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Phonological recoding and self-teaching: *sine qua non* of reading acquisition

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Abstract

The self-teaching hypothesis proposes that phonological recoding functions as a self-teaching mechanism enabling the learner to independently acquire an autonomous orthographic lexicon. Successful decoding encounters with novel letter strings provide opportunities to learn word-specific print-to-meaning connections. Although it may not play a central role in skilled word recognition, phonological recoding, by virtue of its self-teaching function, is regarded as critical to successful reading acquisition. This paper elaborates the self-teaching hypothesis proposed by Jorm and Share (1983), and reviews relevant evidence. Key features of phonological recoding include an item-based rather than stage-based role in development, the progressive "lexicalization" of the process of recoding, and the importance of phonological awareness and contextual information in resolving decoding ambiguity. Although phonological skills have been shown to be primary in reading acquisition, orthographic processing appears to be an important but secondary source of individual differences. This implies an asymmetrical pattern of dissociations in both developmental and acquired reading disorders. Strong relationships between word recognition, basic phonological processing abilities and phonemic awareness are also consistent with the self-teaching notion. Finally, it is noted that current models of word recognition (both PDP and dual-route) fail to address the quintessential problem of reading acquisition – *independent* generation of target pronunciations for novel orthographic strings.

1. Introduction

The following essay elaborates the view, first put forward by Firth (1972) then developed by Jorm and Share (1983; Share & Jorm, 1987), that

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phonological recoding (print-to-sound translation) functions as a self-teaching mechanism enabling the learner to acquire the detailed orthographic representations necessary for rapid, autonomous, visual word recognition.[1]

I begin by introducing the self-teaching idea within the context of alternative options for acquiring word recognition skill. A detailed discussion of the developmental properties of phonological recoding is then presented, followed by a review of the evidence on the importance of basic, cognitive abilities (principally phonological processing) which are assumed to underlie the development of phonological recoding. Two further sections discuss issues relevant to self-teaching in the literature on phonemic awareness and early reading instruction. Finally, a number of conclusions are drawn regarding the broader psychological and pedagogical implications of the self-teaching hypothesis.

1.1. Non-phonological options for printed word learning

There are a number of mechanisms that may serve to build an orthographic lexicon. These include direct instruction, contextual guessing, and phonological recoding. Consideration of these alternatives suggests that only phonological recoding offers a viable means for printed word learning, although later discussion of the development of phonological recoding points to a potentially important role of contextual information in resolving decoding ambiguity.

1.1.1. Direct instruction

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. (The view that printed word learning is possible via direct classroom instruction is one which was incorporated into basal readers for many years (see Chall, 1987)). The problem with this

[1] A wide variety of terms have been used to refer to the role of speech-based information in reading, including acoustic/articulatory/phonetic/phonemic/phonological route/routine/mechanism/procedure/process/coding/recoding/decoding/activation and more. Although many of these terms are often used interchangeably, each embodies a somewhat different set of assumptions. However, no single term is likely to be correct because different processes may be operating at different stages of development. As the precise nature of these representations and the manner of their activation/derivation is still unclear, this article adopts the umbrella term "phonological recoding" or simply "decoding" to refer to the class of processes by which speech-based information is derived from, or activated by, printed letter strings at any point along the developmental continuum. This class includes, but is not confined to, application of letter-sound correspondence rules (operating on single or multi-letter groups in invariant or probabilistic fashion (Coltheart, 1978; Coltheart et al., 1993; Patterson & V. Coltheart, 1987), an analogical mechanism which synthesizes stored information from orthographically related words (Baron, 1979; Glushko, 1979; Kay & Marcel, 1981), and automatic activation of a distributed network of connections between orthographic and phonological units (Seidenberg & McClelland, 1989; Van Orden et al., 1990).

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 (Ehri, 1992).[2]

1.1.2. Contextual guessing

The use of syntactic, semantic, and pragmatic information in the surrounding text to predict unfamiliar words represents a second option which has received considerable attention in the literature (Goodman, 1967; Smith, 1988). 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 (1977–1978) analysis of data originally reported by Bormuth (1966). In this study, the "cloze easiness" of over 5000 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;

[2] Some limited direct instruction at the very beginning of reading instruction may not be entirely unprofitable. Because a small number (around 100) of super-high-frequency but often highly irregular words, such as SOME, HAVE, WERE, WOULD, etc., account for approximately half of all the items appearing in children's reading material (Carroll et al., 1971), direct instruction of some of these phonetically intractible items may make good pedagogical sense for beginner readers still acquiring the rudiments of the symbol–sound system. An additional reason for some limited early direct instruction relates to the accumulation of a small stock of "undissected orthographic specimens" from which certain regularities between spelling and sound may later be extracted once sufficient phonological awareness and knowledge of spelling–sound relationships have been acquired (Frith, 1985).

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 carry most of 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, 1977–1978). It seems that contextual guessing is least helpful where it is needed most.

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* lexical item. The ability of a child to use contextual information to derive a semantically *plausible* candidate for an orthographically (and perhaps also semantically) unfamiliar word may be satisfactory from the standpoint of immediate 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.

The inadequacy of contextual guessing is related, in part, to the extraordinary number of synonyms or near-synonyms found in the English language. (In theory, one could envision a lexically primitive language in which synonymy is minimal and consequently contextual guessing might prove to be more effective.) 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, that is, anyone with a restaurant "schema" or "script" (Rumelhart, 1975). 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). Pictures, key words, titles, subheadings, etc., must be supplied to enable the reader to identify and activate the relevant background information. Information that represents a routine or "default" constituent of the relevant schema will normally be inferred 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 do not normally exist. There is simply no need to state the obvious. Contextual guessing therefore *must* fail because natural text is normally non-redundant.[3]

[3] Although contextual guessing, *per se*, may not enable a child to identify new orthographic items, later it is argued that contextual information may play an important developmental role in supplementing partial or incomplete decodings stemming from weak phonological recoding skill or phonetically recalcitrant ("irregular") words.

2. Phonological recoding and the 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 assumes 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. A relatively small number of (successful) exposures appear to be sufficient for acquiring orthographic representations, both for adult skilled readers (Brooks, 1977) and young children (Manis, 1985; Reitsma, 1983a, 1983b). In this way, phonological recoding acts as a self-teaching mechanism or built-in teacher enabling a child to independently develop both (word)-specific and general orthographic knowledge. Although it may not be crucial in skilled word recognition, phonological recoding may be the principal means by which the learner attains word recognition proficiency.

The proposed self-teaching function of phonological recoding has three key features, each of which is introduced here, then expanded below. First, the developmental role of phonological recoding (as distinct from the development of phonological recoding itself) is seen as *item-based* rather than *stage-based*. Traditionally, researchers have 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 stage-based theories have not fared well 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. Taking an item-based perspective, the self-teaching hypothesis argues that the process of word recognition will depend primarily on the frequency to which a child has been exposed to a particular word together, of course, with the nature and success of item identification. Because orthographic information is acquired rapidly (Brooks, 1977; Manis, 1985; Reitsma, 1983a, 1983b), high-frequency items are likely to be recognized visually with minimal phonological processing 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. Because the frequency range in children's natural reading materials is normally very wide (Carroll et al., 1971), the incidence of phonological recoding will vary according to the distribution of item familiarities. This phonology by familiarity account resolves much of the conflicting evidence, reviewed below, regarding the use of visual versus phonological word recognition processes among young readers. A majority of words in natural text will be recognized visually by virtue of their high frequencies, while the smaller number of low-frequency items will provide opportunities for self-teaching with minimal disruption of ongoing comprehension processes. It is further proposed that the self-teaching opportunities afforded by phonological recoding represent the "cutting edge" of reading development not merely for the beginner, but throughout the entire ability range.

A second key feature of the self-teaching notion is that the process of phonological recoding becomes increasingly "lexicalized" in the course of reading development. Simple letter–sound correspondences become modified in the light of lexical constraints imposed 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, positional, and morphemic constraints. 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 wholly lexical mechanism that maintains no sublexical spelling-sound correspondence rules. For the beginner, however, an initial set of simple one-to-one correspondences (whose mastery represents no small accomplishment, see Ehri, 1986) may represent the logical point of entry since it offers a minimum number of rules with the maximum generative power. Both Gough and Hillinger (1980) and Maclean (1988) note that the spelling–sound correspondence rules to which a child is first introduced are very different from those he or she will eventually acquire as a skilled reader. But this simpler, more manageable set is sufficient to kickstart the self-teaching mechanism which is then able to refine itself in the light of expanding orthographic knowledge.

Third, the self-teaching mechanism involves two component processes: phonological and orthographic. Both components make independent contributions to the acquisition of fluent word recognition, although the phonological component is primary, accounting for the lion's share of variance in individual differences in reading ability. The orthographic component represents an additional, independent but secondary component. The phonological component is simply the ability to use knowledge of spelling–sound relationships to identify unfamiliar words. This ability represents the sine qua non of reading acquisition. However, over and above the ability to decode unfamiliar words, there exist individual differences in the ability to store and retrieve word-specific orthographic information. Differences in visual/orthographic processing will determine how quickly and accurately orthographic representations are acquired. These visual/orthographic factors, however, will depend heavily on the successful operation of the phonological component. Thus, visual/orthographic processes are seen not merely as a second source of variance, but as a *secondary* source of individual differences in reading acquisition.

The following section expands the points outlined above.

2.1. Phonological recoding is item-based, not stage-based

The popular view that children initially read words by phonological recoding with a later developmental shift to visual access has served as the focus of a number of experimental investigations (see Barron, 1986 and Jorm and Share, 1983 for reviews of this work). Results, however, have been consistently inconsistent. Several 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). Although many of these studies are plagued by interpretational difficulties (such as non-crossover task by grade interactions, use of the controversial technique of concurrent vocalization, and changing concepts of spelling–sound regularity), there is a clear pattern to these findings when differences in item frequency are considered. All studies reporting evidence of direct access in even their youngest readers employed a restricted range of high-frequency words.[4] In each case of positive 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 item familiarity by phonology interaction – a developmental analogue of the well-known frequency by regularity interaction (see Seidenberg, 1985). High-frequency items require relatively little phonological "assistance", whereas less familiar items are more dependent on phonology.

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).[5] If these data, which were obtained using isolated word presentation, are found to generalize to natural text, it seems reasonable to conclude that the acquisition of word-specific orthographic information is generally quite rapid. Although this does not necessarily imply a "switch" to direct visual recognition, Reitsma (1990) has shown that the development of these word-specific representations is accompanied by a declining role for phonology. Consequently, high-frequency words may be recognized visually from the very earliest stages of reading acquisition. It is not surprising, therefore,

[4] Although the Bryant and Bradley (1983) study reported inclusion of both "easy" and "difficult" items, the two examples of "difficult" items (EYE and PICTURE) are among the most frequent 200 words in school reading material (Carroll et al., 1971).

[5] This does not imply that these representations are acquired in an all-or-none fashion (see Gill, 1992; Perfetti, 1992). Clearly, there will be important individual differences in the efficiency of assimilating orthographic information attributable not only to variation in decoding skill (Reitsma, 1983b; Manis, 1985) and to processing styles (Frith, 1985; Olson et al., 1985; Perfetti, 1992), but also to general knowledge of orthographic conventions (Olson et al., 1985, 1990; Stanovich & West, 1989).

that studies employing a restricted range of high-frequency words have concluded that direct visual access is evident at the onset of learning to read, whereas studies including low-familiarity items have found evidence for phonological recoding. As stated above, the critical question is *which* items. *Reductio ad absurdum*, it should be possible to find reliance on phonological recoding among skilled readers yet direct visual recognition among beginning readers by appropriate manipulation of the item pool.

2.1.1. Phonological recoding represents the "cutting edge" of reading development

A further implication of this item-based conceptualization of the role of phonological recoding relates to the extreme skew in the distribution of word frequencies in natural text. Because approximately 100 items account for around half of all the words appearing in printed school English (Carroll et al., 1971), these "heavy-duty" items will be recognized visually from the very earliest stages of reading acquisition. This small pool of "sight" words may represent only a tiny fraction of the many thousands of word-types that will eventually become part of the child's recognition vocabulary, but from a functional point of view, the novice reader is already visually familiar with a substantial proportion (possibly a majority) of the items in his or her everyday reading material. At the other extreme of the frequency continuum are words that are seldom encountered but which nevertheless constitute a large proportion of the total corpus of word-types. This implies that when reading natural text with its wide range of item frequencies, recognition of most items will be fast, autonomous and visual while a smaller number of items will involve slower, more resource-draining phonological recoding. Too great a number of unfamiliar words will disrupt ongoing comprehension processes by siphoning off available cognitive resources (Perfetti, 1985), but the occasional novel string will provide relatively unintrusive self-teaching opportunities. It also follows that a judicious mix of visual and phonological recognition processes should, by and large, characterize the word recognition processes of readers at most ability levels, provided of course that reading material is pitched at the appropriate level of difficulty. In other words, the occasional self-teaching opportunity should constitute the "cutting edge" of reading acquisition for both unskilled and skilled readers alike, enabling a gradual, unobtrusive expansion of the orthographic lexicon.

2.2. The onset and lexicalization of self-teaching

2.2.1. Reading prior to self-teaching?

In addition to the phonological-to-visual stage theory discussed above, there is another visual-to-phonological stage-based theory, which postulates an initial stage of reading in which a limited number of words become recognized by sight or "logographically" (Frith, 1985; Gough, Juel, & Roper-Schneider, 1983; Marsh, Friedman, Welch, & Desberg, 1981). These are 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 at any sublexical (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 an unfamiliar word, the "logographic" reader may substitute a word in their existing sight vocabulary (Gough et al., 1983; Biemiller, 1970; Seymour & Elder, 1986), or may guess on the basis of prior context (Biemiller, 1970; Cohen, 1974–1975; 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). Complete non-responses also occur, but nonsense word responses (indicating some attempt to phonologically recode) are conspicuously absent. Because it ignores correspondences between print and sound at the sublexical level, logographic "reading" is impotent in the face of a novel word and therefore has no functional value in view of the 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, 1982; Stahl & Miller, 1989), from the standpoint of acquiring proficient word recognition skill, it may best be regarded as pre-reading.

Even if it exists, logographic reading must necessarily be short-lived because the alphabetic nature of English orthography dictates complete or near-complete processing of orthographic detail. Only letter-by-letter processing such as phonological recoding or spelling are likely to provide this. 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. There may exist a few rare individuals (typified by the idiot-savant played by Dustin Hoffman in the film *Rain Man*) who are capable of memorizing entire telephone directories, but for a normal child about to learn to read, the absurdity of this task should be obvious. Ironically, evidence of unimpaired logographic learning among disabled readers together with early holistic notions of visual/gestalt word recognition processes (see, for example, Boder, 1973; Johnson & Myklebust, 1967) may have helped promote the common misconception that non-phonological, visual learning represents a feasible alternative to phonological recoding. When the task calls for memorizing a small number of visually distinct symbol strings, logographic learning succeeds because the learner need only attend to one or two visual features. But when the number of to-be-learned symbols reaches double figures, and these symbols each contain common visual elements, the task becomes extraordinarily difficult (Ehri & Wilce, 1987a; Jorm, 1981).

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 exposure alone has not been found to spontaneously induce discovery of the alphabetic principle (Byrne, 1992; Byrne & Fielding-Barnsley, 1989; Ehri & Sweet, 1991; Juel, 1983; Seymour & Elder, 1986). Evidence discussed in the following section suggests that it is explicit instruction in letter-sound knowledge together with some basic phonemic awareness that bring the decoding possibilities of an alphabetic orthography to a child's attention.

2.2.2. *The beginning of self-teaching*

A growing number of studies, and in particular the ground-breaking work of Ehri and her colleagues, now indicate that some limited but functional self-teaching skill in the form of partial decoding 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, 1987b; Ehri & Sweet, 1991; Morris, 1992; Scott & Ehri, 1990; Stuart & Coltheart, 1988; Stuart, 1990). This rudimentary self-teaching depends on three factors: letter-sound knowledge, basic phonemic awareness, 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, 1987b; 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.[6] Ehri (1991) proposes that learning words through the use of even partial symbol-sound associations is superior to purely visual learning because associations are non-arbitrary unlike visual cues. A partial decoding strategy, however, cannot succeed on the basis of letter-sound knowledge alone. It necessarily depends on phonemic awareness, specifically, the ability to recognize identity between learned letter names or sounds and sublexical phonological segments in spoken words. Knowing that the letter S has the sound /s/ is of no help learning the word sail 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 with a minimal level of phonemic awareness, 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 he or she 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 phonemic awareness is consistent with the wealth of evidence, outlined below, 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 & Jorm, 1987; Tunmer, Herriman, & Nesdale, 1988).

Empirical support for the role of phonemic awareness 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 1 reading ability. Non-phonological errors – those with either no letters in common (LOOK – "baby") or which shared common letters but incorrect locations (MILK – "like"), were negatively related to reading ability. In addition, the ratio between these two error types was correlated with a child's pre-school phoneme segmentation ability and knowledge of letter-sounds. Furthermore, the point at which phonological errors became more common than

[6] Examples such as these in both reading and spelling (see below) raise the possibility that some cases of "phonetic cue" reading may, in fact, be *syllabic* reading. The greater perceptibility of the syllable as opposed to the phoneme (Liberman et al., 1967) taken together with the work of Ferreiro and Teberosky (1982), suggests that this possibility may warrant further investigation (see also Rozin & Gleitman, 1977).

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 two out of six tests of phonemic awareness.

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 behaviour 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 segmentation and letter-sound knowledge (Morris, 1992; Ehri & Sweet, 1991).

In summary, from the very beginnings of reading acquisition, a minimal level of phonemic awareness 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, 1987a; 22.5% in Ehri & Wilce, 1987b), so phonetic-cue reading would appear to have questionable value.

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, 1985; 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, 1985; 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 (Nicholson, 1991; Stanovich, 1980, 1986). The role of contextual information in resolving decoding ambiguity may also partly explain the surprisingly strong relationship between measures of syntactic awareness (such as sentence correction) and word recognition (Bowey, 1986a, 1986b; Bowey & Patel, 1988; Fowler, 1988; Siegel & Ryan, 1988; Tunmer, Nesdale, & Wright, 1987; Tunmer et al., 1988; Willows & Ryan, 1986) – an association reliably stronger than that between syntactic awareness and reading comprehension (Bowey, 1986a; Bowey & Patel, 1988; Willows & Ryan, 1986; Siegel & Ryan, 1988).

To sum up, there is evidence that rudimentary, yet functional self-teaching may develop at the very outset of learning to read, sufficient perhaps to lay down primitive orthographic representations (see Perfetti, 1992) well before a child has acquired "conventional" decoding skill. This notion of partial decoding also has important implications for the regularity/irregularity controversy to which I return later.

2.2.3. The development and lexicalization of phonological recoding

Consonantal correspondences appear the earliest and easiest to acquire (Bryson & Werker, 1989; Fowler, Liberman, & Shankweiler, 1977; Lovett, 1987; Mason, 1976; Siegel & Faux, 1989; Stuart & Coltheart, 1988; Stuart, 1990). This advantage is generally attributed to their relatively invariant letter–sound relationships in contrast to vowels. Final consonant correspondences may be more difficult (Fowler et al., 1977) partly because of their position at the end of words. A number of factors may account for this difficulty. Sensitivity to initial consonants (alliteration) appears to develop early (Bryant, Maclean, & Bradley 1990; Kirtley, Bryant, Maclean, & Bradley 1989; Treiman, 1992), whereas final consonants may be relatively "bound" within the rime unit (vocalic nucleus and final consonant(s)), and hence more difficult to isolate. Initial consonant blends require several years to master (Siegel & Faux, 1989) probably because they too are bound in "onset" units (pre-vocalic consonants). Memory limitations may also restrict decoding to initial elements when decoding is slow and effortful. A further advantage for initial consonants may be the mileage gained by a strategy that depends solely on the use of initial phonetic cues in conjunction with contextual information. Finally, reliance on initial letter-sound information enjoys the added advantage of not requiring blending skill.

The acquisition of consonant correspondences, however, is not without its complexities. Variable correspondences for consonants such as the hard/soft "c" alternation present considerable difficulties for young readers (Marsh, Desberg, & Cooper, 1977; Marsh et al., 1981; Venezky & Johnson, 1973). By the same token, the multiple correspondences of vowels require sensitivity to orthographic context. Early decoding skill appears to be based on simple one-to-one correspondences that are relatively insensitive to orthographic and morphemic context. Later, knowledge of correspondences between orthography and phonology becomes increasingly context-sensitive or "lexicalized". There are a number of converging 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 (Coltheart & Leahy, 1992; Manis, 1985; Marsh et al., 1981; Siegel & Faux, 1989; Zinna, Liberman, & Shankweiler, 1986). For example, single vowel letters are easier to read in simple CVCs 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 et al., 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 over-generalize 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 neighbourhood. As the orthographic lexicon 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 neighbours (e.g., TEAK) than items with consistent neighbours (DEAN). For first graders, 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 make a higher proportion of lexicalization errors (substituting 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.

The literature on early spelling development provides further support for the lexicalization hypothesis. Because reading and spelling in young children are strongly related (see, for example, Ehri and Wilce 1987b; Morris & Perney, 1984; Zutell, 1992), spellings, and in particular spelling errors, may provide valuable insights into the nature and development of children's orthographic representations. In parallel with the reading data, children's spelling development appears to move through a sequence of stages characterized by initial adherence to the principle of one letter (or digraph) for each sound prior to acquisition of higher-order regularities such as spelling patterns, positional constraints, and morpheme-based units (Ehri, 1986; Gentry, 1982; Henderson & Beers, 1980; Marsh, Freidman, Welch, & Desberg, 1980; Read, 1971, 1986; Templeton & Bear, 1992).

In sum, there is a considerable volume of reading and spelling data indicating that an initially incomplete and oversimplified representation of the English spelling–sound system becomes modified and refined in the light of print experience, progressively evolving into a more complete, more accurate and highly sophisticated understanding of the relationships between orthography and phonology. Because of 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. Ironically, the product of this lexicalization process is a system so finely tailored to the complexities of orthography/phonology relationships, that lexical-analogy models of word recognition (e.g., Brown, 1987; Glushko, 1979) which dispense entirely with a non-lexical decoding mechanism are able to provide plausible accounts of skilled readers' pronunciation of print. For this reason, the perennial controversy over the role of phonological recoding in printed word recognition may well be unresolvable if divorced from developmental considerations.

2.2.4. *Irregularity and partial decoding*

It is often argued, sometimes by parody, that English spelling is too irregular for decoding to be useful in word identification. Indeed, there is no dispute that an orthographically *unfamiliar* item with an "exception" pronunciation, when presented in *isolation*, is unlikely to be identified correctly. In isolation, the reader simply has no way of distinguishing between alternative pronunciations. But it is clear from the earlier discussion of the (non)viability of direct instruction as a means for developing an orthographic lexicon, that words are not normally *learned* in isolation but in coherent text, and textual constraints may play a significant role in resolving decoding ambiguity (Goswami, 1990; Nicholson, 1991; Nicholson & Hill, 1985; Pring & Snowling, 1986; Stanovich, 1980, 1986). Pre-occupation with isolated word recognition may be partly responsible for the false dichotomy between regular words which are presumed to be pronounceable by means of phonological recoding and exception words supposedly inaccessible to the recoding mechanism. Consistent with the prevailing view that regularity represents a continuum rather than a dichotomy (see, for example, Patterson & Morton, 1985; Stanovich, 1991) is the observation that even hermits such a CHOIR and YACHT are not entirely irregular. Most importantly, the irregularity of printed English (at least low-level or "small-unit" regularity) is largely restricted to the vowels 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, as in the case of the partial decoding hypothesis discussed above, on phonemic awareness, sensitivity to contextual constraints, and the reader's willingness to test multiple alternative pronunciations for "goodness of fit". For the latter reason, it would be highly counterproductive for a reader to remain wedded to a belief in invariant one-to-one spelling–sound relationships, particularly with regard to vowels.

The hypothesis being proposed 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.

2.2.5. *Empirical evidence for irregular word dependence on phonological recoding*

There are several lines of evidence indicating a central role for phonological recoding in the acquisition of irregular words. First, pseudoword reading (the standard measure of phonological recoding) correlates substantially with exception word reading (Baron, 1979; Baron & Treiman, 1980;

Freebody & Byrne, 1988; Gough & Walsh, 1991; Jorm, 1981; Spring & Davis, 1988; Stanovich & West, 1989; Treiman, 1984). Most children are either good on both tasks or poor on both tasks (see Byrne, Freebody, & Gates, 1992; Freebody & Byrne, 1988).

Beyond these purely correlational data, there is evidence to support the specific interpretation proposed here, namely, that irregular word *learning* is dependent on decoding ability. Scatterplots of the relationship between pseudoword and exception word reading (see Gough & Walsh, 1991; Byrne et al., 1992) highlight a scarcity of cases with poor pseudoword reading but good exception word reading relative to cases of good pseudoword reading but poor exception word reading. This implies that skilled decoding does not ensure good exception word reading, but without good decoding, exception word reading is likely to be poor.

There is also direct experimental support for the hypothesis that exception word reading depends on decoding skill. Gough and Walsh (1991) found that the ability of first graders to learn unfamiliar exception words in isolation correlated positively (.56) with decoding skill. Similarly, Manis (1985) reported that poor fifth and sixth grade readers who had weak decoding skill had great difficulty learning to read novel irregular words relative to good readers. These findings also appear to extend to regular classroom settings (Foorman, Francis, Novy, & Liberman, 1991).

In summary, both irregular and regular words appear to depend on the self-teaching afforded by phonological recoding. Furthermore, the role of decoding in learning exception words appears to overshadow the role played by those word-specific visual/orthographic factors generally assumed to be of primary importance precisely because of the presumed inadequacy of letter-sound rules. Stanovich and West (1989) found that pseudoword naming and phonological choice (Which sounds like a word – KAKE/DAKE?) correlated more highly with exception word reading (.46/.57) than either of two orthographic tasks (orthographic choice – RUME/ROOM (.36) and homophone choice: Which is a fruit – PEAR/PAIR? (.30)). These data suggest that decoding skill accounts for over twice as much variance in exception word reading as orthographic processing. Moreover, there is, as yet, no firm evidence to support the popular assumption that exception words are more dependent on visual/orthographic factors than regular words (cf. Olson, Kliegl, Davidson, & Foltz, 1985; Stanovich & West, 1989).

Although the acquisition of irregular words, like regular words, appears to depend heavily on decoding skill, the ubiquity of the regularity effect demonstrates that these exceptions are somehow different.

2.2.6. What's exceptional about exception words?

Consider again the distinction between word identification and word recognition. The basic self-teaching hypothesis proposes that a series of successful decoding encounters enable a word to be *re*cognized on the basis of stored information regarding its unique letter pattern. Because English, unlike most other alphabetic orthographies, has multiple ways of representing almost every speech sound, virtually *every* spelling is unique and therefore unpredictable. There is no *a priori* reason why the spoken word /slip/ is spelled SLEEP and not SLEAP. If the development of skilled word recognition involves mastery (or near-mastery) of each word-specific letter configuration, it follows that both regular and irregular words alike must be dependent on the ability to assimilate word-specific information. Until sufficient orthographic information is compiled (regularity effects are normally apparent only with low-familiarity items, Seidenberg, 1985), differences between these items may simply be a product of different types of spelling–sound knowledge required for word identification. Only a single pronunciation is required to read a regular word or pseudoword, hence a basic knowledge of one-to-one grapheme–phoneme correspondences will often suffice. Exception words, on the other hand, call for a different kind of print–sound knowledge (both low-level and high-level), specifically, the ability to generate multiple pronunciations (consider BREAD) as contextually appropriate candidates. Conventional pseudoword decoding tests, therefore, overlook an important aspect of decoding – knowledge of multiple alternative pronunciations. It is not surprising, then, that correlations between conventional measures of pseudoword reading and exception word reading are relatively low, giving the perhaps false impression that exception words are somehow less dependent on decoding. If decoding tests also tapped higher level decoding knowledge (perhaps by giving credit for knowledge of both common and less common pronunciations), pseudoword/exception correlations may match or even exceed pseudoword/regular correlations.

Differential decodability of exception and regular words, however, may not be the whole story. By virtue of their obtuseness, exception words may prompt a child to resort to greater contextual guessing more often or to ask someone to supply the pronunciation. The small proportion of occasions when either or both of these strategies may be effective may explain a diminished role for decoding in learning to read exception words (if such exists). Possibly owing to their distinctive spellings, some exception words, such as LISTEN and ANSWER, which are also *orthographically* irregular (Seidenberg's "strange" words), may even have an advantage from the point of view of acquiring word-specific letter patterns (see Ehri, 1986).

2.2.7. Summary

According to the self-teaching hypothesis, orthographic knowledge develops primarily as a result of the self-teaching opportunities provided by successful decoding. If contextual information helps resolve decoding ambiguity in the way suggested by the partial decoding hypothesis, then decoding will be essential both for regular and exception words.

But decoding skill only provides *opportunites* for self-teaching. Other factors such as the quantity and quality of print exposure together with the ability and/or inclination to attend to and remember orthographic detail will determine the extent to which these opportunities are exploited. 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 individual differences in orthographic processing appear to make an independent contribution to word recognition skill (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.

2.3. Phonological skills are primary, orthographic skills secondary

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 *re*cognition, 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 account for unique additional variance in reading skill over and above variance attributable to 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.

It is worth remarking that an evaluation of the relative roles of phonological versus orthographic factors in word identification is clouded by the fact that there exists an extensive data base on phonological recoding with standard, agreed-upon measures. Research into orthographic processing, on the other hand, is a much newer venture and still lacks a consensual metric. This observation alone speaks to the issue under question.

2.3.1. The primacy of phonological recoding

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 & 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). To appreciate the magnitude of these differences, consider data reported by Siegel and Ryan (1988). These authors found that reading disabled children aged 13–14 years obtained scores on pseudoword reading comparable only to a group of normal children aged 7–8 years. That is, it took the disabled readers 7–8 years to achieve a level of decoding skill attained by normal readers in only 12–24 months!

These data are very clear on one point. If visual/orthographic learning offered a feasible means for achieving skilled word recognition, poor decoding skill should only handicap children unable to exploit the non-phonological alternative. As we shall see below, *most* disabled readers are not impaired in their ability to form direct print-meaning connections.

2.3.2. The secondary role of orthographic processing

As noted above, the evaluation of the contribution of visual/orthographic skills has been hampered by a lack of agreement regarding the nature of this construct (see, for example, Olson et al., 1994; Vellutino, Scanlon, & Tanzman, 1994; Wagner & Barker, in press).[7] Earlier information-processing attempts to assess visual/orthographic factors were based on faulty notions of holistic, visual/gestalt processes which stand in complete opposi-

[7] Definitions of orthographic processes include (a) direct print–meaning connections that invoke no phonological recoding (i.e., direct visual word recognition) (Stanovich, 1993), (b) knowledge of specific word spellings (Ehri, 1980b), (c) more general knowledge of orthographic conventions governing permissible letter sequences (Perfetti, 1985), higher-order linguistic constraints (e.g., morphological and syntactic) on word spellings (Assink & Kattenberg, in press) and more (see Wagner & Barker, in press, Table 1). It is not my intention to become embroiled in this debate, only to point out the consistency *across* measures with respect to the secondary role of visual/orthographic factors *vis-à-vis* phonology.

tion to current views of orthographic processing as attention to orthographic (letter-based) *detail* (Adams, 1990; Perfetti, 1992).[8]

In an effort to tap word-specific orthographic factors in word recognition, several groups of investigators have compared pseudoword reading with exception word reading (Baron, 1979; Baron & Strawson, 1976; Baron & Treiman, 1980; Byrne et al., 1992; Freebody & Byrne, 1988) on the assumption that exception words, unlike regular words, cannot be pronounced correctly with symbol–sound rules and must therefore depend primarily on word-specific visual/orthographic factors. Although there is no firm evidence to support the view that exception words depend to any greater extent on word-specific information than regular words (Stanovich & West, 1989), there is no dispute that exception words (like all real words) must depend more on word-specific factors than pseudowords. Thus, individual differences between exception word reading and pseudoword reading should correlate with word-specific factors.

Working within the dual-route framework, Baron and Strawson (1976) developed the notion of Phoenician and Chinese reading styles to describe individual differences *among* proficient readers who rely more on word-specific associations (Chinese) or more on rule-based (decoding) mechanisms (Phoenicians). Although the major focus of this work was variation in reading styles *within* groups at comparable levels of reading ability, Baron and his colleagues also investigated the role of this Phoenician/Chinese continuum in determining differences *between* ability levels by matching pairs of children on regular word reading ability but who differed in age by 2 years (Baron & Treiman, 1980). The younger high-progress readers were superior on pseudoword reading but inferior on exception word reading supporting the conclusion that decoding is more important than word-specific ability.

Freebody and Byrne (1988) cluster-analysed pseudoword and exception word scores in a large sample of second and third grade children. In addition to the two major subgroups who were either good at both or poor at both, two smaller subgroups were identified; Phoenicians had average pseudoword reading but below average exception word reading, Chinese had average exception word reading but poor pseudoword reading. One year later, the

[8] Indeed, the visual form of words dictates letter-based processing because neither shape, length nor letter identity provides a unique specification of orthographic items. Few printed words have unique global configurations or even distinctive sets of component letters. In general, only unique sequences (ordering) of letters distinguish printed words. This follows from the alphabetic nature of English orthography which is designed, first and foremost, to represent a small number of recombinant speech segments. Only a fairly thorough processing of letter order and letter identity can determine word identity, and hence is the necessary form of processing. (This form of processing is almost always sufficient, at least in English, because letter information represents a fairly complete maping of a word's phonemic form, and because English has few homophones and even fewer homographs (such as WIND, SEAL)).

Phoenicians had improved their relative standing in the sample on both regular and exception word reading, while the Chinese lost ground (Byrne et al., 1992). In the case of regular words, Phoenicians who, as a group, lagged in grade 2 surpassed the Chinese by grade 3. The deterioration in word recognition skill among Chinese was also confirmed in the grade 4 data.

Bradley (1988) has also reported longitudinal data corroborating the primacy of phonological factors. She assessed orthographic memory and phonological awareness at the beginning and end of grade 1. The measure of orthographic skill was the ability to reproduce irregular words exposed for 5 seconds then removed from view. Age 6 phonological skill predicted age 7 orthographic skill but not the converse. This relationship held even when age 6 orthographic skill was controlled. This suggests, as hypothesized, that orthographic factors are secondary to phonological skill.

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 exception/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, Wise, Connors, & Rack, 1990; Olson et al., 1994; Stanovich, West, & Cunningham, 1991; 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). Effect sizes are typically around half those for phonological factors.[9] In contrast to the literature on pseudoword reading (Rack et al., 1992), disabled readers' orthographic skills tend to match or even exceed reading-age controls (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. (This same argument was advanced

[9] An important exception to these findings, and one worth pursuing in future research, is a finding reported by Barker et al. (1992) that orthographic variables predicted *reading fluency* more strongly than phonological variables.

earlier with regard to the dependence of exception word reading on decoding skill.) This does not mean that orthographic knowledge is solely a consequence of phonological skill. Neither print exposure nor pseudoword reading ability exhausts the reading-related variance of orthographic knowledge (Cunningham & Stanovich, 1990a; Stanovich & West, 1989). Individual differences in the ability to acquire word-specific knowledge may be related to cognitive factors such as reading styles (see, for example, Frith, 1980; Olson et al., 1985) and/or visual processing (see, for example, Willows, Cruk, & Corcos, 1993; Johnston, Anderson, Perrett, & Holligan, 1990; Lovegrove, Martin, & Slaghuis, 1986). More research will be needed to clarify this issue.

In the case of disabled readers, poor decoding will reduce opportunities to acquire word-specific knowledge. However, the *ability* to acquire word-specific information, given the opportunity, appears to be relatively less impaired among disabled readers (or possibly impaired only for a subgroup), hence the correlation between orthographic and phonological factors is lower in this group (Barker et al., 1992; Manis et al., 1993; McBride-Chang et al., 1993; Olson et al., 1990). At the same time, however, orthographic processing plays a greater role in the word recognition of disabled readers (McBride-Chang et al., 1993; Olson et al., 1985). This is analogous to the role of context effects in individual differences in word recognition (Stanovich, 1980, 1986). Context assists both good and poor readers' word recognition, but poor readers rely more on contextual information to compensate for weak decoding despite their generally inferior context-related knowledge. Greater reliance on orthographic factors among disabled readers may be another example of a general tendency among poor readers to rely more on non-phonological sources of information to compensate for weak phonological skills. Other examples are to be found in spelling (Pennington et al., 1986; Rohl & Tunmer, 1988; Waters, Bruck, & Malus-Abramowitz, 1988), the identification of ambiguous spoken syllables (Reed, 1989), and in the recognition and recall of verbal material (Byrne & Shea, 1979; Holligan & Johnston, 1988; Rack, 1985; Vellutino, Steger, De Sotto, & Phillips, 1975).

2.3.3. Acquired and developmental reading disorders, and dissociation asymmetry

The phonology-primary orthography-secondary notion has a number of implications for the pattern of dissociations that may arise as a result of developmental or acquired deficits affecting either or both mechanisms.

According to the self-teaching hypothesis, the phonological mechanism is not merely more important than the visual/orthographic mechanism, it is the *sine qua non* of successful reading acquisition. It follows that there can be *no* case of competent reading in the absence of functional decoding. Furthermore, accumulated word-specific knowledge, although drawing on separate cognitive abilities, cannot be entirely dissociated from the phonological skills on which it depends. Consequently, the pattern of developmental dissociations must be *partial* and *asymmetric*. Deficits that cause impaired phonological recoding should be far more detrimental to reading progress than deficits resulting in impaired orthographic knowledge. Furthermore, this developmental asymmetry excludes the possibility of pure "phonological" dyslexia (abolished pseudoword reading but intact real word reading) in *developmentally* disabled populations because word-specific associations depend on self-teaching. The existence of *acquired* phonological (or deep) dyslexia is not pertinent to the issue of reading acquisition because such cases may have lost the very mechanism responsible for the establishment of word-specific associations. This implies the possibility of greater degrees of dissociation among acquired phonological dyslexics than among developmental phonological dyslexics. On the other hand, basic phonological skills do not depend on the successful operation of orthographic skills hence developmental and acquired "surface" cases resulting from deficient ability to form word-specific associations should have much in common.

By contrast, conventional wisdom holds that phonological and visual/orthographic mechanisms are independent and equally functional, alternative pathways to acquiring word recognition skill. If so, it should be possible to find individuals for whom one of these mechanisms is absent but the other intact. A pure "phonological" dyslexic would rely exclusively on word-specific associations, and consequently be able to read real words, whether regular or exception, but not pseudowords. Strictly speaking, there should be individuals with no decoding skill whatsoever, yet who are competent (albeit atypical) readers, because all words, both regular and irregular, are accessible to the word-specific mechanism. (Note that this view presupposes the viability of direct instruction and/or contextual guessing as discussed earlier.) On the other hand, a pure "surface" dyslexic, owing to a complete inability to learn word-specific information, would be wholly dependent on the phonological mechanism, and thus be able to read pseudowords and regular words. Only exception words would present difficulties for the "surface" dyslexic.[10] Unlike pure phonological dyslexics, pure surface dyslexics should be less than competent readers able to read pseudowords and regular words and probably some exception words also.[11]

[10] As noted above, some ability to read irregular words should be evident because these items are only partly irregular and consonant correspondences alone may be sufficient for guessing a pronunciation even when an unfamiliar item is presented in isolation. Consider PINT: a knowledge of consonant correspondences together with an awareness that /PiNT/ is not a real word may lead to a correct guess if the alternatives (paint/point/pant/pent etc.) can be eliminated on the basis of knowledge of simple vowel and vowel digraph correspondences.

[11] It is perhaps a little unfortunate that the Phoenician/Chinese and phonological/surface terminology seem contradictory; the former label a reader's strengths whereas the latter label the weaknesses. Boder's popular terms "dysphonetic" and "dyseidetic" are self-explanatory but are based on highly questionable assumptions regarding the nature of the "visual/orthographic" mechanisms (see below).

To date, neither of these two patterns of complete dissociation has been reported. In most cases there is evidence of impairment in both mechanisms (Wilding, 1989) consistent with the self-teaching view that phonological recoding skill and orthographic knowledge are not independent. This accords with the findings, discussed above, of significant, but moderate pseudoword/exception and phonological/orthographic correlations observed in normal populations. Most individuals are either good at both or poor at both (Byrne et al., 1992; Freebody & Byrne, 1988).

To reiterate the central claim of this paper, there can be no developmental case of a reader with no decoding skill yet unimpaired word recognition. Cases such as the acquired phonological dyslexic patient W.B. (Funnell, 1983) are not relevant to the present discussion because word-specific knowledge may have been acquired via functional pre-traumatic decoding skill. Put simply, the fact that Beethoven was profoundly deaf in his terminal years does not imply that musical expertise can be *acquired* in the absence of hearing. Nevertheless, there have been reports of developmental phonological dyslexics - individuals who appear to have acquired word recognition skill without ever having acquired decoding skill (Campbell & Butterworth, 1985; Snowling, Stackhouse, & Rack, 1986; Snowling & Hulme, 1989; Temple & Marshall, 1983). Because the existence of such cases would appear to falsify the strong claim regarding the indispensability of phonological recoding, these cases call for detailed comment.

Campbell and Butterworth's (1985) report of R.E., a case of developmental phonological dyslexia in a highly literate adult, is often cited as evidence that, at least for some individuals, reading competence can be acquired without decoding. However, R.E. correctly read aloud approximately two thirds of both the one- and two-syllable pseudowords presented. On long multisyllabic pseudowords, R.E. scored only 3/20, but even here, errors were mostly neologisms which were often close approximations (ELECTRIFATIONIC - "electrifatonic"). R.E.'s decoding is relatively poor for her level of reading skill, but she is by no means without any decoding skill. As discussed above, there may be functional self-teaching if an individual (a) has some minimal phonemic awareness (such as the ability to generate a word on the basis of an initial letter sound) and (b) is able to determine the contextual plausibility of candidate items. According to Campbell and Butterworth (1985), "R.E. generates words very fluently when given a starting letter, either orally or in writing" (p. 472). She also succeeded on approximately half the items in several phonemic awareness tasks. R.E.'s verbal IQ is 123, so she should be sensitive to contextual information needed to distinguish alternative pronunciations. Thus, it seems reasonable to assume that R.E. possesses *functional* self-teaching skill. This does not necessarily imply that R.E. actually *uses* these skills. This can only be established by examining the identification of new items in text. The case of R.E. does not appear to be particularly convincing evidence of successful non-phonological reading.

The same considerations can be aplied to several of the developmental cases of phonological dyslexia purported to have little or no decoding skill (Seymour & Evans, 1988; Snowling & Hulme, 1989; Snowling, Stackhouse, & Rack, 1986; Temple & Marshall, 1983). Two of these cases, however (J.M. and T.W., Snowling, Stackhouse, & Rack, 1986), appeared to show no evidence of even minimal decoding skill. Both were 8 years old with reading ages of 7 and spelling ages of 6. Neither succeeded on *any* monosyllabic or multisyllabic pseudoword although simple CVC pseudowords do not appear to have been tested. However, approximately 30% of the errors of both subjects were classified as unsuccessful decoding attempts all of which were nonsense words (GRILL – "glot"). Although one cannot totally rule out some minimal self-teaching, these children are clearly profoundly impaired decoders. Four years later, J.M. had developed some limited decoding skill, scoring 26% on pseudoword reading (Snowling & Hulme, 1989). Phonological deficits were still evident in naming, verbal repetition, and phonemic segmentation, but visual memory was above average. J.M. had good semantic and syntactic skills which enable him to use contextual information to compensate for weak decoding. If visual/orthographic learning were viable, why would J.M. need to develop *any* decoding skill given his good visual memory and language skills?

Only a single case study has appeared in which there is unequivocal evidence of non-decoding. Temple (1988) reported the developmental case of a deep dyslexic, K.S., who, at age 9, was unable to name or sound out any letters other than his initials. Nor could he write letter sounds to dictation. Minimal phonemic awareness was also absent. "Attempts at fluency tasks using initial letters produced complete failure" (p. 26). K.S. was unable to read a single pseudoword or correctly spell any word. At age 9, K.S. was virtually alexic – he could read only two words on the Schonell word reading test. Unfortunately, K.S. has a borderline to low-average IQ and showed impaired visual memory. It would be of interest to identify a case of normal IQ and unimpaired visual skills to establish to what extent, if any, progress is possible in the complete absence of decoding skill. Like J.M., follow-up assessment of K.S. in adolescence revealed limited decoding skill, again suggesting that decoding skill is indispensable for reading progress.

In summary, neither skilled adult readers nor developmental phonological dyslexics provide convincing evidence that reading competence can be acquired in the absence of decoding skill. Rather, the available evidence indicates that an inability to decode reliably leads to severe reading disability at best, or alexia at worst.

The "surface" pattern of dissociation (relatively good pseudoword reading but deficient word-specific knowledge) contrasts markedly with the findings for phonologically disabled readers. This follows from the notion of decoding as a necessary but not sufficient condition for the acquisition of skilled word recognition. To be a proficient reader (and certainly to be a proficient speller) demands both phonological and orthographic mechanisms (Coltheart, 1978; Coltheart et al., 1993; Gough & Walsh, 1991). Consequently, there are likely to be cases of individuals who, for various reasons, experience difficulty in learning orthographic detail despite multiple (successful) decoding encounters. Such individuals include both developmental *and* acquired cases who have good pseudoword and regular word reading, but have difficulty with exception words which are frequently "regularized" (BREAK – "breek"), and who also tend to confuse homophones (Patterson et al., 1985). Reading may be excellent but spelling remains poor with a high proportion of phonetically plausible spelling errors (see, for example, Goulandris & Snowling, 1991; Hanley, Hastie, & Kay, 1992). A "pure" phonological reader should perform at chance on homophone tasks and also be unable to spell lexical hermits such as PINT and YACHT.

Although surface dyslexics are often impaired on both phonological and visual/orthographic dimensions (see, for example, Coltheart, Masterson, Byng, Prior, & Riddoch, 1983; Temple, 1984), some individuals (e.g., *Allan*, Hanley et al., 1992; N.G., Temple, 1984; W.B., Bub, Cancelliere, & Kertesz, 1985; JAS, Goulandris & Snowling, 1991) achieve near-perfect scores on pseudoword reading. If orthographic processes are dependent on phonological processing and not the converse, then it should be possible to find cases of complete (one-way) dissociation between (good) phonological and (poor) orthographic skills. On the other hand, if higher-order "lexicalized" decoding depends to some extent on the ability to recall specific multi-letter patterns – the same form of processing involved in the acquisition of word-specific orthographic knowledge – then there can be no complete phonology/orthography dissociations because orthographic impairments would result in imperfect (higher-order) decoding.

The adult surface dyslexic/dysgraphic *Allan* (Hanley et al., 1992) demonstrated above-average pseudoword reading relative to normal adult controls but homophone definition was close to chance (27/44). Irregular word spelling was very poor (15/45) but by no means abolished (he successfully spelled several hermits such as SWORD and ISLAND) with a high proportion of phonologically appropriate misspellings (BISCUIT – biscit). (As there was no evidence of impairment in either phonological or visual memory skills the source of Allan's reading and spelling difficulties remains unclear.) The surface dyslexic JAS (Goulandris & Snowling, 1991) achieved close to normal adult levels on pseudoword reading. Irregular word spelling was also extremely poor but, again, not entirely disabled, although spelling choice was at chance. Homophone processing was highly impaired and also not far beyond chance. Goulandris and Snowling concluded that there were "islets" of word-specific orthographic knowledge. In addition, poor performance on some auditory and phonological awareness tasks indicated that subtle phonological deficits cannot be ruled out in this case. However, gross impairments were evident on visual analysis and visual memory. Although neither of these cases provide unequivocal evidence of complete dissociation between phonological and orthographic mechanisms, the magnitude of these dissociations is certainly impressive and tends to favour the view that proficient decoding depends only minimally on word-specific orthographic skills.

Whether or not certain aspects of decoding require good orthographic skills, it is clear that the accumulation of word-specific knowledge relies heavily on proficient decoding, hence it may be tempting to misattribute surface-type reading to an over-reliance on presumably intact phonology and/or inadequate orthographic skills, when, in fact, higher-order decoding is at fault. In order to determine which processes are the source of reading difficulties it will be necessary to evaluate both the *ability* to form word-specific representations, and the accumulated store of word-specific *knowledge*. In addition, the efficiency (both accuracy and speed) of basic and higher-order decoding will need to be assessed with measures that take into account the ability to generate multiple, alternative pronunciations of pseudowords (see earlier comments on exception word reading).

2.3.4. Self-teaching and reading disability subtypes

The view that phonological and orthographic processing play respectively primary and secondary roles in reading acquisition has a number of implications for the subtyping of reading disabled populations. It follows that, at the word recognition level, there are potentially at least three types of disabled readers; those with phonological deficits, those with orthographic deficits and those with both forms of deficit. It further follows that disabled readers with phonological deficits should tend to be more prevalent and more severely disabled than those with orthographic deficits while cases with both phonological and orthographic deficits should be the most severely disabled. Although a review of the subtyping literature is beyond the scope of this paper, several methodological/conceptual points are pertinent to the evaluation of these claims.

First, the ubiquitous finding of phonological deficits in developmentally reading-disabled *groups* does not preclude the possibility that deficits of a purely non-phonological nature may characterize a subgroup of dyslexics provided, of course, that such a subgroup is small.

A second point is that the typology of poor readers proposed here does not imply that subtypes represent discrete groups. Current evidence indicates that subgroups are located in a bivariate continuum (Ellis, 1985; Manis et al., 1990; Olson et al., 1985; Stanovich, 1988), although the self-teaching hypothesis, in contrast to current theorizing, implies non-orthogonal (phonological and orthographic) axes consistent with the dependency of orthographic knowledge on the successful operation of phonological/self-teaching skills (cf. Ellis, 1985; Stanovich, 1988).

With regard to the evidence, there is considerable need for caution as much of the subtyping research has been marred by questionable measures of "visual" memory processes (see reviews by Vellutino, 1979 and Jorm, 1983), differing views on visual/orthographic processes, divergent interpretations of reading errors (consider, for example, the substitution PAGE – "paper": visual, partially phonetic, or semantic?) and, above all, faulty notions of holistic visual/gestalt reading processes. In view of these reservations, and the paucity of relevant data on subgroup size and reading levels, it may be too early to assess the validity of the subtype patterns predicted by the self-teaching hypothesis. However, one particularly influential typology deserves some comment. This is Boder's (1973) distinction between "dyseidetic" and "dysphonetic" dyslexia.

Investigations employing Boder's system fairly consistently report that a majority of dyslexics (dysphonetics) have primary difficulty with the phonological aspects of reading and spelling; a small subgroup (dyseidetics) have difficulty with "visual/gestalt" functioning, while a third group, the most severely disabled cases, show both dyseidetic and dysphonetic symptoms (Boder, 1973). To the extent that Boder's typology may be tapping the phonology/orthography dimension of differences, these data are consistent, at least numerically, with the predicted subtype patterns. Boder's clinical descriptions of her subtypes certainly appear to have much in common with the phonological and surface features discussed in the preceding section. Dysphonetic dyslexics, according to Boder, lack word-attack skills, make non-phonetic spelling errors, and have a limited sight vocabulary.[12] Dyseidetics, on the other hand, have a severely limited sight vocabulary, read each word as if for the first time by sounding out and blending, tend to regularize irregular words and make phonetic spelling errors. One might speculate that the dysphonetic/dyseidetic typology has achieved much of its staying power precisely because it taps the phonological/orthographic dimension of differences discussed here. Ironically, failures to link dyseidetic reading directly to visual/gestalt functioning claimed by Boder to underlie dyseidetic dyslexia (e.g., Van den Bos, 1984; Hooper and Hynd, 1985; Olson et al., 1985) serve to strengthen this interpretation.

It is suggested that future subtyping research routinely report reading ability in addition to subgroup size. Disabled readers, regardless of age, who are at low levels of reading attainment should tend to be dysphonetic while those at more advanced levels of reading ability should include a greater proportion of dyseidetics.

3. Phonological processing and reading ability

If phonological recoding is the key to successful reading acquisition, there should exist strong, significant, and causal relationships between performance on basic cognitive tasks assessing phonological processing ability and individual differences in reading achievement. The term "phonological

[12] As suggested earlier, even the most severely dysphonetic dyslexics showed some minimal phonological skill, as evident in partially phonetic spellings such as SCHOLAR – sker (see Boder, 1973).

processing" is used to refer collectively to all psycholinguistic aspects of the processing of speech-based information including perception, immediate memory, short-term and long-term memory. In departure from current usage, however, the term is reserved strictly for abilities evident in non-reading tasks, and whose development is not primarily contingent on literacy experiences. This formulation does not rule out reciprocal influences between underlying cognitive factors and reading progress, but it explicitly excludes factors such as phonemic awareness and letter naming speed which, for reasons elaborated below, are considered to be an integral part of alphabetic reading acquisition, and which are dependent on the efficiency of the basic phonological processes discussed in this section. (The issue of phonemic awareness is addressed in a later section.)

The following section reviews findings demonstrating a strong association between phonological processing and reading ability. Although much of this research has taken the form of comparisons between good and poor readers, phonological processing is seen here as a continuum of individual differences related to all points along the continuum of reading ability. Correlations between phonological tasks and reading, and good/poor reader comparisons are referred to interchangeably, as are epithets "poor", "disabled" and "dyslexic".

Although the evidence reviewed below shows that poor readers, *as a group*, are characterized by deficient phonological processing, this does not imply that all poor readers are phonologically impaired. The phonology-primary/orthography-secondary view makes clear that a unitary deficit explanation of reading difficulties is untenable. Nevertheless, the evidence clearly attests to the primacy of phonological factors which collectively account for a majority of the variance in early reading ability (Mann, 1991; Share, Jorm, Maclean, & Matthews, 1984). Furthermore, of the few studies which have examined specific relationships between phonological processing and components of reading skill, most have reported stronger associations between phonology and word recognition than between phonology and reading comprehension. This indicates that phonological processing has direct relevance to the self-teaching hypothesis and not merely to general text comprehension.

This section begins with a review of the evidence for an association between reading and phonological processes in perception, immediate-memory, short-term and long-term memory, goes on to discuss the interrelationships between these and related findings, then concludes with a discussion of the impact of these factors on the development of phonological recoding and self-teaching.

3.1. Speech perception and verbal repetition

Although there is no reliable evidence of impaired vowel discrimination in disabled reader groups (Bryson & Werker, 1989; Hurford, Gilliland, &

Ginavan, 1992; Reed, 1989; Steffens, Eilers, Gross-Glenn, & Jallad, 1992), studies of categorical perception of stop consonants have consistently demonstrated less "sharpness" in discimination (Brandt & Rosen, 1980; Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Hurford & Sanders, 1990; Hurford et al., 1992; Steffens et al., 1992; Werker & Tees, 1987). These differences are generally small and not always statistically significant, but appear to be consistent. There is also evidence that speech perception deficits are present at or before school entry (de Weirdt, 1988; Mann, 1991), suggesting that these differences are not merely a consequence of reading difficulties, although again, the effect sizes are weak. It should be added that all these studies of the speech perceptual capabilities of disabled readers routinely screen for hearing loss.

In spite of the consistency of the data on speech perception, the somewhat subtle nature of disabled/control reader differences seems unlikely to explain effects as robust as the other phonological processing deficits discussed below (unless, of course, perceptual tests have generally poor sensitivity).

By contrast to the speech perception findings, differences between disabled and control readers in the ability to repeat aloud spoken words and pseudowords are strong, reliable (Brady, Poggie, & Rapala, 1989; Brady, Shankweiler, & Mann, 1983; Snowling, 1981; Snowling, Goulandris, Bowlby, & Howell, 1986; Taylor, Lean, & Schwartz, 1989), and longitudinally predictive (Gathercole, Emslie, & Baddeley, 1990 cited in Baddeley, 1992). Although an earlier report (Brady et al., 1983) of a selective deficit in verbal repetition under noise-masked, as opposed to clear listening conditions, pointed to a perceptual locus for this deficit, this finding has not been replicated (Bentin, Deutsch, & Liberman, 1990; Read, personal communication, 1988; Snowling et al. 1986). Also, Taylor et al. (1989) have suggested that the nature of disabled readers' errors are difficult to account for in terms of perception (see also Gathercole, Willis, Emslie, and Baddeley, 1991). More generally, however, such robust repetition effects are difficult to pin on marginal difficulties in phoneme identification and discrimination discussed above.

It is important to note that difficulties in verbal repetition appear to be specific to low-familiarity words and pseudowords (Snowling, 1981; Snowling et al. 1986). Despite the fact that pseudowords, owing to their wordlikeness, may partially activate stored lexical-phonological information which may assist in repetition tasks (Gathercole, Willis, Emslie, & Baddeley, 1991), these items clearly place a heavy burden on phonological processes (Snowling et al. 1986; Snowling, 1991). In this regard, the difficulties in processing pseudowords compared to known real words mirror the data showing specific deficits among poor readers in their ability to learn nonsense as opposed to real word names for visual symbols (see below). The specificity of the pseudoword deficit also tends to rule out an articulatory or production account because matched real and pseudowords pose equal articulatory demands (Snowling et al. 1986; Taylor et al., 1989). In addition, Gathercole, Willis, and Baddeley (1991) have shown that the articulatory-motor complexity of pseudoword consonants is not significantly correlated with pseudoword repetition in young children. These data also converge with the finding that phonological processing remains impaired even when overt articulation is not required as in phonological identity judgments (Ellis & Miles, 1978; Olson et al., 1985).

3.2. Naming

Numerous studies have reported that poor readers make errors and are slower to name continuous lists of numbers, letters, pictured objects and colours (Bowers & Swanson, 1991; Denckla & Rudel, 1976; Denckla, Rudel, & Broman, 1981; Felton, Naylor, & Wood, 1990; Lovett, 1987; Murphy, Pollatsek, & Well, 1988; Rudel, Denckla, & Broman 1981; Spring, 1976; Spring & Davis, 1988; Torgesen & Houck, 1980; Wolff, Cohen, & Drake, 1984; Wolff, Michel, & Ovrut, 1990a). Torgesen, Kistner, and Morgan (1987) note that the average digit naming speed for disabled readers with working memory deficits is approximately 50% slower than control children. 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; Wolf, Bally, & Morris, 1986; Wolf & Goodglass, 1986). This 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, Share, Maclean & Matthews, 1986; Wolf et al., 1986; Wolf & Goodglass, 1986). When the same items which cause difficulties are identified by 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).

Not surprisingly, differences between good and poor readers tend to be stronger for print material, such as letters and numerals, than for non-print materials – pictures and colors (Bowers, Steffy, & Tate, 1988; Felton & Brown, 1990; Murphy et al., 1988; Wolf et al., 1986). Because letters and numerals are part of the print world, difficulties with these items may simply be part of a child's reading difficulty in the same way that phonemic awareness is integral to reading acquisition. Even in kindergarten, most children have become acquainted with letters and numerals (Masonheimer et al., 1984). The generality of the name-retrieval deficit as a cognitive precursor of reading difficulties, therefore, depends on the naming of non-print materials such as pictures and colours.

There is little dispute that there exists a strong and reliable deficit among poor readers in rapidly naming a series of non-print items such as pictures and colours. But does this deficit arise owing to the unique demands of rapid serial naming (e.g., sequential scanning (Lovegrove et al., 1986), peripheral preprocessing of adjacent information (Perry, Dember, Warm, & Sacks, 1989; Spring & Davis, 1988), programming and executing speech-motor sequences (Catts, 1989; Wolff et al., 1990a), or is there an intrinsic retrieval deficit? To address this question, researchers have turned to discrete-trial naming tasks.

Studies assessing discrete-trial name retrieval using items of increasing vocabulary difficulty, such as the Boston Naming Test, have reported 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 et al., 1990). These differences are also longitudinally predictive (Scarborough, 1989; Wolf & Goodglass, 1986). As noted above, errors are correlated with reading ability even when receptive vocaculary 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 classfication for the same pictures that cause naming difficulties (Murphy et al., 1988), it seems clear that the processing of semantic features of words is unimpaired. These findings converge with the long-term phonological memory (see below) and the verbal repetition data (see above) in indicating that the difficulty in pseudoword repetition is due primarily, if not exclusively, to phonological rather than semantic deficits.

In sum, it seems that poor readers have a specific difficulty retrieving the names of items in their receptive vocabularies. This occurs regardless of the modality of presentation (Snowling et al., 1988; Lovett, 1987). The predictive significance of this deficit suggests that dysnomia is a candidate for causal status.

The evidence from discrete-trial studies is less convincing on the question of a retrieval *speed* deficit among poor readers. With some exceptions (Ehri & Wilce, 1983; Levy & Hinchley, 1990), studies assessing discrete-trial naming speed for familiar *non-print* material (pictures and colours) have tended to produce negative findings (Cunningham, Stanovich, & Wilson, 1990; Lundberg & Hoien, 1990; Perfetti, Finger, & Hogaboam, 1978; Snowling et al., 1988; Stanovich, 1981; Swanson, 1989, cited in Bowers & Swanson, 1991). Favouring the null findings are studies showing that good and poor readers do not differ in the *speed* of repeating individual polysyllabic pseudowords (Brady et al., 1989; Rapala & Brady, 1990) or in latencies for judging the identity of CV pairs (Hurford & Sanders, 1990). The latter studies all reported reliable differences on errors, however. Studies of discrete-trial naming speed for print materials (digits and letters) have produced only weak and often non-significant findings (Bowers & Swanson, 1991; Lovett, 1987; Lundberg & Hoien, 1990; Olson et al., 1985; Perfetti et al., 1978; Stanovich, 1981; Stanovich, Cunningham, & West, 1981; Stanovich, Feeman, & Cunningham, 1983; Walsh, Price, & Gillingham, 1988).

In summary, the available evidence indicates a reliable, word-finding difficulty among poor readers. More specifically, there is firm evidence for a deficit in both the speed and accuracy of serial naming, and for a deficit in discrete-trial naming accuracy, but not speed. As the effect sizes obtained with discrete-trial naming tend to be more modest than those observed with serial naming tasks (see, for example, Lovett, 1987; Olson et al., 1985), it would appear that serial naming may tap sources of difficulty additional to those tapped in simple naming tasks. Naming difficulties do not appear to be primarily attributable to factors such as sequential scanning (Wolff et al., 1990a) or preprocessing of adjacent visual information (Bowers & Swanson, 1991), but may be related to a more general temporal processing deficit (see below) evident in the processing of stimuli presented in rapid succession (Lovegrove et al., 1986; Wolf, 1991).

The overall pattern of naming findings converges admirably with both the verbal repetition and long-term phonological memory data (see below). When required to process items for which phonological representations are well established, such as familiar words, poor readers perform as competently as good readers. However, unfamiliar material, whether pseudowords or low-familiarity real words, poses special difficulties for poor readers. Although the long-term encoding data, reviewed below, indicate that poor readers experience greater difficulty establishing phonological representations, once established they appear to be processed with the same speed as skilled readers. Indeed, in view of the lack of reliable articulatory onset speed differences in disabled reader groups (Ellis, 1981; Mason, 1978; but see Manis, 1985), one would not expect intrinsic speed differences. Also, subject selection criteria usually rule out sensory deficits such as overt speech production problems (e.g., Snowling et al., 1988; Wolff et al., 1990a). Further support comes from Kamhi, Catts, and Mauer (1990) who report experimental data showing that (discrete-trial) production difficulties in poor readers are due for the most part to encoding difficulties rather than to output *per se*.

Finally, it is important to note that naming difficulties often correlate more highly with word recognition than with reading comprehension (Bowers & Swanson, 1991; Catts, 1986; Kamhi, Catts, Mauer, Appel, & Gentry, 1988; Spring & Davis, 1988; Wolf et al., 1986), although there is no evidence that naming is more strongly related to pseudoword reading than to real word or exception word reading (Spring & Davis, 1988; Bowers & Swanson, 1991; Wolf et al., 1986).

3.3. *Short-term phonological memory*

There is abundant evidence that poor 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 & Glencross, 1990; Holligan & Johnston, 1988; Johnston, Rugg, & Scott, 1987; Jorm, Share, Maclean, & Matthews, 1984a; Katz, Shankweiler, & Liberman, 1981; Liberman, Mann, Shankweiler, & Werfelman, 1982; Mann & Ditunno, 1990; Rapala & Brady, 1990; Siegel & Ryan, 1988). There is also ample evidence indicating that performance on these tasks depends on the storage of information in a speech-based or phonological code (see for reviews, Baddeley, 1986, 1990). Moreover, the short-term memory deficit appears to be specific to tasks requiring phonological coding, as there is no firm evidence for memory deficits when phonological coding is not required, as in visuospatial or motor tasks (Baddeley, 1986; Hulme, 1981; Jorm, 1983; but see Willows et al., 1993). Although some earlier studies reported reader group differences on nonverbal short-term memory measures, most failed to control for verbal coding. In his review of this literature, Jorm (1983) noted that when verbal coding was controlled, these between-group differences generally disappeared. The conclusion that poor readers do not exhibit a general short-term memory deficit has been reinforced by studies comparing good and poor readers on the Corsi blocks test – a visuospatial analogue of the traditional digit span measure. This task requires a child to reproduce a tapped sequence of randomly arranged blocks. On this test, poor readers perform as well as good readers (Gould & Glencross, 1990; Mann & Liberman, 1984; Rapala & Brady, 1990).

Short-term memory impairment in reading disabled groups does not appear to be simply a product of their reading problems since memory performance assessed at or prior to school entry predicts later reading ability (Cohen, 1982; Ellis & Large, 1987; Jorm et al., 1984a; Mann & Ditunno, 1990; Mann & Liberman, 1984). Nevertheless, as with most reading-related predictors, the relationship is not simply unidirectional, as reading acquisition itself appears to promote subsequent memory development (Ellis, 1990; Goldstein, 1976).

In sum, the memory deficit in disabled readers is specific to tasks requiring phonological processes. There is also evidence that poor readers attempt to compensate for their phonological deficiencies by relying more on alternative sources of information such as semantic (Byrne & Shea, 1979) or orthographic cues (Holligan & Johnston, 1988; Rack, 1985). In this regard, these data provide another illustration of the general tendency among poor readers to rely on alternative, non-phonological sources in an effort to compensate for deficient phonological processing in both reading and cognitive domains.

Unfortunately, few studies have specifically examined whether deficient working memory performance is related more to general text integration processes or to general word recognition, let alone specific component processes of word recognition. Torgesen, Rashotte, Greenstein, Houck, and Portes (1987) reported that learning disabled (LD) children with memory span deficits did not differ from controls on listening comprehension but were inferior on pseudoword reading and sound blending. Furthermore, differences between LD children with span deficits were greater on pseudoword and oral sound blending than real word reading. Siegel and Ryan (1988) also found that simple memory span correlated more highly with pseudoword reading than with (reading) comprehension.

3.4. Long-term phonological memory

A large number of studies have reported that poor readers 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 on these 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). This again demonstrates the tendency among poor readers to rely more on semantic information to encode pseudowords.

3.4.1. Summary

There is virtually unassailable evidence that poor readers, as a group, are impaired in a very wide range of cognitive tasks in the phonological domain. This applies both to specific reading disabled and so-called "garden-variety" poor readers (Stanovich, 1988; 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 processes. Impressive as this body of evidence appears, it represents only a broad-brush picture of the cognitive processes underlying reading acquisition. There are virtually no direct experimental tests of the causal status of phonological abilities. In stark contrast to the phonemic awareness literature, experimental training studies in the cognitive literature are almost unknown. Furthermore, as Wagner and Torgesen (1987) have noted, few studies have attempted to determine which component processes of reading are differentially affected by the various phonological abilities. Most researchers have been content simply to show significant relationships between performance on phonological processing tasks and overall scores on standardized reading measures. Although the available evidence suggests that phonological processing is strongly related to word recognition *per se*, even this general conclusion lacks a firm research foundation.

3.5. Interrelationships between the basic phonological processing abilities

In reviewing the research on phonological processing, a majority of theorists have attempted to subsume all the findings in this literature under a singly rubric *within* the phonological domain (see, for example, Brady, 1986; Jorm, 1979; Jorm & Share, 1983; Shankweiler & Crain, 1986; Snowling, 1991). However, to explain all the findings it may be necessary to move beyond the phonological module. A short-term memory account, for example, is insufficient given the data from tasks with minimal memory demands such as pseudoword repetition, speech discrimination, repetitive and serial naming. A specific deficit in phonological short-term memory may partly be a product of deficiencies in verbal rehearsal stemming from difficulties in rapid, repeated vocalization, but differences remain even when verbal rehearsal is unavailable. This implicates deficiencies in the basic quality of phonological representations.

There is unquestionably a basic deficiency in establishing phonological representations (Brady, 1986; Jorm & Share, 1983; Snowling, 1991). From the point of view of reading acquisition, this may well represent the single most important limiting factor. But this too falls short of encompassing all the findings. Whereas poorly encoded phonological information may explain retrieval inaccuracies or outright retrieval failure, it is difficult to see why this should cause a *serial* rather than a *discrete* naming latency deficit, particularly in the absence of production difficulties *per se*. This suggests that difficulties in coordinating a rapid sequence of speech–motor acts may interfere with serial naming and verbal rehearsal in a way unrelated to impoverished representations. A growing body of evidence now suggests a link between speech–motor sequencing and a basic temporal processing deficit that extends well beyond the phonological domain.

3.5.1. Temporal processing

An extensive body of findings point to a general temporal processing dysfunction evident across a wide range of phonological, auditory, speech–motor, bimanual and visual tasks (Bakker, 1972; Wolf, 1991; Zurif & Carson, 1970). Disabled readers have difficulties processing (discriminating, coordinating and integrating) multiple events (input or output) occurring in close temporal proximity in the domains of speech (stop consonant syllables; Tobey, Cullen, Rampp, & Fleischer-Gallagher, 1979; Dermody, Mackie, & Katsch, 1983; Reed, 1989; Steffens et al., 1992; Watson, 1992), and nonverbal audition (pure and complex tones; de Weirdt, 1988; Tallal, 1980; Ludlow, Cudahy, Bassich, & Brown, 1983; Watson, 1992). Processing of *single* stimuli is not impaired even where these are very brief or presented with competing stimuli (Dickstein & Tallal, 1987; Ludlow et al., 1983; Tobey & Cullen, 1984; but see Watson, 1992).

There is also evidence of disturbed temporal integration in both speech-motor and bimanual tasks (Catts, 1986, 1989; Denckla, Rudel, Chapman, & Krieger, 1985; Kamhi & Catts, 1986; Rousselle & Wolff, 1991; Wolff et al., 1984; Wolff, Michel, Ovrut & Drake, 1990; Wolff, Michel & Ovrut, 1990b; Nicholson & Fawcett, 1990). Disabled readers, as a group, appear to have difficulties in rate and timing precision on bimanual tasks requiring integration of asynchronous responses such as tapping alternate limbs in time to a metronome (Rousselle & Wolff, 1991; Wolff et al., 1984; Wolff, Michel, Ovrut, & Drake, 1990). Disabled readers are also slower and less accurate at rapidly repeating nonsense syllable sequences ("pa-ta"), (Wolff, Michel, & Ovrut, 1990a) and phonologically complex tongue-twisters – "she sells shirts" (Catts, 1989). It is worth noting that this distinctive pattern of deficits in coordinating multiple events (input or output) rather than speed of processing/executing discrete events tends to reinforce the distinction between serial versus discrete naming speed differences.

A number of studies have also reported poor visual temporal resolution in dyslexics (see, for example, Di Lollo, Hanson, & McIntyre, 1983; Lovegrove et al., 1986; May, Williams, & Dunlap, 1988; Solman & May, 1990; Williams, LeCluyse, & Bologna, 1990; Winters, Patterson, & Shontz, 1989; but see Reed, 1989). Dyslexics appear to have lower thresholds for temporal integration or fusion of stimuli presented in rapid succession and are also poorer at judging temporal order. Interestingly, the data regarding impaired transient as opposed to intact sustained visual function (see Breitmeyer, 1993; Lovegrove et al., 1986) appear to mirror the auditory/phonetic data showing unimpaired processing of steady state information such as vowels but impaired processing of rapidly changing temporal acoustic information such as stop consonants.

A general temporal processing deficit would offer a unitary explanation for all the phonological deficits observed in disabled reader groups. Poor-quality phonological representations would be attributable to the high degree of processing overlap associated with the parallel transmission of speech (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967). Difficulties in the rapid sequencing of speech-motor acts necessary for serial naming and verbal rehearsal would constitute an independent expression of the temporal deficit.

The available evidence suggests that visual (transient system) deficits among poor readers may simply reflect a common (distal) temporal deficit whose impact on reading is solely via phonology. It should perhaps be added that attempts to link deficient transient system functioning to a visual subtype of reading disability may be ill-founded insofar as transient deficits appear to characterize a *majority* of disabled readers. It seems that the once popular notion of visual/perceptual deficits as a *cause* of reading failure, laid to rest by Vellutino (1979), has indeed been exhumed (see, for example, Willows et al., 1993), but not, as yet, resurrected.

3.6. *The impact of deficient phonological processing on phonological recoding*

Because letter names and sounds are, in effect, pseudowords – novel phonological strings – deficient phonological memory would be expected to impede the mastery of letter identities. Work by Baddeley 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, 1988; 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 sublexical correspondences when attempting to decode novel letter strings.

The demands of blending decoded elements will impose a heavy burden on short-term memory. Although retrieval speed of individual symbol–sound correspondences may be unimpaired, serial naming difficulties should 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 lexical item 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.

Deficient working memory function should also affect the availability of prior context to the extent that this is required to resolve decoding ambiguity or to arbitrate between multiple pronunciations. For novel strings not in the reader's spoken vocabulary, even a successfully decoded item will be more poorly encoded in long-term memory and consequently prove less helpful when encountered again in the same or later texts. Weak context-related knowledge (semantic, syntactic and pragmatic), or failure to activate this knowledge will further reduce the reader's ability to exploit contextual information in the process of word identification.

The foregoing clearly implies a major role for phonemic awareness in resolving decoding ambiguity. As noted above, even a minimal level of phonemic awareness such as the ability to generate a word with a given initial phoneme, may be sufficient for a rudimentary self-teaching mechanism provided a basic knowledge of simple letter–sound correspondences also exists. A partial decoding, however, will be of no avail to a reader oblivious to sublexical 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 sublexical phonological structure 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; Venezky, 1970; Ehri, 1980a, 1992). Spelling is clearly another such process.

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 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 is also lost.

4. Phonological awareness

Perhaps the strongest support for the centrality of phonological recoding in reading acquisition comes from the vast literature on phonological awareness (Adams, 1990; Brady & Shankweiler, 1991; Goswami & Bryant, 1990; Gough, Ehri, & Treiman, 1992; Rieben & Perfetti, 1991; Sawyer & Fox, 1991; Shankweiler & Liberman, 1989). In order to exploit the self-teaching advantages of an alphabetic orthography, the learner must have a working knowledge of those phonological units mapped by the orthography. This requires an appreciation that spoken words are composed of a limited number of phonemic segments which can be combined to generate a virtually infinite number of possible words.[13] Although an awareness of phonemes is necessary for successful reading acquisition it is not sufficient. Hand in hand with this phonemic understanding, the learner must possess a thorough knowledge of the written symbols that transcribe these units, that is, a knowledge of symbol-sound correspondences. Unfortunately, the remarkable economy and generative power of the alphabet does not come cheaply, because, unlike syllables, many phonemes are not acoustically distinct and cannot be pronounced in isolation (Liberman et al., 1967). Phonemes are, in fact, abstract representations of families of phonetic sounds (allophones) that vary considerably owing to factors such as stress, speech rate, intonation, dialect, and, above all, co-articulation (Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977).

It is essential to distinguish between phonemic awareness and the tacit ability to perceive and discriminate speech sounds, an ability normally present at birth (Eimas, Siqueland, Jusczyk, & Vigorito, 1971), and which is only weakly related to the ability to explicitly identify, isolate and manipulate these sounds (Backman, 1983; Stanovich, Cunningham, & Cramer, 1984; Yopp, 1988). It is the child's *explicit* awareness of the phonemic structure of spoken language, as demonstrated in tasks requiring the identification and manipulation of phonemic segments, that has been shown (by literally hundreds of cross-sectional, longitudinal and experimental studies) to be critical in early reading. The growing number of experimental training studies, in particular, has provided the most important evidence regarding the role of phonemic awareness in reading.

4.1. Phonemic awareness – co-requisite for successful reading acquisition

Reliable and substantial gains in reading ability have been consistently obtained in both laboratory and field settings when *both* phonemic awareness *and* symbol-sound correspondences have been trained (Ball & Blachman, 1991; Bradley & Bryant, 1983; Byrne & Fielding-Barnsley, 1989, 1991; Fox & Routh, 1984; Goldstein, 1976; Haddock, 1976; Jeffrey & Samuels, 1967; Jenkins, Bausell, & Jenkins, 1972; Muller, 1972–73; Treiman & Baron, 1983; Vellutino & Scanlon, 1987). Since training studies tend to show that neither letter-sound knowledge alone (Ball & Blachman, 1991; Byrne, 1992; Goldstein, 1976; Jenkins et al., 1972; Johnson, 1969 (cited in Ehri, 1983); Ohnmacht, 1969 (cited in Ehri, 1983); Samuels, 1972; Silberberg,

[13] Although a variety of units (morphemic, syllabic, sub-syllabic and phonemic) are represented in the orthography, English is first and foremost a phonemic script. Hence the major focus in the following section is phonemic awareness, although it is clear that other forms of phonological awareness may also be relevant to reading acquisition (Goswami & Bryant, 1990; Treiman, 1992). The term "phonological awareness" is used here as a cover term for all forms of awareness of speech units at or below the level of syllables.

Silberberg, & Iversen, 1972), nor phonemic awareness alone (Bradley & Bryant, 1983; Byrne, 1992; Byrne & Fielding-Barnsley, 1989) are sufficient, we can conclude that phonemic awareness (in conjunction with letter-sound knowledge) is a causal *co-requisite* for successful reading acquisition. Three additional studies (Cunningham, 1990; Lie, 1991; Lundberg, Frost, & Petersen, 1988) obtained positive results when phonemic awareness alone was trained but it seems likely that concurrent or subsequent classroom reading instruction in phonics supplied the symbol–sound knowledge necessary for a child to benefit from phonemic awareness training.

The consistency and magnitude of the effect sizes in predictive and experimental studies indicates that knowledge of the alphabetic code and the phonological units represented by that code constitute critical co-requisites to successful early reading acquisition. Jointly, these two factors account for a majority of the variance in early reading achievement (Share et al., 1984; Tunmer et al., 1988).

Phonemic awareness is also a co-requisite in another sense, in this case a temporal rather than logical one. Phonemic awareness is not a *pre*condition in the sense of being necessary *prior* to learning to read, provided the learner is either taught or able to induce awareness in the course of reading instruction (Morais, Alegria, & Content, 1987; Wimmer, Landerl, Linortner, & Hummer, 1991).

There are several important qualifications, however, to this broad conclusion regarding the causal, co-requisite status of phonemic awareness. First, the pattern of results appears to depend on precisely *which* phonemic awareness skills (synthesis versus analysis) are taught. Second, there are unresolved discrepancies between laboratory-style and longer-term field studies. Most laboratory-type investigations train children over a short period of time (usually several days or weeks) on a restricted set of items with invariant symbol–sound correspondences. Although this permits rigorous control over the skills acquired, generalizability is limited relative to longer-term field studies in which training extends over a number of months or years and training effects are evaluated with standardized measures of reading which normally include both regular and irregular words. On the other hand, the longer-term investigations often suffer from a lack of control over classroom practices. These studies do not routinely monitor the extent to which aspects of concurrent or subsequent classroom instruction may interact with trained skills. This substantially complicates interpretation of this work. Differences in long-term outcomes (cf. Bradley & Bryant, 1983; and Lundberg et al., 1988) may partly hinge on classroom reading practice. Worse yet, when instructional practices are not monitored, there exists the possibility that between-group differences *within studies* are attributable to differential instructional experiences.

Another problem in long-term field work is that training often includes a host of instructional activities that are not always fully specified. Without direct experimental manipulation and/or task analysis (see, for example, Iversen & Tunmer, 1993), it is difficult to determine which elements of a program are responsible for treatment gains. Similarly, different phonological segments (syllables, subsyllabic units, and phonemes) are frequently confounded. Different segments may have different roles at varying stages of reading acquisition. It is becoming increasingly evident that awareness of single phonemes is not the only form of phonological awareness relevant to reading acquisition (Adams, 1990; Goswami & Bryant, 1990; Treiman, 1992).

4.1.1. Phoneme synthesis or analysis?

In the light of important differences between laboratory-style studies and longer-term field studies, each will be considered separately before amalgamating the findings.

Turning first to the results of laboratory-style studies, a reasonably clear picture emerges. When phonemic awareness training includes a blending component (in addition, of course, to letter-sound training), trained groups consistently outperform controls (Fox & Routh, 1984; Haddock, 1976; Jeffrey & Samuels, 1967; Jenkins et al., 1972; Muller, 1972–1973; Treiman & Baron, 1983; Vellutino & Scanlon, 1987). When phonemic *analysis* (segmentation) alone is trained (even in conjunction with symbol–sound knowledge), findings are consistently negative (Byrne & Fielding-Barnsley, 1989, 1990; Fox & Routh, 1984; Hohn & Ehri, 1983; Treiman & Baron, 1983). The laboratory-style research clearly points to synthesis as the critical factor as far as reading is concerned.

With regard to longer-term field research, studies which have included an explicit blending component, and for which letter-sound knowledge can be assumed to be acquired in the course of regular classroom reading instruction, have produced, by and large, positive results (Cunningham, 1990; Goldstein, 1976; Lie, 1991; Lundberg et al., 1988; Oloffson & Lundberg, 1985). Overall, then, these findings tend to reinforce the laboratory work demonstrating that the combination of phoneme synthesis and letter-sound knowledge are co-requisite, causal factors in reading acquisition.

Mixed results were obtained in several other studies which did not include an explicit blending component in their training regimen. Bradley and Bryant (1983) obtained strong and significant long-term gains for a group taught both sound–symbol knowledge and sound analysis. Adopting Bradley and Bryant's teaching methods, Ball and Blachman (1991) also reported significant gains on an immediate post-test for children taught both letter-sounds and phonemic analysis. Lie (1991), however, found no significant long-term reading gains for a group trained in phoneme identification, although significant gains were obtained for spelling. The results of the Bradley and Bryant (1983) and Ball and Blachman (1991) studies stand in direct opposition to laboratory findings indicating that analysis and letter-sound knowledge are not sufficient conditions for the development of reading. There are several possible explanations for this discrepancy.

First, blending skill may be acquired spontaneously in the course of extended training in phoneme analysis. More specifically, it has been suggested that the training techniques used by both Bradley and Bryant, and Ball and Blachman may have invoked some blending processes (see Torgesen & Morgan, 1990). Another possibility is suggested by a series of studies by Byrne and Fielding-Barnsley (1989, 1990, 1991, 1993) which obtained significant (classroom and laboratory) effects without teaching blending. These studies obtained reliable effects by training awareness of "segment identity" (in addition to letter-sound knowledge). This involved teaching children that words such as "mat" and mum" begin with the same sound. This awareness of segment identity might also explain the positive findings obtained in the Bradley and Bryant and Ball and Blachman studies which were designed to teach children that words with common sounds have common spellings. Whatever the source of the discrepancies between laboratory and field studies of phoneme analysis, the relationship between segment identity and blending would seem to warrant further investigation.

In summary, there is strong evidence for a causal role of phoneme synthesis as a twin co-requisite (alongside symbol-sound knowledge) for successful reading acquisition. This conclusion is supported by both laboratory and field studies. Additional support comes from research comparing initial programs of reading instruction. Phonics programs which explicitly teach blending produce superior results compared to "analytic" programs which generally do not include a blending component (Chall, 1967, 1983; Johnson & Bauman, 1984; Pflaum, Walberg, Karegianes, & Rasher, 1980). Owing to the conflicting findings in laboratory and field studies, the causal status of phonemic analysis in reading acquisition remains uncertain. It seems plausible that blending may be critical for reading but analysis for spelling.

4.1.2. Summary

The experimental evidence discussed above firmly establishes phonemic awareness as one of the cornerstones of reading acquisition. However, our understanding of the precise role that phonological insights play in the process of early reading acquisition is still very coarse-grained. Many issues remain unresolved such as the developmental role of different phonological units (syllables, subsyllables and phonemes), their phonetic class and position, as well as the significance of different operations performed on these units (analysis/synthesis, implicit/explicit). Each of these issues has far reaching implications for instruction. The major research challenge now is to specify precise links between awareness and developmental reading and spelling processes.

4.2. Phonemic awareness is reading-specific

A number of converging lines of evidence indicate that phonemic awareness is not a basic cognitive ability, antecedent to reading acquisition, but, like letter knowledge, is an integral part of (alphabetic) reading acquisition as proposed by the Brussels group (Algeria & Morais, 1991; Morais et al., 1987).

First, a number of studies have shown that both adult illiterates (Bertelson, de Gelder, Tfouni, & Morais, 1989; Morais, Bertelson, Cary, & Algeria, 1986; Morais, Cary, Algeria, & Bertelson, 1979) and individuals literate only in non-alphabetic scripts (Read, Zhang, Nie, & Ding, 1986; Mann, 1986) essentially lack awareness of phonemes. Inability to perform phonemic analysis does not appear to be attributable to general difficulties in perceptual analysis, low intellectual level, or motivation. Literates and illiterates perform at comparable levels on rhyme judgment and syllabic vowel deletion tasks indicating that awareness of syllabic but not phonemic segments develops without the experience of learning to read (Bertelson et al., 1989; Morais et al., 1986). These findings suggest that phonemic awareness does not develop spontaneously in the normal course of cognitive and linguistic development but only in the specific context of learning to read an alphabetic script. (Phonemic awareness can, of course, be acquired outside the reading context if directly taught.)

Second, and directly reinforcing these findings with illiterates, is the observation that the largest performance gains on tests of phonemic awareness tend to occur during the first year of reading instruction, largely irrespective of age (Bentin, Hammer, & Cahan, 1991; Bowey & Francis, 1991; Cardoso-Martins, 1991; Morrison, 1988; Liberman, Shankweiler, Fischer, & Carter, 1974; Torgesen et al., 1989; Wimmer et al., 1991). This developmental trajectory is not observed for basic phonological processing abilities such as pseudoword repetition (see, for example, Wimmer et al., 1991). Type of instruction is also influential. Alegria, Pignot, and Morais (1982) observed that code-emphasis instruction accelerated the development of phonemic awareness to a greater extent than "whole word" instruction. Together, the data from both illiterate and preliterate samples indicate that *most* children develop an awareness of phonemes *as* they learn to read.

Third, both experimental training studies and naturalistic classroom studies have shown that mere exposure to an alphabetic orthography, even over an entire school year, does not lead to spontaneous induction of the alphabetic principle (Byrne, 1992; Carnine, 1977; Seymour & Elder, 1986). Indeed, in view of the psychoacoustic opaqueness of phonemes (Liberman et al., 1967), it is difficult to see how a young child might induce awareness of such abstract units.

Finally, phonemic awareness has been shown to be relatively independent of general intelligence, general language ability, verbal memory, and perceptual analysis (Bradley & Bryant, 1985; Bryant et al., 1990; Ellis & Large, 1987; Jorm, Share, MacLean, & Matthews, 1986; Morais et al., 1986; Stanovich et al., 1984; Wagner & Torgesen, 1987; but see Bowey & Patel, 1988).

In summary, present evidence indicates that phonemic awareness is best classified not as a basic phonological processing ability, but as a reading skill. Phonemic awareness itself should, therefore, be dependent on phonological processing together, of course, with the appropriate instructional/learning experiences. Thus a lack of phonemic awareness does not necessarily imply a basic phonological deficiency. Such a deficiency will be manifest in unusual difficulties in acquiring phonological awareness despite appropriate learning experiences (see, for example, Lundberg, 1989). The reading-specific conceptualization of phonemic awareness also implies that training programs of the type developed in the experimental literature surveyed above are, in essence, reading instruction no less than letter-sound teaching. Indeed, in terms of predictive correlations, these twin skills behave in an almost identical fashion. Does this mean that phonemic awareness is vulnerable to the common disclaimer regarding letter name knowledge – that predictive data are trivial in showing merely that early reading predicts later reading? Or worse still, does the training literature simply demonstrate that teaching children reading skills can help them learn to read?

However one chooses to view phonemic awareness, the experimental training studies have unequivocally demonstrated that phonemic awareness represents a critical and causal co-requisite for successful reading acquisition, one that is not universally acquired within current instructional frameworks. The longitudinal and experimental training studies considered *together* show that lack of phonemic awareness not merely *can* but *does cause* reading failure (Bradley & Bryant, 1983). This is hardly a trivial statement. Conceivably, curriculum innovation, whether at the school or pre-school level, might reduce the substantial variance associated with large individual differences in phonemic awareness (see Ehri, 1989). Even when viewed as a form of reading instruction, the phonemic awareness training literature indicates that existing curricula are failing to meet the needs of certain children.

If positive outcomes obtained in phonemic awareness training studies can be interpreted as pinpointing effective components of reading instruction, then the experimental training literature becomes relocated within the broader context of beginning reading instruction. Here too, the importance of self-teaching should find expression in superior (word recognition) outcomes for instructional methods that place greater emphasis on the alphabetic code. Evaluations of beginning reading instructional programs bear out this expectation.

5. Instructional factors

5.1. Beginning reading instruction

Although conducting rigorous research in classroom settings is notoriously difficult and renders the interpretation of any one study virtually impossible, both qualitative and quantitative syntheses of large numbers of program comparisons have revealed recurrent patterns. Beginning (grade 1) reading programs with a stronger, earlier, and more systematic emphasis on learning the alphabetic code outperform initial programs with less code emphasis (Adams, 1990; Adams & Bruck, 1993; Anderson, Hiebert, Scott, & Wilkinson, 1985; Bond & Dykstra, 1967; Chall, 1967, 1983; Dykstra, 1968; Guthrie et al., 1976; Iversen & Tunmer, 1993; Johnson & Bauman, 1984; Pflaum et al., 1980; Stahl & Miller, 1989). (Importantly, superior results in word recognition are not obtained at the expense of reading comprehension.)

The advantage of an early code emphasis is substantial and not merely statistically significant. In their meta-analysis of research on early reading instruction, Pflaum et al. (1980) found that synthetic phonics (letter-sound instruction with explicit blending) produced an *average* outcome 35 percentile points higher than the mean of control groups compared to an average 15-point advantage for experimental groups generally. This elegantly dovetails with the conclusions reached above regarding the twin causal roles of letter-sound knowledge and phoneme blending. It also supports the notion that phonemic awareness training is reading instruction proper, and by implication the view that phonemic awareness is essentially a reading (sub)skill and not a basic phonological processing ability.

In spite of these observations regarding the advantage of early code-emphasis instruction in English, the existence of widespread literacy in countries such as China and Taiwan which purportedly use a logographic script would appear to constitute *prima facie* evidence for the argument that skilled word recognition can be acquired "Chinese"-style, without recourse to symbol-sound translation.

5.1.1. Self-teaching in logographic writing systems

Contrary to popular belief, however, Chinese is not a logography; it is a "word-syllabic" system (Gelb, 1963; Mattingly, 1985). Most Chinese characters are compounds comprising a semantic radical and a phonetic element (Wang, 1973). This compounding is based on the principle of phoneticization (Gelb, 1963) by which the sound value of a character rather than its meaning is used to indicate the pronunciation of a similar sounding (homophonic or rhyming) word. Wang (1973) suggests that "the average Chinese can often guess correctly a character he has never seen before simply be making a shrewd guess at its phonetic", (Wang, 1973, p. 54). Zhou (1978) cited in Taylor and Taylor (1983) estimated a 39% success rate in using the phonetic to guess a character's pronunciation. Paradis (1989) gives figures of 25% (exact pronunciation including tone), 42% (exact pronunciation without tone) and 66% (exact or partial pronunciation). With the exception of the last figure, these estimates would appear to suggest that phonetic decoding fails on the majority of occasions and is consequently non-functional. However, if contextual information can help resolve decoding ambiguity, as suggested earlier, one might speculate that in natural text, phonetic information may be sufficient for functional self-teaching. Whether this is true for the skilled Chinese reader, let alone the beginner, remains to be investigated. It should also be kept in mind that the semantic radical sometimes provides meaning (ideographic and pictographic) "clues" that are entirely absent in alphabetic scripts.

According to Gelb (1963), the Chinese writing system, like all the other ancient systems, was never a pure logography, but "word-syllabic" from its earliest beginnings. In fact, a strict logography has never existed (Gelb, 1963), because it would not be productive (see Liberman & Liberman, 1992; Mattingly, 1985) in the sense of incorporating a set of orthographic conventions by which new lexical items can be transcribed and deciphered. The logographic learner is forced to rely on interminable memorization of thousands of symbols. The traditional process of learning Chinese characters extends over the entire period of schooling and beyond, consuming an estimated 30% of each school day (Ohara, 1978, cited in Taylor and Taylor, 1983). Perhaps because the phonetic in Chinese compounds fails to provide a reliable guide to sound, children in China today are first introduced to an alphabetic script – "pinyin". During their first few months at school, children are taught the symbol–sound correspondences of pinyin together with phonemic analysis (Liu, 1978). Pinyin is then used solely as a self-teaching mechanism to aid learning of the characters which appear with adjacent pinyin.

Similarly, in Japan, a phonologically recodeable (in this case syllabic) script – Hiragana – is used to aid the acquisition of the logographic Kanji, which are accesible only via visual processes (Mason et al., 1989). Kanji are taught one by one throughout schooling (80, 160, 200, 200, 185, 181 characters, in grades 1 to 6 respectively). After completing 9 years of compulsory schooling, a child is expected to have mastered most of the official 2000 Kanji.

In summary, self-teaching appears to be central not only to the acquisition of alphabetic orthographies, but also to the efficient learning of logo-syllabic and logographic scripts.

6. Concluding comments

Taken together, the literature on phonological recoding, basic phonological processing, phonemic awareness, and beginning reading instruction furnish strong support for the proposed self-teaching role of phonological recoding in the acquisition of fluent word recognition. Direct evidence for the self-teaching hypothesis is still lacking. Jorm, Share, Maclean, and Matthews (1984b) attempted to test this hypothesis by selecting two groups of children at the end of their first year of reading instruction who differed in pseudoword reading but who were matched for sight word vocabulary, verbal IQ, age, sex and school attended. As predicted, the group with superior decoding skill made more progress in word recognition over the subsequent two years. Significantly, there was a divergence over time between these groups amounting to 9 months of reading age after 2 years. Unfortunately, it was not possible to find comparable groups matched on decoding but who differed on sight vocabulary.

Direct tests of the self-teaching hypothesis will require online studies of word identification in natural text.[14] Currently, I am working with an experimental paradigm consisting of multiple presentations of (orthographically) unfamiliar targets embedded in text. Within a context of reading for enjoyment and understanding, a variety of on-line and post-test measures are designed to assess initial word identification processes, the transition from identification to recognition, and above all, the acquisition of orthographic information.

Partly because they have grown out of the standard, isolated word recognition paradigm, distributed, connectionist models of printed word learning, at least as currently implemented (Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990), have some serious limitations with regard to their developmental plausibility. These models represent orthography–phonology and orthography–meaning relationships as a distributed network of weighted connections between simple processing units that encode information about orthography, phonology and meaning. In Seidenberg and McClelland's (1989) simulation of word naming, for example, weights are initialized to arbitrary, random values then modified by a learning algorithm during a training phase in which the model is exposed to a large number of words and their pronunciations. The weights gradually come to encode information about spelling–sound correspondences such that the correct pronunciation is computed from a printed string without recourse to pronunciation rules or word-level representations.

Although connectionist models claim to simulate human printed word learning, direct input of target pronunciations for the several thousand words used in the training corpus implies subscription to the dubious direct teaching option discussed at the very beginning of this paper. On the other hand, the system has no built-in structure; this emerges only during the training phase. This introduces a paradox (Skoyles, 1988). In the absence of externally supplied pronunciations, the system has no way of generating the target pronunciation necessary to boot the learning procedure. It could be argued that, in practice, initial reading instruction often begins with a small set of sight words taught logographically. These might provide some early, non-random weighting of spelling–sound connections, perhaps sufficient to

[14] Studies of isolated word recognition have limited value in informing theories about word learning because the potential role of context in resolving decoding uncertainty is necessarily overlooked. The standard word recognition paradigm also misconstrues the decodability of so-called irregular words and, more generally, the phonological regularity of deep orthographies such as English.

kickstart the system. But mere exposure to the pronunciation of printed words has not been found to induce the phonemic awareness implied in these models' representation of sublexical phonological structure (see, for example, Seidenberg and McClelland's phoneme triplets, or Van Orden et al.'s phoneme singletons). Some explicit, initial representation of spelling-sound correspondence would appear to be necessary. By implicitly assuming extensive direct instruction and built-in phonemic awareness in the form of sublexical phonological parsing, current connectionist models fail to address the quintessential problem of reading acquisition – *independent* generation of target pronunciations for novel orthographic patterns. These same flaws also inhere in the computational Dual-Route (DRC) model developed by Coltheart et al. (1993). Borrowing the PDP principle of an initial training phase, the DRC's (grapheme–phoneme correspondence rule) learning algorithm is initially force-fed the pronunciations of nearly 3000 letter strings (again, direct instruction). In this learning phase, the spelling of each word is presented together with its complete phonetic transcription (instant phonemic awareness). The task of modelling the development of phonemic awareness (overlooked by both PDP and DRC models) and specifying its precise role in word learning represents one of the major challenges for theories of reading acquisition. Additionally, if lexical and contextual information is important in resolving decoding ambiguity, then these processes will deserve more than the passing mention received to date in current models of word recognition.

It should be stressed that the self-teaching hypothesis is not a single-factor theory of printed word learning. It emphasizes the primacy of phonological processes in word identification but also acknowledges the secondary roles of orthographic processing and contextual knowledge. This almost certainly does not exhaust the list of potential sources of individual differences in word learning. For example, kinaesthetic factors may also be implicated in the initial mastery of letter forms and orientation and perhaps also later in learning word-specific letter sequences (Bradley, 1981; Cunningham & Stanovich, 1990b; Fernald, 1943; Hulme, 1981; Hulme, Monk, & Ives, 1987; Montessori, 1915). Even within the phonological module, a variety of subprocesses may result in deficient decoding. Snowling et al. (1986) have elegantly demonstrated how different phonological processes (input, output and central) can differentially affect reading as manifest in patterns of reading and spelling errors. In addition to these child-based cognitive factors, the phonological awareness literature emphasizes the contribution of environmental/instructional factors. There are, clearly, many reasons why an individual may experience decoding difficulties.

This constrained view of heterogeneity differs sharply from the popular view that phonologically impaired individuals may benefit most from whole-word visual instruction whereas the visually impaired learner is best taught with phonic-emphasis instruction. Given the make-up of an alphabetic orthography, purely non-phonological, visual learning is a developmental non-sequitur. However, instruction that capitalizes on a learner's strengths *for the purposes of teaching essential phonological skills* is entirely consistent with the self-teaching view. The distinction between instructional method versus instructional content is paramount. The self-teaching hypothesis is a psychological theory about the skills necessary for successful reading acquisition. It is not a pedagogical theory. It specifies *what* must be required not *how* these skills are to be taught. The fact that phonic-emphasis programs of initial reading instruction are generally superior to meaning-emphasis programs is taken as (indirect) empirical support for the psychological importance of decoding skill, not as a prescription for teaching reading. Alternative approaches or others yet-to-be developed may prove superior to existing phonic-emphasis programs.

Another important point concerns the relationship between learning and instruction. The complexity of the skilled reader's lexicalized knowledge of English spelling–sound relationships precludes the possibility of imparting this system directly to the novice. It follows that teachers can only provide simplified models of spelling–sound correspondence that offer the learner a functional scaffold for developing and refining this knowledge base. This implies that teachers cannot teach children to read as such, only teach them how to teach themselves. The self-teaching hypothesis is precisely this – a theory about how children teach themselves to read.

The fact that the twin co-requisites for self-teaching (symbol–sound knowledge and phonemic awareness) do not develop spontaneously in the course of exposure to alphabetic writing has far-reaching instructional implicatins for getting children "ready" to read (Coltheart, 1980; Ehri, 1989). As Coltheart (1980) has forcefully argued, getting children ready to read means teaching them the skills they will need in order to read.

A final comment. The strong claim made here regarding the indispensability of phonological recoding may seem trivial in the sense that the ability to turn pages is also a *sine qua non* of successful reading acquisition. But page-turning skill is not a source of difficulty for most learners; the abstract nature of the speech units mapped by an alphabet is.

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