Cognitive Processes in Early Reading Development: Accommodating Individual Differences into a Model of Acquisition

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Share, D. L., & Stanovich, K. E. (1995). Cognitive processes in early reading development: Accommodating individual differences into a model of acquisition. Issues in Education: Contributions from Educational Psychology, 1, 1-57.

Abstract

In this target article, we present a model of early reading acquisition that represents an explicit attempt to account for data on individual differences as well as developmental patterns. We survey the literature on individual differences in reading acquisition with a view to evaluating some of the loci of individual differences that have been the focus of the most intense investigation. We then present the self-teaching hypothesis in which it is proposed that phonological recoding functions as a self-teaching mechanism enabling the learner to independently acquire an autonomous orthographic lexicon. We address the issue of whether the model can account for the extent data on the cognitive correlates of individual differences in reading acquisition. Finally, we address the instructional implications of the literature that we have surveyed.

In the past decade, important progress has been made in understanding the earliest stages of reading acquisition (Brady & Shankweiler, 1991; Ehri, 1991, 1992; Goswami, 1993; Gough, Ehri, & Treiman, 1992; Juel, 1994; Rack, Hulme, Snowling, & Wightman, 1994; Share, in press). Likewise, important progress has been made in understanding individual differences in the cognitive subprocesses that lead to varying rates of reading acquisition (Fletcher et al., 1994; Olson, Forsberg, Wise, & Rack, 1994; Share, in press; Stanovich, 1986b, 1991b, 1994a; Stanovich & Siegel, 1994; Wagner, Torgesen, & Rashotte, 1994). However, one curious aspect of our literature is that what is known about individual differences in reading is not always well integrated with models of the acquisition process. This has allowed speculations about the causes of individual differences in reading acquisition to be unconstrained by a specified model of the reading acquisition process itself. Studies of individual differences have encovered a plethora of information processing tasks on which the performance of skilled and less-skilled readers differ. For example, Byrne (1992) has stated that

> One thing that could be said about this rather long list of possible causes of reading problems is that it is needed, because reading is multifaceted and because there are many kinds of problems. This is a standard line of reasoning....[but] given the uncertainty about a typology of reading difficulties and given that fewer explanatory constructs than reading problems may be needed, there may well be too much explanatory power for the job at hand. A way is needed to constrain the power. Economy of explanation characterizes the scientific endeavor and should be invoked in this branch of science. It is possible that the explanatory power available could be constrained if it were required that each of the many hypothetical causes of reading problems fits a well-worked-out account of the acquisition procedure" (p. 3).

However, few papers in the reading literature have attempted the type of integration that Byrne recommends: fitting the empirical research on individual differences with a model of the acquisition process. Most investigators have either focused on developing generic developmental models of stages that all children traverse or they have concentrated on looking for patterns of correlations in studies of individual differences. In the present target article we hope to achieve more integration than is typical by explicitly attempting to mesh the literature on individual differences with one of the more comprehensive models of early reading

acquisition (Share, in press). We hope, by attempting such an integration, to increase the explanatory coherence (Thagard, 1992) of current models of reading acquisition.

Our target article is organized into three parts. First, we survey the literature on individual differences in reading acquisition with a view to evaluating some of the "classic" loci of individual differences that have been the focus of the most intense investigation. In the next section, we give a precis of a self-teaching model of early reading acquisition (Jorm & Share, 1983; Share, in press) which attempts to encompass most of the extant literature on early reading acquisition and we examine whether this model can accommodate the empirical findings on individual differences discussed in the first section. Finally, we address the instructional implications of the literature that we have surveyed. Reading education is currently divided by instructional philosophies that are drastically opposed in their assumptions about the psychology of early reading acquisition. We argue that the empirical literature on individual differences and models of early reading acquisition now displays enough convergence that we can derive some conclusions regarding disputes in the so-called "reading wars" (see Chall, 1989, 1992; McKenna, Robinson, & Miller, 1990; McKenna, Stahl, & Reinking, 1994; Stanovich, 1990a, 1994).

I. Individual Differences in the Cognitive Subprocesses of Reading

In this part of our review, we employ Gough's (Gough & Tunmer, 1986; Hoover & Gough, 1990) Simple View of reading as a rationale for our emphasis. Gough has demonstrated that, empirically, we can get quite surprisingly far by considering reading to be the product of decoding and listening comprehension. Using this simple demarcation, we focus on the cognitive aspects of the acquisition of word recognition skill because our review is centered around early reading acquisition where the development of word recognition skill is the task of overwhelming importance. In short, word recognition is the foundational process of early reading acquisition. Obviously, to emphasize the centrality of word recognition is not to deny that the ultimate purpose of reading is comprehension. Adequate word recognition ability clearly does not guarantee good comprehension. Nevertheless, while it is possible for adequate word recognition skill to be accompanied by poor comprehension abilities, the converse virtually never occurs. There is no known teaching method that has resulted in good reading comprehension without simultaneously leading to the development of at least adequate word recognition ability. Furthermore, an overwhelming amount of evidence indicates that the proximal impediment to reading in at-risk and reading-disabled children is difficulty recognizing words (e.g., Adams & Bruck, 1993; Bruck, 1988, 1990; Morrison, 1991;

Perfetti, 1985; Share, in press; Siegel, 1993; Stanovich, 1986b, 1992; Vellutino & Scanlon, 1987).

In fact, word recognition is so central to the total reading process that it can serve as a proxy diagnostic for instructional methods. Since word recognition skill will be a by-product of any successful approach to developing reading ability--whether or not the approach specifically targets word recognition--lack of skill at recognizing words is always a reasonable predictor of difficulties in developing reading comprehension ability. Finally, although it is true that as the general level of reading ability increases, the proportion of variance in reading ability accounted for by word recognition decreases and the proportion of variance in reading linked to listening comprehension abilities increases (Chall, 1983; Curtis, 1980; Daneman & Carpenter, 1980; Stanovich, Cunningham, & Feeman, 1984a; Sticht & James, 1984), even among adults, word recognition efficiency accounts for a substantial amount of variance in reading ability (Briggs & Underwood, 1982; Butler & Haines, 1979; Cunningham, Stanovich, & Wilson, 1990; Frederiksen, 1978; Liberman, Rubin, Duques, & Carlisle, 1985; Perfetti, 1985; Read & Ruyter, 1985; Scarborough, 1984) and it accounts for a sizeable proportion of reading comprehension variance even after listening comprehension ability has been partialled out (Cunningham et al., 1990). Thus, our review will focus on cognitive subprocesses that underly word recognition ability. In the studies to be reviewed, skilled and less skilled readers were usually defined on the basis of performance on a standardized word recognition test. However, in virtually all cases there were also significant difference between the subject groups in reading comprehension ability.

The Use of Context as a Locus of Individual Differences in Word Recognition

Advocates of top-down models of reading have repeatedly argued that skilled readers rely less on graphic cues than less-skilled readers. Smith's (1971, 1973, 1975) well-known hypothesis is that, being sensitive to the redundancy afforded by sentences, good readers develop hypotheses about upcoming words and are then able to confirm the identity of a word by sampling only a few features in the visual array. Good readers should process words faster since their use of redundancy lightens the load on their stimulus-analysis mechanisms. This claim--that variation in the use of context in part determines reading efficiency, and that contextual effects are more implicated in the performance of better readers--has often been made in the reading literature:

> Skill in reading involves not greater precision, but more accurate first guesses based on better sampling techniques, greater control over language

> structure, broadened experiences and increased conceptual development. (Goodman, 1976, p. 504)
>
> Guessing in the way I have described it is not just a preferred strategy for beginners and fluent readers alike; it is the most efficient manner in which to read and learn to read. (Smith, 1979, p. 67)
>
> 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. (Smith, 1971, p. 221)
>
> Less often the possibility is considered that use of context makes better readers. (Smith, 1982, p. 230)

These claims still serve as foundational assumptions about reading acquisition in the whole language literature. Before reviewing the research evidence, however, it is imperative to highlight the issue of levels of processing, because failure to emphasize this principle has confused the literature on the effects of context for so long. For example, there is considerable evidence that better readers are better able to use contextual information to facilitate their comprehension processes (Baker & Brown, 1984; Stanovich & Cunningham, 1991). However, research in recent years has shown that hypotheses about context use as an individual difference variable were inappropriately generalized from the comprehension level to the word recognition level. Our review, for the reasons outlined above, will focus on the issue of individual differences in context effects at the word recognition level.

Studies employing a wide variety of paradigms have failed to find that good readers rely more on context for word recognition than poorer readers. Many discrete-trial reaction-time studies of context effects have been conducted to investigate this question. Most of these studies have used priming paradigms where a context (sometimes a word, sometimes a sentence, and sometimes several sentences or paragraphs) precedes a target word to which the subject must make a naming or lexical decision response. Although this paradigm does not completely isolate the word-recognition level of processing (Seidenberg, Waters, Sanders, & Langer, 1984; West & Stanovich, 1982, 1986), it does so more than most other methodologies that have been used. The finding has consistently been that not only do the poorer readers in these studies use context, but they often show somewhat larger contextual effects than do the better readers (Becker, 1985; Ben-Dror, Pollatsek, & Scarpati, 1991; Briggs, Austin, & Underwood, 1984; Bruck, 1988, 1990; Perfetti, 1985; Pring & Snowling, 1986; Schvaneveldt, Ackerman, & Semlear, 1977; Schwantes, 1985, 1991;

Simpson & Foster, 1986; Simpson, Lorsbach, & Whitehouse, 1983; Stanovich, 1980, 1986b; Stanovich, et al., 1985; Stanovich, West, & Feeman, 1981; West & Stanovich, 1978; West et al., 1983).

Because the reaction-time paradigms that more specifically isolate the pre-lexical from the post-lexical level of processing (Seidenberg, Waters, Sanders, & Langer, 1984; West & Stanovich, 1982, 1986) have generally not been applied to children at the earliest stages of reading acquisition, researchers have relied largely on analyses of oral reading errors to make inferences about the use of context by these children. This is problematic because, as has often been pointed out (e.g., Kibby, 1979; Leu, 1982; Wixson, 1979), an oral reading error can occur for a variety of reasons. Many oral reading errors reflect comprehension processes as well as word recognition processes. This is certainly the case for self-corrections, for example, which clearly implicate comprehension processes occurring well after lexical access. Creating indices of contextual processing based on measures such as self-corrections seriously confounds levels of processing. For example, both verbal efficiency theory (Perfetti, 1985) and the interactive-compensatory model (Stanovich, 1980, 1984) posit that skilled readers normally rely less on context to identify words than less skilled readers. However, neither theory denies that the better reader may have superior comprehension skill in addition to their superior decoding skills.

Nevertheless, analyses of initial substitution errors (first errors--before self correction--in which one phoneme is substituted for another) have been used to throw light on the issue of the facilitation of word recognition by context, and it is likely that these errors do partially implicate processes operating at the word-recognition level. Fortunately, the results of oral reading error studies largely converge with those of reaction-time studies. When skilled and less-skilled readers are reading materials of comparable difficulty (an important control, see Stanovich, 1986b) the reliance on contextual information relative to graphic information is just as great--in many cases greater--for the less-skilled readers (Allington & Fleming, 1978; Biemiller, 1970, 1979; Harding, 1984; Juel, 1980; Lesgold, Resnick, & Hammond, 1985; Leu, DeGroff, & Simons, 1986; Nicholson & Hill, 1985; Nicholson, Lillas, & Rzoska, 1988; Perfetti & Roth, 1981; Richardson, DiBenedetto, & Adler, 1982; Simons & Leu, 1987; Whaley & Kibby, 1981). The results from studies of text disruption effects, timed text reading, and a variety of other paradigms also display a similar pattern (Allington & Strange, 1977; Biemiller, 1977-1978; Ehrlich, 1981; Lovett, 1986; Nicholson, 1991; Schwartz & Stanovich, 1981; Stanovich, Cunningham & Feeman, 1984b; Strange, 1979). Thus, the results from a variety of different paradigms indicate the effects of background knowledge and contextual information attenuate as the

efficiency of word recognition processes increases. Efficient word recognition has the properties of autonomous, or modular, processing as defined in recent work in cognitive science (e.g., Fodor, 1983; Forster, 1979; Humphreys, 1985; Perfetti & McCutchen, 1987; Stanovich, 1990b; Sternberg, 1985)--the properties of speed, low capacity usage, and obligatory execution, free from interference by other ongoing operations. It is word recognition having these properties that is the key to the rapid acquisition of reading skill.

Why, if this evidence is so consistent, has the idea that poor readers fail at a "psycholinguistic guessing game" (Goodman, 1976) remained so popular among some reading researchers and practitioners? One reason is the failure to distinguish between the comprehension level and the word recognition level, as discussed above. Another reason is the failure to take into account the interaction between the difficulty of materials and reader skill that leads to a misinterpretation of the frequent reports from teachers of children who "just plod through and don't use context". These reports usually turn out to be spurious, not because they are untrue, but because the common interpretation--that the children are plodding (recognizing words slowly) <u>because</u> they are not using context--is false. The research reviewed above leads to just the opposite conclusion: the children are not using context because they are plodding: decoding inefficiently. Given texts of equal functional difficulty, good readers would also "plod" (see Biemiller, 1979; Perfetti, Goldman & Hogaboam, 1979; Stanovich et al., 1984b).

Perhaps another reason for the popularity of the context use hypothesis as an explanation of individual differences in reading ability is that--as mentioned above--there has been a tendency in the reading literature to obscure the distinction between the importance of a processing mechanism as a determinant of a general developmental sequence and the importance of the mechanism as a determinant of individual differences in acquisition. McCall's (1981) classic paper warning developmental psychologists not to obscure the difference has largely gone unheeded by reading researchers. It is possible for a processing mechanism to be critically involved in developmental change yet not necessary to be a critical source of individual differences. However, it still is not generally recognized in the reading literature that demonstrating the importance of a processing mechanism in a general developmental model does not necessarily mean that the processing mechanism is a source of individual differences. Thus, the error of the top-down theorists was not in emphasizing that context use occurs in reading, but in generalizing it as a mechanism that explained individual differences.

Much empirical evidence indicates considerable context use by first-grade children, and models of first-grade reading acquisition often include at least one stage defined in part by context use. For example, Biemiller's (1970) proposed early reading stages include an initial stage of contextual dependency, a stage of increasing attention to graphic processing, and a stage where the integration of both graphic and contextual cues occurs. These stages defined in part by ways of using context may indeed be real, but they may misleadingly serve to suggest that context use is a source of individual differences. Compared to other prerequisite skills--such as phonological sensitivity, for example--the variability in the ability to use context to facilitate word recognition may be so low that it is not a major determinant of individual differences in reading acquisition. The very ubiquity of contextual facilitation--the thing that has led some theorists to single it out as a mechanism for generating ability differences--is precisely the factor that prevents its association with individual differences.

Processes of Spelling-Sound Conversion

In contrast to the research on context effects--which leads to negative conclusions--studies of other processing loci have uncovered strong evidence of linkage with individual differences in reading ability. We know unequivocally that less-skilled readers have difficulty turning spellings into sounds. This processing deficit is revealed by the most reliable indicator of a reading disability: difficulty in rapidly and accurately reading pseudowords (Bruck, 1988, 1990; Castles & Coltheart, 1993; Jorm & Share, 1983; Manis, Custodio, & Szeszulski, 1993; Olson et al., 1994; Perfetti, 1985; Perfetti & Hogaboam, 1975; Rack, Snowling, & Olson, 1992; Siegel, 1989; Siegel & Ryan, 1988; Stanovich, Nathan, & Zolman, 1988; Stanovich & Siegel, 1994). Tasks that do not involve pseudoword reading but that likewise implicate the conversion of spelling into sounds also display large differences between skilled and less-skilled readers (Barron, 1981; Hogaboam & Perfetti, 1978; Jorm & Share, 1983; Olson et al., 1994; Siegel & Ryan, 1988; Snowling, 1980; Stanovich & Siegel, 1994). This relationship is so strong that it deserves to be identified as one, if not the defining feature of reading disability at a fairly surface or proximal level of processing.

There is currently considerable controversy surrounding the issue of which type of information processing model gives the proper theoretical account of the process of turning spellings into sounds. For many years, research in this area was dominated by versions of so-called dual-route models (Coltheart, 1978; Forster & Chambers, 1973; Meyer, Schvaneveldt, & Ruddy, 1974). This class of model posits two alternate recognition pathways to the lexicon: a direct visual access route that does not involve

phonological mediation and indirect route through phonology that utilizes stored spelling-to-sound correspondences. The size of the spelling-to-sound correspondences that make up the phonological route differ from model to model. Versions of dual-route models also differ in assumptions about the various speeds of the two access mechanisms involved and how conflicting information is resolved. Excellent discussions of the many variants of dual-route models are contained in several recent publications (see Carr & Pollatsek, 1985; Henderson, 1982, 1985; Humphreys & Evett, 1985; Patterson & Coltheart, 1987; Patterson & Morton, 1985; Rayner & Pollatsek, 1989), and a contemporary implementation of such a model is described in Coltheart, Curtis, Atkins, and Haller (1993). However, the questions about the nature of spelling-sound conversion have recently been in flux due to the increasing popularity of models based on distributed, connectionist networks (Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990). Regardless of how these issues are adjudicated at the theoretical level, the basic finding will remain: problems with spelling-sound conversion is the defining feature of reading disability.

Phonological Processing

Regardless of how one conceptualizes the process of spelling-sound conversion, the deficits in the spelling-sound conversion process that research has identified must still be conceived as fairly proximal--that is, close to the phenotypic performance pattern that defines poor reading: difficulty in recognizing words. Researchers have naturally conducted inquiries at a more distal level of analysis: into what underlying process and cognitive structure differences might be associated with difficulties in spelling-sound conversion. It has not been difficult to find associations in the phonological domain. This is why phonological processing problems have often been termed the core deficit that characterizes developmental dyslexia (Jorm & Share, 1983; Share, in press; Stanovich, 1988)

It is now well established that dyslexic children display deficits in various aspects of basic phonological processing. For example, studies of the categorical perception of stop consonants have consistently demonstrated less "sharpness" in discrimination (Brandt & Rosen, 1980; Godfrey, Syrdal-Lasky, Millay & Knox, 1981; Hurford & Sanders, 1990; Hurford et al., 1992; Lieberman, Meskill, Chatillon, & Schupack, 1985; Manis, McBride, Seidenberg, Doi, & Custodio, 1993; Read, 1989; Steffens et al., 1992; Werker & Tees, 1987). Furthermore, speech perception deficits that are present very early in development (de Weirdt, 1988; Mann, 1991) suggest that these differences are not merely a consequence of reading difficulties.

The oral repetition of spoken words and pseudowords reveals strong and reliable differences between disabled and control readers (Brady, Poggie & Rapala, 1989; Brady, Shankweiler & Mann, 1983; Gathercole & Baddeley, 1993; Gathercole, Willis, & Baddeley, 1991; Snowling, 1981; Snowling, Goulandris, Bowlby & Howell, 1986; Taylor, Lean & Schwartz, 1989) which again are longitudinally predictive (Gathercole, Emslie & Baddeley, 1990 cited in Baddeley, 1992). Disabled readers make errors and are slower to name continuous lists of numbers, letters, pictured objects and colors (Bowers & Swanson, 1991; Denckla & Rudel, 1976; Denckla, Rudel & Broman, 1981; Rudel, Denckla & Broman 1981; Felton, Naylor & Wood, 1990; Lovett, 1987; Murphy, Pollatsek & Well, 1988; Spring, 1976; Spring & Davis, 1988; Torgesen & Houck, 1980; Wolf, 1991; Wolff, Cohen & Drake, 1984; Wolff, Michel & Ovrut, 1990a). This serial naming deficit does not appear to be simply the result of poor reading as this relationship has been observed in longitudinal studies assessing naming in kindergarten (Ellis & Large, 1987; Felton & Brown, 1990; Share et al., 1984; Torgesen, Wagner, & Rashotte, 1994; Wolf, Bally & Morris, 1986; Wolf & Goodglass, 1986). The deficit also appears to be independent of knowledge of word meanings. Group differences remain even when good and poor readers are matched on receptive vocabulary (Jorm et al., 1986; Wolf et al, 1986; Wolf & Goodglass, 1986). When the same items that cause difficulties are to be identified on the basis of spoken name or must be classified into semantic categories, disabled readers perform as well as controls (Katz, 1986; Murphy et al, 1988; Snowling, van Wagtendonk & Stafford, 1988; Wolf & Goodglass, 1986).

Studies assessing discrete-trial name retrieval using items of increasing vocabulary difficulty, such as the Boston Naming Test, also report consistently higher error rates among poor readers (Catts, 1986; Katz, 1986; Rubin, Zimmerman & Katz, 1989; Snowling et al, 1988; Scarborough, 1989; Wolf & Goodglass, 1986, but see Felton, Naylor & Wood, 1990). As noted above, errors are correlated with reading ability even when receptive vocabulary is controlled either statistically (Wolf & Goodglass 1986), by way of subject selection (Snowling et al., 1988), or by adjusting for items not recognized by spoken name (Katz, 1986; Rubin et al., 1989). Because disabled readers perform as well as controls on semantic classification for the same pictures that cause naming difficulties (Murphy et al., 1988), it seems clear that the processing of semantic features of words is not the source of the problem.

There is also abundant evidence that disabled readers have difficulty in the short-term retention of verbal material presented either aurally or visually (see for reviews, Baddeley, 1986; Brady, 1986; Cohen, 1982; 1986; Jorm, 1983; Wagner & Torgesen, 1987). Reduced memory span in poor reader groups is evident in a variety

of verbal materials, including digits, letters, word strings, and sentences, as well as nameable objects and pictures (Brady, Mann & Schmidt, 1987; Ellis & Large, 1987; Gould & Glenncross 1990; Holligan & Johnston, 1988; Johnston, Rugg & Scott, 1987; Jorm et al 1984; Katz, Shankweiler & Liberman, 1981; Liberman, Mann, Shankweiler & Werfelman, 1982; Mann & Ditunno, 1990; Rapala & Brady, 1990; Siegel & Ryan, 1988). Performance on these tasks depends on the storage of information in a speech-based or phonological code (for reviews, see Baddeley, 1986, 1990).

Disabled readers also have greater difficulty than good readers learning associations between visual stimuli and spoken pseudowords (see reviews by Jorm, 1983, Lovett, 1987, and Vellutino & Scanlon, 1987). In concert with the word-finding difficulties of poor readers, poor performance on these tasks does not appear to reflect difficulties storing visual or semantic information, because poor readers generally perform as well as good readers onthese simple memory tasks when items other than pseudowords are used (but see Willows et al., 1993). The errors of good readers tend to be novel combinations of the phonemes in the pseudowords whereas poor readers' errors tend to be real words (Vellutino, Steger, Harding & Phillips, 1975).

In summary, there is virtually unassailable evidence that poor readers, as a group, are impaired in a very wide range of basic cognitive tasks in the phonological domain. This applies both to reading disabled children with discrepancies from IQ and to those without such discrepancies (Fletcher et al., 1994; Stanovich, 1994a; Stanovich & Siegel, 1994). These deficits are consistently found to be domain-specific, longitudinally predictive, and not primarily attributable to non-phonological factors such as general intelligence, semantic or visual processing. Additionally, poor readers display performance deficits on tasks tapping a shallow form of phonological sensitivity (Stanovich, 1992), for example, rhyme production tasks or tasks requiring the segmentation of onset and rime (Ackerman, Dykman, & Gardner, 1990; Bentin, 1992; Bradley & Bryant, 1983, 1985; Bruck & Treiman, 1990; Olson, Wise, Conners, & Rack, 1990; Pennington, 1986; Stanovich, Cunningham, & Cramer, 1984).

In addition to differences in basic phonological processes and in the shallower forms of phonological sensitivity, there is also voluminous evidence that reading difficulties are associated with poor performance in tasks that demand a deeper form of phonological sensitivity--in particular, tasks that require the more explicit forms of phonemic segmentation. There is evidence that the relationship between reading and this deeper form of phonological sensitivity is one of reciprocal causation (Ehri, 1979, 1984, 1985; Ehri, Wilce, & Taylor, 1987; Morais, Alegria, & Content, 1987; Perfetti, Beck, Bell, & Hughes, 1987). Nevertheless, it is indisputable that poor readers display

large deficits on a variety of different tasks that require the complete segmentation of a word or nonword into phoneme units (e.g., Bentin, 1992; Bowey, Cain, & Ryan, 1992; Bruck, 1990, 1992; Cunningham, 1990; Mann, 1993; Olson et al., 1990; Share, in press; Stanovich, 1982, 1992; Stanovich, Cunningham, & Cramer, 1984; Stanovich, Cunningham, & Feeman, 1984a; Tunmer & Hoover, 1992; Vellutino & Scanlon, 1987; Wagner & Torgesen, 1987; Wagner et al.,1994; Wagner et al., 1993; Yopp, 1988).

Whether all of the phonological deficits listed above are reflective of a single underlying processing problem and whether all of them can be considered causal or are instead correlates is a matter for future research, but some important progress is being made on this issue (e.g., Fowler, 1991; Hansen & Bowey, 1994; Pennington, Van Orden, Kirson, & Haith, 1991; Pennington et al., 1990; Wagner, Torgesen, & Rashotte, 1994; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993). Finally, there is growing evidence for a causal link leading from phonological processing to early reading acquisition (Ball, 1993; Bradley & Bryant, 1985; Byrne, & Fielding-Barnsley, 1991, 1993; Cunningham, 1990; Hatcher, Hulme, & Ellis, 1994; Lie, 1991; Lundberg, Frost, & Peterson, 1988; Torgesen, Morgan, & Davis, 1992; Wagner et al., 1994). In Section 2, we explore whether this linkage fits within an integrated theory of reading acquisition.

Visual Deficits

The idea that visual processing problems were closely linked to reading disability/dyslexia was once quite popular but, by the mid-1980s, had been drastically de-emphasized in several major reviews (Mitchell, 1982; Rutter, 1978; Stanovich, 1982, 1985, 1986a; Vellutino, 1979). Nevertheless, interest in visual deficit hypotheses remains strong among some investigators (Willows, Kruk, & Corcos, 1993). There are several reasons why several experiments reporting negative findings (e.g., Morrison, Giordani, & Nagy, 1977; Vellutino, 1979) have not completely closed the case on visual deficits.

First, there have been several recent reports of differences between disabled and nondisabled children in visual processing experiments using nonverbal stimuli, brief presentations, and psychophysical procedures (Lovegrove, 1992, 1993; Lovegrove, Martin, & Slaghuis, 1986; Solman & May, 1990). Some of these investigators have argued that visual perception tasks where the stimulus is continuously exposed are not good indicators of the subtle visual problems of some disabled children (e.g., Willows, 1991). However, the replicability of some of the visual deficits that have been reported has not been established (Hayduk, Bruck, & Cavanagh, 1992; Kruk, 1991), and they are not embedded in the context of the converging evidence and theory that characterizes our knowledge of phonological-core deficits (Hulme, 1988;

Shankweiler et al., 1992; Vellutino, 1979; Vellutino & Scanlon, 1987). Nevertheless, the new reports of visual processing differences have occurred with enough regularity that they deserve some further experimental attention (Bowers & Wolf, 1993).

A further point often raised in the context of discussions of visual deficits is that these processing problems may not be general but may characterize a small group of severely affected children. It is often argued that the data from this subgroup of children get swamped in samples containing mostly children with a variety of other deficits. This alternative explanation will remain a viable hypothesis until a large-scale epidemiological study is conducted that allows the precise demarcation of a subpopulation with visual deficits. Nevertheless, it must be noted that investigators studying deficits in basic phonological processes do not have a similar worry. That is, they are not concerned that the speech segmentation performance of the children with phonological problems will be statistically diluted by their being grouped together within a heterogeneous sample including children with visual problems. In short, phonological problems are so prevalent that they can be detected even under the most disadvantageous sampling conditions. This, of course, is not an argument against the idea of a visual subtype, but it does argue that there are already some rough indications in the literature that the prevalence of the visual subtype must be small in comparison to those children with difficulty in the language/phonological domain.

Finally, it should be noted that many of the investigators who argue for the possibility of visual deficits do not rule out the possibility of visual deficits co-existing with phonological deficits. But it will be easier to demarcate visual processing problems if they do not always co-occur with phonological or verbal problems. It would be convincing, for example, to demonstrate that a group of pre-kindergarten children with better than average phonological awareness, but visual processing problems, developed into children with reading disabilities. This convincing evidence will not be obtainable if the processing problems always co-occur.

Orthographic Analysis and Orthographic Memory

Interest in deficits in basic visual processing as a cause of reading disability has been partly spawned by the conjecture that individual differences in basic phonological processes do not account for all of the variance in reading ability. Indeed, although the correlations between phonological processing skill and word recognition ability are quite high, they still probably leave reliable word recognition variance unaccounted for (Stanovich, Cunningham, & Cramer, 1984; Wagner, 1988; Wagner & Torgesen, 1987; Wagner et al., 1994; Yopp, 1988). Tunmer and Nesdale

(1985) and Juel, Griffith, and Gough (1986) have demonstrated this by showing that phonemic segmentation ability is a necessary, but not sufficient, condition for rapid reading acquisition. If deep phonological sensitivity is a necessary but not sufficient condition for efficient reading acquisition, there must exist at least one other cognitive "sticking point" where reading acquisition can run aground. What is this second problem area?

Ehri (1979, 1980, 1985, 1987, 1991; see also, Barron, 1981, 1986) has emphasized that ultimately, rapid lexical access depends on the establishment of accurate orthographic representations in memory--stored representations of the coded visual features of the letters in words. However, the issue is complicated because the formation of orthographic representations would also be facilitated by extensive knowledge of spelling-to-sound correspondences (see Jorm & Share, 1983; Juel et al., 1986). For example, it is clearly the case that a child with efficiently functioning spelling-sound conversion processes will develop a richer orthographic lexicon due to a greater number of successful "self-teaching" trials (Jorm & Share, 1983) with words: instances where accurate decoding leads to the complete phonological representation of a word becoming associated with its visual form. Such positive learning trials lead to the amalgamation of orthographic and phonological representations in memory (Barron, 1986; Ehri, 1980, 1984, 1987, 1991), and the amalgamated orthographic representation is what eventually enables rapid and efficient processes of direct access to the lexicon.

Thus, there is little doubt that the development of orthographic processing skill must be somewhat dependent on phonological processing abilities. The critical question for research is whether the development of the orthographic lexicon is entirely parasitic on the operation of phonological processes. Might there be individual differences in the ability to establish orthographic representations that are independent of basic phonological abilities and spelling-to-sound decoding skill? There is some suggestive evidence relevant to this hypothesis.

Reitsma (1983) gave children practice at recognizing a set of words with standard spellings and three days later tested their recognition of these words and a matched set of homophonic spellings of the words. Among a group of first-grade readers, only four trials of practice led to superior performance on the standard spellings three days later. However, a group of learning-disabled children two years older but approximately matched to the first graders on reading level did not perform better on the standard spellings even after six trials of practice. This result suggests that specific problems in forming visual-orthographic representations may characterize some less-skilled readers. Reitsma (1983) concluded that "Facility in

decoding does not automatically predict the capability of learning to recognize the unique letter sequence of words" (p. 335).

Case studies of adults with acquired surface dyslexia (Patterson, Marshall, & Coltheart, 1985) have suggested that there exist reading problems specifically associated with difficulties in accessing and/or forming representations in the orthographic lexicon (see also, Castles & Coltheart, 1993). Clinical studies of dyslexic children have also repeatedly suggested the existence of a subtype of poor readers with unique difficulties in dealing with the visual representations of words (e.g., Bodor, 1973), although the interpretation of this clinical work is very equivocal (Hooper & Hynd, 1985; Olsen, Kliegl, Davidson, & Foltz, 1985; Perfetti, 1985). However, some studies of individual differences across the normal continuum of ability have also suggested that children show marked differences in their tendency to utilize print-specific information when recognizing words (Baron & Treiman, 1980; Bryant & Impey, 1986; Freebody & Byrne, 1988; Treiman, 1984). Several studies have demonstrated that, in both children and adults, tasks assessing the efficiency of orthographic processing account for variance in word recognition ability even after the variance associated with phonological processing skills has been partialed out (Barker, Torgesen, & Wagner, 1992; Cunningham & Stanovich, 1990; McBride-Chang, Manis, Seidenberg, Custodio, & Doi, 1993; Olson, Forsberg, & Wise, in press; Stanovich & West, 1989).

II. Linking Individual Differences in Cognitive Processing to Models of Reading Acquisition

The literature on individual differences in cognitive processing that we have just reviewed indicates that any plausible model of reading acquisition must assign phonology a leading role. However, the explanatory coherence of this literature on phonological processing is considerably diminished by a lack of consensus regarding the specific role of phonology in the process of learning to read. Suppose, for one moment, that the research literature had unequivocally established that hand-standing proficiency was a major source of individual differences in early reading skill. One could justifiably question whether such a finding represented a significant advance in our understanding of early reading if there were, as we would guess, no plausible way to link hand-standing to reading acquisition once age was controlled.

To what extent has the literature on phonology advanced beyond the "hand-standing" stage? Consideration of some of the common explanations proposed to account for the role of phonology in early reading acquisition reveals just how poorly the evidence on cognitive processes is grounded in a tenable model of reading

acquisition. We briefly review some of the traditional arguments put forward by proponents of phonology to account for the role of phonology in reading acquisition.

Is Phonological Mediation Essential for General Word-Recognition?

The simplest and most straightforward explanation of the role of phonology in reading would ideally be that word recognition in general involves translation of print to sound prior to the identification of meaning. There are now a number of studies employing a variety of research paradigms ranging from brief presentation of isolation words through to the reading of connected text which suggest that the activation of phonological information is a ubiquitous feature of skilled word recognition (Perfetti, Bell & Delaney, 1988; Perfetti & Bell, 1991; Van Orden, 1987; Van Orden, Johnston & Hale, 1988; Van Orden, Stone, Garlington, Markson, Pinnt, Simonfy & Brichetto, 1992).

Unfortunately, most recent research into phonological processes in word recognition has been directed to the question of whether or not phonology is involved rather than the question of what purpose this information may serve. Does evidence of phonology imply an essential role in visual word recognition (see, e.g., Van Orden, Pennington & Stone, 1990), or is it merely an epiphenomenon -- a vestige perhaps of an earlier developmental stage in which print-to-sound translation was dominant? Currently, most theorists would reject a strong version of the traditional recoding hypothesis (see, e.g., Gough, 1972) which proposes that word recognition can be accomplished only by translating print into sound prior to accessing meaning. Many theorists (e.g., Perfetti, 1992; Seidenberg, 1992) consider this activation to be helpful in word recognition, or helpful at least in the case of low-frequency words (Jared & Seidenberg, 1991; Seidenberg, 1992), but few would go as far as to claim that phonological access is a prerequisite for word recognition in the fluent adult reader. Most would agree that visual/orthographic information is preeminent in the recognition of most familiar words by skilled readers (Seidenberg, 1992).

In sum, it seems difficult to place the weight of the evidence reviewed in the previous section on the shoulders of a strong hypothesis postulating necessary print-to-sound translation in the recognition of printed words. Our "ideal" account of the role of phonology in word recognition simply does not have the necessary support.

Is Phonological Mediation Essential for Beginning Readers?

Although phonology may not be critical for skilled readers, it might still be the case that novice readers depend heavily on print-to-sound translation. Indeed, one of the earliest and most popular stage theories of reading development (Edfeldt, 1959) proposed that all words are initially recoded to sound with a later developmental shift to visual access. This stage theory became the focus of a number of empirical

investigations partly owing to its intuitive appeal. Equipped with an extensive oral vocabulary, the beginning reader brings to the reading domain a large store of word meanings accessible via phonology. Mastering the systematic relationships between print and sound permits the learner to capitalize on these existing links. It also seemed reasonable to expect a certain bias toward reliance on sound given the extensive experience in the spoken domain up to school entry. Another reason for the popularity of the phonological-to-visual stage theory was the developmental trend toward less overt vocalization during reading (Edfelt, 1959; McGuigan, Keller & Stanton, 1964) which was widely interpreted as greater dependence in the younger reader on phonological recoding (Gibson & Levin, 1975; Mackworth, 1972; Tinker, 1952).

Empirical investigations of the phonological-to-visual stage hypothesis, however, have been consistently inconsistent. Some studies (Barron & Baron, 1977; Bryant & Bradley, 1983; Condry, McMahon-Rideout & Levy, 1979; Kimura & Bryant, 1983; Rader, 1975) found evidence of direct visual access even in grades one and two, with no suggestion of the hypothesized transition from a phonological to a visual stage. Other studies, however, have reported evidence of early reliance on phonological recoding together with a developmental shift toward direct visual access (Backman, Bruck, Hebert & Seidenberg, 1984; Doctor & Coltheart, 1980; Reitsma, 1984; Waters, Seidenberg & Bruck, 1984). To make matters worse, many of these studies are plagued by interpretational difficulties (such as ordinal task by grade interactions, use of the controversial technique of concurrent vocalization, and changing concepts of spelling-sound regularity). The notion that children must first pass through a print–to–sound recoding stage is left unresolved by this body of evidence. Indeed, the conflicting findings are equally problematic for <u>any</u> stage-based model,whether phonological-to-visual or visual-to-phonological. Below we offer an alternative conceptualization of this literature that we believe resolves much of the conflicting evidence.

<u>Low-Frequency Words Are Very Common</u>

An alternative account of the role of phonological skills in early reading, — one which has received only scant consideration — suggests that print-to-sound is essential for the large numbers of low-frequency words which cannot be recognized on a visual basis. Whereas just over 100 "heavy-duty" words (e.g., THE, IN, WAS etc.) account for around half of all the letter strings appearing in printed school English, a very large number of words exist which appear very rarely in print (Carroll, Davies & Richman, 1971; Nagy & Anderson, 1984). In fact, fully eighty percent of English words occur less than once in a million words of running text (Carroll et al., 1971,

Table B–5). For reasons elaborated below, neither direct instruction (Nagy & Anderson, 1984) nor contextual guessing are likely to be useful in identifying these novel orthographic patterns (Finn, 1977-78; Gough, 1983; Rubenstein & Aborn, 1958; Schatz & Baldwin, 1986). Hence print-to-sound translation is essential.

Among this set of low–frequency words are certainly many compounds that should not pose orthographic difficulties (e.g., LIVE-BORN, NOSEDIVE), as well as a number of archaic and esoteric items (e.g., FORSOOTH, TRUFFLE), However, also among these rarely seen items are many general purpose content words (e.g., AMNESTY, CONTEMPORARY, FLUENT), technical and scientific words terms (e.g., GIB, STAMEN), proper names (e.g., NAPOLEON, COLORADO), and pseudowords (e.g., 'TWAS BRILLIG AND THE SLITHY TOVES...). In some of these cases, contextual guesses that capture the essential semantic features of the target will suffice for the purposes of immediate text comprehension. Certain children may be able to progress considerably by relying on good language skills (see, for example, the case of J.M., Snowling and Hulme, 1989). On the other hand, it seems reasonable to assume that the ability to identify substantial numbers of these orthographically novel items should be helpful, and in some cases critical, for both the immediate enjoyment and understanding of the text being read, to say nothing of longer-term conceptual and vocabulary development that depends much on the quantity and quality of print exposure (Stanovich, 1993). Thus, although no child need be concerned about identifying the thousands of new words encountered each year in print (see Nagy & Herman, 1987), s/he can ill afford to skip them all either! A child who either skips an unfamiliar item or derives a contextually appropriate but orthographically mismatched word, foregoes the opportunity to acquire word-specific orthographic information--the foundation of fluent word recognition--and to refine knowledge of orthography-phonology relationships. If the skipped item is not in a learner's spoken vocabulary, an opportunity to expand vocabulary and general knowledge is also foregone.

Although we think it likely that decoding via spelling–sound conversion will be of major importance for the large number of low-frequency words in print, we doubt whether this account is sufficiently robust to bear the weight of all the evidence from the phonological processing literature.

But consider the fact that every printed word is, at some point, a novel orthographic string. If, as we argue below, neither contextual guessing nor direct instruction offers a viable means for identifying specific printed words, decoding must surely play an essential role in the initial identification of virtually every printed

letter string. The self–teaching model of reading acquisition summarized below takes this argument one step further.

Decoding and Self-Teaching

A lesser known account of the role of phonology in early reading has been developed by Share and Jorm (Jorm & Share, 1983; Share & Jorm, 1987; Share, in press). This model is presented in some detail because it provides a useful illustration of a model which attempts to integrate the research on early reading processes with the extensive literature on individual differences in cognitive processing reviewed above.

According to the self-teaching model, phonological recoding (print-to-sound translation) functions as a self-teaching mechanism enabling the learner to acquire the detailed orthographic representations necessary for both fast, efficient, visual word recognition and for proficient spelling. Although other mechanisms such as direct instruction and contextual guessing may conceivably serve to develop orthographic knowledge, consideration of these alternatives suggests that only phonological recoding offers a viable means for printed word learning.

Options for Printed Word Learning

Either by direct teaching of new words in the classroom, or through less formal assistance in other settings from parents or peers who supply the identity of visually unfamiliar words, a child may be able to acquire reading vocabulary by direct rote association. As alluded to above, the problem with this approach is that it ignores the vast number of unfamiliar words continually being encountered in printed text (Carroll, Davies & Richman, 1971). Nagy and Anderson (1984) estimated that printed school English contains around 88,500 distinct word families (a "family" was defined as a group of words with clear and predictable relationships of form and meaning; e.g., persecute(-d,- s,-ing), persecution (s), persecutor(s)). Additional analyses reported by Nagy and Herman (1987) suggested that the average fifth grader encounters around 10,000 new words per year. Frequency counts for reading material prior to Grade 3 (e.g., Firth, 1972; Rodenborn & Washburn, 1974) reinforce the picture of the young reader continually encountering new items. In the face of this orthographic avalanche, direct instruction is unlikely to offer a feasible acquisition strategy. Neither programs of direct vocabulary instruction (Calfee & Drum, 1986; Nagy & Herman, 1987), nor item-by-item teaching of characters in so-called "logographic" writing systems such as Chinese or Japanese (Kanji) aim to impart more than a few hundred items per year (Mason, Anderson, Omura, Uchida & Imai, 1989; Taylor & Taylor, 1983). Moreover, it is questionable whether providing the identity of a printed word at the whole-word level is likely to draw a child's attention

to the detailed orthographic structure which ultimately forms the basis for proficient word recognition (see Ehri, 1992).

Another possible solution to the problem of learning printed word forms is the use of syntactic, semantic, and pragmatic information in surrounding text to predict unfamiliar words. In sentences of the form, "We walked into the restaurant and sat down at a _____," it is not difficult to supply the missing word. But how predictable is natural text? Probably the most authoritative study of this issue is Finn's (1977- 78) analysis of data originally reported by Bormuth (1966). In this study, the "cloze easiness" (how well they could be predicted when deleted) of over 5,000 words was evaluated in a sample of 675 children in grades 4 to 8. The average predictability was only 29.5%, that is, guesses were twice as likely to be wrong than right (see also Gough, 1983; Nicholson & Hill, 1985; Perfetti, Goldman & Hogaboam, 1979; Rubenstein & Aborn, 1958; Schatz & Baldwin, 1986). Finn also found a correlation of .55 between frequency and predictability: low frequency words, those least likely to be familiar, were the least guessable. In a similar vein, Gough (1983) observed substantially higher predictability for function words (40%) than for content words (10%). Because content words convey virtually all the meaning of a text they are the most important for building the context required for guessing. But it is precisely these items which are the less frequent and hence least guessable (Finn, 1977-78). It seems that contextual guessing is least helpful where it is needed most.

The inadequacy of contextual guessing is related, in part, to the extraordinary number of synonyms or near-synonyms found in the English language. But there is a deeper reason why contextual guessing fails and, indeed, must fail. Consider again the sentence at the beginning of this section, "We walked into the restaurant and sat down at a _____". The target item will be readily identified by anyone familiar with eating-out-in-a-restaurant scenarios (Rumelhart, 1975; Schank & Abelson, 1977). Because text comprehension is an interaction between a reader's knowledge base and the printed text (Kintsch, 1988), writers need only build on what is already known, or "given" (Grice, 1975; Haviland & Clark, 1974). Information that will normally be inferred on the basis of prior knowledge and hence does not require explicit reference. Because people dining in restaurants are normally seated at tables, this information is inferable and hence redundant. Sentences such as the above which permit successful prediction of specific content words consequently violate the basic communicative convention of conveying non-redundant information (Grice, 1975; Haviland & Clark, 1974). It is precisely because the word "table" is entirely predictable that sentences of this type are rare and are unimportant even when they do occur. There is simply no need to state the obvious. Contextual guessing therefore

must fail because the purpose of text is normally to convey non-redundant information.

From the point of view of building word recognition skill it is not merely guessing the correct meaning that is important, but identifying the exact word. The ability of a child to use contextual information to derive a contextually plausible candidate for an orthographically (and perhaps also semantically) unfamiliar word may be satisfactory from the standpoint of text comprehension, but as a means for developing a child's recognition vocabulary it is simply not viable because, on the majority of occasions, guesses are orthographically awry.

Phonological Recoding as a Self-Teaching Mechanism

Because neither contextual guessing nor direct instruction, in and of themselves, are likely to contribute substantially to printed word learning, the ability to translate printed words independently into their spoken equivalents must assume a central role in reading acquisition. According to the self-teaching hypothesis, each successful decoding encounter with an unfamiliar word provides an opportunity to acquire the word-specific orthographic information that is the foundation of skilled word recognition and spelling. In this way, phonological recoding acts as a self-teaching mechanism or built-in teacher enabling a child to independently develop knowledge of specific word spellings and more general knowledge of orthographic conventions. Although it may be less than crucial in skilled word recognition, phonological recoding may be the principal means by which the learner attains word recognition proficiency.

Share (in press) discusses four key features of the self-teaching role of phonological recoding; the item–based as opposed to stage–based role of recoding in development, early onset, the progressive "lexicalization" of the process of print–sound conversion, and the asymmetric relationship between (primary) phonological and (secondary) orthographic components in the self–teaching process.

Phonological Recoding is Item-Based Not Stage-Based

According to the self-teaching hypothesis, the developmental role of phonological recoding (as distinct from the development of phonological recoding itself) is seen as item-based rather than stage-based. As noted above, researchers have traditionally responded to the question of how children access the meaning of printed words by proposing a developmental progression, often in the form of a transition from a phonological to visual "stage". But, as discussed above, stage-based theories have fared poorly in the light of empirical findings (Barron, 1986; Jorm & Share, 1983). It may be more appropriate to ask how children get meaning from which words. Adopting an item-based perspective, the self-teaching hypothesis argues that

the process of word recognition will depend primarily on the frequency to which an individual child has been exposed to a particular word together, of course, with the nature and success of item identification.

Several studies have observed that relatively few (successful) exposures to a word may be sufficient for the acquisition of word-specific orthographic information (Brooks, 1977; Manis, 1985; Reitsma, 1983b). Furthermore, Reitsma (1990) has also shown that the development of these word-specific representations is accompanied by a declining role for phonology. If these data, which were obtained with isolated word presentation, are found to generalize to word learning in natural text, it would appear to indicate that the acquisition of orthographic information is quite rapid. This suggests that high frequency items may well be recognized visually with minimal phonological recoding from the very earliest stages of reading acquisition. Novel, and less familiar items for which the child has yet to acquire orthographic representations, will be more dependent on phonology. The incidence of phonological recoding should vary according to the distribution of item familiarities.

This account resolves much of the conflicting evidence, discussed above, on the question of an initial print-to-sound recoding stage in early reading. When differences in word frequency are considered there is a clear pattern to these findings. All studies reporting evidence of direct access in even their youngest readers employed a restricted range of high-frequency words. In each case of positive phonological findings, both high and low frequency items were included--the natural frequency range found in children's reading material (Carroll et al., 1971). These studies included low frequency items (Backman et al., 1984; Waters et al., 1984) unfamiliar words (Reitsma, 1984) or pseudowords (Doctor & Coltheart, 1980). The pattern of findings can by summed up as a general word familiarity by phonology interaction -- a developmental analogue of the well known frequency by regularity interaction (see Seidenberg, 1985, 1992). High frequency items require relatively little phonological "assistance", whereas less familiar items are more dependent on phonology.

Given the extreme asymmetry in the word frequency distribution, a majority of words in natural text will be recognized visually by virtue of their high frequencies, while the occasional low frequency item will provide opportunities for self-teaching with minimal disruption of ongoing comprehension processes. Because so very many words occur so infrequently in print the self-teaching opportunities afforded by phonological recoding may well represent the "cutting edge" of reading development not merely for the beginner, but throughout the entire ability range.

Early Onset: Beginning Reading is Beginning Self–Teaching

Reading prior to self-teaching? There has been much discussion (and indeed controversy) concerning the notion of an initial visual or logographic stage in learning to read (Ehri & Wilce, 1985; Frith, 1985; Gough, Juel & Roper/Schneider, 1983; Liberman & Liberman, 1992; Marsh, Friedman, Welch & Desberg, 1981; Stuart & Coltheart, 1988; Wimmer, 1990). Logographic reading appears to involve rote associations between unanalysed spoken words and one or more salient and often arbitrary graphic features of the printed word or its surrounding context. Connections between print and sound below the whole-word level (single or multi-letter units) play little or no role in either identification or recognition at this phase. Perhaps the most telling feature of this putative stage is the child's inability to read new words.

When confronted with a new word, the "logographic" reader may substitute a word in their existing sight vocabulary (Gough, Juel & Roper/Schneider, 1983; Biemiller, 1970; Seymour & Elder, 1986), or may guess on the basis of prior context (Biemiller, 1970; Cohen, 1974-75; Juel, 1983). For the reasons discussed previously, these guesses are often contextually adequate but seldom orthographically accurate (Barr, 1974-1975; Biemiller, 1970; Cohen, 1974-1975; Marsh et al., 1981). Nonsense word responses (indicating some attempt to phonologically recode) are conspicuously absent. Because it ignores correspondences between print and sound at the sub-lexical level, logographic"reading" is impotent in the face of a novel word and therefore has no functional value in view of the word learning task ahead. If the ability to form rote, holistic, "logographic-style" associations between spoken and printed words were of value in reading development, one would expect to find positive correlations with reading ability. The evidence on this issue, however, is uniformly negative (Budoff & Quinlan, 1964; Firth, 1972; Jorm, 1977;1981; Masonheimer, Drum & Ehri, 1984; Rozin, Poritsky & Sotsky, 1971). Although logographic reading may be of some value in helping the preschooler acquire certain print concepts (see Ferreiro & Teberosky, 1979; Stahl, 1992; Stahl & Miller, 1989), from the standpoint of acquiring proficient word recognition skill, it may best be regarded as pre-reading.

Even if this controversial "stage" does exist, logographic reading must necessarily be shortlived because the alphabetic nature of English orthography dictates complete or near-complete processing of orthographic detail (Adams, 1990). Learning to read logographically, or "Chinese-style", can be likened to memorizing large slabs of a telephone directory. Like printed letter strings, telephone numbers contain a small set of symbols arranged in strings of fairly uniform length. Unless all numbers are dialled correctly and in the right order the connection will fail. So each

string must be fully memorized. Unfortunately, there are no systematic or predictable relationships between these strings and their corresponding entries, so each of the many thousands of such associations must be painstakingly committed to memory.

Although it is often assumed that the logographic strategy is abandoned when the reader is no longer able to discriminate between the growing number of words in his or her orthographic lexicon (Harris & Coltheart, 1986; Marsh et. al., 1981; Gough & Hillinger, 1980), this factor alone seems unlikely to explain the switch to a phonological strategy because, as noted earlier, exposure alone has not been found to spontaneously induce discovery of the alphabetic principle: the principle that sequences of letters map into sequences of sounds (Byrne, 1992; Byrne & Fielding-Barnsley, 1989; Ehri & Sweet, 1991; Juel, 1983; Seymour & Elder, 1986). Evidence discussed in section 1 above indicates that it is the acquisition of letter-sound knowledge together with a basic level of phonological sensitivity that bring the decoding possibilities of an alphabetic orthography to a child's attention.

The beginnings of self-teaching. A growing number of studies, and in particular the ground-breaking work of Ehri and her colleagues, now indicate that some rudimentary self-teaching skill, perhaps sufficient to establish primitive orthographic representations of the kind discussed by Perfetti (1992), may exist at the very earliest stages of learning to read even before a child possesses any decoding skill in the conventional sense of being able to sound out and blend even simple pseudowords (Ehri & Wilce, 1985; 1987a,b; Ehri & Sweet, 1991; Morris, 1992; Scott & Ehri, 1990; Stuart & Coltheart, 1988; Stuart, 1990). This early self-teaching depends on three factors; letter-sound knowledge, some minimal phonological sensitivity, and the ability to utilize contextual information to determine exact word pronunciations on the basis of partial decodings.

Ehri and her colleagues (Ehri & Wilce, 1985; 1987a,b; Scott & Ehri 1990; Ehri & Sweet, 1991) have demonstrated that even kindergarten children are capable of learning words on a phonetic rather than visual basis provided they have some knowledge of print-sound relationships. Ehri suggests that once children gain sufficient knowledge of letter names or sounds, words can be learned by associating one or more printed letters with sounds in the pronunciation. For example, knowledge of the names of the letters J and L may enable a child to read the word JAIL even in the absence of blending skill. Ehri (1991) proposes that learning words through the use of even partial symbol-sound associations is superior to purely visual learning because associations are systematic and non-arbitrary unlike visual cues. A partial decoding strategy, however, cannot succeed on the basis of letter-sound knowledge alone. It necessarily depends on the ability to recognize identity between

learned letter names or sounds and phonological segments in spoken words. Knowing that the letter S has the sound /s/ is of no help learning the word SAIL if a child is unaware that the initial phonological segment of the spoken word SAIL corresponds to the same /s/ sound. But a child who is able to generate words beginning with a given sound, and who has also acquired a basic knowledge of simple letter-sound correspondences will be in a position to generate a plausible candidate for a novel item. This will be revealed by real word errors with one or more sounds in common with the printed item (most probably initial consonants) but which are not in the child's existing reading vocabulary. A child oblivious to the phonemic structure of speech, that is, for whom spoken words are indivisible wholes, will have no way of generating a candidate pronunciation for an unfamiliar word even if s/he has mastered all the letter sounds. In this case, guesses will be visually familiar words with common letters, never pseudowords or visually unfamiliar real words, and hence unproductive in the deepest sense of the word. The joint role of letter-sound knowledge and phonological sensitivity is consistent with the wealth of evidence indicating that these two factors are critical co-requisites in reading acquisition (e.g., Bradley & Bryant, 1983; Ehri & Sweet, 1991; Juel, Griffith & Gough, 1986; Share, in press; Tunmer, Herriman & Nesdale, 1988).

Empirical support for the role of phonological sensitivity in partial decoding has been reported in several studies (Ehri & Sweet, 1991; Stuart, 1990; Stuart & Coltheart, 1988). For example, Stuart and Coltheart (1988) found that "phonological" reading errors -- those sharing the initial letter or initial and final letters of target words, predicted end of grade one reading ability. Non-phonological errors -- those with either no letters in common (LOOK--"baby") or which shared common letters but in incorrect locations (MILK--"like"), were negatively related to reading ability. In addition, the ratio of these two error types was correlated with a child's pre-school phoneme segmentation ability and knowledge of letter-sound relationships. Furthermore, the point at which phonological errors became more common than non-phonological errors coincided with the attainment of "functional" phonological skill as measured by knowledge of at least half of the alphabet (cf. Ehri & Wilce, 1985) together with success on 2 out of 6 tests of phonological sensitivity.

In a follow-up study, Stuart (1990) assessed the ability to segment initial, final and medial sounds in spoken words together with knowledge of sound-letter correspondences in a sample of pre-school nonreaders. Those children able to segment only initial sounds were able to use this knowledge to correctly select target items from two alternatives when the distractor had no letters in common. Children able to segment both initial and final sounds succeeded on items sharing initial but

not initial and final letters, that is, they failed only on item pairs distinguished by medial letters. In a second task requiring children to read aloud isolated words, "initial segmenters" were able to generate a word beginning with the initial letter sound. Additional evidence suggests that this pattern of reading behavior generalizes to natural text. The ability to track the correspondence between spoken and printed words in a memorized text ("finger-point reading") is strongly related to basic phonemic analysis ability and letter-sound knowledge (Morris, 1992; Ehri & Sweet, 1991).

In summary, from the very beginnings of reading acquisition, a minimal level of phonological sensitivity and letter-sound knowledge skill may enable a child to acquire rudimentary self-teaching skill. But is this skill functional in the sense of permitting children to accurately identify new words and thereby acquire primitive orthographic representations. Very few of Ehri and Sweet's subjects succeeded in reading words from the memorized text when they were presented in isolation. Stuart (1990) also observed that accurate decodings of single items presented in isolation were few and far between. Overall success rates among Ehri's phonetic-cue readers learning words with simplified (one-to-one) phonetic spellings were relatively low (16% in Ehri & Wilce, 1987b; 22.5% in Ehri & Wilce, 1987b).

By its very nature, partial decoding must fail in identifying words presented in isolation owing to the complete or near-complete processing of letter information required by an alphabetic orthography. However, contextual information may be the key to resolving decoding ambiguity. This suggestion is essentially speculative but finds support in a small number of studies (Goswami, 1990; Nicholson & Hill, 1986; Pring & Snowling, 1986). For example, Goswami (1990) reported that first graders made fewer nonsense word errors (such as reading DONE to rhyme with BONE) when reading words in meaningful text than when reading the same words in isolation (see also Nicholson & Hill, 1986; Pring & Snowling, 1986). Additional support for the view that children are able to make use of contextual information to supplement low-level decoding comes from the well-established finding of greater reliance on contextual information among readers with relatively weak word recognition skill that was discussed in section 1 (e.g., Nicholson, 1991; Stanovich, 1980; 1986b).

In summary, there is evidence that rudimentary, yet functional self-teaching may develop at the very outset of learning to read, sufficient perhaps to establish primitive orthographic representations (see Perfetti, 1992) well before a child has acquired "conventional" decoding skill.

Irregularity and partial decoding. The notion of partial decoding has a number of implications for the reading of so-called irrregular words. Consistent with the prevailing view that regularity represents a continuum rather than a dichotomy (see e.g., Patterson & Morton, 1987; Stanovich, 1991b), is the observation that even "hermits" such as CHOIR and YACHT are not entirely irregular. Most importantly, the irregularity of printed English is largely restricted to the vowels (Berndt, Reggia & Mitchum, 1987; Cronnell, 1973; Venezky, 1970) which may have a marginal role in word recognition (Adams, 1990; Shimron, 1993). With the exception of silent consonants, both regular and irregular words are equally regular consonantally, hence phonological recoding may be important for learning both types of items. The validity of this argument depends on the reader's willingness to test multiple alternative pronunciations for "goodness of fit".

The claim being made here is that most irregular words, when encountered in natural text, have sufficient letter-sound regularity (primarily consonantal) to permit selection of the correct target among a set of candidate pronunciations. That is, even an approximate or partial decoding may be adequate for learning irregular words encountered in the course of everyday reading. Note that for an unskilled novice, even regular words will be "irregular" in the sense of being phonologically underdetermined.

Empirical support for the role for phonological recoding in the acquisition of irregular words comes from both observations of strong correlations between pseudoword and irregular word reading (Baron, 1979; Baron & Treiman 1980; Freebody & Byrne, 1988; Gough & Walsh, 1991; Jorm, 1981; Spring & Davis, 1988; Stanovich & West, 1989; Treiman, 1984) and experimental training studies showing that the ability to learn unfamiliar irregular words is strongly predicted by decoding skill (Foorman, Francis, Novy & Liberman, 1991; Gough & Walsh, 1991; Manis, 1985). Thus, phonological recoding appears to be essential both for regular and irregular words.

The Lexicalization of Phonological Recoding

Early decoding skill appears to be based on simple one-to-one correspondences that are relatively insensitive to orthographic and morphemic context. With print exposure, these simple letter-sound correspondences become "lexicalized" -- modified by a growing body of orthographic knowledge. The expanding print lexicon alerts the child to regularities beyond the level of simple one-to-one grapheme-phoneme correspondences, such as context-sensitive (soft and hard g and c), positional (final versus initial y), and morphemic constraints (DOGS rather than DOGZ). Ironically, the outcome of this process of "lexicalization" is a skilled reader whose knowledge of

the relationships between print and sound has evolved to a degree that makes it indistinguishable from a purely whole-word mechanism that maintains no spelling-sound correspondence rules at the level of individual letters and digraphs (see, for example, Brown, 1987; Glushko, 1979). There are a number of lines of evidence to support the "lexicalization" hypothesis.

First, young skilled readers make fewer errors and are faster reading items that only require knowledge of invariant context-free letter or digraph correspondences (V. Coltheart & Leahy, 1992; Manis, 1985; Marsh, et al., 1981; Siegel & Faux, 1989; Zinna, Shankweiler & Liberman, 1986). For example, single vowel letters are easier to read in simple monosyllables than in context-dependent environments as in the case of r-controlled vowels and final E (Siegel & Faux, 1989; Marsh et al., 1981). Similarly, invariant vowel digraphs such as EE and OA produce lower error rates than context-sensitive digraphs EA and OU (Zinna et al., 1986). The data from studies of spelling acquisition paint a similar picture (see Fischer, Shankweiler & Liberman, 1985; Holligan & Johnston, 1991; Waters, Bruck & Malus- Abramowitz,1988).

To the extent that the advantage of (phonetically) regular words over irregular words can be attributed to overapplication of simple one-to-one letter-sound correspondences, then the attenuation of regularity effects that accompany increased reading skill can be taken as further support for the "lexicalization" hypothesis (Backman, Bruck, Hebert & Seidenberg, 1984; Coltheart & Leahy, 1992; Manis, 1985; Siegel & Faux, 1989; Waters et al., 1984; Stanovich, Nathan & Zolman, 1988).

Error analyses reinforce this picture. Less skilled readers often overgeneralize simple correspondences resulting in so-called "regularization" errors. These include overgeneralizations of short vowels (BULL to rhyme with DULL, Coltheart & Leahy, 1992), long vowels (BREAK to rhyme with LEAK, Mason, 1976) and also context-sensitive consonants such as hard/soft c (Venezky & Johnson 1973; Marsh et al., 1981). Beginning readers may even pronounce the first letter in a digraph and simply ignore the second (RAIN "ran") or pronounce each separately (Bryson & Werker, 1989; Mason, 1976).

The corollary of declining regularity effects is a growing influence of orthographic neighborhood. As the knowledge of word spellings expands to include a greater number of items and a richer network of connections between these items, the influence of orthographically related items becomes apparent in growing consistency effects (Coltheart & Leahy, 1992; Zinna et al., 1986) and analogy-based responses (Marsh et al., 1977; 1981; Treiman, Goswami & Bruck, 1990). Zinna et al (1986), for example, found that both grade 3 and grade 5 children made more errors reading low frequency words with inconsistent neighbors (e.g., TEAK, whose

neighbors with inconsistent spelling-sound relationships include STEAK and BREAK) than items with consistent neighbors (DEAN). For first graders, however, there was no consistency effect either for low-frequency items (TEAK/DEAN) or high-frequency items (SPEAK/CLEAN). Marsh and his colleagues (Marsh et al., 1977; 1981) found that the incidence of analogy-based pronunciations (pronouncing FAUGH by analogy to LAUGH) increased steadily with reading skill across groups of children, adolescents and adults. Moreover, the probability of reading a pseudoword, such as PUSCLE by analogy to a known analogue (MUSCLE) was found to be higher among adults than among children (Marsh et al., 1977). Treiman et al (1990) found that both children and adults more often substitute real words for pseudowords when reading consistent pseudowords with many neighbors than consistent pseudowords with few neighbors. This effect was stronger for third graders than for first graders.

This convergent pattern of findings suggests that a child's progressively more detailed analysis of the internal structure of printed words is likely to result in increasingly explicit and more fully specified orthographic representations. More accurate representations in turn should promote greater word recognition efficiency by virtue of autonomy (Stanovich, 1990b, 1991b). The reader has less need to resort to extra-word information to disambiguate word identity. Parallel changes in children's spellings from initial adherence to the principle of one letter (or digraph) for each sound prior to acquisition of higher-order positional and morphophonemic regularities (Ehri, 1986; Gentry, 1982; Henderson & Beers, 1980; Marsh, Freidman,Welch & Desberg, 1980; Read, 1971;1986; Templeton & Bear, 1992), together, of course, with the close association between reading and spelling ability (Ehri & Wilce 1987b; Morris & Perney, 1984; Shanahan, 1984; Zutell, 1992) is consistent with this view. Also noteworthy is Frith's (1980) "partial cue" explanation of the phenomenon of good reading/poor spelling in terms a reading style involving attention to a minimum of orthographic information sufficient for rapid word identification yet detrimental to spelling.

The notion of lexicalization also resolves one of the classic enigmas of decoding, namely that the rules (whether these are conceived in connectionist or non-connectionist terms) that are required for proficient decoding are far removed in their complexity from the patently simplistic and (sometimes plainly false) rules imparted to beginners (Gough & Hillinger, 1980; Maclean, 1988). Owing to the complexity of the system, a basic knowledge of simple one-to-one correspondences may represent the logical starting point for the beginning reader, insofar as a workable set of rules offer considerable generative power both as a means for acquiring basic orthographic

representations and as a scaffold for refining and expanding knowledge of the spelling-sound system. Maclean (1988) has suggested that simple one-to-one letter-sound relationships may be a good example of what Glaser (1984) calls "pedagogical theories" -- temporary models suitable for novices at the initial stages of knowledge acquisition in a new domain. These rudimentary knowledge structures provide a scaffold for developing the complex lexically-constrained knowledge of spelling-sound relationships that characterize the expert reader.

Reading Acquisition: Phonological Skills Are Primary; Orthographic Skills Are Secondary

Decoding skill, however, is no guarantee of self-teaching: it only provides opportunities for self-teaching. Others factors such as the quantity and quality of exposure to print (Stanovich, 1993; Stanovich & Cunningham, 1993) together with the ability and/or inclination to attend to and remember orthographic detail will determine the extent to which these opportunities are exploited. As discussed in section 1, differences in visual/orthographic memory and cognitive style are likely to give rise to a range of individual differences in the ability to recognize and recall word-specific orthographic information. At one end of this continuum there may exist extreme cases characterized by severe deficits in visual/orthographic memory. Even with good decoding skill, such ("surface-type") readers are obliged to tackle every word as if encountered for the first time. At the other extreme, it is conceivable that some individuals may recall word-specific letter patterns after only a single exposure.

Although the literature reviewed in section 1 indicates that individual differences in orthographic processing appear to make an independent contribution to word recognition skill (Barker, Torgesen & Wagner, 1992; Cunningham & Stanovich, 1990; McBride–Chang, Manis, Seidenberg, Custodio & Doi, 1993; Olson, Forsberg, Wise & Rack, 1994; Stanovich & West, 1989), this contribution must necessarily be secondary to the role of phonological factors because orthographic factors, in and of themselves, have little self-teaching potential.

The distinction between direct (visual) and indirect (phonological) pathways to meaning (Coltheart, 1978; Coltheart, Curtis, Atkins & Haller, 1993), surface and phonological syndromes of acquired and developmental dyslexia (Castles & Coltheart, 1993; Patterson, Marshall & Coltheart, 1985), dyseidetic and dysphonetic subtypes of disabled readers (Boder, 1973), Chinese and Phoenician readers in both normal and reading-disabled populations (Baron & Strawson, 1976; Freebody & Byrne, 1988), phonic versus look-say/whole-word methods of teaching word identification, are all manifestations of the common belief that visual/orthographic

and phonological mechanisms represent equivalent alternatives for acquiring skilled word recognition. Whatever relevance this dichotomy may have for word recognition, it follows from the self-teaching conception of phonological recoding that the contribution of visual/orthographic factors to the acquisition of fluent word recognition skill must be secondary, and cannot be equivalent, because only phonology offers a functional self-teaching mechanism. Consequently, the contribution of orthographic skill should be largely (but not entirely) parasitic upon self-teaching opportunities provided by decoding and print exposure. Orthographic factors come into play primarily as a result of successful decoding. However, orthographic skill should make a unique contribution to reading skill over and above the contribution of phonological factors, as there is no reason to assume that the ability to remember word-specific letter patterns depends on the same underlying cognitive processes as phonological recoding.

The research findings essentially bear out these predictions. The ability to read pseudowords -- the benchmark measure of phonological recoding, is probably the strongest known correlate of word recognition skill (see reviews by Jorm & Share, 1983; Rack, Snowling & Olson, 1992; Snowling, 1991; Stanovich, 1994a; Stanovich & Siegel, 1994; Wagner & Torgesen, 1987). Correlation coefficients between pseudoword reading and word recognition in the early elementary grades typically exceed .70, indicating that phonological recoding accounts for a majority of reliable variance. Indeed, studies often report little overlap in the distributions of pseudoword reading for disabled and control readers (see, for example, Lundberg & Hoien, 1990, Fig. 2).

Although the evaluation of the contribution of visual/orthographic skills has been hampered by a lack of agreement regarding the nature of this construct (see e.g., Olson et al., 1994; Vellutino, Scanlon & Tanzman, 1994; Wagner & Barker, in press), there is considerable consistency across measures in the pattern of findings. Studies comparing pseudoword with exception word reading have consistently demonstrated that orthographic factors are secondary to phonological skill (Baron, 1979; Baron & Strawson, 1976; Baron & Treiman, 1980; Byrne, Freebody & Gates, 1992; Freebody & Byrne 1988; see also Bradley, 1988). Research employing the increasingly popular measures of spelling choice (Which is a word? RANE/RAIN) and homophone choice (Which is a fruit? PEAR/PAIR) has largely confirmed the findings from the irregular/pseudoword studies. Although these orthographic measures add significant variance to word recognition over and above the contribution of pseudoword processing (Barker, Torgesen & Wagner, 1992; Cunningham & Stanovich, 1990a,1993; Olson et al., 1990,1994; Stanovich & West, 1989, but see Manis, Custodio & Szeszulski, 1993), simple correlations for

orthographic measures are consistently more modest, at least in non-disabled populations (Barker et al., 1992; Cunningham & Stanovich, 1990a; Manis et al., 1993; Masterson, Laxon & Stuart, 1992; McBride-Chang, Manis, Seidenberg, Custodio & Doi, 1993; Stanovich & West, 1989).

In contrast to the literature on pseudoword reading (Rack et al., 1992), disabled readers' orthographic skills tend to match or even exceed younger non-disabled readers matched on reading ability (Bruck, 1990; Olson et al., 1985; Stanovich & Siegel, 1994), while within-group comparisons report reduced orthographic deficits in disabled groups relative to their pseudoword deficits (Manis, Szeszulski, Holt & Graves, 1990; Manis et al., 1993; Olson et al., 1985; Stanovich & Siegel, 1994). In short, orthographic factors assume a significant, albeit secondary role in printed word learning.

The positive association between orthographic and phonological factors among normal readers (Barker et al., 1992; Cunningham & Stanovich, 1990a; Manis et al., 1993; McBride-Chang et al., 1993; Olson et al., 1990;) is consistent with the view that word-specific orthographic knowledge is acquired in the wake of successful self-teaching opportunities provided by decoding skill and print exposure.

The Impact of Individual Differences in Phonological Processing on Phonological Recoding

If we grant a central role for decoding in early reading acquisition, it is possible to identify a number of loci in the decoding process that can be linked to individual differences in the basic phonological processes discussed in section 1.

At the initial stages of learning letter identities, it is often overlooked that letter names and sounds are, in effect, pseudowords -- novel phonological strings. Hence, deficient phonological memory would be expected to impede the mastery of letter identities. Work by Baddeley, Gathercole, and others has established that poor phonological memory impairs the learning of novel items in both normal (Gathercole & Baddeley, 1989;1990a; Papagno & Vallar, 1992; Service, 1992) and abnormal populations (Baddeley, Papagno & Vallar, 1986; Gathercole & Baddeley, 1990b). One might speculate that the well known predictive power of letter name knowledge (Bond & Dykstra, 1967; Chall, 1967; Share et al., 1984) may stem partly from this phonological memory component. Difficulties encoding these meaningless phonological strings should create difficulties retrieving letter sounds and other print-sound correspondences when attempting to decode novel letter strings.

The demands of blending decoded elements will impose a heavy burden on short-term memory. Serial naming difficulties could also substantially reduce the speed with which a sequence of decoded elements can be articulated. This will limit

the number of elements that can be maintained in working memory through rehearsal until decoding is completed and/or a known word is identified. The longer the string, the more likely that this process will break down, although "chunking" of each newly decoded element may serve to reduce memory load. Phonologically complex strings should cause special difficulties.

Torgesen et al. (1989) provide evidence for a specific link between working memory and blending. They manipulated working memory load by varying item presentation rates in an oral phoneme synthesis task. Blending performance improved with faster presentation rates which are known to place less stress on working memory. This effect tended to be larger for real words than for pseudowords, but significantly so only for the reading disabled group. Memory load effects also correlated more strongly with pseudoword reading than with real word reading. The latter finding suggests that poor quality long-term phonological representations (and, more generally, poor oral vocabulary) will introduce additional obstacles for the phonologically disabled reader, over and above "pure" isolated decoding skill. Poor quality representations, particularly for low familiarity words, will reduce the likelihood of achieving a correct match between a known pronunciation and an incomplete or inaccurate decoding.

The research reviewed in section 1 points to a strong link between phonological sensitivity and individual differences in reading acquisition. The self–teaching model implies a major role for phonological sensitivity in resolving decoding ambiguity. As noted above, even a minimal level of sensitivity such as the ability the generate a word with a given initial phoneme, may be sufficient for a rudimentary self-teaching mechanism provided a child posseses a basic knowledge of simple letter-sound correspondences. A partial decoding, however, will be of no avail to a reader oblivious to a word's phonological structure. The same applies to an inaccurate decoding resulting in a pseudoword. Close phonological proximity to a known pronunciation will be of little help. In order to decode words containing unknown or low frequency correspondences, a rich knowledge of the phonological structure of words will be needed to test candidate pronunciations for goodness of contextual "fit". If successfully decoded, an item containing unknown or unfamiliar correspondences will provide the reader with an opportunity to learn new correspondences and thereby expand the power of his or her self-teaching mechanism. However, this is contingent on the learner being able to match up letters and sounds (Ehri, 1992). If the "rime" unit in the word FEAST (/ist/) is perceived as an impenetrable whole, then individual letter/digraph correspondences within this unit are less likely to be attended to and incorporated into an orthographic

representation. The letter-by-letter processing involved in sequential decoding may be the principal means by which letter order and identity become incorporated into a well-specified orthographic representation (Adams, 1990; Barron, 1981; Ehri, 1980a;1992; Venezky, 1976; Venezky & Massaro, 1979; Vellutino & Scanlon, 1984). Spelling is clearly another such process.

By the same token, phonological sensitivity may help economize the process of decoding even for the skilled decoder by permitting early identification of a target pronunciation prior to completion of exhaustive letter-by-letter print-to-sound conversion. A phonemically segmented lexicon in conjunction with the ability to supplement a not-yet-completed decoding with contextual information may permit the reader to achieve early "closure" thereby easing the memory burden in decoding and reducing the likelihood that prior sentence context will be lost as a consequence of slow and inefficient word identification.

Can Individual Differences in Visual Processing Be Linked to a Model of Reading Acquisition?

The previous section has illustrated how it is possible to link a theory of acquisition with what is known about individual differences in phonological processing. Is it possible to develop a similar linkage with visually-based processes?

Despite the considerable interest aroused by the new generation of evidence of visual system deficits among disabled readers (see, for example, Willows et al., 1993), there has been little consideration given to linking deficient visual processing to clearly spelled out models of reading and reading acquisition (see, Hulme, 1988). In contrast to the convergent nature of the literature on phonology, the few attempts to develop the necessary linkage between visual differences and reading have been highly divergent, with little common ground (e.g., Bowers & Wolf, 1993; Corballis, 1993; Johnston, Anderson, Perret & Holligan, 1990; Lovegrove & Williams, 1993; Stein, 1993). The few efforts to develop differential predictions regarding those components of the reading process likely to be impaired by deficient visual processes have met with only limited success (see, e.g., Lovegrove & Williams, 1993). This literature fails to display the convergence that is apparent when one surveys the literature on phonological processing.

However, it is possible that these studies are focused on the wrong level of analysis from the standpoint of a causal theory. For example, it is possible that visual (transient system) deficits among poor readers may simply reflect a more pervasive but distal temporal deficit (Bakker, 1972; Tallal, Sainburg, & Jernigan, 1991; Wolf, 1991; Wolff, Michel, Ovrut & Drake, 1990; Zurif & Carson, 1970) whose impact on reading is solely via phonology by reason of the unique temporal demands of

speech (Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967). By this account there is no direct linkage between visual processing differences and reading ability. That is, visual deficits may not cause reading problems. Until the visual processing literature actually attains a greater degree of convergence, a common-cause explanation via temporal processing may perhaps give the most parsimonious account of the visual data.

III. Instructional Implications

The "reading wars" in educational psychology in North America and elsewhere have graduated from the old whole-word versus phonics controversy of the 1970s to the whole language versus code emphasis controversy of the 1990s (e.g., Goodman, 1992; Groff, 1989; Liberman & Liberman, 1990; Mather, 1992; McKenna, Robinson, & Miller, 1990; McKenna, Stahl, & Reinking, 1994; Mosenthal, 1989; Perfetti, 1991; Weaver, 1989). Although several investigators have recently recommended a pragmatic amalgamation of views (e.g., Adams, 1990; Stanovich, 1990a, 1991a, 1994b), it is not the case that all sides are equally culpable. A pragmatic stance does not necessitate equality in the allocation of credit and blame. In the latest incarnation of the Great Debate (see Chall, 1967, 1983, 1989, 1992), it is the whole language movement that has strayed the furthest from the empirical evidence. In the rest of this chapter, we will explore the issue of whether it is possible to salvage a scientifically respectable whole language philosophy from the current debate. We begin by discussing tenets of the whole language philosophy that depart from the empirical evidence on reading acquisition and individual differences in reading that we have reviewed above.

The Efficacy of Contextual Guessing Has Been Overestimated

It should be clear from the previous review that a foundational tenet of whole language instruction in many incarnations--that guessing words based on the previous context of the passage is an efficacious way of reading and of learning to read--is markedly at variance with the empirical evidence. The whole language movement has carried over this assumption from the top-down models of the 1970s (Goodman, 1976; Smith, 1971) and its association with those models appears to have been a classic case of mistaken analogy in science. That is, these early models were considerably influenced by interactive models of recognition that were derived from artificial intelligence work in speech perception (e.g., Rumelhart, 1977). The problem here is that the analogy to written language is not apt. The ambiguity in decontextualized speech is well known. For example, excised words from normal conversation are often not recognized out of context. This does not hold for written language, obviously. A fluent reader can identify written words with near perfect

accuracy out of context. In short, the physical stimulus alone completely specifies the lexical representation in writing, whereas this is not always true in speech. The greater diagnosticity of the external stimulus in reading, as opposed to listening, puts a greater premium on an input system that can deliver a complete representation of the stimulus to higher-level cognitive systems. More important than these theoretical and logical considerations, however, is that the empirical evidence has falsified the basic prediction that skilled readers rely more on context for word recognition than poorer readers. In fact, the word recognition skills of the good reader are so rapid, automatic, and efficient that the skilled reader need not rely on contextual information.

Reading Acquisition as Oral Language Acquisition

A recurring theme in the writings of whole-language advocates (e.g., Edelsky, Altwerger, & Flores, 1991; Goodman, 1986, 1992; Smith, 1982) is the equating of written language learning with oral language learning. Typical is the statement from Goodman's (1986) popular book for parents and teachers, What's Whole in Whole Language:

> Why do people create and learn written language? They need it! How do they learn it? The same way they learn oral language, by using it in authentic literacy events that meet their needs. Often children have trouble learning written language in school. It's not because it's harder than learning oral language, or learned differently. It's because we've made it hard by trying to make it easy. (p. 24)

The analogy of written language learning with oral language learning ignores the obvious facts that all communities of human beings have developed spoken languages but only a minority of these exist in written form, that speech is almost as old as the human species but that written language is a recent cultural invention of only the last three or four thousand years, and that virtually all children in normal environments develop speech easily, whereas most children require explicit tuition to learn to read and substantial numbers of children have difficulty even after intensive efforts on the part of teachers and parents. The argument of Liberman and Liberman (1990) is typical of current scientific thinking on the oral/written language distinction:

> Reflecting biological roots that run deep, speech employs a single, universal strategy for constructing utterances. All languages form all words by combining and permuting a few dozen consonants and vowels, meaningless segments that we will sometimes refer to,

> loosely, as phonemes. On the other hand, scripts, being artifacts, choose variably from a menu of strategies. Some, like the one we use, represent the phonemes. Others represent the more numerous syllables. Still others, like the Chinese, take the considerably more numerous morphemes as their irreducible units....Surely it is plain that speech is biologically primary in a way that reading and writing are not. Accordingly, we suppose that learning to speak is, by the very nature of the underlying process, much like learning to walk or to perceive visual depth and distance, while learning to read and write is more like learning to do arithmetic or to play checkers. (p. 55)

Research has consistently supported the view that reading is not acquired naturally, in the same way as speech. Byrne (1992) has presented evidence indicating that fully analytic processing of words is not the natural processing set of preliterate four-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. Byrne (1992) argued that it might be instructive to view reading disability--the failure to develop reliable spelling-to-sound decoding skills--as functional fixation of the natural acquisition procedure of all beginning readers, namely, nonanalytic processing.

Gough (1993; Gough & Juel, 1991) had a group of five-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 which accompanied it during training. Almost all children named the word that accompanied the thumbprint during training, rather than the word that was present on the card

The results of Gough (1993) converge nicely with those of Byrne (1992) and are consistent with the idea that learning spelling-to-sound correspondences is an "unnatural" act for young children (Gough & Hillinger, 1980). Results from an important classroom study also support this conclusion. Seymour and Elder (1986) studied a class of new entrants in 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 generative: 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, the error responses of these children were drawn only from the set of words that they had been taught.

Sometimes, Fractionating Language Processes Helps

We have argued that successful reading acquisition seems to require the development of an analytic processing stance towards words that is probably not the "natural" processing set adopted by most children and that some children have extreme difficulty in adopting an analytic processing set. The latter group of children will, as a result, have considerable difficulty building up knowledge of subword spelling-sound correspondences--and such knowledge appears to be a necessary prerequisite of fluent reading (Adams, 1990; Adams & Bruck, 1993; Gough et al., 1992; Jorm & Share, 1983; Stanovich, 1982, 1986b, 1992; Vellutino, 1991; Vellutino & Scanlon, 1987). Not surprisingly, then, the evidence indicates that a code emphasis is more efficacious in reading instruction--especially for poor readers (Adams, 1990; Adams & Bruck; Brown & Felton, 1990; Chall, 1983, 1989; Evans & Carr, 1985; Wise, 1991). Recommendations to integrate systematic and explicit code instruction into the reading of connected text (Adams, 1990; Anderson, Hiebert, Scott, & Wilkinson, 1985; Chall, 1967; 1983) are particularly apt in view of the hypothesized role, discussed in section 2, of lexical and contextual information in resolving word identification ambiguity stemming either from poor decoding skills or spelling-sound irregularity.

Likewise, training kindergarten and preschool children in various phonological sensitivity skills can lead to faster rates of reading and spelling acquisition (Ball, 1993; Ball & Blachman, 1991; Blachman, 1989; Bradley & Bryant, 1983, 1985; Byrne, & Fielding-Barnsley, 1991, 1993; Cunningham, 1990; Hatcher, Hulme, & Ellis, 1994; Lie, 1991; Lundberg, Frost, & Peterson, 1988; Torgesen, Morgan, & Davis, 1992; Treiman & Baron, 1983; Williams, 1980; Wise, 1991), and this training appears to be particularly efficacious when provided in the context of programs which stress the purpose of the phonological activities (see Cunningham, 1990).

Because these training programs invariably involve the segmentation of words, this research evidence flies in the face of the frequent admonitions on the part of whole language advocates not to fractionate language:

> Careful observation is helping us to understand better what makes language easy or hard to learn. Many school traditions seem to have actually hindered language development. In our zeal to make it easy, we've made it hard. How? Primarily by breaking whole (natural) language up into bite-size, but abstract little pieces. It seemed so

> logical to think that little children could best learn simple little things. We took apart the language and turned it into words, syllables, and isolated sounds. Unfortunately, we also postponed its natural purpose—the communication of meaning—and turned it into a set of abstractions, unrelated to the needs and experiences of the children we sought to help. (p. 7, Goodman, 1986)

A large data base now contradicts this position (e.g., Adams, 1990; Brady & Shankweiler, 1991; Goswami & Bryant, 1990; Gough, Ehri, & Treiman, 1992). Liberman and Liberman (1990) argue that, from a linguistic perspective, this is not surprising:

> Communication among nonhuman animals is different in a critically important way, for, so far as anyone has been able to determine, the natural animal systems have no phonology (nor do they have syntax, for that matter), and, as a consequence, their message-carrying potential is severely limited. Lacking the phonological structures that make lexical generativity possible, nonhuman animals can convey in their natural communication only as many word-meanings as there are distinctively different signals they can make and perceive, and that is, at most, a few dozen....Thus, in contrast to language, which is lexically open because word meanings are conveyed by arranging and rearranging meaningless signal elements, the nonhuman systems attach meaning directly to each element and are, as a consequence, tightly and irremediably closed. We see, then, that language would pay a terrible price if it were not phonologically based. Perhaps it would be of some comfort to the Whole Language people that in such a nonphonological world there would be no "bite-size abstract little pieces" for teachers to break a word into....Each word would be conveyed by an unanalyzable signal, so meaning would be conveyed directly, just as Whole Language seems to think it should be. Unfortunately, there would not be many words. (pp. 56-57)

The admonition to "not break up" language is not very helpful to teachers faced with children who are struggling in reading (neither, by the way, is the admonition to "not break up" the comprehension process, see Palincsar & Brown, 1984). In contrast, the growing knowledge of the role of phonological processing in reading holds out great hope for educational applications. First, it can be assessed very early in development, prior to school entrance (Blachman, 1989; Fox & Routh, 1975; Maclean et al., 1987; Mann, 1983; Share et al., 1984). Secondly, as noted above, a growing number of training studies have been conducted that indicate that

phonological sensitivity can be increased through appropriate preschool experiences, and that such training results in a significant increase in word recognition and spelling skills. This training is even more effective when combined with practice in recognizing letter-sound correspondences (Bradley & Bryant, 1983; Ehri, 1989; Hatcher, Hulme, & Ellis, 1994).

Adjudicating the Reading Wars

Clearly, the work on phonological processes and context effects contradicts the philosophical tenets of the more "hard line" whole language advocates. Nevertheless, it is not difficult to demonstrate that there is actually more agreement among reading educators than is sometimes apparent to those obsessively focused on the so-called "reading wars". For example, Chall (1989) has repeatedly pointed out that many of the recommendations and practices that are commonly associated with whole language have appeared repeatedly in her writings. She reminds us that "Teaching only phonics--and in isolation--was not a recommendation of the Great Debate in 1967 or 1983" (p. 525). Chall is at pains to remind her readers that, in common with many whole language advocates, she "also recommended that library books, rather than workbooks, be used by children not working with the teacher and that writing be incorporated into the teaching of reading" (p. 525). Chall (1989) has no compunctions about admitting that "Some teachers may inadvertently overdo the teaching of phonics, leaving little time for the reading of stories and other connected texts" but she notes that "The history of reading instruction teaches us that literature, writing, and thinking are not exclusive properties of any one approach to beginning reading" (p. 531).

Clearly there is an opportunity for rapprochement here. Corresponding to Chall's statement that "some teachers may inadvertently overdo the teaching of phonics" we simply need the companion admission that "some children in whole language classrooms do not pick up the alphabetic principle through simple immersion in print and writing activities, and such children need explicit instruction in alphabetic coding"--a concession having the considerable advantage of being consistent with voluminous research evidence (e.g., Adams, 1990; Vellutino, 1991). It seems inconceivable that we will continue wasting energy on the "reading wars" simply because we cannot get both sides to say, simultaneously, "some teachers overdo phonics" and "some children need explicit instruction in alphabetic coding".

Adams (1991) is likewise boggled at what, seemingly, is the cause of all the acrimony in the field of reading education. She points to the defining features of the whole language philosophy that Bergeron (1990) gleaned from an extensive review

of the literature: "Construction of meaning, wherein an emphasis is placed on comprehending what is read; functional language, or language that has purpose and relevance to the learner; the use of literature in a variety of forms; the writing process, through which learners write, revise, and edit their written works; cooperative student work; and an emphasis on affective aspects of the students' learning experience, such as motivation, enthusiasm, and interest" (p. 319). Adams (1991) asks rhetorically "Is this what the field has been feuding about?" (p. 41). Probably not. Instead, she argues that "the whole language movement carries or is carried by certain other issues that do merit serious concern...these issues are: (1) teacher empowerment, (2) child-centered instruction, (3) integration of reading and writing, (4) a disavowal of the value of teaching or learning phonics, and (5) subscription to the view that children are naturally predisposed toward written language acquisition" (p. 41). Educators working from a variety of different perspectives might well endorse points #1 to #3. Clearly the key points of difference are issues #4 and #5. However, Adams (1991) makes the seemingly startling--but actually very wise--suggestion that the "positions of the whole language movement on teaching and learning about spellings and sounds are historical artifacts. Although they are central to its rhetoric and focal to its detractors, they may well be peripheral to the social and pedagogical concerns that drive the movement....Yet their continuing centrality to the rhetoric of the movement may be owed no less to their historical precedence than to the fact that...they were tightly connected to the other issues of teacher empowerment, child-centered education, and the reading-writing connection. I believe, moreover, that it is these latter issues that inspire the deepest commitment and passion of the movement....To treat it today as an issue of phonics versus no phonics is not only to misrepresent it, but to place all of its valuable components at genuine risk" (p.42, p. 51).

Adams is pointing toward some dangers that lie in wait for whole language advocates but also toward a possible rapprochement within the reading education community. The danger is this. In holding to an irrationally extreme view on the role of phonics in reading education--for failing to acknowledge that some children do not discover the alphabetic principle on their own and need systematic direct instruction in the alphabet principle, phonological analysis, and alphabetic coding--whole language proponents threaten all of their legitimate accomplishments. By taking a stand so clearly at variance with the empirical evidence, whole-language advocates put at risk all of the legitimate issues of empowerment that are central to their philosophy.

In her seminal book, Beginning to Read: Thinking and Learning About Print, Marilyn Adams (1990) argued that "Reading may be the most politicized topic in the field of education" (p. 13). Sadly, education has suffered greatly because of the excessive politicization of the subject. Much is known about early reading. The information we have could be used to improve practice. Liberman (1988) has lamented that "Prospective teachers are not being taught the critical role that this kind of phonological awareness can play in the child's mastery of the alphabetic principle even though its relevance has been confirmed over and over again" (p. 171). Instead, the endless "reading wars" within education dissipate energy and confuse teachers. They needlessly pit teacher against teacher and researcher against researcher in a battle in which we should all be standing on common ground.

One strategy for ending this ongoing dispute has been suggested here. The way seems clear for whole language advocates to reconstitute their position in a scientifically respectable way. They could retain most of their broad socioeducational goals (teacher empowerment, equal opportunity for all learners, engaged learning, etc.), but jettison the unwarranted adherence to a processing model of reading that is outdated and not congruent with the latest research evidence. Such a "pragmatic move" might offend those who value philosophical purity above all else. However, actual empirical research is highly pragmatic in a way that philosophically-based educational polemic is not.

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Footnote

This manuscript represents an equal collaborative effort; authorship is listed in alphabetical order. Preparation of the manuscript was supported by grant #0GP0001607 from the Natural Sciences and Engineering Research Council of Canada to Keith E. Stanovich. The manuscript was prepared while David Share was a visiting scholar at the Ontario Institute for Studies in Education. He acknowledges with gratitude the support of both the faculty and administrative staff in the Department of Applied Psychology. Correspondence should be addressed to David L. Share, Department of Education, University of Haifa, Mount Carmel, Haifa 31999 Israel, or Keith E. Stanovich, Department of Applied Psychology, Ontario Institute for Studies in Education, 252 Bloor St. West, Toronto, Ontario, Canada M5S 1V6.