beginning of the paper, metacognition refers to one's knowledge of and control over her/his own thinking. Many reading tasks can be thought of as forms of problem solving. An ideal instance of reading involves four aspects (Baker and Brown, 1984). *Problem definition*: A reader first defines her/his goal in reading, for example, to find the gist of a passage. (2) *Strategy selection*: Upon specifying a goal, the reader selects a strategy for attaining the goal, for instance, skimming. (3) *Comprehension monitoring*: While using the strategy and immediately following strategy use, the reader considers several questions. Is my strategy working? Having I achieved my goal? These questions need not be explicitly stated; rather, it is evident from a reader's behavior that s/he is checking to see if the passage has been understood. The reader may, for instance, try to paraphrase passage content. Inability to do so will provide the occasion for the next metacognitive aspect. (4) *Regulation*: If comprehension monitoring reveals a comprehension failure, the reader must either redefine the reading goal or choose a different strategy. If skimming has proven unsuccessful, a reader can reread the text, focusing on the first and last sentences of each paragraph, with knowledge that these sentences typically convey gist information.

The Model Above is Prescriptive. Although the preceding description of metacognitive behavior is characteristic of many readers, many more fall outside its scope (see Baker and Brown, 1984). Research documents (see below) that poor readers at any age fall short of good readers in each of these four aspects. A number of reading problems may be due to metacognitive deficits. Therefore, it is essential to any general reading diagnostic system to include a metacognitive assessment component.

To help flesh out reading behaviors that may be attached to some of the four metacognitive aspects above, McKeachie, Pintrich, Lin, Yi-Guang, Smith, and Sharma (1990) have established a taxonomy of metacognitive behaviors, many of which are relevant to reading. Under planning strategies (i.e., strategies concerned with guiding the reading process) are listed setting goals, skimming, and generating questions before reading in anticipation of the information that may be encountered. Comprehension-monitoring strategies include self-testing, generating questions, and responding, or paraphrasing. Finally, examples of regulating strategies are adjusting reading rate, rereading, and reviewing.

As a reader matures, s/he typically shows improvement in each of the four aspects of metacognition. Also, at any age, better readers are more able in each of these aspects (Brown, 1980; Baker and Brown, 1984). Baker and Brown (1984) have noted that, for younger readers, *reading is decoding*. That is, first- or second-graders are typically unaware of the layers of processes of reading beyond decoding and are unaware of the active text modeling (meaning construction) necessary to understand text. On the other hand, older reader and better readers at any age are more likely to view reading as problem solving (Baker and Brown, 1984). They have a larger repertoire of available strategies for meeting cognitive goals (Brown, 1980). They are more likely to assess accurately the difficulty of a comprehension task. When reading a difficult or unfamiliar text, they will slow reading rate, pause more frequently, pause to check comprehension, and so forth (Baker and Brown, 1984; Markman, 1979). Finally, if comprehension failure occurs, they are more likely to take effective remedial action (Brown, 1980).

Are some reading problems due to metacognitive deficits? If so, an obvious question is: Are strategies trainable? It is worth reviewing briefly some research that answers yes to both these questions. Once again, often students are observed to be metacognitively unaware of the active processing required to comprehend difficult texts. Bransford, Stein, Vye, Franks, Auble, Mezynski, and Perfetto (1982) presented unsuccessful fifth-graders with texts written such that bridging transitions were not made between sentences (transitions which explicitly connected information). These investigators observed that the unsuccessful students had poor memory for such text. Bransford et al. (1982) discovered that these students did not spontaneously generate bridging inferences as did their successful counterparts. This fact seemed to suggest a metacognitive deficit; unsuccessful students did not appreciate the need to make inferences to connect information logically. This view gained credibility when, in a follow-up study, the less successful fifth-graders were trained to generate bridging inferences. Their memory for text then approached that of the successful students. Interestingly, many of the unsuccessful students were surprised that they could have this kind of control over their own reading. They are reminiscent of the first and second graders for whom reading is decoding.

It is not enough for a student to be taught a metacognitive strategy. Knowledge of when to use it is also crucial. Metacognitive interventions must include training in conditionalized knowledge for strategy use to generalize (Paris, Cross, and Lipson, 1986). In short, there must be a metacognitive component in the training. Such instruction identifies contexts to which the strategy generalizes. Students are also given opportunities to use the strategy outside the classroom.

One of the most successful programs in terms of showing generalized, long-term strategic gains is the reciprocal teaching method of Palincsar and Brown (1984). The authors taught middle-school readers with good decoding but deficient comprehension strategies for finding the main idea of a passage and for monitoring their comprehension. Comprehension monitoring strategies included predicting what a passage was about from its title and first sentence and asking questions both before and after reading. The teacher, working with a group of students, modeled strategy use. Later, students were asked to act as the "teacher" while the instructor provided cues and feedback. Importantly, the training emphasized when students should use these strategies and why they are effective. Significant gains in comprehension were observed even after 8 weeks of training.

The two studies described above focus on training strategies and comprehension monitoring (aspects 2 and 3 above). As another example of a simple intervention that can easily be incorporated into a metacognitive training program, Walczyk and Hall (1989) observed that adult readers have more accurate self-assessments of their level of comprehension if they ask themselves questions during the course of reading. That is, if they test themselves while reading, they gain valuable feedback on their actual understanding. Markman (1979) and Baker (1979) observed that students forewarned that text contained inconsistencies were more likely to detect contradictions embedded within (show evidence of comprehension monitoring). Andre and Anderson (1978) observed that, when encouraged, students can acquire comprehension monitoring skills. They are thus better able to determine the adequacy of their own understanding. The point is that metacognitive skills are highly trainable, sometimes simply by creating an awareness of them. Still, knowing when metacognitive training is appropriate to handle specific reading problems will depend on a keen understanding of not only how a comprehension problem arose (its etiology) but also of how it can most effectively be remediated (which may not be in the most obvious way). One conclusion is clear. Metacognitive interventions hold much promise for the future as a means of redressing a variety of reading problems.

A MODEL OF THE DEVELOPMENT OF THE INTERPLAY BETWEEN VERBAL EFFICIENCIES, RESOURCES, AND METACOGNITIVE COMPETENCIES

I now propose a model of the development of the interplay between low- and high-level aspects of reading. The model is speculative and not fully specified. However, it is consistent with available data. The model is an embellishment of a recent, interactive theory of reading, compensatory-encoding theory (Walczyk, 1993). Furthermore, this model accounts for some data that general resource models and other interactive models do not account for. The theory specifies what happens when reading occurs under pressure, as when taking a standardized test.

According to the model, resource notions (i.e., competition between subprocesses for limited resources) apply almost exclusively during the earliest stages of reading skill development: typically during first or second grade and less so by the third grade. According to Anderson's (1983) ACT* theory of skill acquisition, during early stages of procedural learning, performance is under the control of attentional processes. When a child first learns the phoneme-grapheme correspondence rules, all of her/his capacity-limited attention and working memory are taken up in the endeavor. Under these circumstances, correlations should be observed between subcomponent efficiencies and comprehension outcomes.

According to the model, for most older children and adults, the efficiencies of reading subcomponents become relatively uncorrelated with reading comprehension outcomes (Frederiksen and Warren, 1987; Roth and Beck, 1987; Walczyk and Raska, 1992). Readers beyond the third-grade level are typically relatively efficient at decoding and can have efficient semantic memory access, and so forth (Perfetti, 1985). Of course, some individuals beyond the third grade lack efficient subcomponents and are in need of interventions targeted at improving the efficiencies of one or more subcomponents.

The lack of correlation often observed in older children and adults between subcomponent efficiencies and comprehension measures (Walczyk, 1990; Walczyk and Raska, 1992) may have to do with the fact that, by fourth or fifth grade, children's metacognitive competencies are beginning to approach those of adults (Baker and Brown, 1984). Older readers are more likely to adjust reading rate or pause appropriately given difficult text. I believe that, at some point, older readers come upon the metacognitive insight that one can overcome inefficient subcomponents and limited resources through the use of *compensatory mechanisms*. Of course, when this happens, comprehension will not be strongly related to subcomponent efficiencies.

Consider three reading situations students experience and how compensatory mechanisms may or may not operate in each. Students frequently read familiar text in nonpressure situations. In this case, subcomponent inefficiency or limited resources should not impair comprehension, especially for subcomponents that reach an early asymptote. Reading can proceed on autopilot. Furthermore, readers are free to use compensatory mechanisms. If a comprehension failure occurs, that individual can slow reading rate. If information is lost from memory or if an individual has a small working-memory capacity, s/he can look back in text or reread earlier portions. An individual can pause to consolidate information in memory, integrate propositions, and so on. Thus, compensatory mechanisms are a form of remediation (metacognition) that older readers may use to head off comprehension failure.

A second situation involves reading difficult text, but not under severe time or evaluation pressures. Compensatory mechanisms (tools for dealing with subcomponent inefficiencies and resource limitations) become even more important. Imagine giving an older child a passage about a new, unfamiliar scientific principle such as the *lever* (physics). Because many of the words will be unfamiliar along with the underlying concepts, the reader will have to reallocate attention to sound the words out (Perfetti, 1988), pause more frequently to consolidate information, slow reading rate more often, and so on. Readers who do not use these compensatory approaches (even older readers can be metacognitively naive) are more likely to experience comprehension problems. Of course, some readers may be unaware of the need to slow reading rate in response to difficult text (Brown, 1980). In this situation, metacognitive strategy training would be appropriate.

The last situation, relating to older children and adults, involves having to read under moderate to severe time or performance pressures. Although these occasions are comparatively rare in school, their impact is profound. The reading competency of children in the elementary grades is usually assessed via a standardized reading achievement test, usually with time limitations. Time limitations and the performance pressure associated with testing will certainly make it more difficult to pause, slow reading rate, look back, reread, reallocate attention, and use a variety of other metacognitive strategies. Also, because compensatory mechanisms probably developed in nonpressured situations, a reader may forget to apply metacognitive strategies while in the testing situation. Metacognitive strategies, imparted as a result of training, often do not generalize to new situations. The result is that subcomponent inefficiencies and limited resources should exert a deleterious effect on comprehension.

Walczyk (1993) observed stronger correlations between subcomponent efficiencies and comprehension measures when reading occurs under pressure. An individual with inefficient subcomponents is more likely to reallocate attention. The diagnostic implication is that when comprehension is assessed in time-restricted testing situations, the score may not reflect a reader's typical comprehension level. Reading under the pressure of a standardized achievement test may implicate different reading subcomponents as being important. The efficiency of decoding, normally irrelevant to comprehension for older readers, may become important. Thus, those with slightly more efficient decoding may enjoy an advantage. The conclusion is that reading assessments obtained under pressure may underestimate actual comprehension.

DIAGNOSTIC IMPLICATIONS

This model suggests how, for older children and adults, subcomponents, resources, and metacognitive strategies affect comprehension in different reading situations. What are the diagnostic implications of the model? If resource notions apply early on in reading development, then a likely source of a young reader's comprehension problem is inefficiency in one or more subcomponent processes. If a reader falls behind his/her peers, interventions designed to improve subcomponent efficiencies, such as those developed by Frederiksen and his colleagues (1987), may result in improved comprehension. One developmental concern has to do with the immediacy of the effects of training. Training on a subcomponent, such as lexical access, may not result in improved comprehension until other subcomponent skills are in place. Thus, beneficial results due to training may only be seen later.

Clearly there are older children and adults for whom training in subcomponent skills will produce comprehension gains. Individuals with impoverished linguistic backgrounds, such as deaf readers or those with dyslexia, may benefit. Also, if a subcomponent for whatever reason is highly inefficient, it will exercise a deleterious effect on comprehension. An intervention designed to increase an individuals verbal working memory span should result in better comprehension generally (Walczyk and Raska, 1992). Such an intervention might involve vocabulary building. Also, the reader might be exposed repeatedly to phrases often encountered in English prose so that these word combinations will become chunks in working memory. Especially for older children and adults, however, who often tend to have reasonably efficient subcomponents skills but who may nonetheless have faulty comprehension, other interventions may be optimal. Recall that the readers of the Palincsar and Brown's (1984) study had good decoding but poor comprehension. As children acquire reading skills, their metacognitive competencies improve. Many readers discover a number of ways in which to compensate for the potentially deleterious effects of inefficient subcomponents and resource limitations. From a compensatory-encoding standpoint, a subcomponent like lexical access or access to information from semantic memory, that may not appear inefficient when reading occurs under minimal pressure, may appear so when reading occurs under pressure.

As noted above, many older readers become aware of a number of comprehension-fostering activities such as generating inferences to connect logically related ideas across sentences. However, not all readers attain these metacognitive competencies at the appropriate levels or in a timely fashion. A reading diagnostic system will need to take these observations into account.

How should a reading diagnostic system be designed? For beginning readers, a diagnostic approach such as the CAAS system of Royer and his colleagues (see this issue) seems appropriate. When assessing the reading problems of older children and adults, presumably with metacognitive competencies, some adjustments must be made. At the front end of the diagnostic system, reading comprehension and language comprehension tests should be administered. If the problem is generic to language comprehension and not just to reading, language-based interventions are required. If the problem is particular to reading, then the next step is to administer the CAAS system.

As mentioned, occasionally older children and adults can have *highly* inefficient reading subcomponents. If so, training on those subcomponents is appropriate. Even though interventions designed to promote subcomponent efficiencies (i.e., Frederiksen and Warren, 1987; Roth and Beck, 1987) failed to result in improved comprehension at the passage levels, these approaches were not used with the youngest readers for whom they may have been of the greatest benefit. I concede that subcomponent training, especially when it involves, for instance, improving verbal working memory span, or the efficiency with which information is retrieved from semantic memory, may improve comprehension, even in adult readers.

If no subcomponent is found to be highly inefficient, then the next likely source of a reading problem is a metacognitive deficit. An assessment system must be created to measure metacognitive strategy use on-line. A paper and pencil test of metacognitive knowledge is not, in my opinion, very informative. Metacognitive strategy use *occurs in real time.* Strategic behaviors such as slowing reading rate or looking back are exhibited in response to increasing task demands while reading. The focus of the metacognitive component of a reading diagnostic system should be on garnering evidence of metacognitive competencies embodied in actual behavior rather than on a student's theoretical metacognitive knowledge as displayed by paper and pencil tests. I am unaware of any on-line system currently available with which to assess metacognitive competencies. On an upbeat note, computer technology makes such a system feasible.

The prime consideration in designing a system of this sort concerns how the effectiveness of metacognitive or compensatory mechanisms can be assessed. Preliminary to such a system is garnering a research base that determines the optimal metacognitive (compensatory) strategies for overcoming the effects of specific forms of subcomponent inefficiencies or limited resources. Optimal strategies for meeting specific reading goals under different task demands must also be identified. Does a reader with inefficient decoding slow reading rate sufficiently when confronted with difficult text? Does a reader look back or pause upon reading the second of two sentences, assuming that a bridging inference must be made to integrate the two sentences? If a reader has a small verbal working memory span, does s/he pause more when resolving anaphorical references? With such data, the computer can compare a particular individual's metacognitive strategy use against a normative sample which includes both effective and less effective readers. Below I list some detectable forms of strategy use (alluded to above).

1. Does a reader alter reading rate in response to varying text difficulty?
2. If text is written with unclear references, does the reader look back to earlier portions of text to resolve ambiguity?
3. If two sentences are presented that require readers to pause strategically at the end of the second in order to integrate information across the two sentences, does the reader pause?
4. Does a reader reread portions of text when later text is encountered that contains contradictory or anomalous information?

The Computer Assessment System

Examinees can be required to read texts of varying difficulty and sophistication off of the computer screen either a word or a sentence at a time. Word or sentence reading times can be recorded. Reading time is a rough index of the rate of information encoding. Obviously, the reader must be free to control her/his own rate. By pressing the arrow keys of the keyboard, the reader can be free to scroll at her/his leisure through the text, both forward and backward. One important assessment is the extent to which the reader varies reading rate as a function of text difficulty. As noted above, by adjusting reading rate, a reader can compensate metacognitively for the difficulty of a science text or for the unfamiliarity of the words being read. By noting word or sentence reading times, the computer program can assess if sufficient amounts of time have been spent on particular words or sentences (compared against a normative database). By observing patterns of scrolling, evidence of looking back and rereading can be obtained. The amount of time spent on the last word of a sentence or between sentences can provide evidence of pausing. After students read a passage, a measure of comprehension should be administered to determine if poor strategy use is associated with poor comprehension.

Which strategies compensate for inefficiencies in subcomponents? The normative database for the diagnostic system would help answer this question. Here are a few possibilities. I believe that inefficient decoding or semantic memory access can be compensated for by slowing reading rate. A small verbal working memory span can be dealt with by looking back in text to reinstantiate lost information to working memory. Inefficient proposition integration processes may be dealt with primarily by pausing. Inefficient anaphorical resolution, which typically occurs automatically (Rayner and Pollatsek, 1989), can be compensated for by rereading or looking back in text. Inefficient word recognition can also be compensated for by reallocating attention from comprehension-fostering activities to decoding. The reader can use word attack skills, in other words (Perfetti, 1988).

An Intervention System

If readers are not slowing reading rate, looking back in text, pausing, rereading, and so forth appropriately given their profile of subcomponent efficiencies or given increasing task difficulty, a computer-based intervention can be designed to develop metacognitive competencies. This system can prompt the reader to note difficult text and remind her/him to slow down if s/he is reading too quickly. Spot assessments of comprehension (sudden interruptions of reading, testing the reader) can help the reader note if comprehension goals are not being met (comprehension monitoring will be encouraged). If comprehension goals are not being met, a reader can be induced to redress the problem by slowing reading rate, by elaborating, and so forth. The computer program can also interrupt reading at crucial points to query the reader if s/he has resolved crucial anaphors. If not, the program can prompt the user to look back. By forcing a reader to be vigilant on-line, metacognitive strategy use should become a permanent weapon in a deficient reader's arsenal. It would be interesting to know how generalizable this metacognitive training can be. By including a variety of texts, presumably the training could prove generalizable.

An Alternate Assessment Approach

I would like to briefly suggest an exciting, noncomputer-based, strategy-use assessment approach. This method would be far more labor-intensive than the computer-based approach yet would yield a wealth of on-line data in a more naturalistic way. Students can be induced to read texts of varying difficulties while being videotaped. Optimally, students would not know that they are being monitored. Students would be encouraged to read and think out loud as effective reading strategies. These videotapes could be scored later for evidence of compensatory strategy use. Evidence of rereading, inference making pausing, elaborating, slowing reading rate in response to difficult text, and so forth could be garnered.

CONCLUSION

This paper addressed the question of how metacognitive, resource, and subcomponent aspects of reading interrelate and how this interplay changes developmentally. The diagnostic implications of this interplay were considered. A tentative answer was presented in the proposed model. At the beginning of reading-skill acquisition, resource notions apply, suggesting a linkage between subcomponent efficiencies and comprehension. Older children and adults can compensate for inefficient subcomponent processes. Indeed, the metacognitive aspect of reading compensates for limited resources and inefficient subcomponents in light of varying task demands. One implication of this argument is that comprehension abilities may be underestimated in standardized testing situations inasmuch as compensatory mechanism use is much more difficult.

A diagnostic approach, consistent with the CAAS system and my model, was outlined. At the tail-end of the CAAS system, I would include a metacognitive-strategy assessment component (also computer-based). The system would determine, for instance, if a reader was slowing sufficiently to handle difficult text or poor decoding; or whether the reader was pausing when necessary, rereading, or looking back, to choose a few more examples. Inasmuch as many reading problems may reflect metacognitive deficits

(Baker and Brown, 1984; Palinscar and Brown, 1984), especially for older teachers and adults, the addition of an On-line Strategic Assessment System (OSAS), would greatly expand the range of applicability of the CAAS system. On OSAS assessment could lead to effective intervention for a variety of problems, especially for older readers.

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