Changing Models of Reading and Reading Acquisition

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INTRODUCTION

Just 20 years ago writings about word recognition in textbooks and in curriculum materials were nine parts speculation to one part information. There were so few established facts about word recognition that many authors simply started out with a theoretical view on the nature of reading and then developed the implications of their theory for word recognition. Thus, it is not surprising that the reading literature came to contain much theoretical speculation masquerading as established scientific fact. However, far more is known now, and many of the issues that just two decades ago were in the realm of speculation have been empirically resolved and are the subject of a broad-based scientific consensus. Parts of that consensus are discussed here.

The Importance of Word Recognition Skill

There is now overwhelming evidence that problems at the word recognition level of processing are a critical factor in most cases of dyslexia; that word recognition efficiency accounts for a large proportion of the variance in reading ability in the early elementary grades; and that even among adults word recognition efficiency accounts for a sizeable amount of variance in reading ability (Bertelson, 1986; Gough & Tunmer, 1986; Morrison, 1984, 1987; Perfetti, 1985; Vellutino, 1979).

As the evidence linking word recognition skill to reading ability became more and more overwhelming, the debate about how to conceptualize word recognition in reading shifted from questioning the linkage itself to a dispute about what psychological mechanisms were responsible for the superior word recognition skill of the better reader. This dispute evolved into the famous top-down versus bottom-up debate in reading theory. The debate boiled down to the question of whether the superior word recognition efficiency was due to skill at bottom-up processes of spelling-to-sound decoding and direct visual recognition or whether it was due to superior top-down processes of expectancy generation and contextual prediction. Evidence is now strongly on the side of the former view. Poorer readers are markedly inferior at the bottom-up skills of word recognition but appear to be relatively competent at using top-down processes to facilitate decoding. Several reviews and summaries of the large literature on this issue have been published (see Gough, 1983; Perfetti, 1985; Stanovich, 1980, 1984, 1986, 1988). The consensus in this research area has recently been bolstered by developments in two additional areas: the study of eye movements and advances in computer simulation and artificial intelligence.

What Eye Movement Studies Reveal About Word Recognition

Research is consistent in indicating that the vast majority of content words in text receive a direct visual fixation (Balota, Pollatsek, & Rayner, 1985; Ehrlich & Rayner, 1981; Just & Carpenter, 1980, 1987; Perfetti, 1985). Short function words and highly predictable words are more likely to be skipped, but even the majority of these are fixated. In short, the sampling of visual information in reading, as indicated by fixation points, is relatively dense. Readers do not engage in the wholesale skipping of words that is sometimes implied in presentations of top-down models.

The study of the processing of visual information within a fixation has indicated that the visual array is rather completely processed during each fixation. It appears that visual features are not minimally sampled in order to confirm "hypotheses" but instead are rather exhaustively processed, even when the word is highly predictable (Balota et al., 1985; Ehrlich & Rayner, 1981; McConkie & Zola, 1981; Zola, 1984). An important study by Rayner and Bertera (1979) demonstrated that efficient reading is dependent on a detailed sampling of the visual information in the text. Using the contingent display possibilities afforded by modern computer technology, they had subjects read text while a computer masked one letter in their foveal vision on each fixation. The loss of this *single letter* reduced reading speed by 50%. Clearly, efficient reading depended on the visual information contained in each of the individual letters that were within foveal vision.

In summary, research indicates that (a) sampling of the text during reading, as indicated by fixation points, is relatively dense; (b) visual feature extraction during a fixation is relatively complete. These research findings indicate that the implication of some of the early top-down models of reading, that the visual information in text is almost of secondary importance (e.g., "it is clear that the better reader barely looks at the individual words on the page." Smith, 1973, p.190), is quite patently false. Nevertheless, a critical point emphasized in the early top-down writings—that efficient reading occurs when the reader expends processing capacity on higher level comprehension processes rather than on word recognition—is shared by bottom-up models and appears to be a valid insight. We now know, however, *how* this occurs: via efficient decoding processes rather than by using context to speed word recognition. Where the top-down models went wrong was in their tendency to conflate the use of the visual features in the text with the cognitive resources necessary to process those features. It is not that the good reader relies less on visual information, but that the visual analysis mechanisms of the good reader use less capacity. Good readers are efficient processors in every sense: They completely sample the visual array *and* use fewer resources to do so.

Reading and Models in Cognitive Science

Models of word recognition in reading have always been heavily influenced by theoretical developments within the interrelated fields of cognitive science. For example, early models of word recognition were heavily influenced by the analysis-by-synthesis models of speech perception and by the highly interactive computer models that were popular in artificial intelligence work. For example, Rumelhart's (1977) interactive model has had considerable influence on reading theory. Drawing on work in artificial intelligence during the preceding 10 years (the Hearsay speech recognition system, for example), his model emphasized top-down influences and hypothesis testing at every level of the processing hierarchy, including the lexical and letter levels.

The problem for reading theory—and especially for top-down theories that rested their case primarily on the then-current consensus in AI research—is that the worm has turned. The current vogue is not top-down, hypothesis-testing models, but parallel-architecture connectionist models (McClelland & Rumelhart, 1986; Rumelhart & McClelland, 1986; Schneider, 1987; Tanenhaus, Dell, & Carlson, 1988) that have a heavy bottom-up emphasis. There are no explicit "hypotheses" in such models at all. Learning and recognition do not occur via hypothesis testing but by the updating of connection strengths in the network and by a settling of activation after a stimulus has been presented. Solutions to problems emerge from patterns of activation generated by incoming information and previously established connections; they are not expressed as "hypotheses" put forth by an executive processor. One such model, NETtalk (Sejnowski & Rosenberg, 1986, 1987), learns to read by being exposed to pairings of letter strings and phoneme strings. The simulation contains no spelling-to sound "rules," makes no use of contextual information beyond learned letter constraints within a seven-space window, and has no executive processors that make hypotheses or generate expectancies. The network learns simply by readjusting connections between units after being exposed to input.

A similar example occurs in the psychology of perception. Some of the first top-down models of the reading process (e.g., Smith, 1971) were influenced by developments in what has been termed the *New Look* in perceptual research, a theoretical framework that emphasized the influence of context and expectancies on perception. However, the current vogue in the study of perception is completely antithetical to the New Look framework. The popular concept is now modularity (Fodor, 1983, 1985; Seidenberg, 1985; Tanenhaus, Dell, & Carlson, 1988; Tanenhaus & Lucas, 1987)—the idea that basic perceptual processes are "informationally encapsulated": that they are not driven by higher level hypotheses and real-world knowledge.

Both of these examples indicate that current models in artificial intelligence and cognitive science provide no sustenance at all for top-down models of word recognition in reading. Nevertheless, the purpose of highlighting these examples is not to argue for one class of model over another. Considering them does serve as a caution, however, that theories of reading should probably always rest more on empirical facts about the process of reading than on the latest theoretical fashion in cognitive psychology and artificial intelligence.

Phonological Sensitivity and Early Reading Acquisition

One exciting outcome of research in reading during the last 20 years is that researchers have isolated a process that is a major determinant of the early acquisition of reading skill and one of the keys to the prevention of reading disability. Whereas there are many correlates of the ease of initial reading acquisition, a large number of studies have demonstrated that phonological abilities stand out as the most potent specific predictor (Juel, Griffith, & Gough, 1986; Liberman, 1982; Share, Jorm, Maclean, & Matthews, 1984; Stanovich, in preparation; Stanovich, Cunningham, & Cramer, 1984; Tunmer & Nesdale, 1985; Wagner & Torgesen, 1987). Additional research has supported the existence of a causal link running from phonological abilities to reading skill (Bradley & Bryant, 1983, 1985; Fox & Routh, 1984; Lundberg, 1987; Maclean, Bryant, & Bradley, 1987; Olofsson & Lundberg, 1985; Perfetti, Beck, Bell, & Hughes, 1987; Torneus, 1984; Treiman & Baron, 1983; Vellutino & Scanlon, 1987).

Research on phonological processing has recently moved from merely documenting the causal connection with reading and has begun to address more specific questions. For example, researchers are currently linking experiences prior to school entry—such as experience with nursery rhymes—to the development of phonological sensitivity (e.g., Maclean, Bryant, & Bradley, 1987) and are speculating on how to model phonological process training on what is known about syllable structure (Treiman, 1988).

Researchers are largely agreed on why phonological abilities are so important in the early stages of reading. To enable the powerful self-teaching mechanism inherent in an alphabetic orthography (Gough & Hillinger, 1980; Jorm & Share, 1983), the child must learn the general principle that spelling corresponds to sound and then must learn sufficient examples of spelling-to-sound correspondences to support efficient decoding. To utilize the alphabetic principle, the child must adopt an analytic attitude toward both written words and the spoken words they represent; that is, the child must discover and exploit the fact that the mapping takes place at the level of letters and phonemes. Segmenting visual words into letter units is well within the perceptual capabilities of every nonimpaired school-age child, but the development of the tendency to exhaustively process all of the visual detail in words (particularly the sequence of interior letters) may be difficult for some children (Frith, 1985; Gough & Hillinger, 1980). However, an even greater source of individual differences resides in the sounds to which the letters map. Segmenting speech at the level of phonemes is notoriously difficult for young children (Bruce, 1964; Calfee, Chapman, & Venezky, 1972; Lewkowitz, 1980; Liberman, Shankweiler, Fischer, & Carter, 1974). Phonological sensitivity tasks relate to reading acquisition because they predict the ease or difficulty with which a child will learn to segment spoken words at levels below the syllable.

In a seminal and provocative paper, Gough and Hillinger (1980) asserted that we should consider learning to read to be an "unnatural act." This characterization followed from their two-stage model of the earliest stages of reading acquisition. Gough and Hillinger posited that the first stage was one of paired-associate learning utilizing minimal cues; that is, children initially begin to associate spoken words with particularly salient cues in the visual array. For example, "dog" might be associated with the initial letter, "hole in the middle," or "tail at the end"; in short, visual distinctiveness is a key factor at this stage. Gough and Hillinger hypothesized that this paired-associate procedures works well for the first few items but quickly breaks down because of the difficulty in finding a unique distinctive visual cue for each new word encountered. The paired-associate procedure based on distinctive visual cues is not generative (i.e., it is of no help in recognizing unfamiliar words), becomes more difficult as the number of items to be learned increases, and inevitably must be discarded. Normal progress in reading dictates that the child make the transition to the next stage of acquisition, that characterized by fully analytic processing—where words are fully segmented, both visually and phonologically. Unlike the first stage, where the child acquires words naturally and often spontaneously, the fully analytic stage (what Gough and Hillinger term the cipher stage) is not natural and almost always requires intervention by an outsider (teacher, parent, sibling) who gives cues to support analytic processing and/or presents words in ways that foster such processing. Thus, a basic discontinuity in word acquisition is proposed.

Subsequent research has tended to support Gough and Hillinger's (1980) conceptualization. Byrne (1988) has presented evidence indicating that fully analytic processing of words is not the natural processing set of preliterate 4-year-old children. He demonstrated that learning to discriminate FAT from BAT did not enable the children to discriminate FUN from BUN with greater than chance accuracy. Their performance illustrates what would be expected from a child who had not passed beyond Gough and Hillinger's (1980) paired-associate stage.

Young preliterate children often spontaneously learn to name words on television, advertisements, cereal boxes, and billboards. This particular phenomenon has frequently spawned characterizations of reading diametrically opposed to that of Gough and Hillinger (1980), characterizations that view learning to read as a "natural" act, directly analogous to learning spoken language. (To consider other evidence, we put aside the obvious objection that many children require extensive adult intervention in order to acquire reading skills and that some children fail in the acquisition process despite herculean efforts on the part of teachers and parents—a situation vastly unlike that of spoken language.) However, the results of a study by Masonheimer, Drum, and Ehri, (1984) indicate that this type of word learning is like that of Gough and Hillinger's paired-associate stage, and that later stages of beginning reading are not continuous extensions of this type of spontaneous word learning.

Masonheimer et al. studied 3- to 5-year-old children who were environmental print "experts": those who, based on a preliminary survey, could identify at least 8 of the 10 most commonly known environmental labels (McDonald's, K Mart, Crayola Crayons, The Incredible Hulk, Pepsi, etc.) Most of these children ($N = 96$) had virtually no ability to read words outside of the set of labels that they knew. Because a few children ($N = 6$) read all the test words, the distribution of reading ability was markedly bimodal and "was not distributed continuously as one might expect if it were true that the accumulation of environmental print experience leads children into word reading" (Masonheimer et al., 1984, p. 268). The 96 prereaders were completely unable to report anything wrong with labels that had letter alterations (e.g., Xepsi). In addition, the ability to read the labels dropped dramatically when the logos were removed, indicating that the children were "reading the environment" rather than the print. However, Masonheimer et al. are careful to point out that their conclusions refer directly only to the information-processing characteristics of two adjacent stages in early reading acquisition, and to one particular experiential variable: knowledge of the labels of common environmental signs. Their results should not be read as arguing against the general efficacy of prereading experiences.

Gough, Juel, and Griffith (in preparation) report several intriguing tests of the nature of the paired-associate learning-by-selective-cues stage in early reading acquisition. They had a group of 5-year-olds learn sets of words written on flashcards to a criterion of two successive correct trials. One of the flashcards was deliberately marred by a thumbprint on the corner. During the test phase, when the children were shown the thumbprinted word on a clean card, less than half could identify the word. Almost all of them, however, produced the word when shown a thumbprinted card with no word on it. As an additional test, children were shown a thumbprinted card containing a word other than the one that accompanied it during training. Almost all children named the word that accompanied the thumbprint during training, rather than the word that was presently on the card.

The results of Gough et al. (in preparation) clearly converge nicely with those of Byrne (1988) and Masonheimer et al. (1984) and are consistent with the idea that learning fully analytic spelling-to-sound correspondences is an "unnatural" act for young children. Results from an important classroom study also support this conclusion. Seymour and Elder (1986) studied a class of new entrants into a Scottish primary school where the emphasis was on the development of a "sight vocabulary" via whole-word methods, and no phonics training occurred during the first two terms. An examination of their subsequently developed word recognition skills indicated that they were not productive: The children could not recognize unfamiliar words that they had not been taught. Unlike the case of children who have developed some spelling-to-sound decoding skills (see Gough et al., in preparation), the error responses of these children were drawn only from the set of words that they had been taught. The characteristics of their discrimination performance were similar to those that would be expected from Gough and Hillinger's selective cue learning. Bertelson (1986) has argued that the most important implication of the results of Seymour and Elder (1986) is "that there is no continuity between early logographic reading and the direct orthographic reading of the skilled adult, where typically all the available orthographic evidence is taken into account" (p.19).

Controversies About Decoding and the Regularity of English

How does the recent research on word recognition and early reading acquisition that is previously described relate to some of the oldest controversies in reading instruction? First, there is obviously no contradiction between the conclusions in Chall's classic work (1967; and update, 1983) and the basic research outlined here. Word recognition is a critical component of the reading process; individual differences in this component account for substantial variance at all levels of reading; to become fluent, all readers must have stored in memory spelling–sound correspondences that can function as efficient recognition mechanisms. However phonics advocates must resist the temptation to uncritically view the results of research like that outlined earlier as providing justification for their particular methods of instruction. For example, it could well be the case that language experience or whole-language approaches might provide the child with the optimum amount of exposure for the induction of spelling–sound correspondences (although research does seem to indicate that the explicit teaching of specific letter–sound correspondences does facilitate reading acquisition; Anderson, Hiebert, Scott, & Wilkinson, 1985; Chall, 1983; Share & Jorm, 1987; Williams, 1985). Similarly, the conclusion that all readers must acquire functional spelling-to-sound knowledge is not the same as saying that all children must learn phonics rules. The child needs to associate orthographic with phonological patterns in memory, but this need not be done by the learning of rules. Somewhat of an existence proof for this point is contained in the previously mentioned work of Sejnowski and Rosenberg (1986, 1987). They have designed a connectionist computer model that learns to read English words after being exposed to a large number of pairings of letter strings and phoneme strings. This parallel model contains no "rules" at all but simply learns by updating—based on new input—the strengths of connections between elements.

Likewise, however, opponents of phonics as an instructional method have also on occasion jumped too hastily from basic research models of reading and theoretical work in other disciplines to instructional conclusions. One example, the overgeneralization of the early top-down cognitive models, was discussed previously. Another example that recurs in the writings of those hostile to phonics is a tendency to overemphasize the irregularity of the spelling–sound correspondences in English. It is a common ploy in such writings to litter the text with examples of correspondences that are ambiguous in reading (e.g., *ea* can be pronounced as in *teach, bread, great,* or *create*) or spelling (e.g., /f/ can be written as in *frog, phone, tough, stuff,* etc.). Although it is true that English is one of the most irregular of the alphabetic orthographies, it is misleading to imply that the regularities that are present are not sufficient to support a substantial role in reading acquisition for spelling–sound correspondences.

First, it is important to distinguish the use of spelling–sound correspondences in reading from the use of sound–spelling correspondences for spelling (Berndt, Reggia, & Mitchum, 1987; Haas, 1970; Henderson, 1982). The distinction is important because the spelling–sound correspondences of English are more regular than the sound–spelling correspondences (Cronnell, 1978; Henderson, 1982; Henderson & Chard, 1980). For example, whereas the phoneme /f/ can map to f, ff, ph, or gh, the letter f regularly maps to /f/, with the exception of the high frequency *of*. Thus, an emphasis on spelling irregularities is somewhat misleading. Most of the consonants of English, like f, have regular reading correspondences (Berndt et al., 1987; Cronnell, 1973; Venezky, 1970). The most notorious irregularities virtually all concern vowels. This fact interacts with the tacit assumption in many critiques that if the correspondences do not yield a unique pronunciation, then they are useless. To the contrary, partially diagnostic cues can indeed be useful. The c-ns-n-nts -r- th- m-st -mp-rt-nt c-mp-n-nts -f w-rds -nd -t -s p-ss-bl- t- r—d w-th—t th-m provided you have some context. Thus, even if a child could only decode the regular consonants, this would be a considerable aid in early reading.

Other critiques ignore the fact that the English orthography is considerably more regular if the positions of letters and/or if units larger than the letter are taken into account. George Bernard Shaw's famous example, that *ghoti* could be pronounced the same as *fish* (gh as in *tough*, o as in *women*, ti as in *nation*), ignores the position-specific constraints of the orthography: gh is never pronounced /f/ when word initial and ti never as /s/ when word final. Furthermore, all analyses of the orthography indicate that there is considerable regularity when groups of letters are considered (Treiman, 1988), particularly when a medical vowel is combined with the following consonant or consonant cluster.

Treiman (in preparation) has imaginatively linked the VC(C) regularity of English orthography with experimental demonstrations of the psychological reality of intrasyllabic speech units (onset and rime—units intermediate between the phoneme and syllable; see Treiman, 1986) for young children. Treiman has found that young children's segmentation skills pass through an intermediate stage where they are much more sensitive to the onset/rime distinction than to the phoneme distinction. She has proposed that at certain points in reading acquisition working with onset/rime (and corresponding C and VC(C) structures) might be optimal because these intrasyllabic units are more generative than syllables but do not require the phonemic segmentation ability that may not be developed in some children until later reading stages where more experience with reading and spelling has been acquired (see Ehri, 1984, 1987; Ehri, Wilce, & Taylor, 1987). The larger point reinforced by Treiman's work is that there may be more ways to exploit the regularities that exist in the English orthography than is commonly recognized (see also, Bryant & Goswami, 1987; Goswami, 1986; Goswami & Bryant, 1988). Treiman's suggestions neatly bypass the biggest problem with the orthography—irregularities at the individual letter level—because they necessitate working with larger units that are considerably more regular.

SUMMARY AND CONCLUSIONS

In summary, research on reading acquisition has recently entered a new era. The top-down versus bottom-up controversy, as it applied to issues surrounding word recognition, has been resolved, at least at a global level. Researchers have turned their attention to microanalyses of word learning, particularly during the very earliest stages of reading acquisition. There is a broad consensus on the importance of phonological sensitivity at this very early stage. Attention has now turned to more specific issues such as identifying the developmental precursors of phonological sensitivity (Maclean et al., 1987) and determining how a child's particular level of phonological sensitivity can be best exploited in reading instruction (Treiman, in preparation). The increasing specificity of the questions being asked are a sure sign of scientific progress. The prognosis for future scientific advance in the area of reading and reading acquisition remains optimistic.

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