Toward an Interactive-Compensatory Model of Individual Differences in the Development of Reading Fluency

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Toward an interactive-compensatory model of individual differences in the development of reading fluency

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INTERACTIVE MODELS OF READING appear to provide a more accurate conceptualization of reading performance than do strictly top-down or bottom-up models. When combined with an assumption of compensatory processing (that a deficit in any particular process will result in a greater reliance on other knowledge sources, regardless of their level in the processing hierarchy), interactive models provide a better account of the existing data on the use of orthographic structure and sentence context by good and poor readers. A review of the research literature seems to indicate that, beyond the initial stages of reading acquisition, superior reading ability is not associated with a greater tendency to use the redundancy inherent in natural language to speed word recognition. Instead, general comprehension strategies and rapid context-free word recognition appear to be the processes that most clearly distinguish good from poor readers.

Vers un modèle compensatoire interdépendant de différences individuelles dans le développement de lecture courante.

LES MODÈLES INTERDÉPENDANTS de lecture semblent pourvoir une conceptualisation plus précise d'accomplissement de lecture que les modèles strictement du haut au bas et du bas au haut. Lorsqu'ils sont combinés avec une hypothèse de procédure compensatoire (qu'un deficit dans tout procédé particulier causera une plus grande confiance en d'autres sources de connaissance, sans tenir compte de leur niveau dans la hiérarchie de procédure), les modèles interdépendants fournissent un meilleur compte-rendu de données existantes dans l'usage de structures orthographiques et de contexte de phrases par des lecteurs bons et médiocres. Une revue des écrits de recherche semble indiquer que, sa-delà des étapes initiales d'acquisition de lecture, la capacité de lecture supérieure n'est pas associée à une tendance plus vaste d'utiliser l'excédent inhérent dans le langage naturel pour accélerer la reconnaissance des mots. Au lieu, les stratégies de compréhension générale et, de maniére plus importante, la reconnaissance rapide de mots à contexte libre semble être les procédés qui distinguent le plus clairement les bons lecteurs des mauvais.

Hacia un modelo interactivo-compensatorio de diferencias individuales en el desarrollo de facilidad de lectura

MODELOS DE INTERACCIÓN de lectura parecen proveer una percepción intelectual mas precisa de lecturabilidad que los modelos estrictamente conceptuales ("top-down") o de desciframiento ("bottom-up"). Cuando se combinan asumiendo el proceso compensatorio (que el déficit en cualquier proceso resultará en mayor dependencia de otras fuentes de conocimiento, sin consideración de nivel en la jerarquía de procesos), modelos de interacción proveen una mejor enumeración de los datos existentes sobre el uso, por buenos y deficientes lectores, de estructura ortográfica y contexto de oración. Un repaso de la literatura de investigación parece indicar que, más allá de la fase inicial de aprendizaje de lectura, la habilidad superior de lectura no está asociada con una mayor tendencia de uso de la redundancia existente en lenguaje natural para acelerar la identificación de palabras. Por otro lado, estrategias de comprensión general y descifre rápido de palabras de contexto libre parecen ser los procesos que separan más claramente los lectores buenos de los deficientes.

During the last two decades experimental psychologists have developed a renewed interest in phenomena that have a heavy cognitive component (e.g., mental imagery, psycholinguistics). Nowhere is this more apparent than in the literature on the reading process. (See Venezky, 1977.) Cognitive psychologists have recently applied their information processing perspective to many components of reading performance (cf., Massaro, 1975, 1978).

There was a strong tendency in early cognitive theorizing to depict information processing as a series of discrete stages, each performing a specific transformation on its input and passing on the new recoded representation as an input to a subsequent stage (Sperling, 1967; Sternberg, 1969; Theios, 1973). Since the sequence of processing operations proceeds from the incoming data to higher-level encodings, such conceptualizations have been termed bottom-up models. It is not surprising that, since these models were so influential in the early development of information processing theorizing, they were the first to be applied to reading. Thus, several bottom-up serial-stage models of reading and word recognition have been introduced into the literature

(Geyer, 1970; Gough, 1972; LaBerge & Samuels, 1974; Smith & Spoehr, 1974). However, it is now reasonably well-established that such models are inadequate because they fail to account for many important empirical results in the reading literature. Rumelhart (1977) and Danks (1978) discuss many experimental phenomena (e.g., word, syntactic, and semantic context effects) that provide problems for bottom-up models. Serial-stage models of reading run into difficulty because they usually contain no mechanism whereby higher-level processes can affect lower levels. Samuels (1977) revised the LaBerge and Samuels (1974) model for just this reason.

Top-Down Models

There exists, however, a class of models that conceptualize reading in a manner diametrically opposed to that embodied in serial-stage models. These have been termed top-down models because higher-level processes interact with, and direct the flow of information through, lower-level processes. Although several different top-down conceptualizations of reading exist (Goodman, 1976; Hochberg, 1970; Kolers, 1972; Levin & Kaplan, 1970; Neisser, 1967; Neville & Pugh, 1976-1977; Smith, 1971, 1973), they all have in common a view of the fluent reader as being actively engaged in hypothesis-testing as he proceeds through text. Since the reader is only sampling textual information in order to test hypotheses, the reading process is viewed as being driven by higher-level conceptual processes rather than by low-level stimulus analysis.[1,2] In short, top-down analyses start with hypotheses and then attempt to verify them by processing the stimulus, whereas bottom-up analyses start by processing the stimulus. (See Eisenstadt & Kareeve, 1975.)

While the top-down hypothesis-testing models have often been attacked for excessive vagueness in their conceptualization, there are even more serious criticisms of the entire class of models. First, several authors (McConkie & Rayner, 1976; Samuels, Dahl, & Archwamety, 1974; Wildman & Kling, 1978-1979) have questioned the hypothesis-testing models because they require implausible assumptions about the relative speeds of the processes involved. Specifically, the generation of hypotheses about a subsequent word, or words, must take less time than is necessary to recognize the words on the basis of purely visual information, otherwise the hypothesis generation is unnecessary. However, it seems unlikely that a hypothesis based on complex syntactic and semantic analyses can be formed in less than the few hundred milliseconds that is required for a fluent reader to recognize most words.

This argument against hypothesis-testing models is reinforced by recent research indicating that fluent readers do not use conscious expectancies to facilitate word recognition (Mitchell & Green, 1978; Stanovich & West, 1979b). In summary, it appears that most top-down models have serious deficiencies as explanations of fluent reading. It will be argued later in this paper that their account of individual differences in reading skill is also inadequate.

Interactive Models and the Compensatory Hypothesis

A third class of theories is formed by those models that posit neither a strictly bottom-up nor strictly top-down processing, but instead assume that a pattern is synthesized based on information provided *simultaneously* from several knowledge sources (e.g., feature extraction, orthographic knowledge, lexical knowledge, syntactic knowledge, semantic knowledge). Rumelhart (1977) provides the best example of such a model, although Morton's (1969, 1970) logogen model embodies many of the assumptions of the interactive-processes conception at the level of word recognition.

As has been previously discussed by Mosenthal, Walmsley, and Allington (1978), interactive models differ from top-down models primarily in terms of the relative independence of processes at different levels. In top-down models, semantic processes direct lower-level processes, whereas in interactive models semantic processes constrain the alternatives of lower levels but are themselves constrained by lower-level analyses. Thus, each level of processing is not merely a data source for higher levels, but instead seeks to synthesize the stimulus based on its own analysis and the constraints imposed by both higher and lower-level processes. Rumelhart (1977) argues convincingly that many experimental findings in the reading literature seem to require an interactive model for their explanation.

Although several authors have recently alluded to the potential of an interactive-processes model of reading and recognition (Lesgold & Perfetti, 1978; Levy, 1978; Marslen-Wilson, 1975; Pearson & Kamil, 1977-1978; Schwartz, 1980; Wildman & Kling, 1978-1979; Wisher, 1976), few have discussed the relation of the interactive model to current theorizing on the nature of individual differences in reading fluency. It will be argued here that an interactive model, when coupled with the assumption that the various component subskills of reading can operate in a compensatory manner, leads to a reconceptualization of the nature of individual differences in reading. Furthermore, this new model of individual differences can explain a series of results that, until now, had seemed paradoxical.

In order to make the compensatory assumption, we must first agree on the invalidity of bottom-up models of reading. That is, we must assume that it is not necessarily the case that the initiation of a higher-level process must await the completion of all lower ones. Once we have dispensed with bottom-up models, we are free to assume that a process at *any* level can compensate for deficiencies at any other level. This is the essence of the compensatory hypothesis. Notice that we are now free to consider a possibility that has been inadequately explored in the reading literature, namely, that higher-level processes can actually compensate for deficiencies in lower-level processes. Thus, a reader with poor word recognition skills may actually be prone to a greater reliance on contextual factors because these provide additional sources of information. It is precisely this possibility that is suggested by the interactive model developed by Rumelhart (1977). Notice also that a compensatory assumption is *not* embodied in most top-down models of reading (e.g., Levin & Kaplan, 1970; Smith, 1971). In these models, higher-level processes (i.e., hypothesis-testing based on contextual expectancies) are usually *less* implicated in the performance of poorer readers. These models seldom consider the possibility that the poorer reader may compensate for a deficit in a lower-level process, such as letter or word recognition, by relying more on a higher-level knowledge source. In contrast, working from the interactive-processes conception, one might assume that, given a deficit in a particular process, the reader would rely more on other knowledge sources, *regardless* of their level. (In fact, Seymour, 1976, has previously discussed how Morton's logogen model predicts that, when stimulus analysis is relatively slow, nonsensory factors will have a greater effect on recognition time.) Thus, it is possible that, given a deficit in a lower-level process, poor readers might actually rely *more* on higher-level contextual factors. Evidence to be reviewed below indicates that this is sometimes the case.

It should be noted in addition that bottom-up models also contain no compensatory mechanism. In fact, they make the same prediction as the top-down models regarding the relatively greater reliance of the better reader on higher-level processes. This is because it is assumed that the efficiency of the good reader's lower-level stimulus-analysis processes free capacity for higher-level processes. Thus, the findings that, under certain circumstances, poorer readers show a greater reliance on higher-level processes also invalidates the bottom-up conception of individual differences in reading skill.

Masson and Sala (1978) have perhaps come closest to combining a compensatory hypothesis with an interactive model of reading (although see Frederiksen, Note 1, and Perfetti & Roth, 1981). In order to explain results indicating that sentences originally read in transformed typography were recognized better than sentences read in normal typography, they argued that, due to the unfamiliarity of inverted typography, the data-driven stimulus-analysis mechanisms (Bobrow & Norman, 1975; Norman, 1976) were slowed, and decoding was more dependent on conceptually-driven processing. This explanation suggests the possibility that a similar trade-off might occur when the data-driven operations are slower because of developmental immaturity and/or unfamiliarity with written language, rather than the presence of an inverted typography. However, Masson and Sala (1978) did not extend their argument to deal with individual differences in reading ability or the development of reading fluency. In the present study, it will be shown that an interactive-compensatory model of reading is consistent with much research on individual differences in the use of orthographic structure and sentence context, and that many studies in this same literature present problems for bottom-up and top-down models. In the following review, studies that compared readers at different developmental levels and studies that compared skilled and less skilled readers at the same age will both be considered. The interactive-compensatory model is equally applicable to developmental and individual difference studies.

Orthographic Structure Effects

The redundancy inherent in written language is assigned a central role in most contemporary theories of the reading process (cf., Gibson & Levin, 1975). Intraword redundancy arises because of the sequential and position-specific constraints on the letters within words. Thus, written language is orthographically structured. The ability to use orthographic structure to speed word recognition has been emphasized by several theorists. For example, Smith (1971) hypothesizes that what distinguishes the good from the poor reader is the ability to use the redundancy of text at all levels of processing. His theoretical orientation predicts that better readers should show more of a tendency to use orthographic structure to speed word recognition. This follows, since in top-down theories the higher-level processes (e.g., use of the intraword sequential constraints that are stored in long-term memory) should be relatively more important than the lower-level processes (e.g., grapheme segmentation and identification) in the fluent reader. Thus, Smith's (1971) view is that the fluent reader identifies words faster than the poorer reader largely because his increased use of orthographic redundancy enables him to identify a word on the basis of fewer visually extracted features. The research evidence, however, is not entirely consistent with this position.

Several studies (Allington, 1978b; Lefton, Spragins, & Byrnes, 1973; Lott & Smith, 1970; Rosinski & Wheeler, 1972; Scheerer-Newman, 1978) have found better readers to have greater knowledge of the orthographic structure of words than do poorer readers. However, the interpretation of these studies is problematical, since they all measured conscious knowledge of orthographic constraints rather than the ability to use orthographic structure to actually *speed* word recognition. Acquisition of knowledge does not necessarily imply its *use* in a particular situation (e.g., reading), especially when that situation may have processing requirements very different from those of the task used to tap the knowledge. Thus, it is not enough that an individual *know* the sequential constraints of the orthography. For this knowledge source to be facilitative, it must be applied to word recognition quickly, before individual letter recognition is completed, or else recognition will be based solely on stimulus information even *though* the reader had the knowledge. (A similar argument was mentioned above, in the context of the discussion of the top-down theorists' position that prior hypotheses facilitate ongoing word recognition.) The question concerns what skills predominate in the *actual* reading situation, not which group of readers has more of a certain type of knowledge stored in long-term memory. (See Schvaneveldt, Ackerman, & Semlear, 1977, for a similar argument.) Since the speed of recognition is now widely acknowledged as being crucial to reading (even among investigators of vastly different theoretical persuasions—see Biemiller, 1977-1978; Doehring, 1976; LaBerge & Samuels, 1974; Smith, 1971; Smith & Holmes, 1971), it would seem necessary to focus on how readers of different abilities use orthographic structure to speed word recognition.

The difficulty with most of the previous studies of orthographic structure effects is that they have often used experimental procedures that more closely resembled problem-solving tasks than speeded recognition tasks. For example, Rosinski and Wheeler (1972) and Allington (1978b) had subjects discriminate which of two nonword letter strings was more wordlike. Lefton et al. (1973) had subjects guess a missing letter in seven-item sequences that varied in approximation to English. Scheerer-Newman (1978) had subjects give a whole-report of eight tachistoscopically presented letters, a procedure that heavily implicates short-term memory processes. Though all of these studies showed increases in orthographic knowledge with age and fluency, none tapped the extent to which the constraints of words act to speed recognition, which is really the predication that is crucial. Nevertheless, it is interesting that even these studies demonstrated a good deal of orthographic knowledge on the part of very young readers. The third-grade students of Rosinski and Wheeler (1972) were well above chance accuracy in discriminating pronounceable from unpronouceable non-words. In fact, the fifth-grade students did no better. Even the second-grade poor readers of Allington (1978b) discriminated zero-order from fourth-order approximation to English. The third-graders of Lefton et al. (1972) also displayed a redundancy effect that was nearly as large as that of the adults. Lott and Smith (1970) obtained similar results with first-grade subjects.

Studies that have examined the effect of orthographic structure on the speed of recognition have consistently found that this variable does not distinguish good from poor readers once the child has passed the initial stages of reading acquisition. Changes in the use of orthographic structure occur only very early in the development of reading skill. Krueger, Keen, and Rublevich (1974) found that both fourth-graders and adults searched for a letter faster through word than through nonword displays. However, the magnitude of the effect, as indicated by the relative reduction in search times, was the same for both age groups. In fact, the absolute reduction was actually greater for the children. The hypothesis that the speeded recognition performance of better readers would be more affected by orthographic structure fared no better in correlational analyses. The correlations between standardized measures of reading ability and the magnitude of the orthographic structure effect were near zero for both groups. Juola, Schadler, Chabot, and McCaughey (1978) also used a letter-search task and found that the orthographic structure of the display affected the search times of second-grade subjects just as much as adults. Only the search times of the kindergarten children did not show a word superiority effect. Stanovich, Purcell, and West (1979) obtained similar results using a letter-search task. (See also Massaro, Venezky, & Taylor, 1979; Krueger, 1979.)

Studies using letter-search paradigms can perhaps be criticized for having little ecological validity. Although it could be argued that the experiments that have attempted to tap the use of orthographic structure with nonspeeded tasks are even less related to actual reading, it is necessary to inquire whether the same results would occur in tasks where the subject was forced to process a higher-level unit, such as a word. This issue of generalizability is important because much research in cognitive psychology attests to the fact that the level of processing at which a subject is set to operate can influence the effect of many experimental variables (Ball, Wood, & Smith, 1975; Shulman, 1970; Shulman & Davison, 1977). Thus, Stanovich, West, and Pollak (1978) measured the time for third-grade, sixth-grade, and adult subjects to search for target words through lists of nonwords, pseudowords, and words. The search times of all the groups increased as the lists become more wordlike (i.e., confusable with the target words), and the relative increases in time scores did not differ across the age groups. As in the Krueger, Keen, and Rublevich (1974) study, when absolute time scores were considered, the younger children actually showed a larger orthographic structure effect.

Stanovich and West (1979a) used the same word-search task with third-grade readers who were either above- or below-average readers and observed, once again, a similar pattern of results. The word-search times of poor readers were equally affected by orthographic structure when relative time-scores were considered and more affected when absolute time-scores were employed. An interesting pattern emerged in this study when error rates were considered. Good readers made few errors, and those that did occur were not correlated with experimental condition. The poor readers produced many more errors and their frequency of occurrence was strongly correlated with experimental condition, such that over twice as many errors were made when searching through word lists than through nonword lists. Again, this finding suggests *greater* sensitivity to intraword structure on the part of the poorer reader. The errors in this task can be broken down into two types. Omissions occur when the subject misses a target. Errors of commission occur when the subject responds to a letter string that is not one of the targets. Only four of the 48 good readers made even one error of commission and these four subjects produced a total of only five such errors. In contrast, 38 of the 48 poor readers made at least one error of commission and these 38 subjects made a total of 88 such errors. These errors were highly correlated with experimental condition and almost always involved the children responding to a string that had several letters in common with a target or that had the same shape as one of the targets. This would seem to indicate that these subjects were not completing the analysis of the internal letter structure of the strings.

Henderson and Chard (Note 2) employed a lexical-decision reaction-time task to study the processing of orthographic information by second- and fourth-grade readers. The focus of their study was on how the time to classify letter-strings as nonwords was affected by the structural features of the strings. Both vowel presence and the summed single-letter positional frequency of the nonwords were varied factorially. These two variables had significant effects on the reaction times of the two groups of children. The magnitudes of both of the effects were larger in the times of the second-grade readers. Thus, Henderson and Chard concluded that the second-grade readers were sensitive to quite subtle features of orthographic structure. Barron (1979) reports a study in which the lexical-decision times of sixth-grade poor readers, but not sixth-grade good readers, were affected by the single-letter positional frequency of the words.

It should be noted that, in all of the reaction-time studies discussed above, the older and/or better readers had overall shorter latencies, even though there was no tendency for their times to be more affected by orthographic structure. Thus, Smith's (1971) conjecture that the rapid processing times of fluent readers result from a heavy reliance on redundancy appears to have little support. In fact, research employing adult readers of different abilities complements the pattern displayed in the developmental studies. Using a speeded-identification task, Frederiksen (1978) found that although the reaction times of the better readers were faster, only the poor readers were affected by the bigram frequencies of the component letters of the strings. Although Mason (1975) found the letter-search times of sixth-grade good readers to be more affected by single-letter positional frequency, her subsequent work with adults (Mason, 1978) has failed to produce similar results. Using a more ecologically valid word-naming task, she found that good readers named words 57 msec faster than poor readers and that *neither* group responded faster to words that were high in summed single-letter positional frequency.

In a paper that reviewed the processing differences between good and poor readers, Golinkoff (1975-1976) referred to a study by Coomber and Hogie (Note 3) that found poor readers to be *more* sensitive to spelling pattern violations than good readers and from this concluded, "slow decoding may not be due to a failure to utilize intraword information in the form of spelling patterns" (p. 654). There is now much more evidence to support this conclusion. Once beyond the very initial stages of reading acquisition, the poor reader not only uses orthographic redundancy to facilitate word recognition, but there is evidence indicating that in some situations the poor reader may even rely more on this stored knowledge source than the good reader. Such findings present problems for models oriented to top-down processing such as that presented by Smith (1971), since these models account for the good readers' fluency by attributing to them a greater use of redundancy at all levels. However, these findings present no problem for interactive-compensatory models, which imply that a reader deficient in letter-analysis skills would be more likely to use other knowledge sources (intraword redundancy, semantic context, etc.) to aid word recognition than would the reader who had efficient stimulus-analysis mechanisms. This appears to be the explanation for the error pattern observed by Stanovich and West (1979a). Unlike the good readers, poor readers made a large number of commission errors, and these errors were strongly correlated with conditions. (The more the field items approximated target items in structure, the more likely they were to be mistakenly checked.) The incorrectly identified items also tended to share letters and/or shape with the targets. These results seem to indicate that the poorer readers were less likely to complete the internal analysis of the item, probably due to poor letter-analysis mechanisms.

Sentence Context Effects and Top-Down Models

The way in which good and poor readers process contextual information has been frequently discussed in the reading literature. However, it is useful to distinguish two types of contextual processes. First, there are those that are involved in constructing a knowledge structure from the text, processes such as semantic integration (Bransford & Franks, 1971), the relation of new information to given information (Haviland & Clark, 1974), and all other strategic operations that facilitate comprehension of text. There exists some evidence indicating that these comprehension control processes are superior in the good reader, even when differential word-recognition abilities are controlled (Cromer, 1970; Guthrie, 1973; Jackson & McClelland, 1979; Oakan, Wiener, & Cromer, 1971; Smiley, Oakley, Worthen, Campione, & Brown, 1977; but see Perfetti & Lesgold, 1977, for a dissenting opinion). However, there is a second type of contextual processing that operates much differently than the comprehension strategies just described. This is the contextual hypothesis-testing that is posited by most theorists oriented toward top-down processing (Goodman, 1976; Hochberg, 1970; Levin & Kaplan, 1970; Neisser, 1967; Smith, 1971). According to these theorists, superior readers not only comprehend text better, but also use previously understood material to facilitate *ongoing* word recognition. Thus, Smith (1971) hypothesizes that, due to sensitivity to semantic and syntactic redundancy afforded by sentences, the good reader develops hypotheses about upcoming words and is then able to confirm the identity of a word by sampling only a few features in the visual display of a new word. Good readers should then process words faster since their use of redundancy lightens the load on their stimulus-analysis mechanisms. Poor readers, on the other hand, are less facile in their use of contextual redundancy, make incorrect or few hypotheses, are forced to process more visual information in order to recognize a word, and thus read slowly. Smith's (1971) view of reading difficulty is that "the more difficulty a reader has with reading, the more he relies on the visual information; this statement applies to both the fluent reader and the beginner. In each case, the cause of the difficulty is inability to make full use of syntactic and semantic redundancy, of nonvisual sources of information" (p. 221). It will later be argued that this conception of individual differences in reading ability is not supported by the empirical evidence. Before turning to this evidence, a recent study that questions the applicability of the hypothesis-testing models even to fluent reading will be discussed.

Levin and Kaplan (1970) have most forcefully stated the top-down hypothesis-testing view of reading. They characterize the fluent reader as one who

> continually assigns tentative interpretations to a text or message and checks these interpretations. As the material is grammatically or semantically constrained he is able to formulate correct hypotheses about what will come next. When the prediction is confirmed, the material covered by that prediction can be more easily processed and understood. (p. 132)

However, as was previously mentioned, several authors (McConkie & Rayner, 1976; Samuels, Dahl, & Archwamety, 1974; Wildman & Kling, 1978-1979) have questioned whether hypotheses could be generated and tested with a speed that could facilitate ongoing word recognition. Mitchell and Green (1978) recently reported an important series of experiments that appear to answer this question in the negative. They employed a paradigm in which the subject presented a passage to himself on an on-line visual display by pressing a button that presented three words of the passage to be read. Successive presses of the button advanced the subject through the text three words at a time. The inter-response time served as an index of processing difficulty. Mitchell and Green (1978) failed to confirm an important prediction of the hypothesis-testing view, that processing should be faster in more predictable parts of the text.

Since the predictability of most sentences increases from beginning to end, processing difficulty, and hence inter-response time, should decrease as the reader progresses through the sentence. In fact, the data revealed a tendency to slow slightly as ordinal position in the sentence increased.

In further, more sensitive tests, Mitchell and Green (1978) found no tendency for a verb that permitted few structural continuations to speed the processing of the following three-word frame. The presence of a relative pronoun also had no effect on processing time. The results concerning semantically selective words were ambiguous. A post-hoc reanalysis of the data did indicate a tendency for semantically predictive words to speed subsequent processing, but the authors argued for an explanation of this effect that did not involve the facilitation of ongoing processing by prior predictions. However, this result is consistent with an explanation of sentence context effects presented by Stanovich and West (1979b, to be discussed below).

Although Mitchell and Green (1978) did not find sentence predictablity to affect inter-response time, they did find that many other variables affected immediate processing. For instance, word frequency, display size, position in passage, and rated difficulty of the sentence all had significant effects on response time. Thus, it cannot be argued that their experimental technique was insensitive. Based on their failure to find predictability effects and their repeated observations of reliable display size and word frequency effects, Mitchell and Green (1978) concluded that reading rate is more dependent on the speed with which a reader can recognize words and construct a representation than on the ability to use predictions to facilitate word recognition. Note that these investigators do not deny that preceding context can affect comprehension processes, for there is ample evidence for such effects (e.g., Bransford & Johnson, 1973; Haviland & Clark, 1974). They are specifically arguing against the view that prior context can act to facilitate *ongoing* word recognition. Thus, they distinguish between the two types of contextual processing (for comprehension and for facilitation of word recognition) discussed at the beginning of this section. In a similar manner, it will now be argued that distinguishing the two types of contextual processes is useful in understanding the literature on individual differences in the development of fluency.

Smith (1971) has argued that the poor reader is deficient in both types of contextual processing. The hypothesis that the general comprehension strategies of better readers are superior will not be challenged here since there is some support for this position (Guthrie, 1973; Oakan et al., 1971; Schwartz, 1977; Smiley et al., 1977; Forrest & Barron, Note 4). However, the idea that a greater ability to use contextual redundancy to facilitate word recognition also differentiates the good from the poor reader appears to be mistaken. This idea follows from a strong tendency of top-down theorists to assume that *every* higher-level "conceptual" process must be more implicated in the performance of more fluent readers. When empirical evidence contradicts this assumption, as was found in the literature on orthographic structure effects, top-down models run into problems. It will be argued that this assumption also fails to find support in the literature on contextual effects on lexical access in readers of differing abilities and that an interactive-compensatory model more easily accounts for the results.

The Empirical Literature on Sentence Context Effects

There is a body of research that is commonly cited as being supportive of the top-down notion that fluent readers are more reliant on contextual redundancy. Many of the studies (and/or the interpretations of them) fail to distinguish between the two types of contextual processing. Thus, while there are some studies that show that the comprehension strategies of good readers are superior, they are often incorrectly cited as showing support for the position that contextual redundancy actually facilitates word recognition (e.g., Klein's 1976 citation of Oakan, Wiener, & Cromer, 1971).

Another line of research has attempted to show that good readers are better at predicting words that are missing from an incomplete passage than are poor readers. The criticism of this research runs along the lines of the argument already presented in the section on orthographic structure effects. Specifically the issue at hand is whether good readers have a greater tendency to use contextual redundancy to facilitate *ongoing* word recognition, *not* whether given virtually unlimited time, good readers can make better predictions. The question is not whether the good readers actually have better predictive abilities, but whether they are actually more prone to *rely* on such abilities to speed word recognition. Thus, much of the previous research has tapped the presence of contextual knowledge, not its use, and once again many of the tasks resemble problem-solving rather than speeded recognition. For example, the cloze task, where the subject is asked to produce words that are missing from a passage, is obviously measuring the ability to consciously generate predictions under no time constraints. (Thus, the task does not tap potentially important automatic contextual effects; see below.) Consequently, the reported positive correlations between cloze performance and reading proficiency (Bickley, Ellington, & Bickley, 1970; Ruddell, 1965) should not be interpreted as indicating that good readers rely more on context to facilitate word recognition. It is more likely that comprehension processes are being tapped. For example, Perfetti, Goldman, and Hogaboam (1979) have shown that, although the predictive abilities of skilled fifth-grade readers were superior to those of less-skilled fifth graders, the skilled readers' word recognition times were *less* affected by a prior sentence context, a finding corroborated by many studies to be discussed below (e.g., Schvaneveldt, Ackerman, & Semlear, 1977; West & Stanovich, 1978). Perfetti and Roth (1981) present a detailed explanation of how a good reader can be at once more *sensitive* to context but less *dependent* on it (due to the availability of information from other knowledge sources).

A study reported by Klein, Klein, and Bertino (1974) could be interpreted as indicating that the tendency to use prior context to speed word recognition increases with age. They employed materials consisting of word sequences that were printed with a space after every letter but no additional spaces between word boundaries. The subject's task was to go through the sequence and indicate with a slash the boundaries between words, the dependent variable being the number of words determined in a fixed period. The word sequence was either a random string of words or a coherent passage of sentences. Word demarcation was faster when coherent passages were used, and the difference in performance between the coherent and random conditions was an indication of the extent of context usage. Klein et al. found that both fourth- and sixth-grade readers identified more words in the coherent passage than in the random passage during a 90-second search interval. The magnitude of the coherent/random difference was greater for the sixth-graders than for the fourth-graders, indicating a developmental increase in the use of context to speed word identification. There are, however, problems with this interpretation as well as with the word-boundary task itself. The boundary decisions take approximately 2½-3 seconds per word, much slower than the less than one second it takes fourth graders to recognize most words. The unfamiliar orthographic configuration and the instructions to the subject make the task seem closer to an index of problem-solving skills than a measure of word identification in reading. Schwartz (1977) has stated that the Klein et al. (1974) result probably reflects the general strategic advantage of older children. If this interpretation is correct, then the study is not an adequate test of the hypothesis-testing view of the use of prior context by readers of different abilities. (See Goldsmith & Nicolich, 1977, for indications of some additional problems in employing the word-boundary task as a measure of contextual facilitation in young children.) The research employing the word-boundary task shares with work on cloze task performance (Ruddell, 1965), whole-report tachistoscopic perception (Marcel, 1974), and memory tasks (Weinstein & Rabinovitch, 1971) the property that while it may be tapping important psychological processes, it is not a measure of the extent to which readers employ context to facilitate immediate word recognition.

Research that has more closely tapped the ability to use context to speed ongoing word recognition has shown support for the top-down notion that this process occurs during reading performance. However, the view of individual differences in reading ability proposed by the top-down theorists, that contextual facilitation is more implicated in the performance of better readers (e.g., Smith's 1971, 1973, 1975, oft-repeated statement that the good reader relies less on graphic cues), does not receive unanimous support. Instead, the research shows that even the very youngest readers use context to facilitate word recognition. In addition, many studies have failed to show the expected increase in contextual facilitation as reading fluency develops. Just as many, if not more, studies have shown contextual facilitation to *decrease* as reading fluency develops. Finally, recent research (e.g., Fischler & Bloom, 1979; McConkie & Zola, 1981; Mitchell & Green, 1978; Stanovich, 1981; West & Stanovich, 1978; Alford, Note 5) has failed to uncover evidence favorable toward the hypothesis that the rapid word recognition of fluent readers is primarily due to an extensive use of contextual information. For example, McConkie and Zola (1981) examined eye fixation patterns as subjects read passages that contained critical words that were either highly constrained (i.e., were chosen 85% of the time when subjects were attempting to guess them in a cloze task) or relatively unconstrained (chosen less than 15% of the time in a cloze task). Highly constrained target words were just as likely to be fixated, and the fixation durations on highly constrained targets averaged only 14 msec shorter than the durations on the unconstrained targets.

The finding that in some situations poor readers rely more on context than do good readers presents problems for top-down models, which hypothesize that reading becomes more conceptually driven as fluency develops. However, such a finding presents no difficulty for the interactive-compensatory model, where knowledge sources at all levels contribute simultaneously to pattern synthesis and where a lower-level deficit may result in a greater contribution from higher-level knowledge sources. Thus, the interactive-compensatory conception allows for the reader with poor letter or word recognition skills to draw heavily on higher-level knowledge sources.

Studies of oral reading errors have been diagnostic in examining the relative contribution of graphic and contextual information to word recognition during reading. Biemiller (1970) studied the oral reading errors of a group of first-grade students from October to May and argued for the existence of three stages of reading acquisition during this period. In the first stage reading is dominated by the use of contextual information and few of the children's errors are graphically constrained. The second stage is one in which the proportion of non-response and graphically constrained errors increases markedly. Biemiller (1970) interpreted this stage as a transition period in which the children were moving from a context-using phase in which they were attempting to avoid using graphic information to a stage where their attention is more clearly focused on graphic information. The third stage is one where the children's oral reading errors are both contextually and graphically constrained. Across these three first-grade reading stages the increase in the percentage of graphically constrained errors was more marked than the increase in contextually constrained errors. The percentage of errors that were contextually appropriate rose from 74% in stage one to 83% in stage three. However, the graphically similar responses rose from 19% in stage one to 44% in stage three. Particularly striking is the fact that a large proportion of the errors of even the least fluent readers were contextually appropriate.

The results of Weber's (1970) study of oral reading errors are largely consistent with those of Biemiller (1970). She found that approximately 90% of the oral reading errors of first-graders were grammatically acceptable with the preceding text and that good and poor readers were not distinguishable on the basis of the percentage of grammatically acceptable errors that they produced. Weber further analyzed the substitution errors in terms of their graphic similarity to the correct word. The graphic similarity scores of the better readers were higher than the scores of the poorer readers, indicating a greater attention to graphic information on the part of the better readers. This finding contradicts Smith's (1971) hypothesis that better readers are less reliant on graphic information and that the poor reader is a "slave to print." Instead, Weber (1970) argues that

> these findings do not support the characterization of the relatively low achiever as a word-by-word reader. Rather, they suggest that

> children—no matter what their potential for acquiring literacy skills—bring to the task a fundamental linguistic ability, which in its rigidity shapes their reading responses into familiar language structure. (pp. 153-154)

In an additional study, Weber (1970) observed that, once again, there was no significant difference between good and poor readers in the proportion of errors that were grammatically consistent with the preceding sentence context; however, good readers were more likely to correct errors that did not fit into the subsequent context of the sentence as it was written. These results suggest the distinction between the two types of contextual processing discussed above. Specifically, it appears that the ability to use previous context to speed lexical access does not differentiate good from poor readers. (See also Rode, 1974.) However, the general comprehension strategies needed to construct a coherent representation of the text appear to be superior in the better reader.

Perfetti and Roth (1981) report results from a study of oral reading errors that converge nicely with those of Weber (1970) and Biemiller (1970). Perfetti and Roth found that both skilled and less skilled readers could trade off visual for contextual information, and that skilled readers were not more reliant on contextual information. Kolers (1972) has analyzed the oral reading errors of subjects who were reading geometrically transformed text. He found that, in terms of the linguistic pattern of substitution errors, dyslexic adolescents were not differentiated from normal readers. Kolers (1975) employed a similar technique with seventh-grade good and poor readers. He again found the pattern of substitution errors of poor readers to approximate that of good readers. On the basis of other evidence, Kolers (1975) argued that the good reader was, in fact, more sensitive to features of the typography.

Juel (1980) studied the oral reading errors made by second- and third-grade subjects. In her study, she analyzed the number of errors made on a set of target words that varied in decodability, frequency, number of syllables, and contextual constraint. The error analyses indicated that the good readers were predominately text-driven, whereas the poorer readers were more context-driven. Juel (1980) concluded, consistent with the position taken in this review, that

> researchers may be mistaken in interpreting those studies which show good readers can make use of contextual cues better than poorer readers as evidence that they actually do so in normal reading. It may be more efficient for good readers, with well developed decoding skills, to directly identify words in a text-driven manner than to "predict" words based on context. (p. 375)

Allington and Strange (1977) constructed passages where a letter was changed in 5% of the words so that the letter string was transformed into a different word that made the sentence anomalous. Examples of such sentences are "He leaned too fan over the edge of the wall" and "A green frog came hopping oven the snow." Thus, the words "fan" and "oven" have been substituted for "far" and "over." The focus of this study was on whether the subject would read the actual stimulus word (e.g., fan) or the word that would make the sentence meaningful (e.g., far). Reading the actual word would be an indication of reliance on graphic cues whereas substituting the meaningful word would indicate reliance on contextual information. Allington and Strange (1977) found that both good and poor fourth-grade readers responded a majority of the time with the contextually appropriate original word rather than the actual word. However, good readers read the actual word more often than the poor readers, indicating greater attention to graphic information on the part of the better readers. Thus, the results indicate that, while both groups used context to facilitate processing, the good readers paid more attention to graphic information. As in the Stanovich and West (1979a) study, the poor readers in the Allington and Strange (1977) experiment tended not to complete the internal analysis of the word when there was contextual information to rely on. A similar general trend was found in a study by Marsh, Desberg, and Carpenter (Note 6), where a proofreading task was employed. Other studies employing related paradigms (e.g., Siler, 1974; Strange, 1979), while not exactly replicating the trends in the Allington and Strange (1977) study, are in agreement in failing to confirm the top-down prediction of greater contextual effects in better readers.

Allington and Fleming (1978) also found the performance of poorer readers to be more dependent on contextual information. They had subjects read a passage that contained 37 words of low discriminability. Subjects also read a randomly ordered list of the words in the passage. Below-average fourth-grade readers misread more of the words in the random list than did the above-average readers. However, the two groups did not differ significantly in numbers of errors produced when reading the coherent passage. Thus, context had more of a facilitative effect on the performance of the poorer readers.

Studies that have measured oral reading latency have generally found results consistent with the research on oral reading errors. Doehring (1976) found that even first-grade students read connected text faster than passages of random words. The mean contextual gain in seconds per syllable was actually greater in the younger subjects, and the relative gain was invariant after second grade. Biemiller (1977-1978) observed similar results. His second-grade subjects also read connected text faster than random words. The absolute magnitude of the contextual facilitation (in seconds per word) was greater for the younger children; however, there was a slight tendency for older children and adults to show a larger relative gain.

Allington (1978a) tested the ability of good and poor fourth-grade readers to read connected text and random words. Both groups read the connected text faster, and an analysis of variance on the reading times indicated no interaction between group and condition of presentation. However, since the reading latency of the good readers was lower, their relative contextual gain was greater. Statistical analyses of the accuracy of word identification indicated that the good readers were unaffected by experimental condition, but that the poor readers were more accurate reading connected words rather than random words. Allington (1978a) concluded that good readers were more reliant on context for fluency and poor readers were more reliant on context for accuracy. The findings of studies measuring reading latency dovetail with findings from studies of oral reading errors. The common pattern is that all readers appear to use context to facilitate word recognition. However, there seems to be no strong tendency for more fluent readers to show a greater reliance on context. In fact, just as often the opposite is true. It should be noted that there is nothing paradoxical about the conclusion that a process may be an important general determinant of reading speed yet not be a source of individual differences. (See Perfetti & Roth, 1981.) Graessar, Hoffman, and Clark (1980) found that macrostructure processes that integrate information from different sentences accounted for more variance in reading time than did microstructure processes (those operating on the words and syntax within a sentence). However, fast and slow readers differed mainly in microstructure processes.

Studies using somewhat different methodologies also support the above conclusion. Samuels, Begy, and Chen (1975-1976) investigated how the tachistoscopic exposure duration necessary to identify a word was affected by the prior presentation of an associate of the word. The exposure durations of fourth-grade students who were poor readers were affected just as much as the exposure durations of the good readers. The magnitude of the facilitation effect was actually greater in the poor readers. Schvaneveldt, Ackerman, and Semlear (1977) examined the effect of a single-word semantic context on lexical-decision times. They found that the previous presentation of a highly-associated word facilitated the lexical-decision times of both second- and fourth-graders.

The effect of semantic context was greater for the second-grade readers and, within each grade, the correlations between standardized reading measures and the magnitude of the context effect were all negative, indicating greater use of context by the poorer readers. Using full sentence contexts, Perfetti, Goldman, and Hogaboam (1979) and West and Stanovich (1978) found context to have a greater effect on the naming times of poorer readers. In a recent paper, Allington and Strange (1978) stated that

> the role of semantic and syntactic cues in fluent reading has been the basis for much recent controversy. While some have suggested that effective use of the contextual information provided by these cues is the determining factor in differentiating good and poor readers (Goodman & Goodman, 1977; Smith, 1976), others have argued that virtually all readers, regardless of achievement, employ semantic and syntactic cues and that other factors must account for achievement differences (Weber, 1970; Kolers, 1975; Allington & Strange, 1977; Allington, 1978). (p. 56)

The bulk of the relevant research now appears to support the latter position.

The occasional tendency for the poorer readers to use context to a greater extent is not paradoxical if we keep in mind the distinction between the two types of contextual processing discussed above. Using hypotheses to facilitate word recognition may itself take cognitive capacity, thus leaving fewer resources for higher-level comprehension processes such as drawing implications or integrating new information with old. If the contextual facilitation observed in poorer readers is of a type that takes attentional capacity, then these readers may have less capacity left over for comprehension processes. The increased contextual facilitation that poorer readers sometimes display is probably an indication that their slow and nonautomatic word recognition skills make it necessary for them to draw on another knowledge source. However, if this source (prior contextual constraints) also requires attentional resources, then the comprehension of the poorer reader may suffer even though the additional knowledge source has aided in the recognition of individual words. This argument will be developed below.

Automatic and Attentional Context Effects

West and Stanovich (1978) studied the effect of context on word recognition by having subjects of three ages name a target word that had been preceded by either an incomplete sentence that was congruent with the word, an incomplete sentence that was incongruent with the word, or simply by the word "the" (i.e., a no-context condition). Naming time was faster in the congruent condition than in the no-context condition. This contextual facilitation effect did not differ statistically across the three age groups in the study (fourth-graders, sixth-graders, and adults) and was actually somewhat larger in the times of the children. Within each age range, correlations involving a standardized reading measure indicated a slight tendency for poorer readers to show a greater contextual facilitation effect, a result consistent with previous research using a somewhat different paradigm (Schvaneveldt et al., 1977). A significant contextual inhibition effect (longer naming times in the incongruous-context condition than in the no-context condition) was found for both fourth-grade and sixth-grade subjects, but not for adults. In the adult group, mean naming times were virtually identical in the no-context and incongruous condition. (If the unpredictable condition of an experiment reported by Perfetti & Roth, 1981, is comparable to the no-context condition of West & Stanovich, then the results of these two experiments are highly convergent.)

The pattern of results in the West and Stanovich (1978) study fits rather nicely within the framework of the two-process theory of expectancy developed by Posner and Snyder (1975a, 1975b). The Posner-Snyder theory has been applied to the semantic context effect in lexical decision tasks (Fischler, 1977; Neely, 1976, 1977) and can easily be generalized to sentence context effects of the type studied by West and Stanovich (1978). Briefly, Posner and Snyder (1975a, 1975b) proposed that semantic context affects recognition via two processes that act independently and that have different properties. (The two simultaneously acting processes in the Posner-Snyder theory are very similar to the two expectancy mechanisms originally proposed by Meyer & Schvaneveldt, 1971.) The automatic-activation process occurs because, when stimulus information activates a memory location, some of the activation automatically spreads to semantically related memory locations that are nearby in the network. The automatic spreading-activation process is fast acting, does not use attentional capacity, and does not affect the retrieval of information from memory locations unrelated to those activated by the context. (For a fuller discussion, see Neely, 1977.) Thus, the automatic-activation process quickly results in a contextual facilitation effect, but does not cause an inhibitory effect when a word is incongruous with its preceding context. In contrast, the conscious-attention mechanism responds to a preceding context by directing the limited-capacity processor to the memory location of the expected stimulus. The conscious-attention mechanism is slow acting, utilizes attentional capacity, and inhibits the retrieval of information from unexpected locations because the limited-capacity processor must be "shifted" to a location some distance away in the memory network so that information can be read out.

Several recent studies of semantic context effects have provided some support for the two-process theory of Posner and Snyder (Fischler, 1977; Neely, 1977; Tweedy, Lapinski, & Schvaneveldt, 1977; Yates, 1978). In particular, the idea of contextual facilitation due to an automatic spreading-activation mechanism has received support (Fischler, 1977; Fischler & Goodman, 1978; Swinney, Onifer, Prather, & Hirshkowitz, 1978; Tversky, Havousha, & Poller, 1979; Underwood, 1977).

The results obtained by West and Stanovich (1978) can be interpreted as indicating that word recognition in adults is so fast that the target word can be named before the slow-acting conscious-attention mechanism can have an inhibitory effect (i.e., can direct the limited-capacity processor to a memory location far from the target word when it is preceded by an incongruous context). Instead, only the automatic spreading-activation component of contextual processing has time to operate before the word is recognized, thus resulting in contextual facilitation, but no corresponding inhibition in the reaction times of the adults. The word recognition processes of children, however, may be slow enough to allow the conscious-attention mechanism to have an effect. This results in both contextual facilitation and inhibition in the reaction times of the children. Thus, the Posner-Snyder theory explains the age differences without hypothesizing qualitative changes in syntactic and semantic processing across this particular age range. Rather, the seemingly discontinuous disappearance of the contextual inhibition effect between grade six and adulthood appears to be due, instead, to the gradual increase in word-recognition speed during this age range. Thus, for adults, word recognition is accomplished before the conscious-attention expectancy mechanism can have an effect. The two-process expectancy theory of Posner and Snyder can also account for the results of several recent studies indicating that poorer readers show greater contextual facilitation effects (e.g., Biemiller, 1977-1978; Perfetti, Goldman, & Hogaboam, 1979; Schvaneveldt, Ackerman, & Semlear, 1977; Roth, Perfetti, & Lesgold, Note 7). This occurs because poorer readers have slower word-recognition times (Doehring, 1976; Perfetti & Hogaboam, 1975), and as word recognition is slower, there is a greater tendency for contextual facilitation to result from the conscious-attention, as well as the automatic-activation, mechanism.

In further experiments, Stanovich and West (1979b) found additional support for the Posner-Snyder theory. They obtained the same finding of contextual facilitation without inhibition in the response times of adult readers. More importantly, when target word recognition was slowed (via contrast reduction) to a speed comparable to that of the fourth-grade children, adults displayed a significant contextual-inhibition effect. (Roth, Perfetti, & Lesgold, Note 7, have also shown that, as regards the effect of context, visual degradation can cause the performance of skilled readers to mimic that of less-skilled readers.) Inhibition was also evident in the reaction times of the adults when the interval between the reading of the context and the onset of the target word was increased. Degrading the target word and increasing the response-stimulus interval both have the effect of delaying word recognition and thus providing the necessary time for the conscious-attention mechanism to become implicated in performance. These results support an interpretation of the developmental results of West and Stanovich (1978) in terms of the Posner-Snyder theory and also support the hypothesis that in the fluent reader it is through automatic activation rather than conscious prediction that context acts to speed word recognition. (See Stanovich, 1981, and Stanovich & West, 1980, for a report of further tests of the Posner-Snyder theory.) The rapid word recognition of fluent readers simply short-circuits the conscious-attention mechanism. The Posner-Snyder theory thus posits a mechanism whereby the compensatory processing discussed above might work. Higher-level processes of conscious contextual prediction become implicated in performance when the bottom-up word-recognition processes are slowed. Whether the slowness of bottom-up processing is due to developmental immaturity or inadequate stimulus information appears to make no difference, since several studies have found that when fluent readers must identify visually degraded words their performance is more affected by prior context (Becker & Killion, 1977; Forster, 1976; Massaro, Jones, Lipscomb, & Scholz, 1978; Meyer, Schvaneveldt, & Ruddy, 1975; Sanford, Garrod, & Boyle, 1977; Sperber, McCauley, Ragain, & Weil, 1979).

A consideration of the way in which the two expectancy mechanisms of the Posner-Snyder theory act to compensate for slow word-recognition speed suggests an interesting distinction between types of compensatory processing. This is the distinction between an optional and an obligatory compensatory trade-off. An obligatory trade-off is one that is necessitated by the structure of the processing system. For example, according to Morton's (1969, 1970) logogen model, when the processing rate is slowed, factors affecting the evidence requirements of logogens (word detection devices) have a greater effect on performance. (See Seymour, 1976.) This trade-off is inherent in the structure of the system. In a similar manner, the increased facilitation produced by spreading activation when word recognition is slowed also represents an obligatory tradeoff since spreading activation is automatic (not under subject control) and is a function of the structure of the semantic memory system. In contrast, the greater facilitation due to the formation of conscious expectancies that results when word recognition is slowed is an optional compensation. Conscious expectancy formation is under the control of the subject and need not necessarily be invoked when word recognition is slow. (See Posner & Rogers, 1978.)

It should be noted that the results of Stanovich and West (1979b) are not necessarily in conflict with the findings of Mitchell and Green (1978), who found that prior clues to future syntactic structure did not facilitate ongoing processing. In contrast, a post hoc analysis indicated that there was a tendency for semantically predictive verbs to facilitate subsequent processing. Mitchell and Green (1978) argued against interpreting the latter result as indicating that context facilitates ongoing word recognition due to semantic predictions that are made by the reader. Although their alternative explanation is plausible, it is possible that they have taken a position that is unnecessarily extreme. As should be clear from the above discussion, the observation of a contextual facilitation effect does not necessarily implicate conscious prediction on the part of the subject. Facilitation effects can occur via automatic processes that do not involve conscious attention. Thus, in order to argue against the idea of conscious prediction, Mitchell and Green (1978) do not have to deny the existence of all facilitation effects. Indeed, this would be unwise since there have recently appeared in the literature several demonstrations that a prior sentence context can speed word recognition (Fischler & Bloom, 1979; Schuberth & Eimas, 1977; Stanovich & West, 1979b; West & Stanovich, 1978). In fact, the Mitchell and Green (1978) results are entirely consistent with an explanation of sentence context effects in terms of the Posner-Snyder theory. Note that automatic spreading-activation is a semantically-based effect (see Collins & Loftus, 1975), and that Mitchell and Green (1978) observed facilitation due to semantically constraining contexts. Thus, their results could be interpreted as indicating that in the fluent reader prior context facilitates word recognition primarily via an automatic semantically-based spreading-activation process, precisely the conclusion of Stanovich and West (1979b).

If one distinguishes two types of contextual processing that a subject might engage in, then the implications of the Posner-Snyder conception for theories of individual differences in reading ability become apparent. That is, a reader might use cognitive capacity in order to construct a new knowledge structure or to integrate new material into an old knowledge structure. On the other hand, a reader may also use the knowledge structures built up from previous context to aid in the processing of words that are currently undergoing recognition. Notice that the less cognitive capacity that is used to engage in the latter process, the more that is left over for the more important former processes. It is argued here that this is precisely what the fluent reader is doing. He recognizes words rapidly and mostly on the basis of physical cues, so that expectancy processes that draw cognitive capacity are not necessary. Thus his capacity is being used for comprehension, rather than for conscious prediction processes that aid individual word recognition. Based on the results of their studies of sentence context effects using a lexical-decision task, Fischler and Bloom (1979) argued similarly that "skilled readers, then, may not typically generate particular expectancies, even though it may result in slight facilitation of word recognition at no cost, because there is effort involved which may slow reading, and they simply will not be correct often enough for such a strategy to be worthwhile" (p. 12).

Note that the argument stated above does not imply that the word recognition of better readers is not facilitated by prior context. Quite the contrary, such facilitation is a reasonably well-established empirical fact. However, the facilitation displayed in the performance of the fluent reader is probably due to automatic-activation processes that use no cognitive capacity. One implication of this view is that prior context should facilitate the word recognition of poorer readers to a *greater* extent (since both automatic-activation and conscious-attention expectancy mechanisms are operative in these readers). However, the net result of using context in this way is that the poorer reader has less capacity left for integrative comprehension processes. The literature reviewed above is largely consistent with these predictions. Many studies have shown the poorer reader to be just as prone as the better reader to use context to facilitate word recognition and some studies have found poor readers to be more reliant on prior context. The prediction of the pure top-down models, that the word recognition speed of poor readers is slow because they fail to use contextual information, finds little support in the literature.

It is interesting that the findings of a good deal of contextual processing on the part of poor readers have generally been ignored by reading theorists. This has probably been because neither purely top-down models nor purely bottom-up models can easily handle these results. The compensatory hypothesis generally, and the Posner-Snyder theory in particular, render these findings understandable. It is the processing of the *good* readers that is primarily data-driven, in that it is the speed of their context-free word recognition that allows capacity to be freed for comprehension processes. This view is similar to the automaticity model of reading developed by LaBerge and Samuels (1974), in that both theories assume that efficient low-level recognition processes can free up capacity for higher-level processes. However, there are differences between the two models, and these differences center around the issues of what type of processing occurs at the word-recognition level and what happens when word recognition is slow and inefficient. The view presented above assumes that interactive-compensatory processing occurs at the word level, and that when word identification is slow, the reader can draw on higher-level knowledge sources (e.g., prior contextual constraints) to aid recognition. No such compensation involving contextual knowledge can occur in the LaBerge and Samuels (1974) model (although such a possibility may be present in the revised model, see Samuels, 1977). However, when the higher-level compensatory processes require capacity, they also serve to deplete the cognitive resources available to comprehension processes. Thus, the interactive-compensatory model and the LaBerge and Samuels (1974) model are in agreement on one important point, that fast and automatic word recognition is an important determinant of fluent reading.

The model presented above is also closely related to the limited-capacity model discussed by Lesgold and Perfetti (1978). The major difference, again, is that their model contains no mechanism for interactive-compensatory processing at the level of word recognition. Thus, the present model might best be conceptualized as a limited-capacity model with interactive-compensatory processing at the word level. It should be noted, however, that some recent studies have not found evidence for the performance linkages that are predicted by limited-capacity models of the type described above. Using somewhat different methodologies, Patberg and Yonas (1978) and Wilkinson, Guminski, Stanovich, and West (1981) found that disrupting the visual characteristics of the text so that reading was markedly slowed did not affect the memory or comprehension of the text. In a study of first- and second-grade children, Lovett (1979) found that the higher-order processing of sentential information was not related to decoding ability. It is possible that interactive processing is even more pervasive than that allowed for in the limited-capacity model with interactive-compensatory processing at the word level. Perhaps, as Wilkinson et al. (1981) have suggested, recognition and comprehension processes are so completely interactive that they maintain an equilibrium whereby comprehension processes are meshed with recognition processes in such a way that the former can accommodate to changes in the latter. The issues are sufficiently complex, and the current empirical data sufficiently sparse, that the only reasonable conclusion at this point is that it remains for future research to elucidate whether a fully interactive model is to be preferred over a limited-capacity model with interactive processing at the word level.

Where Are the Differences?

We are now in a position to consider the relative importance of three general loci of individual differences in reading skill, namely, context-free word recognition, the use of context to facilitate word recognition, and comprehension strategies.

The imprint of the hypothesis-testing models is evident in much of the theorizing on individual differences in reading skill. The dominance of the top-down perspective has been such that it is widely assumed that the ability to use context to facilitate word recognition is a major determinant of individual differences in reading ability. Evidence reviewed above suggests, to the contrary, that poor readers make use of prior context just as much, if not more, than good readers. Thus, it may be that good readers use context more effectively to monitor comprehension, whereas poor readers use it to aid word recognition.

There is evidence that the comprehension strategies of good readers are superior to those of the poor reader (Cromer, 1970; DiVesta, Hayward, & Orlando, 1979; Guthrie, 1973; Jackson & McClelland, 1979; Oakan et al., 1971; Schwartz, 1977; Smiley et al., 1977; Forrest & Baron, Note 4). However, Perfetti and Lesgold (1977) argue convincingly that this is not the case. A review of this literature is beyond the scope of this paper. Suffice it to say that individual differences in reading performance could well be related to the ability to use sophisticated comprehension strategies. Instead, a more clear-cut case will be argued, namely, that context-free processes at the word and subword level are major determinants of individual differences in reading fluency. The three specific abilities that will be discussed are the ability to recognize words automatically (i.e., without using attentional capacity), the ability to rapidly recognize word and subword units, and the ability to recode print items into phonological form. The ability to recognize words automatically is important because it frees capacity for higher-level integrative and semantic processing. The speed of recognition, independent of the issue of automaticity, is another important factor in reading because rapid coding of information into short-term memory facilitates the integrative comprehension processes that operate on the information that is stored there (Lesgold & Perfetti, 1978; Perfetti & Lesgold, 1977). Finally, phonological coding abilities facilitate reading in two ways, by providing a redundant pathway for lexical access and by providing a more stable code for information that must be held in short-term memory.

There is some evidence from developmental studies indicating that better readers show a greater tendency to recognize words automatically (Guttentag & Haith, 1978; Pace & Golinkoff, 1978; West & Stanovich, 1979). However, the results from several studies (Ehri & Wilce, 1979; Golinkoff & Rosinski, 1976; Guttentag & Haith, 1978; 1979; Rosinski, Golinkoff, & Kukish, 1975; West & Stanovich, 1979; Stanovich, Cunningham, & West, Note 8) have indicated that the recognition of words becomes automatized much earlier in reading practice than previously thought. In particular, the above studies suggest that most high frequency words are automatized to adult levels by the third grade. Thus, the developing ability to recognize words automatically does not seem to be the main factor accounting for reading ability increases beyond the second grade. However, during the time that automaticity is developing, and even after a word is fully automatized, recognition time continues to decrease. The latter point is often lost in discussions that center on the automaticity concept itself, even though there is ample evidence in the literature documenting the fact that recognition time continues to decrease after words have become fully automatized. Several studies have failed to find an increase in automatic processing after the second- or third-grade reading level has been reached (Golinkoff & Rosinski, 1976; Guttentag & Haith, 1978, 1979; Rosinski, Golinkoff, & Kukish, 1975; West & Stanovich, 1979), but marked increases in word-recognition speed occur as children progress beyond the second-grade level of reading ability (Biemiller, 1977-1978; Perfetti, Finger, & Hogaboam, 1978; Perfetti & Hogaboam, 1975). Thus, it is possible that beyond the initial levels of reading fluency it is word recognition *speed* rather than automaticity that is the major factor in skill development. Indeed, it is now reasonably well established that context-free recognition speed is a major determinant of individual differences in reading fluency.

Shankweiler and Liberman (1972) observed correlations in the range of .5 to .8 when word-naming speed and accuracy were correlated with paragraph reading fluency. These high correlations were observed for second-, third-, and fourth-grade readers. Employing second-grade subjects, McCormick and Samuels (1979) found correlations of approximately -.55 between word-recognition speed and comprehension ability, and approximately .60 between word-recognition accuracy and comprehension ability. In a study where vocalization latency was carefully measured, Perfetti and Hogaboam (1975) found that third- and fifth-grade poor readers named even high-frequency words approximately 200 msec slower than good readers. Low-frequency words were named approximately one second slower by the poorer readers. In further experiments, Perfetti, Finger, and Hogaboam (1978) found that third-grade poor readers named colors, digits, and pictures just as fast as good readers of the same age. However, the speed of naming words clearly differentiated the two groups. (See also Staller & Sekuler, 1975.) Biemiller (1977-1978) also found a strong relationship between reading ability and word-naming time in children. His argument, consistent with the previous review, is that

> the high degree of association between the two non-contextual tasks and text reading times strongly suggests that the ability to use context to increase speed, while facilitating times for all readers, may not represent a major source of *individual differences* in reading speed for text since a very large proportion of text time variance is associated with non-contextual measures. (p. 240)

The relationship between word-naming speed and reading ability also holds for adults. Using adult subjects, Mason (1978) found that good readers named words 57 msec faster than poor readers. Stanovich and Bauer (1979) also found a relation between reading ability and word-naming time, as did Butler and Hains (1979) and Frederiksen (Note 9). Jackson and McClelland (1975, 1979) found that, even when only fluent adult readers were considered, the ability to rapidly access over-learned memory codes distinguished skilled from less skilled readers. Mason (1980) has presented evidence to support a somewhat different hypothesis, that individual differences in reading fluency are in part due to differences in the speed of processing letter location information. Her research provides additional evidence favoring the more general hypothesis argued above, that differences between skilled and unskilled adult readers can be revealed using tasks that tap the speed of perceptual processing at the word level and below.

The ability to rapidly recode print items into a phonological form also appears to be related to reading ability (Barron, 1978a, 1978b, 1979, 1980; Perfetti & Lesgold, 1977; Spring & Capps, 1974; Spring & Farmer, 1975), even among relatively fluent adult readers (Goldberg, Schwartz, & Stewart, 1977). Perhaps it is this relationship that accounts for finding that, for adults as well as children, the speed of naming pronounceable nonwords is one of the tasks that most clearly differentiates good from poor readers (Barron 1978a; Firth, 1972; Hogaboam & Perfetti, 1978; Perfetti & Hogaboam, 1975; Seymour & Porpodas, 1979; Frederiksen, Note 9). Mason (1978) has argued that this relationship is due to the superior decoding skills of the better readers, but that decoding skill is an epiphenomenon of skilled reading in the adult. She suggested the intriguing hypothesis that nonword decoding tasks provide measures of linguistic awareness, which determined the ease with which reading *was* acquired in adult readers.

It is interesting to consider Mason's (1978) hypothesis in conjunction with other research on phonological processing, automaticity, and speed of word recognition. Certainly there exists much evidence indicating that phonological awareness, phonetic segmentation ability, and phonological recoding skills are important determinants of early reading success (Bradley & Bryant, 1978; Fox & Routh, 1975, 1976; Golinkoff, 1978; Jorm, 1979; Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977; Steinheiser & Guthrie, 1978; Torgeson & Murphey, 1979; Vellutino, 1977; Williams, 1980). This relationship may obtain either because phonological processing facilitates lexical access (see Barron, 1978a) or because it facilitates the formation of a stable code for the maintenance of information in short-term memory (e.g., Byrne & Shea, 1979; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979). Perhaps as Mason (1978) suggests, an alphabetic writing system serves as a powerful reinforcer during the initial stages of reading only if the child has the phonological skills to make use of the alphabetic principle. However, children that do grasp the alphabetic principle are likely to read more and this additional practice leads to the development of the rapid, automatic, context-free word-recognition ability that is one key to fluent reading. Thus, adult good and poor readers are differentiated on word-naming tasks (which tap rapid context-free recognition) *and* nonword pronunciation tasks (which reflect the phonological skills that determined the ease with which they traversed the early stages of reading acquisition). Rozin and Gleitman (1977) summarize the research literature in a similar manner, stating,

> there seems to be strong evidence that good and poor readers, as well as younger and older individuals, will respond similarly to meaning distinctions and meaningful contexts. At the other extreme, the ability to read word lists aloud distinguishes very reliably between good and poor readers (Firth, 1972; Shankweiler & Liberman, 1972); the ability to make explicit phonological distinctions distinguishes between younger and older individuals and between good and poor readers. Apparently, an inability to notice and cope with phonological aspects of the language poses a stumbling block to reading acquisition. (pp. 97-98)

The work of Perfetti, Finger, and Hogaboam (1978) also leads to this conclusion. They summarized their results by stating, "the ability of the less skilled reader to use constraining knowledge as well as the skilled reader is established. The persistent differences between skilled and less skilled readers in reaction times to words and pseudowords seem to be due to processes of verbal coding, including processes operating on subword units" (p. 739).

Conclusion

Both top-down and bottom-up models of reading predict that higher-level conceptual processes will be more implicated in the performance of better readers. A review of the literature on the use of orthographic structure and the effect of contextual information on word recognition indicated that this prediction has not been borne out. It has been argued that an interactive-compensatory model of individual differences in reading ability best accounts for the pattern of results in the literature. Interactive models, best exemplified in the work of Rumelhart (1977), assume that a pattern is synthesized based on information provided simultaneously from several knowledge sources. The compensatory assumption states that a deficit in any knowledge source results in a heavier reliance on other knowledge sources, *regardless* of their level in the processing hierarchy. Thus, according to the interactive-compensatory model, the poor reader who has deficient word analysis skills might possibly show a *greater* reliance on contextual factors. In fact, several studies have shown this to be the case.

Word recognition during ongoing reading can be facilitated by expectancies based on the prior sentence context. Interactive-compensatory processing appears to be operating during this process, since poorer readers often show larger contextual facilitation effects than do good readers. The Posner-Snyder theory of expectancy provides an explanation of how this compensatory processing operates. When context-free word recognition is rapid, only the fast-acting spreading-activation process is responsible for contextual-facilitation effects. When word recognition is slow, the conscious-attention expectancy process has time to operate and provides another source of contextual facilitation. Thus, the reader with poor context-free word-recognition skills has an additional contextual expectancy process acting to aid his identification of a word. However, this additional contextual facilitation is purchased at a cost. The conscious-expectancy process uses attentional capacity and thus leaves fewer cognitive resources left over for comprehension operations that work on integrating larger text units. This trade-off among processes sharing a limited pool of cognitive resources is common to many information processing models (e.g., LaBerge & Samuels, 1974; Lesgold & Perfetti, 1978).

Given that the ability to use prior context to facilitate word recognition is not a skill that differentiates good from poor readers, there appear to be two general types of processes that good readers perform more efficiently than poor readers. Good readers appear to have superior strategies for comprehending and remembering large units of text. In addition, good readers are superior at context-free word recognition. There is some evidence indicating that good readers have automatized the recognition of word and subword units to a greater extent than poor readers. However, good readers recognize even fully automated words faster than poor readers. In addition, good readers appear to have superior phonetic segmentation and recoding abilities so that they can rapidly decode a word even when visual recognition fails. In short, the good reader identifies words automatically and rapidly, whether by direct visual recognition or phonological recoding. The existence of this rapid context-free recognition ability means that the word recognition of good readers is less reliant on conscious expectancies generated from the prior sentence context. The result is that more attentional capacity is left over for integrative comprehension processes.

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Footnotes

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[1]The proliferation of nomenclature to describe these models may be confusing to the reader. When dealing with other treatments that use a different vocabulary, the reader would be advised to note that the following terms have been used in the literature to describe top-down and bottom-up processing: Top-down: conceptually-driven, inside-out, reader-based, prediction-based, schema-driven, hypothesis-testing. Bottom-up: data-driven, outside-inm text-based, text-driven, decoding.

[2]Of course, top-down models do allow that the reader may occasionally operate in a bottom-up mode (primarily when he is faced with a contextually meagre situation). Similarly, Samuels (1977) has revised the LaBerge and Samuels (1974) model so that top-down processing can occur in some situations. Nonetheless, it is fair to say that there is a *strong preference* for conceptually-driven processing in top-down models and for data-driven processing in bottom-up models. Thus, the notion of a processing mode preference, as opposed to a clear-cut dichotomous classification based upon processing directionality, may be preferable. The two classes of models are still distinguishable given this alternative conceptualization.