POOR READERS' USE OF ORTHOGRAPHIC INFORMATION IN READING, MEMORY AND PHONOLOGICAL TASKS

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Poor Readers' Use of Orthographic Information in Reading, Memory and Phonological Tasks

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Submitted in fulfillment of
the requirements for the degree of
Ph.D.
School of Psychology, University of St. Andrews

2002

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For

Joseph & Agnes, Edward & Jeannie

without whom there would be no record.

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Alan Morrison McNeil, Upper Largo, Fife Scotland 2002

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Abstract

This thesis examined the abilities of 10-12 year old poor readers and reading age controls in phonological processing, printed word learning, reading and memory based tasks. It was found that the poor readers showed little impairment in carrying out phonological segmentation of spoken words, though there was more marked impairment with nonwords. Nonword reading was found to be slower than that of controls and poor readers also demonstrated a tendency to provide letter names rather than sounds in a phoneme identification task. In a study of learning new print vocabulary it was found that the poor readers were slower than controls to learn to read the set of nonwords accurately, and had poorer auditory memory for the items. However, they were much better at identifying these items in a visual recognition task. They also showed a less marked regularity effect and were more influenced by the visual appearance of words in an auditory rhyme judgement task. In a study of their working memories, the poor readers showed a visual bias in their memory codes for serial recall of pictorial stimuli, i.e. they showed no word length effect, a phonemic similarity effect of reduced magnitude, and a visual similarity effect. This indicated the use of a visual strategy to remember pictures, rather than the verbal coding preferred by the controls. When words were presented auditorily or in print form, however, the poor readers showed normal phonemic similarity and word length effects. It was concluded that poor readers rely on visual information where the presented images are highly codable, and verbal recoding is not obligatory, but that they will make use of phonological coding when the stimuli are not easily codable visually in memory. The results of these investigations suggest that these poor readers' visual and verbal coding systems might be poorly linked. Thus, when learning to read new words poor readers might prefer to use visual coding. Accordingly, poor readers may rely on intact visual processes because they need to compensate for inefficient or poorly connected visual and verbal systems, rather than because they have inefficient phonological processing skills as such.

CHAPTER ONE

INTRODUCTION

It is widely held that phonological processing deficits underlie the difficulties faced by the majority of poor readers (Bradley & Bryant, 1978; Bruck & Treiman, 1990; Jorm & Share, 1983). Indeed, research over the last twenty years has produced a substantial body of literature in support of the contention that developmental reading disabilities (in otherwise normal children) are connected to difficulties in processing phonological information (Lundberg, Frost, & Petersen, 1988; Mann & Liberman, 1984; Share, 1995). Although phonological skill is viewed to be independent of general cognitive ability (Stanovich, 1986), it is nevertheless viewed as an integral part of reading development. Moreover, it is generally accepted that early phonological skill stands as a powerful predictor of subsequent reading achievement (Ball & Blachman, 1991; Bradley & Bryant, 1983).

Much of the empirical evidence regarding the poor readers' difficulty in using phonological information in both memory and reading-related tasks points to deficits in verbal short-term memory (Brady, Shankweiler, & Mann, 1983; Jorm, 1983). However, although impairments have been found in poor readers' recall of digits, letters and words, research has not uncovered differences between poor and normal readers when the items to be recalled are not easily codable as a verbal form (Brady, 1986; Liberman, Mann, Shankweiler, & Werfelman, 1982). For example, it has been shown in many tasks that poor readers' visual skills are unimpaired, their recall of nonsense pictures, abstract shapes (Swanson, 1984; 1987), and symbols (letters) from an unfamiliar orthography (Vellutino, Pruzek, Steger, & Meshoulam, 1973; Vellutino, Steger, DeSetto, & Philips, 1975) being appropriate for chronological age. Therefore, as these difficulties are specific to tasks involving verbal materials, reading disability is no longer attributed to inadequate visual memory or to dysfunction in some aspect of visual learning. The phonological (verbal coding) deficit hypothesis is, therefore, interpretable on the basis that poor readers only encounter difficulty when visual stimuli have to be named (Ellis, 1981; Swanson, 1984; Vellutino et al., 1973; 1975), or when the visual and verbal codes need to be integrated (Swanson, 1987).

Apart from the noted impairments in verbal short term memory (Brady et al., 1983; Jorm, 1983), in the phonological domain poor readers have also been known to have difficulty in reading nonwords (Baddeley, Ellis, Miles, & Lewis 1982; Snowling 1981), and in carrying out phonemic and phonological awareness tasks (Bruck & Treiman, 1990; Jorm & Share, 1983; Manis, Custodio, & Szeszulski, 1993; Stanovich, Cunningham, & Cramer, 1984). Nevertheless, there are also a number of studies citing no impairment in these domains for reading age (e.g., Beech & Harding, 1984; Holligan & Johnston, 1988; Treiman & Hirsh-Pasek, 1985). It is these latter findings, which make a detailed investigation of the role that phonological awareness plays in reading development appear fruitful, and deserving of further inquiry. Moreover, some poor readers are known to have reached levels of reading competency in spite of these cited deficiencies (Campbell & Butterworth, 1985; Temple & Marshall, 1983). It therefore remains to be shown which poor readers manifest these deficits, and under what conditions. For example, arrested development prior to reaching the alphabetic stage in reading (Frith, 1985) may result in the poor reader's use of compensatory strategies (Hulme & Mackenzie, 1992; Stanovich, 1986). Thus, it is important to establish how phonological difficulties result in atypical patterns of performance in memory and reading based tasks.

This thesis will examine these issues within the context of the phonological deficit hypothesis advanced for poor readers (Swanson, 1987; Vellutino, 1979). The central interest is to establish which aspects of phonological processing are most problematic for the poor reader, and as such predominate in an account of their reading failure. Secondly, there is an interest in examining the degree to which deficits in phonological processing might result in the application of different coding strategies in print acquisition, phonemic processing and reading related (e.g., memory) tasks. Thirdly, although a rather obvious fact, in many investigations the focus has been on accuracy in word recognition and acquisition processes. Thus, irrespective of the degree to which poor readers might be seen as having a fundamental phonological processing disorder, the thesis further aims to examine the poor readers' overall efficiency in terms of the speed of processing of phonological materials, in both reading and non-reading tasks. These differences might similarly account for the poor readers' lag in reading development, differing strategy use, and resulting atypical performances in reading age matched comparisons. Overviews of cognitive and developmental word reading models are used as a framework for understanding how these processes may qualitatively and developmentally differ for poor readers. However, attention is first given to a definition of dyslexia, and a summary of research designs used to examine developmental reading disability.

Towards A Definition of Poor Reading

In the cognitive view it is well known that reading is not a simple, effortless endeavour, but rather a complex series of interrelated component processes (Perfetti, 1985). These processes include the recognition of words and the connection of these to stored concepts; the development of meaning from grammatical constructs (phrases, clauses, sentences); connecting text; relating what has been learnt or what is already known; etc. Thus, for comprehension to occur, these mental operations must take place, many of them simultaneously. However, it has become evident that human information-processing capacity is limited and that working memory is taxed in the attempt to concurrently process these many elements. Thus, in order to facilitate comprehension, many of these underlying processes have to be developed and exercised to the point of automaticity or profound efficiency (Perfetti, 1985). Word recognition is only one of the lower-level processes that must be mastered to this level of efficiency; otherwise, attention is drawn from the higher-level comprehension processes.

However, without denying the existence of these higher level processes and their contribution to the overall act of reading, in the simplest of views reading is said to comprise only two component processes: one that permits language to be identified by means of a graphic representation, and another which permits language to be comprehended (Hoover & Tunmer, 1993). Therefore, reading is seen as being divisible into two distinct parts: word recognition and linguistic comprehension.

The view that reading largely derives from spoken language and listening in general is firmly established (Vellutino, 1979; Vellutino & Scanlon, 1987; Stanovich, 1986). Likewise, there is compelling evidence to suggest that decoding and linguistic comprehension are positively correlated (Juel, Griffith, & Gough, 1986; Stanovich, 1986). Therefore, within a rudimentary two-component definition of reading it is maintained that the acquisition of literacy primarily refers to the ability to recognise words (Juel, Griffith, & Gough, 1986). The idea is that as readers must also go through a similar set of processes when listening, literacy can be seen as the product of understanding and decoding. (Here, of course, comprehension does not refer to reading comprehension, but rather linguistic comprehension.) Successful reading can therefore be viewed as an outcome of decoding and comprehension skills where each variable ranges from '0' as an absolute value, to '1' (mastery), (i.e., R = D x C) (Gough & Tunmer, 1986). Therefore, in these regards the point must be made that reading comprehension will be constrained if there are limitations in either decoding or oral comprehension. Consequently, researchers believe that there is much to be gained if decoding is treated as the proximal cause of reading failure (Gough, Juel, & Griffith, 1992; Gough & Tunmer, 1986; Stanovich, 1992).

Nevertheless, where poor comprehension in reading is concerned it is important to determine whether the child's difficulties are specific to reading or stem from more general problems in language comprehension. The term specific reading disability is often used to describe what is otherwise referred to as dyslexia. Children whose reading difficulties are of a more general nature are often referred to as 'poor' or 'garden-type variety' poor readers. (Elsewhere within the empirical and discussion sections of this thesis the term 'poor' is used to describe children diagnosed as having a specific reading disability, i.e., who are dyslexic.)

In the literature dyslexia is given a number of definitions depending on the perspective taken, e.g., definitions that are medically, educationally, or cognitively based. In a similar sense there has been considerable debate regarding whether dyslexic children (characterised as having a specific reading disability) should receive differential educational treatment as compared with readers who have a general learning disability. However, the key empirical question in this regard is whether 'poor' reading can be distinguished from dyslexic reading on the basis of qualitatively different cognitive and behavioural characteristics for these two groups. It is believed for example that the magnitude of the severity of the reading problem in dyslexic individuals is extreme to the point of constituting a qualitative difference (Stanovich, 1988). Thus, within the literature, the 'specific' and 'general' distinction appears to be drawn on a number of differences that are said to characterise the reading development of dyslexic individuals, but which do not typify the 'garden-variety' type poor reader (Gough & Tunmer, 1986).

However, making such distinctions is slightly more complicated in practice than the description of the applications given here. A child may be delayed in reading because of the schooling process as opposed to a having a specific cognitive deficit that is contributing to the reading problem. Thus, to make a distinction between readers whose academic performance is generally low due to external factors (e.g., general developmental delay, general learning disability, lack of reading experience or education), and readers whose difficulties result from a specific cognitive impairment can prove to be a delicate process. In practice, this distinction is usually drawn on the basis of intelligence, where a discrepancy is sought between reading test scores and IQ.

Children are generally viewed to have a specific reading disability if their level of reading attainment significantly differs from their general cognitive ability or IQ. The 'garden-variety' type poor reader on the other hand, also has a reading age that is significantly low for his age, however, it is as good as can be expected because his IQ is also relatively low. Nevertheless, as a discrepancy between reading age and IQ could result from missed school, poor tuition, or a home environment in which schooling and literacy is not promoted, children could mistakenly be earmarked as dyslexic according to poor reading test scores. This is the criticism of diagnoses being made at a behavioural level. These children have a reading difficulty that is due to external factors and not to a specific cognitive impairment. Accordingly, the causes of the generally 'poor' or garden-variety type poor reader's reading failure should be reversible, whereas the dyslexic child's difficulties are more persistent. Morton and Frith (1993) suggest that differences between 'poor' readers and dyslexic readers should be sought at a cognitive rather than behavioural level. Part of this reason is that in tests of word reading dyslexic children may perform adequately on the basis of an acquired sight word vocabulary.

In reading age match designs poor (dyslexic) readers and 'good' readers are defined according to rate of progress and not by their respective performance levels at the time of testing. The central idea behind the design therefore, is to compare readers who have taken longer (e.g., two or more years) to attain the reading level that would be expected for their chronological age. Thus, rate of development is the key point of interest; the intent being to identify aspects of the dyslexic readers' performance that differ from the normally developing reader whose rate of development is more or less 'average'. Performance differences on reading and cognitive tasks are therefore used to examine how a particular skill or processing deficit (or strength) impacts on a child's rate of acquisition of development in reading. Equal performances across (unmatched) tasks in a RA match design are taken as evidence for the poor readers' developmental lag on all aspects. However, differential performance (in which the older poor reader differs from the younger normal reader) on some, but not all tasks is taken as evidence that the poor readers are not simply developing at a slower rate, but have some unique characteristics. If the developmental lag hypothesis holds true then the two groups of readers should not differ on any tasks that are causally related to reading (Stanovich, 1988).

Thus, in RA match designs a performance weakness is of etiological value, suggesting that this skill or the requisite processes underlying it are contributing to the reading failure. For example, a nonword reading deficit might imply that the poor reader's difficulty rests in a failure to use phoneme-grapheme translation rules. This specific difficulty is then likely to be considered as a potential candidate for explaining part of the reading failure. In this way, the RA match design is seen as a useful instrument for understanding the nature of reading development and for identifying deviant performance or 'unusual' groups of readers.

Nevertheless, on certain tasks the poor reader's actual performance might be obscured in a RA match design as a result of certain systems being more developed than that of controls, or simply because the poor reader has developed strategies to compensate for his difficulties. For example, the poor reader might perform on nonword tasks as a result of having more knowledge of word pronunciations than the younger controls. This is where data from chronological age controls is helpful in illuminating the extent to which the poor reader's performance is truly unique. Thus, although it is likely that the two groups will differ on most all of the tasks, there is the benefit of knowing which skills and processes do not differ. The CA match approach therefore permits the identification of elements that are not contributing to the reading failure, while providing descriptive information on what levels of performance on word / nonword reading, phonological awareness, and memory tasks are expected for chronological age.

Cognitive Models of Word Reading

Some of the evidence for the view that poor readers suffer from a phonological deficit has come from the dual route model of reading (Coltheart, 1978). The model posits the existence of a direct visual route to reading, and an indirect phonological route. It is proposed that regular words (e.g., hand) can be read by either route whereas it is argued that irregular words (e.g., glove) can only be read by the direct visual route. Attempts to read the latter word type by means of the indirect phonological route would result in mispronunciations known as regularisation errors (e.g., /glŭh/ /ō/ /vŭh/). Consequently, it is said that irregular words require the formation of word specific (or visually-based) associations. The visual recognition of words as 'whole' units is empirically based upon the skilled reader's apparent automatic retrieval of word pronunciations in the absence of sounding out, segmenting, or blending of the word's contained (phonological) identities.

The faster and more accurate reading of regular over irregular words (e.g., the regularity effect) shows that the reader is using phonological information to recognise words in addition to information generated by the direct visual route. Regularity effects are found in skilled adult readers, however these are less pronounced, and largely found only in reaction times as performance is usually at ceiling (Seidenberg, Waters, Barnes, & Tanenhaus, 1984). The reason is that as word forms become familiar (i.e., lexicalised) the direct visual route comes to predominate in skilled adult reading. Accordingly, adults' slower speed of recognition for irregular words is typically restricted to low frequency, orthographically and phonologically irregular forms (e.g., yacht).

Developmental Subtypes

Adult (neuropsychological) models of word reading in which effects of regularity and lexicality (e.g., where words are more easily read than nonwords) are examined in previously skilled adult readers with acquired dyslexia, have similarly played a role in influencing researchers' aims to isolate differences in the psycholinguistic abilities of children with developmental reading disorders. The approach is used to assess whether these children have difficulty, either in the reading of regular words and nonwords (e.g., phonological dyslexics), or in the reading of irregular words (e.g., surface dyslexics). Although in some cases these subtypes appear to exist (e.g., Campbell & Butterworth, 1985; Castles & Coltheart, 1993; Coltheart, Masterson, Byng, Prior, & Riddoch, 1983; Temple & Marshall, 1983), it generally appears that outwith the case study approach normal effects of regularity are usually found for both chronological (Waters, Seidenberg, & Bruck 1984), and reading age (Holligan & Johnston, 1988). Still, apart from the finding that poor readers are generally shown to exhibit normal effects of regularity, it seems that some individuals with severe phonological impairments might arrive at establishing a repository of regular word forms by means of the direct visual route. Thus, there are cases of individuals who present with similar phonological reading impairments as adults with acquired phonological dyslexia. One particularly well noted case is that of RE (Campbell &

Butterworth, 1985), a seventeen year-old girl described as highly literate in spite of her difficulties in reading and spelling nonwords.

Campbell and Butterworth (1985) report RE' s performance on standardised measures of reading, spelling and overall cognitive ability to be at above average levels. Phonological difficulties are noted in RE's performance on aural tasks such as rhyme judgement and homophone matching and the segmentation of spoken words. Her auditory discrimination is reported as normal and her memory span for digits is significantly impaired. What appears striking in the profile of RE is that her performance for rare and irregular word forms (e.g., idyll) is unimpaired, while even the simplest of nonwords prove difficult. Her profile therefore, is seen within a phonological dyslexic context, i.e., she has a distinctive impairment in nonword compared with word reading. As no neurological impairment is evident, it is argued that RE is a developmental example of an acquired phonological dyslexic (e.g., Shallice & Warrington, 1980; Funnel, 1983).

The definitive pattern in RE's cognitive profile provides us with an understanding of how some individuals with impairments in the processes requisite for skilled reading can attain better than adequate ability in word reading and writing. More specifically, this case demonstrates how some individuals with poor phonological skills become literate by virtue of compensatory factors. In the case of RE it is understood that this development was supported by a reliance on visual memory skills.

RE came to the attention of these researchers when she reported being unable to read new words aloud without someone's prior pronunciation of the word. IQ testing revealed that RE was within the normal or superior to normal range apart from auditory digit span, which was two standard deviations below the mean. Assessments were then made of RE's nonword reading and word reading ability, as well as her word and nonword spelling skills in order to establish whether there was a dissociation between her nonword reading and spelling. Further assessments included tests of phonemic awareness, segmentation of spoken words, and immediate serial recall of spoken lists. The results showed good ability for the reading and identification of meaning for 33 out of 45 unusual words (e.g., phlegm, puerperal). RE's errors were largely confined to a failure to offer pronunciations for words that she did not recognise.

The examination of RE's nonword reading skills however, yielded contrastingly different results. In this task RE's reading was slow and laborious in spite of the nonwords being simple three-letter items (e.g., oan, owt). RE averaged three seconds per item and failed to read 9 out of 30 nonwords. RE's difficulties were more marked with complex nonwords. On this measure RE identified only 3 out of 20 nonwords compared with 16 of the 20 real words on which the nonwords had been based. In a subsequent test of orthographic parsing ability it was shown that RE had 100% accuracy in the reading of 40 nonwords comprising two real words (e.g., mannerlaugh), however, her ability to read a set of nonwords that were homophonous with this first set but could not be segmented into two single words was markedly reduced (e.g., mannerlarf) (performance 62%).

Assessment of RE's spelling ability revealed that although she was able to spell 45% (control subject accuracy equalled 60.9%, SD 18.1) of a word list derived from misspellings in undergraduate essays and other commonly misspelled words, less than 60% of her spellings resembled the pronunciation of the target words. This was contrasted with 93% of the control subjects' (n=22) misspellings being phonemically acceptable. A similar pattern emerged with RE's spelling of the nonwords that had been presented to her earlier for reading. In this task only 85% of her nonword spellings were phonemically acceptable, contrasted by the performance of the controls, in which no more than a single phonemically unacceptable misspelling of nonwords was made. Taken together the results suggest that RE is as competent a word reader and writer as college students her own age, however, her difficulties lie in the reading and writing of nonwords.

This sort of profile is problematical for models such as Frith's (1985), as individuals who fail to reach alphabetic competency should not reach the orthographic phase (see section on developmental theories of acquisition). In the case of RE however, it would appear that the alphabetic phase has been by-passed. This is evidenced in RE's overall reading ability, and written competence for words commonly misspelled by college-aged students. Therefore, the case of RE stands in further contrast to Frith's (1985) model, as RE demonstrates that poor spelling does not necessarily accompany impaired nonword reading and writing. (Although RE's word spelling errors were phonemically unacceptable in a comparison to controls, she was nonetheless well within the normal quantitative limits.)

A series of phonological tasks was administered to RE in order to examine the extent to which her reading and spelling difficulties reflected a deficit in her ability to manipulate the sounds of letters in words with which she was unfamiliar. These included a speech sound discrimination task in order to examine whether her difficulties resided at the level of discrimination rather than manipulation, a spoonerism task as an index of segmentation ability, a phoneme counting task, and an auditory rhyme judgement measure.

Overall results from the phonological battery showed RE's phonetic discrimination ability to be normal, but that she encountered difficulties in the remainder of the tasks. Interestingly, in the spoonerism task in which initial phonemes from pairs of spoken words are interchanged (e.g., John Lennon – Lon Jennon), RE made a proportion of errors that was suggestive of her use of an orthographic strategy, (e.g., changing 'Phil Collins' to 'Chill Pollins' rather than to 'Kill Follins'); indication of the attempt to exchange initial letters rather than sounds. With phoneme counting RE made a number of errors on items in which there were more letters than sounds, for example, in reporting that 'ache' contained three rather than two sounds, 'guide' having four rather than three sounds, etc. A similar pattern emerged for nonwords where she reported 'skib' to have three sounds, 'rop' to have four, whereas she accurately reported the contained number of sounds in the words on which these nonwords were based (e.g., 'skid' = 4, 'rod' = 3).

Thus, it would appear that in these instances RE's knowledge for the contained number of sounds in words might have been supported by her memory for spellings. This of course resulted in more errors being made where the number of letters in a word was greater than the number of contained sounds. A similar strategy can be inferred from her performance in the auditory rhyme judgement task where proportionately more orthographically similar rhyming pairs (e.g., lemon-demon) were judged as rhyming, in addition to orthographically dissimilar rhyming pairs (e.g., rough-fluff) being judged as non-rhyming. However, where rhyming and non-rhyming pairs were orthographically or phonologically distinct no errors were made. Taken together, the results of the phonological battery suggest that RE's performance on these tasks is constrained by her apparent reliance on the orthography rather than the phonology of the spoken words. None of the control subjects was as reliant on letter information as RE in these tasks.

Finally, tests of immediate memory were carried out. One of the key questions was whether RE's reduced digit span performance (two standard deviations below the normal range) could be explained in terms of her noted phonological difficulties. The reason is that phonological codes are generally assumed to be used for the retention of serially presented digits, words, and letters. Alternatively, some individual's memory span deficits could be an outcome of other factors such as rehearsal difficulties (see Chapter Four for a review). This likelihood however, was ruled out in the case of RE as her ability to repeat up to four words would not impact on her single word reading, and she was similarly capable of repeating spoken nonwords.

With visual and auditory presentation of 4-, 5- and 6-digit lists for written recall, RE demonstrated better recall of all list lengths in the visual modality presentation. Campbell and Butterworth (1985) suggest that this might be a direct outcome of her phonological difficulties (e.g., in registering and/or maintaining these items in a phonological code). The authors further suggest that RE may have been converting the spoken lists into an orthographic code, and in doing so information would be lost in this conversion; thus, accounting for her reduced performance for spoken over visually presented lists.

In RE's recall of digits she remembered as many items in backward as in forward order. The authors questioned whether this equal performance was due to RE's use of visual codes in this task. The reason is that an ability to manipulate order of recall is said to distinguish visual from phonological encoding processes in immediate memory because phonologically encoded material is more difficult to recall in reverse order compared to visual material (Healy, 1974). RE's equal performance for backward and forward presentation of digits was further verified in a task involving 20 spoken 3 and 4 digit lists, in which she recalled 80% of the 3 digit lists backwards and forwards, and 40% of the 4 digit lists. This gave added confirmation to her use of visual strategies to recall serial information.

Two final tests of immediate memory were employed to examine whether RE would show normal use and functioning of the passive phonological store and articulatory loop components of working memory. The first sought to explore whether RE would demonstrate normal effects of phonemic confusability (i.e., better recall of phonemically dissimilar letters (e.g., G, M, X, Z, L) over phonemically similar letters (e.g., B, G, V, T, E) with visual and auditory presentation of 5- and 6-letter lists. RE failed to show a phonemic similarity effect in either presentation modality, recalling marginally more rhyming than non-rhyming letter strings. These results therefore suggest that RE was relying on visual rather than verbal codes for recall.

The second task sought to examine whether RE would demonstrate normal effects of word length with visual and auditory presentation of 3-, 4- and 5- names of short (e.g., Charles) and long (e.g., Alison) spoken duration, that were matched for letter length. RE's performance showed that long and short names were recalled equally well, moreover, that her recall was better for long names in the 4- and 5-name lists. This latter result provides further evidence of RE's use of visual as opposed to verbal codes to assist recall. In terms of presentation modality her recall of short names was better in the visual condition, whereas long names were recalled equally well with visual and auditory presentation.

Thus, Campbell and Butterworth (1985) present a case study of a developmental phonological dyslexic who attained a level of skilled adult reading in spite of her phonological processing deficits. Given that RE had difficulty in phoneme segmentation, auditory discrimination, and verbal memory tasks, it should come as little surprise that her nonword reading was also impaired. However, her memory for visually presented material was better than her auditory recall. Consequently, it was suggested that her reading development must have been supported by a reliance on visual skills. The authors further suggested that RE learnt to read by virtue of lexical analogies (e.g., Glusko, 1979), in which new words are visually segmented and matched to existing orthographic segments in the lexicon.

Temple and Marshall (1983) similarly reported a case of an individual who could read high frequency regular, and irregular words quite well, but performed poorly on nonwords and rare words, making few regularisation errors, (e.g., 'island' = 'ĭs-land'). Instead, responses to nonwords contained word components, which suggested the use of real word analogies (Temple & Marshall, 1983). However, it has been argued that Temple and Marshall's subject was able to read 39% of nonwords correctly, similarly, that Campbell and Butterworth's subject was able to read 64% of nonwords correctly (Castles & Coltheart, 1993). Therefore, it is suggested that these readers possessed some phonics skills in addition to their whole-word reading skills. These issues aside, an empirical question is whether an individual's ability to read nonwords will necessarily mean that similar approaches will be applied in acquisition.

Overall, the dual route model has therefore provided a reasonable framework from which subtypes of dyslexia can be considered. Within the literature, those who rely more on spelling-sound rules have been referred to as 'Phoenicians', whereas those who rely on word-specific associations, 'Chinese' (Treiman & Hirsh-Pasek, 1985). Accordingly, the type of reader who is able to read regular words, but who has a tendency to 'regularise' the pronunciations for irregular words (e.g., island = 'ĭs-land') has become known as a surface dyslexic. These 'Phoenician' readers appear to have difficulty in forming word-specific associations for words that deviate from corresponding spelling-sound translations. Conversely, it is the phonologic dyslexic, dubbed the 'Chinese' reader for his/her inability to apply grapheme-phoneme correspondence rules, who does not encounter difficulty in reading irregular word forms such as 'aisle'. It therefore follows that the phonological dyslexic will perform poorly on measures of nonword reading, where no existing representations will be present in the visual lexicon. Conversely, the surface dyslexic, who presents with difficulties in accessing representations in the visual lexicon, yet is proficient at using phonological codes, should perform better on an index of nonword reading.

Nonword Reading

The view that skill in reading is marked by an ability to pronounce unfamiliar regular words led to the use of the nonword reading task in which novel letter strings (e.g., brank) are used to gauge phonological reading skill. Thus, although regular words have been used in investigations of phonological reading skill, these items can also be read visually. However, as nonwords do not have lexical representations, these can only be read via the use of the phonological or indirect route. In reading age matched comparisons a nonword reading impairment is therefore taken to mean that the poor readers' word recognition skills have been acquired via a more visual or orthographic approach to printed word learning rather than by phonological recoding strategies. Nevertheless, although a substantial number of studies have found poor readers to be less accurate at reading nonwords for reading age, it has to be noted that there are also studies which do not find this impairment (see Rack, Snowling, & Olson, 1992 for a review). However, it is possible that even when their accuracy is reading age appropriate, in some instances poor readers might be slower to generate pronunciations for words and nonwords, which in itself could be interpreted as a phonological processing impairment. Consequently, the conversion of letters to sounds might be more demanding than trying to read words visually.

Therefore, it would appear fruitful to investigate the degree to which poor readers are impaired in their 'rates of access' for phonological materials in both reading and reading related tasks. However, one argument might be that the poor reader prefers to be accurate, rather than demonstrate speed in identification. Nevertheless, where accuracy is demonstrated, response time differences might hold the key to understanding how phonological impairments may reside in differences in processing speed.

This type of phonological impairment would have direct implications for judging not only the poor readers' difficulties in reading, but also their approach to the learning of new reading words. Thus, when applying this rationale to the strategies involved in acquisition, the slower reading of letters, words and nonwords might result in the poor reader engaging in the cognitively less demanding task of using orthographic processing strategies instead of attempting to map a word's phonology. Indeed, there is consensus that poor readers primarily use visual or orthographically-based strategies in reading rather than recode visual information into a corresponding phonological form (Foorman & Liberman, 1989; Seymour & Porpodas, 1980; Snowling, 1980). However, it is not known whether this approach stems from difficulties in taking a phonological approach to reading, or whether a visual approach is taken because their visual skills are unimpaired for chronological age.

It is generally found that poor readers show normal effects of regularity for reading age (e.g., Holligan & Johnston, 1988), moreover, that these effects are of a similar magnitude to that of controls (Metsala, Stanovich, & Brown, 1998). However, it is noted that in some investigations poor readers have shown reduced effects of regularity, reading proportionately more irregular words for reading age (Siegel & Ryan, 1988). What is certain is that a reliance on orthographic processing strategies would impact on the poor readers' ability to establish and retrieve phonological representations from long-term memory, as concentration on a word's visual form would result in a failure to establish adequate visual-phonological linkages. This reliance on visual coding and/or visual reading strategies may, therefore, be sufficient enough to undermine the development of visual-phonological connections, in turn producing a phonological processing impairment.

Thus, although the dual route model of reading has proven instrumental in demonstrating to researchers that words are identified either by grapheme-phoneme correspondences or by word-specific associations, the model does not differentiate the specifics of how new words are acquired, stored, and subsequently retrieved in identification tasks. In this sense, it can be understood how the model is appropriate for the study of individuals with specific neurological impairment, yet perhaps less suited to the study of children whose difficulties are better reviewed within a developmental framework. Indeed it is argued that in brain-damaged individuals impairment to specific lexical routes are more clearly defined. In contrast, the reading patterns observed in dyslexic children are said to be surface characteristics that may bear a complex relationship to their underlying cognitive impairments (Hulme & Snowling, 1992). However, with time the model may bring greater relevance to the study of developmental reading disorders as new techniques, which permit a better understanding of neurological functions develop. Currently, however, what is known is that individuals with acquired dyslexia, (for whom the areas of impairment have been localised), do appear to demonstrate certain patterns of reading performance which are accounted for by the theoretical propositions of the dual route model.

For example, some adults with acquired surface dyslexia have been known to demonstrate a highly limited ability to access irregular word forms in the visual lexicon, while showing no difficulty in applying phonological reading strategies to access the pronunciations of regular word forms (Ellis & Young, 1988). However, few such extreme parallels have been identified within the reading performances of developmental dyslexics (see Coltheart, Masterson, Byng, Pryor, & Riddoch, 1983). In a similar regard, adults with acquired phonological dyslexia have been known to show virtually no ability at reading simple nonwords (2 of 20), while being able to read 93 of 100 common nouns (Funnell, 1983).

Nevertheless, tasks generated from the model (e.g., regularity and nonword reading) remain to be seen as helpful in gauging the degree to which specific approaches (e.g., phonological and visual) to reading are being taken. In this sense, they differ little from standardised word reading measures in which sight, and phonetically transparent words are used as indices of phonetic versus visual applications in word recognition.

Given a developmental framework in which children are believed to progress through a series of stages in their reading (e.g., Frith, 1985) it is therefore, argued that there are certain parallels to be drawn between developmental and acquired dyslexias. Firstly, as children enter the alphabetic phase, and demonstrate their acquisition of phonics knowledge by reading phonetically regular words they are said to be using the sublexical procedure. In a similar sense, the orthographic stage in reading development is said to correspond with the lexical procedure in which words are read as units in the absence of phonological conversion. According to Frith's (1985) model, arrested development at the alphabetic phase would mean that although the reader would be able to identify words contained within a restricted sight vocabulary, he/she would be unable to identify words requiring phoneme-grapheme correspondence translations, i.e., novel words or nonwords. This pattern would therefore parallel that of the acquired phonological dyslexic. Conversely, arrested development or difficulties with the orthographic phase would mean that problems would occur in the reading of irregular spelling-sound correspondences whereas reading of words that correspond with spelling-sound relationships would not be impaired. Therefore, this pattern would be likened to that of the acquired surface dyslexic.

Approaches to the Identification of Subtypes

The proposition that patterns of reading in developmental dyslexia should bear some resemblance to those found in acquired dyslexia has been examined by a number of researchers, and has produced some interesting results (e.g., Baddeley, Ellis, Miles, & Lewis, 1982; Castles & Coltheart, 1983; Colheart et al, 1983). Castles and Coltheart (1993) aimed to identify phonological and surface dyslexic patterns in a comparison of lexical and sublexical reading skills of 56 developmental dyslexics and 56 normally developing readers. In this investigation they applied a test battery which would allow separate assessment of the functioning of the lexical and sublexical reading procedures; namely a set of irregular words to allow examination of the lexical procedure and a set of pronouncable nonwords to assess the functioning of the sublexical procedure. As the regular and irregular words were matched on frequency and imageability, the correct reading of fewer irregular words was to be taken as evidence for a deficit in lexical reading skills and not to other differences between the lists.

Prior to analysing the results for the dyslexic group simple regression analyses of irregular word reading and nonword reading as a function of chronological age were performed on the control subjects in order to derive a picture of normal development in children based on the performance of the control subjects. These analyses showed highly significant relationships between age and irregular word reading (with age accounting for 52% of the variance in irregular word reading), and age and nonword reading, (with age accounting for 25% of the variance in nonword reading). With linear relationships demonstrated for each type of stimuli it then became possible to use these estimates as a basis for the identification of dyslexic children whose performance in irregular word reading and nonword reading was particularly poor for chronological age.

Upper and lower confidence limits were established for irregular and nonword reading and used for the selection of scores in which only 5% of performances would be expected to fall. Thus, scores which fell outside these limits were outside the range in which 90% of the scores of control subjects fell. This examination showed that scores for 40 of the 53 dyslexic subjects were below the lower confidence limit for irregular word reading, thus placing 75% of these readers in an abnormal range for their age. A similar pattern emerged for nonword reading scores, placing 72% of dyslexic subjects below the lower confidence limit (e.g., 38 of the 53 children). The critical finding, however, is that 18 of the 53 subjects (34%) fell below the lower confidence limits for one of the tasks, but within the limits for the other. Thus, ten of the dyslexic children were outside the range for irregular word reading but within the range for nonword reading, whereas eight children had scores within the range for irregular word reading, but outside of the range for nonword reading.

Overall, given this dissociation between irregular word reading and nonword reading, the results provided evidence for the existence of two varieties of developmental dyslexia, i.e., the results suggested a distinct pattern in the dyslexic children with one group showing a difficulty using the lexical procedure (e.g., in whole word recognition) and the other the sublexical (e.g., in using letter-sound rules).

As can be seen, dyslexia appears to be a disorder of considerable variability. This is most evident from the perspective of presented subtypes in which qualitatively distinct varieties of dyslexia (that may be associated with different causes) are considered to exist. Still other researchers are of the opinion that there is a single underlying cause. The latter perspective therefore views dyslexia as a homogenous condition. Appropriately, the approach to understanding the disorder from this perspective will allow data from a number of dyslexic individuals to be compiled, which can then be compared with normally developing readers matched for reading and chronological age. The aim of this approach is to gather evidence in support of a consistent pattern from which underlying causes can be identified, e.g., phonological processing deficits.

In contrast, the approach to understanding dyslexia as a heterogeneous condition requires the study of individual cases, and the subsequent categorisation of these individuals into subgroups that appear to share a certain pattern of performance, e.g., surface or phonological characteristics. Irrespectively, there must be a theoretical framework in which aspects of the reading process can be separated in order to understand the various possible causes of reading failure. In this way, the identification of specific aspects of impaired processes should inform educational approaches aimed at the amelioration of the affected elements underlying the reading process. Of course, it is understood that correction at a biological level is at least for now, not possible. Nevertheless, the point to be made is that research into the conditions of dyslexia should ultimately be treatment-oriented. However, in order to outline the direction that research should take, the nature of the disorder must be described in terms of its development or chain of causality.

A Causal Model

Morton and Frith (1993) believe that the route from biology to behaviour must be through cognition. Accordingly, the framework proposed for their causal model involves biological, cognitive, and behavioural levels. Potential causes of reading disability are considered from the perspective of skills and processes requisite for normal development; the reason being that what applies to deficits also applies to development. Thus, in terms of the development of skilled reading (A), one might establish that the normal development of (A) depends on the prior development of at least two features, X and Y (e.g., knowledge of the visual features of letters and the ability to segment and assemble phonological strings respectively). Therefore, the normal development of A (reading) will be affected if there is delay of development or some deficit in X or Y. Consequently, there will be two different causal models of failure for (A), according to whether X or Y is affected. In other words, a failure to acquire either the letter knowledge or the phonological skills will result in decoding skill not being acquired.

Therefore, with failure in reading it needs to be ascertained which one of the two prerequisites (X or Y) is lacking or deficient. This can be achieved by way of examining performance on numerous phonological tasks. In this way, a child who cannot decode because of a lack of letter knowledge can be differentiated from a child who cannot decode because of deficient phonological skill according to these general premises of the causal model. This however, is not to say that reading skill will not be developed by compensatory means. Accordingly, a dyslexic individual might exhibit ability (A) in the absence of phonological skill (Y), as in the case of RE where her intact visual skills (X) appear to have compensated for her phonological impairment. However, beyond this simplified explanation of the prerequisites for skilled reading, there are a number of central contingencies for acquiring literacy in an alphabetic script.

At the lowest level a minimum of general processing efficiency is required. Additionally, there must be adequate vision and hearing as these are the input channels requisite for the development of the skill. In terms of the requisite cognitive capacities there must be (a) a normally developing phonological system, P, which many researchers propose is somehow damaged in dyslexics, and (b) a normally developing Supervisory Attentional System (SAS). This system (as proposed by Shallice, 1988) is necessary for formal learning to take place, as teaching will be required for progress in reading to be accomplished. Once all of these factors are in place it is claimed that an automated system for handling phoneme-grapheme correspondences will be established and alphabetic skills will become evident. Proficiency with these skills will lead to the orthographically skilled reader.

Thus, the defining condition within a causal model of dyslexia is a cognitive deficit, and the absence of the cognitive structure P. This in turn produces the absence of the structure GP (grapheme-phoneme correspondences) necessary for relating / translating letters and sounds. However, the outcomes are not restricted to a lack of decoding skills, but might also include naming and speech planning impairments in addition to the assumed alphabetic impairments. Thus, even though the model acknowledges alternative biological origins and a variety of core and other signs and symptoms (at the behavioural level), it contains a single defining cognitive deficit, P (at the cognitive level). Dyslexic individuals are therefore, seen to be deficient in the formation of the particular cognitive structure that is required for translating graphemes into phonemes. In short, it is a deficient P structure, which results in a faulty GP structure and poor alphabetic skills, as well as additional impairments, which concern difficulties in the phonological processing of spoken language. The most critical of these impairments include name retrieval, verbal short-term memory, and speech production. However, as the underlying cognitive deficit in dyslexia is at the level of P, these types of difficulties will be apparent well in advance of the usual age for the onset of literacy.

Nevertheless, although deficits in system P can be examined through a variety of phonological tests (rhyming, nonword reading, segmentation), it is problematical that P is also absent in normal children prior to the start of formal schooling. Given that the relationship between reading and the development of phonological skill is reciprocal, it is therefore difficult to outline causal pathways for reading failure. Some studies suggest a correlational relationship between the development of P and subsequent reading skill (e.g., Bradley & Bryant, 1983; Fox & Routh, 1980). The noted evidence from intervention studies offers further support for a causal relationship (e.g., Lundberg et al, 1988). Yet, at the most basic level, at the pre-school stage a faulty P system is indistinguishable from a slowly developing, or immature one. However, research into the biological basis of dyslexia is still largely in the formative stages of development.

Thus, this model suggests how reading failure can be understood from the perspective of a central cognitive deficit in system P, which produces a variety of behavioural signs and symptoms. The P system deficit arises from certain biological factors. However, this causal model focuses on a phonological deficit whereas the authors claim that there may be other factors (e.g., visual deficits) that underlie at least a subtype of dyslexia. In this example, at the biological level abnormalities might exist in dyslexic brains, for example, in the magnocellular pathways, which deal with low-contrast, high-speed visual functioning (see Lovegrove, Garzia, & Nicholson, 1990). Thus, in certain cases there might be a cognitive deficit that is separate from the proposed P component, which will similarly disrupt the development of alphabetic skills. A defect with the magnocellular system at the biological level for example, might produce a deficit in pattern analysis (at the cognitive level), thus producing poor visual pattern recognition (at the behavioural level). Accordingly, in this causal example a visual deficit caused by a biological fault produces a dyslexic condition in which P is intact. However GP is inhibited as a result of the deficient visual component requisite for letter analysis. Seymour (1990) has suggested that subgroups whose performances can be differentiated according to dissociation in their visual and phonological skills are identifiable at the cognitive level.

Overall, it appears that the general disagreement of Morton and Frith (1993) concerns the relationship of phonemic awareness to reading, and how theories generally do not differentiate between behaviour on the tasks and the cognitive processes and structures which underlie such performance; hence the presence of cognitive and behavioural levels in the addition to biological factors at source in this particular model. The related issue raised by these authors is that every researcher distinguishes between performance on nonword reading tasks and the requisite cognitive skills involved in this performance (e.g., alphabetic competence), but that the same step must also be taken for performance on phonemic awareness tasks to be understood.

To summarise, within a cognitive framework a system by which words are read via letter-sound correspondences is seen as necessary, and central to skilled word acquisition. However, the development of word-specific associations also plays an important role in acquisition, one which might be of greater significance to individuals with a deficient phonological system (e.g., Campbell & Butterworth's RE). In this sense, the poor reader's reliance on word-specific information relative to phonological codes in acquisition seems largely untapped in investigations of developmental reading disability. Nevertheless, perhaps the point of greater relevance is that all readers will make use of these mechanisms to varying degrees. Consequently, some readers might adopt a more holistic approach to word reading and show less ability in letter-by-letter reading of unfamiliar regular words or nonwords. In contrast other children may have a tendency to rely on letter-sound mapping strategies to the point of having an underdeveloped system of whole word recognition. Of course these types of contrasts generally assume that there are two separate channels for the recognition of these different word forms, as in the case of a dual route framework. However, some contrasting interpretations have been provided by computational accounts of word reading designed to simulate detailed aspects of human reading performance. The Seidenberg and McClelland model (1989) represents one such attempt to develop an integrative computational account of the phenomena of orthographic and phonological codes in word reading.

A Connectionist Model

The aim of the connectionist model research was to develop a theory that would provide a unified account of three aspects of word recognition: acquisition, skilled performance, and breakdown. The background of the work stems from examinations of dual route theory in which aspects of normal and impaired visual word recognition are addressed (e.g., Coltheart, 1987).

Within a connectionist framework regular / irregular word reading and nonword reading are handled within the context of a single system as compared to separate lexical and sublexical channels. In the Seidenberg and McClelland (1989) model, weighted connections were established within the system during the presentation of words in a training phase (which involved 2897 monosyllabic words). The mechanics of the model are such that the more often a word is presented the greater the impact on the weights being established. These phonological and orthographic patterns as input are then used to investigate the relative phonological codes as output. Thus, during training the weights mediating the computation from orthography to phonology encode facts about the frequency and consistency of spelling-sound correspondences in the lexicon. Frequency is accounted for because it is determined how often a word is presented during the training stage. In short, the more a word is presented the larger the weighted connections for the word's contained features.

Accordingly, the model is better at reading words that contain sublexical (i.e., letter-sound correspondences) that are present in the majority of words within an English orthography. Thus, the computation of output is more easily accomplished for words in which the contained spelling pattern corresponds with a single pronunciation (e.g., *-est* in *nest*). This is contrasted by the model's poorer performance on words in which the contained spelling pattern has more than one possible pronunciation (e.g., *-ost* in *post, lost*). Again, the reason is that an increased exposure to consistent spelling-sound patterns (e.g., -est) results in heavier weighted connections being established relative to less consistent patterns (e.g., -ost), which push the weights towards values that are less optimal for producing the correct phonology at output. Accordingly, training on a word such as '*post'* negatively impacts on the formation of weights from the perspective that *'lost'* has a different phonology for output. Consequently, with sufficient training on these words the model produces an output that is closer to the actual pronunciation (e.g., *gave-sāve)* than to the alternative pronunciation of the inconsistent spelling pattern (e.g., *ve as in have*).

These outcomes find accordance with lexical neighbourhood based principles (e.g., Glusko, 1979) in which inconsistencies in pronunciation are dictated by the proportion of a word's neighbours (similarly spelled rhymes, e.g., *gave-save*) relative to non-neighbours (similarly spelled nonrhymes, e.g., *gave-have*). In these analogy-based accounts of word recognition overall error scores for non-neighbours are therefore greater than for words that are entirely consistent (neighbours). Apart from these consistency effects the Seidenberg and McClelland (1989) model also shows a correct simulation of latency differences in naming times for different word stimuli. In these respects the model's output closely resembles that of the performance of human subjects in single word reading tasks. Thus, the model will perform better on words that are more easily read by people, and poorer on those that people find more difficult.

Importantly, the Seidenberg and McClelland (1989) model was able to produce correct output for a substantial corpus of words, including regular and irregular word pairs (e.g., gave-have, bone-gone), in addition to simple nonwords on which the model had not been trained (e.g., nust). Thus, the results carry important implications for interpreting dual route models of reading, namely of how word reading can advance by virtue of lexical associations being made between letter strings and whole-word pronunciations, whereas nonword reading is said to require a separate system of grapheme-phoneme correspondences. Thus, it would seem that unfamiliar regular words and nonwords might successfully be read by virtue of established forms in a visual lexicon, quite independently from requiring an efficient phoneme-grapheme correspondence translation system. Indeed, it has been noted that phonological awareness and paired associate learning both make unique contributions to word and nonword reading processes (Windfuhr & Snowling, 2001). Such results therefore, challenge the assertion that separate mechanisms are required for pronouncing nonwords and exception words. The reason is that if the pronunciation of unfamiliar words (e.g., nonwords) is influenced by experiences with familiar (e.g., real) words then there must be a greater interaction between the lexical and sublexical channels than is purported within a dual route framework. In other words, the Seidenberg and McClelland (1989) model does not appear to recognise a distinction between sublexical and lexical reading procedures. This has also been suggested by other work using human subjects (e.g., Kay & Marcel, 1981).

Further simulations by Plaut, McClelland, Seidenberg, and Patterson (1996) suggest that mappings between orthography and phonology need to be extremely fine grained in order for the knowledge that the model has acquired during training trials to permit the reading of novel word forms. Differences in the degree of specification of representations and in the learning procedures can therefore be expected to affect word and nonword reading to varying degrees. The model suggests that associations between letters and sounds are learnt by the reader at various levels, for example between individual letters and phonemes, as well as between letter groupings and syllables, in addition to connections between print and sound at the whole word level, hence, the idea that existing whole word knowledge may be brought to the task of reading an unfamiliar word (e.g., Glusko, 1979).

Nevertheless, the structure and degree of completeness of underlying phonological representations are said to be critical (Brown, 1997; Harm & Seidenberg, 1999). Although quite separate, the role of learning procedures in the acquisition of reading is nevertheless not to be overlooked. Harm and Seidenerg (1999) showed that within a connectionist framework word recognition could be disturbed by changing elements of association learning or by degrading phonological representations. The act of the latter produced the greatest effect on nonword reading, whereas changes that were made to the learning algorithm to create less efficient learning rates considerably affected the model's irregular word reading performance, whereas the effect on the model's nonword reading efficiency was less marked.

Thus, there are important implications for understanding how certain patterns of reading performance can be influenced by different emphasis being placed on learning and/or instruction. For example, a whole word reader may adopt this strategy because they have not been alerted to the alphabetic nature of the English spelling system. Thus, not unlike changes being made to the teaching / learning algorithm in the connectionist framework, children learning by a whole word approach might develop weaknesses in nonword reading. Thompson and Johnston (2000) reported that children in New Zealand are weaker in nonword reading than Scottish children learning phonics because the former are taught by a whole word method.

Above all the dual route model, and related attempts to computationally model skilled reading performance have proven influential in providing a theoretical framework which has enabled understanding of how words from an alphabetic orthography such as English might be accessed via specific lexical and non-lexical routes. However, beyond the simplified explanation of the models given here, it is important to remember that within a cognitive framework the reading of single words is not a simple endeavour. Thus, beyond the processes involved in identification it is worthwhile considering how words are initially acquired, as this will carry implications for how they are stored (i.e., represented) and recognised. It is from a developmental perspective that these processes as they pertain to reading are best described and understood.

Developmental Theories of Acquisition

Although theories of reading development differ on the characterisation of the beginning reader's movement into reading and the types of connections that are made, they nonetheless appear to agree on the basic tenets of skilled reading and, on the general progression towards this end. It is generally held that the initial stages of word acquisition involve code (Gough & Hillinger, 1980) or cue learning (Ehri, 1992), in which readers make use of salient graphic features as cues in recognition, e.g., the two tall sticks in 'yellow' (Frith, 1985; Seymour & Elder, 1986). This cue may arbitrarily (Frith, 1985; Gough & Hillinger, 1980) or systematically (Ehri & Wilce, 1985) correspond with the item's name. The learning of a word's name, and the ability to retain this in memory is viewed as critical to word learning (Jorm & Share, 1983; Paivio, 1978; Perfetti, 1985; Vellutino & Scanlon, 1982).

Referred to as paired-associate learning, this process begins with the reader's first experience with a (printed) word's visual form and accompanying pronunciation provided by an external agent (e.g., teacher, parent, or other). Some structural attribute or visual feature is then associated with the word, and subsequently stored in memory. An example of this might include the reader's perception that the printed letter 'f' in the word 'flower' is somewhat stem-like, or that the 'flow' component of the word resembles the head of a flower. In a similar regard, the claim has been made that the reader may unconsciously choose to base recognition on the visual coding of the first letter of the word only (Gough & Hillinger, 1980; Frith, 1985). In either case, when this word (or another word that is visually similar) is next encountered, the stored association serves as a memory source for recognition. Thus, when presented with the word 'flown' or 'tower', the relative similarities to 'flower' may produce an incorrect reading response, and perhaps another (more discriminating) visual characteristic will be assigned to the new reading word. Therefore, if coded on the basis of the word's first letter only, further discrimination may be sought by adding the word's second letter to the visual memory form (Frith, 1985). Seymour and Elder (1986) noted that a child misread the word 'smaller' as 'yellow', the child claiming to know the word because of its "two sticks". Thus, at this stage of recognition it is quite clear that the identification of words is visually driven. As a corollary, at this stage of development, it may be that during the retention of a word's name in working memory, the attachment of additional information to the auditory representation is more attentionally demanding than simply coding the word visually.

Researchers appear to agree that this system of recognition (which is by some considered to be sight-reading) can assist the development of a reading vocabulary. However, beyond the earliest stages of acquisition, further development is precluded by the system's limitations in enabling finer and more subtle discriminations to be made between words that are visually similar (Ehri & Wilce, 1985; Gough & Hillinger, 1980; Share, 1995). Gough & Hillinger (1980) suggest that the next stage, cipher learning, begins when the reader's knowledge of letter-sound correspondences is fairly accomplished. Accordingly, it is this knowledge that the reader applies to read words.

Within this general description of some of the stages through which beginning readers progress towards skilled word reading, it can be seen how there is a shift that occurs in the reader's approach and understanding of print. However, prior to this realisation that print acts as a medium for accessing language, the beginning reader 'sees' these symbols as visual items as opposed to representations of speech. When the reader recognises that these symbols represent sounds then suddenly a shift in both strategy and understanding seems to occur. Nevertheless, up until this point it appears that the reader will attempt to identify words by means of developed associations that are more visual in nature, rather than apply letter-sound correspondence knowledge. Given this proposition, it would appear possible that the rehearsal of a word's name may occur as a whole, independent of its internal phonological structure being associated with corresponding letter-sound relationships. Therefore, the beginning reader may choose to strengthen the word's name as a whole, while forming a visual code for the stimulus independent of establishing letter-sound associations. This contention carries implications for understanding how some children might fail to establish a sight (e.g., visual) word vocabulary that is supported by adequate linkages to the word's phonology, should the realisation or inability to make this shift not occur. This is why it is beneficial to consider the stages through which less advanced readers progress towards printed word learning. However, acquisition theories which are restricted to distinct or successive phases of development are largely premised upon the learning patterns of the normally developing reader, and therefore may be misleading. The reason is that all readers do not necessarily fit neatly into the stages proposed by many models (Stuart & Coltheart, 1988).

Frith's (1985) three-stage model of reading development (which is heavily based on dual route theory) considers dyslexia within the context of the normally developing reader's progression towards skilled word reading. Normal progression in reading is defined by a reading age that is more or less appropriate for chronological age. Arrested development or difficulty with processes at any stage is said to preclude the individual's advancement to the subsequent stage(s). The first phase of Frith's model, the 'logographic' stage, is similar to other developmental theories in that the earliest stages of word recognition are visually driven. However, although identification is made by virtue of minimal visual features, these cues are not solely based on a word's visual features. Rather, recognition can occur via a child's identification of the word 'stop', as cued by the accompanying hexagonal, red-coloured backing (Frith, 1985). However, devoid of its contextual backdrop, the same word might not be identified. Although there is identification of some letter information at this stage, letter order is of little significance in this type of recognition. Of course, it is important to note that the recognition of a word, whether or not cued by a contextual factor, presupposes that this word is part of the reader's oral vocabulary. Put another way, the early developing reader will already (in spoken form) possess most of the words that s/he will encounter in print for the three years that follow (Nagy & Herman, 1987). What the reader does not know are the words' printed forms (Gough & Juel, 1991). A fruitful key to understanding Frith's logographic phase is to liken it to the recognition of independent visual forms, as instanced in the Chinese orthographic (language) system.

Nevertheless, beyond the emergent literary skills requisite for the identification of environmentally-based word forms, the reader must develop awareness that words are elements of speech represented by orthography. As such the identification of these printed items requires knowledge of letter-sound correspondences. This stage of development in reading is what Frith (1985) refers to as the 'alphabetic' stage. Thus, in order to access the spoken form of a printed word the reader needs to understand the relationships between a variety of speech 'forms' and their respective spellings. Accordingly, failure to develop this awareness will result in the reader's arrested development at the first stage (i.e., the 'logographic'), which Frith (1985) claims marks the onset of what will become developmental dyslexia. However, although arrested development at the logographic stage will permit the identification of familiar words, access to unfamiliar words will be constrained. This is because the 'alphabetic' phase involves the reader's application of systematically governed correspondences between letters and sounds. In a similar sense, a failure to advance to the third and final stage (the orthographic), may result in an over-reliance on grapheme-phoneme conversions, yet because the reader's logographic skills are in place, this reliance will result in the regularisation of spellings for irregular word forms (e.g., 'laff' for 'laugh').

In Frith's final stage, the orthographic, recognition involves the immediate identification of word parts (morphemes), prefixes, suffixes, and intraword syllables. However, it is important to note that at this stage of development, identification is free from the type of visual recognition that occurs in the logographic stage. Similarly, it is also free from the conversion of individual graphemes to phonemes as described in the alphabetic stage. Rather, strategies developed in each of these earlier stages emerge in the orthographic stage as non-visual and non-phonological, and thus operate on larger units, i.e., syllabic or morphemic constituents of whole words (e.g., 'tion' in 'motion', or 'attention'). According to Frith (1985), failure to advance to the orthographic stage will result in the reader's use of letter-sound application strategies acquired during the alphabetic stage, hence regular words (e.g., hand) will be spelled correctly, and difficulties will occur in the reading of irregular words (e.g., glove).

Frith's account of reading development offers some interesting insight into the qualitative side of what reading and spelling might resemble for those arrested at a particular stage in their development. By extension, the model carries strong implications for understanding how these readers are faced with obstacles as the skills requisite for advancement to subsequent stages fail to materialise. Consequently, this account provides an impetus for suggesting how these readers may develop different strategies to compensate for their halted development in reading. For example, her model suggests that a child who fails to reach competency at the alphabetic level, will remain at the logographic stage, and therein continue in the attempt to acquire new reading vocabulary by means of a sight, or visually-based approach. Accordingly, readers who fail to advance to a stage of more efficient learning must rely on existing resources. This pattern of performance is predicted by Ehri's (1992) model.

Ehri's model differs from that of dual route theories (e.g., Coltheart, 1978; Frith, 1985) in which words are identified either by letter-sound mapping strategies or directly at the whole word level (e.g., by word specific associations). According to dual route theory, word specific associations are formed through repeated exposure to a word, which results in connections between the word's printed form and its meaning stored in memory being established. This view therefore maintains that the manner by which these words are identified is a non-phonological, visual-semantic route into memory. Moreover, the established connections are viewed to be arbitrary rather than systematic as the connections are visual, and at early stages of development may involve salient visual features or initial and final letters in a word that are subsequently stored in memory (Gough & Hillinger, 1980; Frith, 1985). Accordingly, the reader is viewed not to be relying on phonetic information at this stage. Ehri (1992) argues that this viewpoint does not acknowledge the role of phonological recoding to any degree, moreover, that there are few investigations of spellings which are totally arbitrary and lack letter-sound correspondences to substantiate the assertion that visual-semantic connections as opposed to visual-phonological connections form the foundation for sight word reading.

Ehri's view is that sight word reading involves the systematic formation of visual-phonological associations between a word's spelling and its pronunciation in memory. Accordingly, for the skilled reader it is word-specific associations as opposed to letter-sound correspondence rules which are used to read words. However, these are not the word-specific associations of dual route theory which emerge as non-visual and non-phonological orthographic units (Frith, 1985). Rather, these word-specific connections are formed through the reader's application of letter-sound knowledge. Consequently, what is formed is a visual-phonological representation that in other words refers to spellings which stand as visual symbols for pronunciations. Accordingly, pronunciations are 'seen' by the reader when the spelling is viewed. In turn, this process produces connections between spellings and meanings. The visual-phonological route therefore means that the reader directly accesses both pronunciations and meanings when reading by this route. Therefore, the type of connection which permits words in memory to be identified is a systematic connection between spellings and pronunciations rather than an arbitrary one between spellings and meanings. Consequently, sight word reading can be thought of as a visual route that is paved with phonological information leading into lexical memory (Ehri, 1992). The reason is that as letter-sound relationships were initially used in phonologically recoding a word, these traces remain and subsequently make a contribution in a reading by memory process. This view clearly differs from the dual route perspective in which it is advocated that up until a certain point readers use phonetic recoding procedures to read words. However, after repeated experiences with a word, specific memory associations are formed and letter-sound translation procedures are no longer required in recognition. Ehri (1992) questions why the phonological correspondences that were initially used in learning the word would suddenly ‘drop out’ of processing when memory processes come to predominate in recognition. Accordingly, she claims that these cues cannot be arbitrary as these are the connecting features for a word’s visual form and its pronunciation in memory. As far as poor readers are concerned, if arrested at the logographic stage, it should be easier for this reader to construct a visual code rather than engage in the more cognitively demanding task of forming auditory-visual associations. In this sense, albeit a slower and more arduous process, a lexicon of visually represented words might nonetheless be established. Similarly, the reader with poor alphabetic skill may give greater emphasis to the formation of visual codes for new reading words than to the development of verbal-visual (phonological) linkages by means of letter-sound applications.

Some poor readers are indeed known to demonstrate greater facility in orthographic processing when compared with their phonological processing skill (Stanovich & Siegel, 1994). In this regard, it seems that a visual approach might be a default outcome of the difficulties the poor reader has had in constructing a phonological representation for new reading words, and in maintaining this representation in working memory while attempting to map it onto a new visual stimulus (Hulme & Mackenzie, 1992). Nevertheless, the poor reader with weak phonological skills is likely to possess visual capabilities that surpass his/her alphabetic skills. Consequently, visual processes may be used as a means to compensate for inefficiencies in applying verbal (i.e., phonological) processes in acquisition and other reading tasks. This supposition is problematical for models such as Frith's, as poor readers, if arrested at the logographic stage should not reach the orthographic stage. In a similar sense, within each of the three stages there will be varying degrees to which the various skills (e.g., logographic, alphabetic, orthographic) are applied. For example, within the second (alphabetic) stage, it appears unlikely that words will necessarily be identified by the application of letter-sound correspondences alone, similarly, that the process by which recognition of words is made by virtue of visually salient features, will otherwise be abandoned. Moreover, it is possible that partial letter-sound applications could be used in conjunction with retrieved prefixes, suffixes, or intrasyllabic units abstracted from already established orthographic forms, (e.g., 'tion' from 'construction' to read 'absorption').

It has been suggested that detailed orthographic representations as a knowledge source, (which are acquired through past experiences), may be retained as stored knowledge and recalled in procedures the same as those used for provided associations (e.g., paired associated learning) (Thompson & Fletcher-Flinn, 1993). This theory not only differs from the dual route model in which phonological mediation and direct access are believed to be functionally independent (Baron, 1977; Coltheart, 1978), but also in the regard that generation procedures include sublexical relations induced by the learner from stored experience of print words. Therefore, pronunciation of a word may involve the integration of phonological and orthographic components common to several print words experienced by the learner (Thompson & Fletcher-Flinn, 1993). In short, recognition of a word can be generated from partial information stemming from specific orthographic information shared with other words, in combination with access to segments of phonology as small as the phoneme (Thompson & Fletcher-Flinn, 1993; Thompson, Cottrell, & Fletcher-Flinn, 1996). This theory may well describe how the level of reading development noted in the subjects of Campbell and Butterworth (1985) and Temple and Marshall (1983) was attained.

Nevertheless, the finding that self-generated responses to new reading words are not solely based on alphabetic mapping seems to be important for two reasons. First, this finding challenges the assertion that unfamiliar words are read only by the reader's application of grapheme-phoneme correspondence rules (Coltheart, 1978; Frith, 1985; Gough & Hillinger, 1980). Second, it suggests that the pronunciation of an unfamiliar word may derive from orthographic representations that have been established as visual memory forms. As a corollary, it also suggests that the qualitative differences that may underlie a reader's application of strategies can differ as a function of overall learning, ability, and instruction.

Ehri's theory similarly, does not differ on the issue of seeing a phonetic analytic system as underlying effective printed word learning, but on when the system can begin to operate and the amount of phonological information that is required. The idea is that in the earliest stages of reading development children begin to establish partial associations between printed letters in words and their corresponding sounds. Importantly, these associations can be based upon names or sounds associated with the letters. Additionally, at this stage consonants and their corresponding sounds play a greater role than those of vowels. In terms of word identification, it is the child's ability to recognise rather than generate the associations between letters and their corresponding sounds which plays a significant role in children's learning to read words. This type of acquisition therefore, clearly differs from the views of Frith (1985) and the dual route model of reading (Coltheart, 1978) in which children systematically ascribe sounds to each individual letter in a word's printed form. Instead, Ehri (1992) proposes that the process by which unfamiliar words are identified need not depend on a child's ability to explicitly assign individual sounds to printed letters in a systematic sequentially-based manner (e.g., cat = /kuh/ah/tuh) followed by blending. Instead the identification of the word can stem from a more or less immediate activation of partial information about the pronunciation gleaned from contained letter sounds or indeed letter *names*. For example, seeing and hearing the word 'jail' may result in the association of the sounds of the word's boundary letters 'j' and 'l', with the word's pronunciation. Similarly, a child who knows only the letter names for 'j' and 'l' might also arrive at the word's pronunciation by virtue of naming these (e.g., 'jay' 'el' = jail). Again, the known associations between consonants and their corresponding sounds or letters are said to be more important than those of vowels. Thus, recognition (in the initial stages of acquisition) may derive from knowing only partial letter-sound correspondences acquired through exposure to letter names. Therefore, as a complete knowledge of letter-sound correspondences has not yet been formed, this stage mainly comprises associations being made by virtue of consonant letters and their constituent sounds to remember spellings (Ehri & Wilce, 1985).

Thus, Ehri's view does not eliminate phonological processes in sight word reading, but does leave out the phonological recoding stage envisaged by Frith as she questions whether children actually apply letter-sound associations to each letter in a word to arrive at its pronunciation. Accordingly, because knowledge of letter-sound correspondences were used to recode the word at the outset it would seem logical that these would be retained and used as part of the reading by memory process. She proposes that poor readers' visual word reading is less well underpinned by phonological information than that of reading age controls.

It appears quite clear that in all accounts phonological skill is necessary for the development of reading skill, i.e., for enabling a child to read unfamiliar words in the early stages of development. Share (1995) believes that this ability functions as a self-teaching mechanism which enables the reader to independently develop a repository of readily accessible orthographic forms. Thus, although a somewhat arduous process at the outset, systematic letter by letter decoding eventually leads to the child being able to identify the word without having to sound it out. In this regard there is no dispute amongst researchers that children learn to read unfamiliar words by applying a letter-sound translation process. However, whether a child will systematically apply letter sound knowledge to each contained character in a word in order to pronounce it is open to some debate; especially in the earliest stages of development when all of the letter-sound associations will not be known.

Possible Causes of Reading Disorders

As a phonological deficit concerns an individual's difficulty in making use of the phonological or 'sound' characteristics as it applies to reading print, researchers have concentrated on which aspects of language processing might best account for failure in reading. This, however, has not been the only type of examination regarding possible causes of reading disorders. Early research viewed visual perceptual deficits as likely candidates for explaining early reading problems. Importantly, the investigation of these factors led researchers to question how verbal processes might be related to the development of skill in reading. Attention is now given to these earlier empirical works which effectively led to the development of the framework within which we now view reading difficulties to be phonologically based.

Visual Perceptual Deficits

For many years, researchers cited visual perceptual deficits (e.g., Orton, 1925) as the specific cause of reading disability. The belief was drawn from clinical observations of letter and word reversals (e.g., b/d, p/q, was/saw) being made by children with reading difficulties. As a result, reversal errors mistakenly became synonymous with the term dyslexia.

Today, many people believe that a child who reads 'was' for 'saw' is necessarily dyslexic. However, importantly it had been noted that reversal errors were also being made by normally developing beginning readers; more noteworthy perhaps, they were made in equal proportion (Holmes & Peper, 1977). Nevertheless, as researchers began to consider that written language comprises visual symbols that were created as a means of recording speech they recognised that reading was not primarily visual in nature, but rather linguistic (i.e., reading is a linguistic function).

The dismissal of the visual perceptual deficit theory largely resulted from a single series of investigations which aimed to evaluate the contention that the poor reader's perceived visual deficiencies were in fact secondary outcomes of difficulties with visual-verbal associative learning (Vellutino, 1979). One of the initial studies conducted by Vellutino et al (1975) used verbal and nonverbal learning tasks to examine the hypothesis that poor and normal readers would not differ on nonverbal measures, but would perform less well on tasks containing both a verbal and a visual component. The tasks comprised geometric designs, English words, and randomised letter and number strings that were shown for brief exposures. In the nonverbal condition the children were asked to reproduce visually presented materials from memory. In the verbal condition, words were to first be pronounced and then spelled letter by letter. Number and letter strings were to be recalled verbally, character by character in sequential order.

As predicted, the groups did not differ in their recall of visually presented items, yet when the children were required to provide a verbal response for presented items, normal readers were at an advantage. A noteworthy finding was that the grade 6 poor readers were more accurate at spelling word stimuli than the normal grade 2 children, even though the poor readers' pronunciation of these stimuli was comparatively much poorer. Thus, although the poor readers appeared to be familiar with orthographic structure (evidenced in their ability to spell words letter by letter), they nonetheless encountered difficulty in pronouncing these words. This suggested facility in forming visual memories for words, while pointing to a deficiency in the ability to verbally code visual stimuli.

Other indications of poor readers' facility in visual processing were noted in an earlier investigation of poor and normal readers' ability to reproduce three, four, and five letter (Hebrew) words which were presented for brief exposures (Vellutino et al., 1973). Neither group had any prior exposure to Hebrew. No group differences were found, which again suggested that poor readers' visual skills are unimpaired for chronological age. However, what was especially interesting was the finding that more reversal errors were made by the normal readers. As these errors were mainly confined to Hebrew letters that closely resembled those of our Roman alphabet, yet in another orientation (e.g., 'э' versus 'є', 'λ' versus 'y'), it was suggested that associations between letter names and their corresponding symbols (e.g., ⊃ = c) were more firmly established for the normal readers. Put another way, although neither group had any prior exposure to Hebrew, it was likely that the normal readers were making use of linguistic codes for visual storage (e.g., ל = gēē), which resulted in a higher proportion of reversal errors being made at the point of being asked to draw these visual forms. Thus, it was seen how similar errors observed in the reading and writing of dyslexic readers were connected to inefficiencies in verbal mediation, and not to visual-spatial confusion. Additionally, if the normal readers' linguistic codes for printed (e.g. alphabetic) stimuli were more intact then underspecified representations might have accounted for fewer reversal errors being made by the poor readers.

Swanson (1984) reported similar findings in an investigation of dyslexic and normal readers' ability to reproduce visually presented angular shaped line drawings from memory. In a second condition these meaningless shapes were assigned arbitrary names. Again, no differences were found in the reproduction of these forms, which suggests that these two groups were similar in their visual-perceptual abilities. However, differences favouring the normal group were found in the naming condition. The results are similarly interpreted to mean that poor readers encounter difficulty when visual stimuli have to be named, or with the integration of visual and verbal codes.

This early experimental work (Vellutino et al., 1973, 1975; Swanson, 1984) proved instrumental in outlining a fundamental aspect of the reading process for which poor readers were not deficient, while changing a century-old view which posited visual processing inefficiencies as the proximal cause of reading failure. Nevertheless, rather than investigate the poor readers' failure to apply verbal codes in reading tasks, it seems that researchers simply viewed deficiencies in reading to be linguistically rather than perceptually-based, and the role of visual and verbal processes in reading largely became areas of inquiry unto themselves. Within the visual processing literature the focus of investigation has included the location of eye fixations and saccades in reading, their duration, and the refinement of neuropsychological models which describe visual processes involved in recognising single written words (e.g., Coltheart, 1981). In the phonological literature investigations of language processing inefficiencies and the phonological deficit have been the main focus of attention. Inquiry into the relationship of visual and verbal processes to reading has been neglected, much to the detriment of our understanding of how children learn to read, and to acquisition models in general.

With a redirected focus on linguistic processing abilities in the 1970's, researchers generally aimed to address the issue of which elements of language were most associated with skilled reading performance, and by extension which skills and processes were most deficient in the poor reader. Generally speaking within this literature, the most commonly investigated verbal processing skills have been phonological awareness, phonological memory, and more recently rate of access for phonological materials stored in long-term memory.

Phonological awareness can be thought of as one's explicit knowledge of the sounds or phonological structures comprising spoken words. Tasks requiring the identification, segmentation, or blending of word segments, and/or individual phonemes commonly measure this awareness. (See Chapter Two).

Phonological memory can be thought of as the codes or representations (i.e., the phonological characteristics of spoken materials) that one uses to maintain or store verbal information (e.g., letters, digits, or words). Span tasks requiring immediate or delayed recall of verbal materials in sequential order are typically used to measure phonological memory function. (See Chapter Four).

Rate of access for phonological materials is generally seen as the speed with which phonological judgements are made, or phonological information retrieved from long-term memory. Tasks, which mark the amount of time taken to name visually presented letters, words or nonwords, are often used to assess this efficiency. (Little recorded investigation appears to have been made of response times for auditory materials.) Rate of access has become increasingly important to the understanding of reading disorders as the speed with which verbal (phonological) representations for letters, word parts, and indeed words can be accessed is seen to be an important indicator of how useful this information will be in word identification (i.e., in decoding) tasks. The reason is that recognition of stimuli that is more or less automatised is viewed as having strong implications for efficiency in decoding and rates of acquisition for new reading words.

Early research conducted by Biemiller (1980) suggested that letter and word naming speed provided important information about the status and probable progress of young children in early stages of their reading development, and more particularly from the end of second grade. This is because independent letter processing is seen as a reliable index of a child's ability to rapidly identify printed materials in the absence of contextual information. Accordingly, letter naming latencies set a limit on how quickly words, and therefore, connected text can be processed. Biemiller found that children could very rarely read words more than .25 seconds faster than they could read letters.

Importantly, Biemiller's data further showed that the most able children (e.g., in the 90th percentile) read individual words out of context in approximately the same or less time than individual letters. Children performing around mid level took .06 to .10 seconds longer to read individual words than they did to read letters. Less able children were shown to take substantially longer to read individual words than letters. Faster reading rates were shown to be strongly associated with the ability to identify difficult words. Overall, the longitudinal data revealed that although letter, word, and simple text reading rates improved with age, children who read letters slowly in the initial testing in grade 3 also read at a slower rate in grade 4.

Some researchers attribute these speed differences to a variety of causes. For example, it is believed that poor readers might have what has been referred to as a storage elaboration deficit resulting from delayed acquisition of initial words (Snyder, 1994). Consequently, lexical entries may not always be complete or well connected within the lexicon. Therefore, phonological representations which are incomplete or underspecified can cause delays in retrieval (e.g., naming) as the child searches the lexicon for a vague entry. Outside of this context, impairments in reading could stem from the poor readers' slowness to apply letter-sound correspondence knowledge. An examination of this ability in speeded recognition tasks (e.g., in nonword reading) could therefore assist explanations of the poor readers' difficulties in reading, even where accuracy has been appropriate for reading age.

Importantly, Biemiller and his colleagues could not identify any practice through which letter naming times could be significantly improved. Story times could however, be improved through a repeated readings or memorisation technique. Nevertheless, these improved rates did not transfer to new texts of similar complexity. Therefore, it can be postulated that naming speed differences in reading age matched comparisons might indicate fundamental differences between these readers and their ability to efficiently access or generate phonological codes stored in long-term memory.

On the surface slower reading rates would seem somewhat unimportant if the child is making progress in reading accuracy, especially when rates are related in terms of milliseconds. However, compounded it means that an individual who reads 1.2 words per second as opposed to 2.4 words per second is reading at half the speed, or in other words takes twice as long to read a given word. The faster reader is therefore able to process twice as much text in the same amount of time. Additionally, this reader will acquire more new words; gain greater knowledge of word meanings through context, while improving overall reading efficiency.

Still, it remains to be seen whether poor readers who present with deficits in accuracy and / or rates of access for phonological materials demonstrate advanced orthographic processing skill relative to their phonological abilities. Stanovich & Siegel (1994) claim that stronger orthographic ability could suggest that the poor readers' word recognition performance might be a consequence of compensatory processing, i.e., visual processes may be compensating for inefficiencies in phonological coding. Certainly, some developmental models of reading (Frith, 1985) are suggestive of the possibility that the arrest of a particular process involved in identification could produce a processing bias. However, indication as such is largely limited to the performance of adult readers, and neuropsychological models of word reading. Accordingly, there is little account of the poor readers' default mechanisms or compensatory strategies resulting from inefficient phonological skill. Similarly, what is not addressed in many current theories is the organisation of the visual code in regards to both auditory and semantic codes in acquisition (Ellis, 1981; Perfetti, 1985). The current series of investigations sought to establish whether difficulties in the integration of visual and verbal codes could be discerned in poor readers and accounted for in terms of deficient phonological skill, a slowness to generate phonological information from print, or from the application of qualitatively different coding strategies.

Thesis Aims

The aim of this thesis therefore, was to examine poor readers' patterns of reading performance in relation to their overall skill in phonological processing tasks. Accordingly, the primary interest was in evaluating the equivocal evidence for a phonological deficit and attempting to outline specific aspects of phonological processing that appear problematic for the poor reader. This was approached through the application of a phonological test battery tapping skill at various levels (e.g., discrimination, syllable, onset-rime and phoneme segmentation, phoneme deletion, word and nonword repetition tasks). An examination of the poor readers' application of phonemic awareness to print was assessed in letter-sound awareness and nonword reading tasks.

The second interest of this thesis concerned the question of whether the poor readers' performance on reading and memory tasks could be regarded as being atypical for reading age, therefore, suggesting that their levels of attainment in reading have been acquired by virtue of qualitatively different processing / reading strategies. Thus, the thesis aimed to examine the degree to which deficits in phonological processing might result in the application of different coding strategies in print acquisition, phonemic processing and reading related (e.g., memory) tasks. These types of differences were primarily sought in reading tasks (e.g., regular versus irregular word reading), but were also examined in the context of phonological (auditory rhyme) and memory (pictorial, auditory, printed word) tasks.

Lastly, irrespective of the degree to which poor readers might be seen as having a fundamental phonological impairment, the thesis further aimed to examine the poor readers' speed of processing of phonological materials. Efficiency in this regard was reviewed in both reading (e.g., nonword, regularity, letter name/sound awareness) and non-reading (e.g., auditory phonological) tasks, the purpose of which was to consider how these differences might further account for lag in reading development, differing strategy use, and resulting atypical performances in reading age matched comparisons.

CHAPTER TWO: PHONOLOGICAL AWARENESS

EXAMINATION OF DEFICITS UNDERLYING CHILDREN'S READING DIFFICULTIES

Mention was made in the introductory chapter about how early phonological awareness is viewed to be critical to the development of word reading skill. This was echoed in the account of emerging interests in linguistic processes in reading as well as in the reviews of developmental word acquisition theories in which the importance of 'cracking' the alphabetic code was stressed. The necessity for this type of ability is the result of early research into phonological awareness and literacy development, which suggested that distinctions could be made between an individual's ability to identify syllables and phonemes in tapping tasks (Liberman, Shankweiler, Fischer, & Carter, 1974) and that this awareness might be linked to reading (Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977).

These types of investigations led to the suggestion that reading skill was closely associated with the ability to hear the sounds in spoken words, and to be able to segment these. Early phonological awareness can be thought of as a child's ability to segment a *spoken* word, such as butterfly into its three respective components or syllables, e.g., /but/ /er/ /fly/. However, the ability to separate spoken words into single speech segments (known as phonemes) is believed to emerge at a later stage. Thus, when a child is able to identify that the word 'cat' comprises the sounds /kuh/ /ah/

/tuh/, the child is said to possess phonemic awareness.

The ability to identify individual sounds in spoken words is believed to be an important pre-reading skill. The reason is that when a child experiences words in print it is necessary to recognise that these visual symbols represent sounds. Indeed, there is a great deal of support for the link between the awareness of speech segments and literacy skills (Bradley & Bryant, 1978; Jorm & Share, 1983; Lundberg, Olofsson, & Wall, 1980). Moreover, many researchers have suggested that reading development is a product of receiving training or developing awareness in phonemic processing (Bradley & Bryant, 1983; Lundberg et al., 1988; Olofsson & Lundberg, 1985; Vellutino & Scanlon, 1987). However, it is also known that as reading skills develop, so too does one's awareness of the structures of spoken language. Thus, within the literature there has been some debate as to what is consequence and what is cause in these regards. A number of studies have therefore been carried out in an effort to examine the effects of phonological awareness training in pre-readers.

In a longitudinal investigation of children's early phonemic awareness and later reading development, Bradley and Bryant (1983) concluded that phonological awareness training improves subsequent reading skill. In their study, children with poor phonemic awareness skills received sound categorisation training in one of two conditions. One training condition made use of printed letters and the other condition did not. Gains in reading were only made by the group that received letter-sound association training, whereas sound categorisation training alone did not advance the latter group's reading skills. However, as phonemic awareness training alone did not boost reading skill, the results could also mean that the 'training with letters' group were able to establish connections between the presented letters and their corresponding sounds; i.e., in effect, through learning to read.

Foorman and Liberman (1989) suggest that phonological awareness promotes beginning reading development only where sounds are represented orthographically. Thus, the attachment of phonological knowledge to a word's printed form is what assists reading development. Consequently, difficulties in reading have been attributed to inadequate bootstrapping of phonological awareness on orthographic awareness (Foorman & Liberman, 1989). This view is supported by other researchers who view this relationship to be a reciprocal one as opposed to being uni-directional (Ellis, 1990; Stanovich, 1986; Stuart & Coltheart, 1988).

Thus, although there is evidence to suggest that phonemic awareness and reading ability are indeed related, the exact nature of the processes involved in this relationship, and the direction of causality has been questioned. One study conducted by Lundberg et al. (1980) initially offered promise in these regards. Their examination of the ability to segment and transfer phonemes in spoken words was found to be the best predictor of later reading achievement in kindergarten aged children. However, it was later discovered that many of the children were to some degree already reading at the point of initially being tested. Consequently, it is difficult to gauge the degree to which phonemic awareness skills were contributing to the children's later reading performance. Fox and Routh (1980) similarly noted that 6-7 year old normally progressing children and children with a 'mild' reading impairment were able to carry out syllable segmentation tasks, whereas severely impaired readers were not. Again, on the surface it is possible that the poor readers' lack of phonemic awareness was contributing to their reading failure. However, it is also difficult to determine whether segmentation skill was better in the normal and mildly impaired reader groups as a result of having greater exposure to print and reading than the severely impaired reader group.

Beech (1985) suggests that although segmentation ability and reading skill are shown to correlate this does not mean that poor segmentation ability is contributing to a failure in reading. Indeed as would appear to be the case in the Bradley and Bryant (1983), and Fox and Routh (1980) studies, the act of learning to read may improve an individual's awareness that words comprise sound segments represented by written forms. As such, a child with good segmentation skill is also good at reading (Beech, 1985).

It is along these lines that the work of Bertelson (1987), Morais, Carey, Alegria, and Bertelson (1979), and others (e.g., Foorman & Liberman, 1989) suggests that phonemic awareness is evident only in individuals who have learnt to read an alphabetic script, and not as some researchers maintain, a product of cognitive maturation. Thus, it is through the experience of establishing connections between print and its corresponding sounds that phonological awareness develops. The most supportive evidence in this regard is found in Morais et al's (1979) study of illiterate and semi-literate adults.

The Morais et al. (1979) study aimed to establish whether awareness of phonemic structure arises spontaneously (i.e., as a natural outcome of cognitive maturation) or whether it requires some specific training. In other words, the question was asked how an explicit knowledge of the phonemic structure of speech is acquired. As mentioned, many studies in which this question has been addressed had included children with some reading skill. Therefore, it may be no coincidence that the age at which the greatest increase in segmentation ability occurs is when formal reading instruction typically begins (e.g., between the ages of 5 and 6). The approach taken by Morais et al. (1979) was to consider how adults with no reading ability would perform on tasks requiring conscious phonetic analysis. The expectation was that these 'illiterate' adults should be unable to perform such tasks if the improvement noted in children is an outcome of early reading instruction. Conversely, it was reasoned that if such awareness is independent of learning to read and instead reflects a more general growth in cognitive development then the adults would be successful at these tasks.

A deletion task (in which subjects deleted the first phoneme from an utterance) and an addition task (in which subjects added a phoneme to the beginning of an utterance) were administered to 30 illiterate adults and 30 adults who had learnt to read beyond the usual age. Within the illiterate group 20 had never received any instruction at all, four had been taught letter names by their children, and six had been in school for 1 – 6 months in childhood. The 'reading' group comprised subjects who had attended government-training classes for illiterates at age 15 or older. (Twenty-two of these subjects were successful in obtaining a certificate through this programme whereas the remaining 8 were unsuccessful.) Half of the participants in each group worked with one of the two tasks. Within each task, five participants worked with one of three phonemes (p, f, and m), therein representing three different consonants (plosives, fricatives, and nasals). In the introductory trials these utterances were nonwords which became words by adding or deleting the phoneme assigned to participants, e.g., 'alhaco' became 'palhaco' (clown), and 'purso' became 'urso' (bear). The experimental trials consisted of two types: word trials in which the utterance became another word with deletion, e.g., 'chuva' (rain) became 'uva' (grape), and vice-versa with addition; and nonword trials in which the nonword utterance became another nonword 'osa' – 'posa', 'chosa' or 'mosa' depending on the phoneme condition.

The results of the Morais et al. (1979) study provided striking evidence in support of the argument that an explicit knowledge of the phonemic structure of speech does not arise spontaneously as part of cognitive maturation, but instead comes from the act of learning to read. The results showed that the greatest errors were made on nonword trials in which 50% of the illiterate subjects failed all of these, whereas no reading subject did. Only one illiterate subject gave more than 8 of 10 correct responses for nonword trials, whereas more than 50% of reading subjects matched this performance. Equally striking is that within the reading subjects group, those who were unsuccessful in gaining a certificate performed at 55% on nonword trials, whereas those who received their certificate performed with 79% accuracy. Although marginally non-significant, within the illiterate group, subjects who had some letter knowledge or had attended school for a brief period in childhood performed slightly better (30%) than the others who had no prior instruction (13%).

Error analysis lent further support for the argument that reading ability has an influential effect on performance in phonemic awareness tasks. Again on nonword trials 19% of the illiterate subjects' responses included accurate deletion / addition of the target phoneme, compared with 56% in the 'reading' subjects group. The authors make the point that the illiterate subjects' performance was slightly poorer than 6 year-old Belgian children who were tested on similar tasks in the third month of their first year of schooling. In contrast, the reading subjects' performance was similar to 7 year-old children in second grade tested in the fourth month of their school year. The findings therefore suggest that awareness of speech as a sequence of phones (speech sounds) is brought about through the act of learning to read (Morais et al., 1979). Importantly, for the purposes of the current investigation the results could also suggest that the development of orthographic codes permits an individual's use of a word's printed form in such a way that phonological judgments and manipulations can be made, a proposition that has received little attention.

Thus, as we have seen, a great deal of effort has been made in the attempt to discern the direction of causality between early phonemic awareness skill and reading development. The issue is an important one as the suggestion that phonemic awareness is causally related to reading has had clear implications for how instructional theory and practice has been viewed. This is why children with reading difficulties typically receive increased tuition in phonemic awareness and phonics-based reading strategies. Thus, the issue of whether pre-readers or poor readers will benefit from training in sound categorisation, rhyming, and/or segmentation tasks carries implications for knowing whether these skills should be taught, and if so in what manner.

Nevertheless, empirically speaking the task of locating individuals whose levels of literacy are limited to spoken language alone seems an almost implausible undertaking. Children who are too young to have developed any awareness of print-sound associations are clearly also unable to carry out the types of tasks necessary to assess this awareness. By extension, there is the question of whether it would be deemed appropriate to restrict a child's exposure to print at such an early, and clearly critical, stage of their literacy development. Opposition to such a proposal would therefore seem sufficient enough to suggest that evidence in these regards is not clearly defined. Therefore, the evidence appears to be inconclusive in terms of determining which is consequence and which is cause when it comes to studying this relationship. Moreover, it is generally accepted that phonemic awareness and reading development are inextricably linked (Stanovich, 1986). Therefore, as children begin to realise that printed symbols are associated with sounds, the two processes mutually interact to establish a working relationship through which knowledge from either process contributes to new learning (Share, 1995; Stanovich, 1986). Consequently, phonemic awareness training is recognised for its contributions to reading skill in the same sense that development of reading skill is viewed to facilitate understanding of phonemic constructs.

Thus, it appears that in order to address the issue of causality in investigations of phonemic awareness and reading, one must find a training study in which alphabetic stimuli have not been used, in combination with having a sample of children who do not possess *any* reading skill. It seems that only then can the contributions made by pre-literate phonological awareness and subsequent reading development be truly tested and understood. However, for now it would appear that the issue of whether phonemic awareness is a cause or a consequence of learning to read remains a matter of contention.

The Reading Age Match Design

One development in experimental design which has enabled the direction of causality to be more closely considered is that of the reading age match (or reading level) design. The central question behind the reading age match design is whether poor readers' skills are slower to develop, or are developing in a different way. To explore this delay versus deficit issue, the poor readers are compared with younger normal readers who have the same level of attainment in reading. Therefore, as the two groups have been matched for reading ability, then they are generally seen to be equated in terms of their reading skills and overall experience with print. Accordingly, any emerging differences are viewed to be of etiological value. The reason is that as the two groups are reading at the same level, lowered performance on a given measure is taken to mean that this factor, or the skills which underlie it are contributing to the reading failure. For example, a difficulty in phoneme identification would imply that there is a phonological cause to the disorder, or some difficulty with the processes requisite for carrying out the task successfully. Importantly, if poor readers are deficient in tasks tapping phonological skill, it is generally viewed that that their levels of reading attainment have been acquired via routes outwith the phonological domain (e.g., a more visual or orthographic approach to reading than that of controls). Conversely, equal performances would indicate that the difficulties are a result of developmental lag (i.e., the poor readers skills are simply taking longer to mature) (Beech & Harding, 1984). The reading age match design therefore permits an understanding of whether the poor readers' patterns of reading performance are developmentally similar to the controls, or whether these are atypical for reading age.

Nevertheless, although the reading age match design has been a welcome addition to experimental undertakings, this has not been without criticism. For example, it has been said that many studies employing the design have not produced consistent results where efforts have been made to identify the direction of causality in phonological analysis, verbal working memory, and word decoding skill (Bowey, Cain, & Ryan, 1992). In a similar sense researchers often report a phonological impairment, whereas poor performance on some tasks may result from the poor readers' difficulty with a cognitive component of the task itself, (i.e., in stimulus comparison, memory processes, output requirements, etc.) (Stanovich et al., 1984).

Task differences may therefore account for the variability across different reading age matched comparisons. A second possibility involves the criteria by which children have been selected for study. Thus, as reading disabled children are known to differ from one another, different group results may stem from subtle differences in sampling procedures (Treiman & Hirsh-Pasek, 1985). Finally, one additional criticism is that by its very nature the reading age match design automatically accords the poor readers a developmental (e.g., chronological) advantage over their controls (Snowling, 1980). Thus, the question is posed whether the two groups can truly be said to be equated in terms of their reading experiences, and more importantly in terms of their cognitive development and resulting abilities (e.g., visual skills, articulatory programmes, etc.). Nevertheless, in comparison to earlier conventional approaches the act of matching children on reading ability does restrict the degree to which deficits might be connected to differences in reading experience (e.g., in chronological age matched comparisons). As a result the reading age match design remains a central feature in investigations of developmental reading disability.

Many different tasks have been applied in the examination of phonological awareness in pre-readers as well as in poor readers who have been matched to their controls for reading ability. The 'odd word out' task (Bradley & Bryant, 1978), in which the child is required to choose the odd member from a list of spoken words (e.g., lot, cot, hat, pot), is one such example. Bradley and Bryant (1978) found that although equated for reading age, the poor readers (who on average were three years older than controls) performed worse on this task, as well as on others marking phonemic processing skill. Given that the two groups had been matched for reading ability, the issue of determining the direction of causation should not be so problematical. Again, this is because unequal performances cannot be said to be due to differences in levels of reading attainment. Accordingly, the poor readers' performances in the Bradley and Bryant (1978) study should be taken as indication that phonological difficulties are contributing to the poor readers' failure in reading.

However, Beech and Harding (1984) failed to replicate these results in a similar study in which poor readers were also matched for reading age, yet showed the same levels of skill as their controls in rhyme oddity, phoneme segmentation, rhyme production, and rhyme recognition tasks. In line with the suggestions of Stanovich et al. (1984), the poor readers' difficulty with the odd word out task could reside in any number of factors associated either with the task itself (e.g., processing of instructions), or the skills which underlie it. Thus, performance differences in the odd word out task could stem from the cognitive demands associated with retaining four words in memory while performing same sound judgments (e.g., stimulus comparison). In a similar sense, difficulties could result from problems with encoding, verbal rehearsal, or output processes. To summarise, difficulties with replication studies might arise because of different sampling procedures, or from the use of different phonological tasks which subtly differ in their complexity, the level of phonological awareness required, or in the cognitive requirements underpinning these. It is therefore, not surprising that other investigations using rhyme oddity and other phonological tasks have also failed to find differences for reading age (Duncan & Johnston, 1999; Johnston, Anderson, Perret, & Holligan, 1990; Snowling, Defty, & Goulandris, 1996).

In the investigation conducted by Duncan and Johnston (1999), the poor readers performed as well as controls in rhyme oddity and auditory rhyme judgment, but were impaired for reading age in a phoneme deletion task. Conversely, other studies have found poor readers to be impaired on measures of rhyme oddity for reading age (e.g., Bowey et al., 1992; Bradley & Bryant, 1978). Bowey et al's (1992) poor readers showed deficits for reading age in onset-rime, and phoneme oddity tasks, and also performed poorly in nonword naming. Thus, although the reading age match design should assist in the identification of skills that directly contribute to reading failure, this examination has yielded inconsistent results. This aside, it is generally held that tasks requiring awareness of larger phonological segments (e.g., odd word out) may not be as sensitive as those involving manipulation at the phoneme level (Bruck & Treiman, 1990). The consensus amongst researchers is that the highest level of awareness resides in a child's ability to manipulate the phonemic structure of words, for example in being able to add, delete, or shift a phoneme to create a new word or nonword (Adams, 1990; Yopp, 1988). Within this experimental genre, phoneme deletion appears to be the task that is most commonly applied.

In this task children are required to delete initial or final phonemes from spoken word forms, and pronounce the embedded form that remains. For example the child would be asked to say the word flat, prior to being asked, "what would be left if we took away the /fuh/ sound"? Again, a number of studies have found poor readers to be deficient for reading age (Bowey et al., 1992; Bradley & Bryant, 1983), whereas others have not (Beech & Harding, 1984; Johnston et al., 1990). Thus, as with the rhyme oddity studies, there is no consistent picture of phoneme deletion deficits for reading age.

Despite the equivocal findings, it is generally viewed that inefficiency in applying phonological information to print is regarded to be an outcome of impairment in either the processing of language, or in the attachment of sounds to printed stimuli (i.e., in the integration of visual and verbal codes). Accordingly, difficulties in making phonological judgments (e.g., odd word out), or in being able to segment sounds (e.g., phoneme deletion) are believed to be principal causes of word recognition problems (Manis et al., 1993; Rack, Snowling, & Olson, 1992). Thus, the conclusion that poor readers make little, or inefficient, use of phonological information in memory and reading tasks is seen within the context of a fundamental phonemic awareness deficit, which by extension manifests in a phonological dysfunction in recognising single written words in reading (Frith, 1985).

So far discussions of the size of units at which children read has focused on the grapheme-phoneme level and the whole word level. However, it is suggested that this may not be the only way in which words can be read. In recent years there has been interest in onsets and rimes as units of print recognition in children and adults. Some experimental work has indeed suggested that orthographic onsets and rimes may function as units of print for adults (e.g., Bowey, 1990; Treiman, Goswami, & Bruck, 1990; Treiman & Zukowski, 1988). However, in terms of the beginning or less skilled reader the evidence is less clear-cut.

Thus, although linguists may acknowledge a hierarchical language structure that comprises syllables, and subsyllabic constructs of onset and rime, which can further be segmented into phonemes, there has been less consensus regarding this hierarchy and its relationship to reading. It has therefore been asked which type of phonological awareness is most important to reading development, and additionally what is the nature of the pathway between phonological awareness and reading (Treiman, 1992; Duncan, Seymour, & Hill, 1997; Seymour, Duncan, & Bolik, 1999). Nevertheless, although not a feature of this particular investigation, the issue is clearly an important one as such distinctions are necessary for defining both educational theory and practice. The two viewpoints are therefore given some consideration here.

In terms of the adult reader it is assumed that subsyllabic units may serve in the identification of words for which partial orthographic forms are already formed in the lexicon (e.g. tion in mo / tion, atten / tion etc). However, in terms of the younger developing reader it is difficult to say whether recognition will involve these constructs to the same extent, if at all. On the one hand, phonemic awareness is generally viewed to be necessary for the efficient learning of letter-sound relationships, which are then applied in the reading of unfamiliar words (Coltheart, 1978; Share, 1995). As such, this ability is said to act as a self-teaching mechanism which enables the reader to establish a repertoire of readily accessible word forms in the visual (e.g., orthographic) lexicon (Share, 1995). Accordingly, in the early stages of reading it is vital that children develop the ability to recognise the relationships between printed letters and their corresponding sounds (Ehri, 1992; Jorm & Share, 1983; Share, 1995). Otherwise, a phonemic awareness deficit would result in a difficulty in developing adequately formed associations between printed letters and spellings and their corresponding sounds in pronunciations requisite for the identification of unfamiliar or novel word forms (Ehri, 1992). In this way, reading development can be seen as a bottom up process in which children master the associations between printed letters and corresponding sounds, working towards the recognition of larger print forms.

This assertion has been tested and there appears to be growing evidence favouring a course of development in which larger (rhyming) units become more important at later stages of development when orthographic representations are more fully formed. This view therefore stands in sharp contrast to a large unit theory, which maintains that children's phonological awareness is restricted to onsets and rimes in the earliest stages of literacy, and that analogies in reading are made between words that share these common units (e.g., 'g-*oat*' – 'b-*oat*'). Thus, the idea is that children will demonstrate a natural tendency to make use of rhyming skills (already in place from their pre-reading stage) when beginning to read. However, although there does not appear to be disagreement concerning the salience of onset and rime as units of phonology in the pre-reading stage, small unit theorists suggest that first encounters with letters produces a sensitivity towards phonology at the level of the phoneme, similarly, that children are more likely to use grapheme-phoneme correspondences to read new words rather than rime-based lexical analogies.

Duncan et al. (1997) reviewed the development of two groups of nursery school children through to the end of their second year of schooling to examine the effects of rhyme awareness training on subsequent reading ability. Children in Group A received a programme aimed at developing rhyme awareness. This included songs and games thought to be appropriate for enhancing this awareness. At the close of the nursery year the two groups of children were tested on receptive vocabulary, letter-sound knowledge, phonological skill (rhyme production and onset-rime oddity detection), and sound blending / segmentation. Although the two groups were matched in terms of their vocabulary, letter-sound knowledge, onset oddity detection and blending skill, Group A performed better on rhyme production and rime oddity detection. According to large unit theory this group would be expected to make greater gains in reading once formal schooling begins.

Seven months into the first year of schooling the children were given sets of nonwords to read. Some of the nonwords contained rime units from the children's reading schemes (since these would be familiar to the children, and would similarly be assimilated with the skills that these children had acquired), whereas other nonwords were not related by rime to any of the words that the children knew. The results showed that there was no advantage for the nonwords that contained the same rime segments from the words used in class. Additionally, levels of attainment in reading were related to letter-sound knowledge and not to pre-school rhyming ability.

At ten months into this same school year the children were given a second task in which they were presented with familiar words from their reading programme, and asked to mark the letters that represented a sound spoken by the experimenter. The sounds that were presented included both large (bodies / rimes) and small units (onsets, peaks, or codas). Again the results proved inconsistent with large unit theory as children from both groups were significantly better at identifying smaller segments than larger rime segments in familiar words. The authors raise the point that these children were learning by a mixed method which included the introduction of a set vocabulary taught in conjunction with the letters of the alphabet, the corresponding sounds and some basic decoding skills. Consequently, the children's awareness in these tasks might be influenced by their reading strategies.

Nevertheless, the view held by small unit theorists (e.g., Ehri, 1992; Seymour et al., 1999) suggests that development begins at the phoneme level (i.e., with small units), followed by an understanding of how these are associated with printed letters, culminating in an awareness of larger structures (e.g., onsets, rimes, syllables), which might then be used as an orthographic system is formed. The large unit theory also acknowledges a general pathway in which phonological awareness permits letter-sound relationships to be recognised, in turn assisting the ability to both read and spell phonetically regular words (e.g., cat). However, it differs by asking whether or not this is the only way in which words can be read (Goswami & Bryant, 1992). The contention is that although a letter-sound pathway is an essential element in learning to read it might not be the only connection.

Large unit theory suggests that development in reading begins with larger sound structures such as rimes (e.g., *oat* in '*coat*' and '*goat*') and progresses towards efficiency with smaller units or phonemes. The contention appears in part to be based on observations of young children's ability to carry out rhyme and alliteration tasks with little difficulty, whereas other tests (e.g., involving phonemes) are more difficult (Bradley & Bryant, 1983; Kirtley, Bryant, Maclean, & Bradley, 1989). The theory follows that a child's realisation that '*mat*', '*hat*', '*bat*' and '*cat*' rhyme will result in the establishment of categories. Once the child learns about spelling patterns then orthographic categories will be formed. As these words also share a common sound then the common orthographic pattern will map onto the already formed rhyme categories. These can then be used to identify printed words with shared orthographies. However, with respect to the emerging evidence discussed in the above, it would appear that knowledge of rime structures develops more slowly than that of phoneme-grapheme correspondence rules. Consequently, it is letter-sound knowledge that children will apply in the earliest stages of learning to read. Nevertheless, within a large unit framework, it would seem that if poor readers have phonemic awareness and onset-rime skills appropriate for reading age, then this would suggest that they have not been held back in their reading by problems at the phonemic rather than onset-rime level of phonological analysis as the former skill as it applies to reading is said to emerge first.

Swan and Goswami (1997) examined the nature of this pathway in poor and normal readers, in an investigation of their phonological skill at the three linguistic levels of syllable, onset-rime and phoneme. Although the aim of the study was to examine the extent to which poor readers' difficulties in phonological processing tasks are the result of incomplete or underspecified phonological representations in the mental lexicon, the authors state that the organisation of phonological representations follows the same developmental pattern as the emergence of phonological awareness skills, i.e., from the level of the syllable, to the intrasyllablic levels of onset and rime, to the phoneme level. Accordingly, tasks requiring syllabic or onset-rime awareness are typically easier for beginning readers than tasks involving phonemes (Swan & Goswami, 1997). The theory further suggests that developmental changes in explicit segmentation ability may indicate that changes in the structure of a child's underlying phonological representations have taken place.

In the study, children were first required to demonstrate (in a picture naming task) that the representations for stimuli on which they were subsequently tested were fully specified. This served the purpose of being able to establish whether or not the poor readers' difficulties could be seen in terms of having poorly established phonological representations, rather than a phonological deficit per se. Prior to the adjustment for proficiency in picture naming, the dyslexic readers showed impairments at all three linguistic levels. However, the examination of performances that were based on proficient picture naming showed no differences at the levels of syllable, onset, and rime. Their performance was nonetheless impaired (in comparison to both chronological and reading age controls) on the segmentation of words at the phoneme level. It was therefore concluded that phonological awareness deficits stem from the encoding and/or retrieval of the phonological representations of words.

However, although technically matched for reading age in a statistical sense, the dyslexic readers in the Swan and Goswami (1997) study had reading ages that were 4.7 months below that of the reading controls. Therefore, it is difficult to ascertain the degree to which these differences in performance are the result of different levels in reading attainment. This is especially troubling since the theory on which the study was based suggests that children at different stages of reading development will inadvertently differ in the degree to which awareness can be demonstrated at various linguistic levels.

Summary of Phonemic Processing Awareness and the Relationship to Skill in Reading

Although a simplification, it seems that phonemic awareness is generally viewed as the driving force behind developing the ability to read nonwords, and in the final analysis the vehicle to skilled reading performance (e.g., phonemic awareness => nonword reading => skilled reading). Conversely, a phonemic awareness deficit would therefore be seen as resulting in a nonword reading deficit, which similarly translates to impaired word reading (e.g., impaired phonemic awareness => impaired nonword reading => impaired word reading). To summarise, the phonological deficit hypothesis is supported by findings which suggest that: A) preschool phonological awareness skills significantly predict later reading ability; B) poor readers have been found to have phonological and phonemic awareness problems for reading age; C) poor readers are often found to be deficient at taking a phonological approach to reading, i.e., they are poor at reading nonwords for reading age.

In the first instance, it is along these lines that poor readers are perceived to have impaired phonological abilities prior to learning to read. Still, it seems that phonemic awareness is a skill which develops through learning to read. Morais et al's (1979) classic study showed that illiterate adults only develop the ability to manipulate phonemes after learning to read. These points aside, it appears that researchers generally accept that difficulties in carrying out phonological tasks (e.g., detecting differences between groups of spoken words as in odd word out or in deleting individual sound segments) are believed to lead to phonemic awareness difficulties; for example saying that the sounds 'c-a-t' comprise the word cat, as well as making use of phonological information in reading tasks, as evidenced in a difficulty in reading nonwords. The poor reader, therefore, would be expected to experience difficulty in pronouncing unfamiliar words, and consequently fail to establish a lexicon of recognisable, rapidly accessible words. For many researchers then, the phonological or phonemic awareness deficit is seen as primary, and the nonword naming deficit is seen as a product of this primary underlying phonological disorder. However, as has been discussed, not all studies show poor readers to have problems in reading nonwords for reading age. Similarly, the same can be said for the poor readers' performance in phonological and phonemic awareness tasks.

Study 1

Many studies carried out over recent years have suggested that children who present with significant delays in reading also demonstrate weaknesses in phoneme discrimination and identification tasks. However, the evidence for the phonological deficit hypothesis is somewhat equivocal, with some studies showing no retardation for reading age. In order to further investigate the relationship between developmental reading disorders and phonological awareness skill, a variety of phonological discrimination, segmentation, and speech production tasks were administered to 30 poor readers and 30 reading age (RA) controls.

The study's aim was to examine the poor readers' phonological skills at the levels of input, in segmentation ability, and output. Input phonology was measured by an auditory discrimination task. Segmentation processing skill was assessed at three linguistic levels (syllable, onset-rime, and phoneme), and by a measure of phoneme deletion. Measures of output phonology comprised the repetition of both word and nonword stimuli. Reading tasks were also included to gauge the poor readers' ability to apply phonological information to print. These included a measure of letter name / letter sound awareness and a speeded nonword reading task.

It was predicted that difficulties in auditory discrimination would impact on all aspects of the phonological processing system and therefore deficits would be seen on the majority of the phonological segmentation measures. Difficulties with the segmentation tasks were expected to result in problems with output phonology (e.g., in word and nonword repetition). Children without repetition (i.e., output) problems were expected to show few if any difficulties with the segmentation tasks as it is generally held that nonword repetition requires accurate perception, in addition to segmentation and blending skill prior to articulation. As a corollary, if children's phonological skill does in fact progress from an awareness of larger to smaller speech segments (Swan & Goswami, 1997) then performance on the segmentation tasks should be better at the level of syllable, than at the levels of onset, rime, and phoneme respectively.

Of course, difficulties with the phonological measures were expected to result in problems with the reading tasks. Letter sound knowledge was used to examine if poor readers' difficulties can be traced to lack of knowledge of grapheme to phoneme correspondences. A speeded nonword reading task was used to examine whether the poor readers would fail to apply phonological knowledge to print, and/or might be slower in this application. The Children's Test of Embedded Figures (Witkin, Oltman, Raskin, & Karp, 1971) was used to see how the poor readers' visual skills compared to the younger control children (e.g., if these skills were superior for reading age).

Study 1

Method

Participants

Sixty children in total were studied. Thirty of these children were identified as having specific reading disability, and were attending a reading unit for intensive remedial tuition twice weekly for half-day periods. Children had been selected to attend the unit on the basis of IQ's of 90 and above. Participation in the study required that each poor reader had a reading age that was at least 2 years behind his/her chronological age. The reading age control children were required to have reading ages appropriate for chronological age. The two ability groups were matched on the British Abilities Scale (BAS) test of word reading (Elliott, Murray, & Pearson, 1977), and the WISC-R (Maxwell, 1959) four-test short form (block design, vocabulary, similarities, object assembly), prorated by the method presented by Sattler (1982). Spelling ability for all children was assessed by the Schonell B (1952) test of spelling ability. All of the children received systematic tuition in phonics, which is important to note since such instruction has been known to influence phonological processing and nonword reading skill (Johnston & Thompson 1989). The characteristics of these groups are presented in Table 1.

Table 1

Participant characteristics

		CA	RA	SA	IQ	V.IQ	P.IQ	EF-test
Poor	M	11.07	7.68	7.63	108.3	107.2	107.91	73.47
	SD	(.599)	(.658)	(.710)	(11.16)	(10.10)	(15.01)	(15.81)
Normal	M	7.46	7.68	7.48	111.8	110.53	109.04	59.60
	SD	(.477)	(.641)	(.733)	(13.94)	(16.09)	(13.07)	(17.01)

Note: M Mean, SD (Standard Deviation), CA = chronological age, RA = reading age, SA = spelling age, V.IQ = verbal IQ, P.IQ = performance IQ, EF-Test = Embedded Figures test.

One-way ANOVA's showed that the two groups (Poor vs RA controls) did not differ for reading age [F(1, 58) = .000, p> .10], or for IQ [F(1, 58) = 1.18, p> .10]. A one-way ANOVA comparing groups (Poor vs RA controls) on The Children's Test of Embedded Figures showed that the poor readers were significantly better than controls at detecting embedded shapes within coloured pictures of varying complexity [F(1, 59) = 10.69, p< .05].

Digit and Auditory Word Span

The WISC-R digit span subtest, in addition to an auditory word span task for one syllable words were used to examine whether the poor readers had memory spans that were appropriate for reading age. The raw score performances for these measures are shown in Table 2.

Table 2

Raw scores on WISC-R digit span, and auditory word span task

Group		Digit	Word
Poor	M	9.13	4.30
	SD	(2.47)	(.651)
Normal	M	9.10	4.37
	SD	(1.94)	(.718)

Note. M Mean, SD (Standard Deviation).

A one-way ANOVA comparing groups (Poor vs RA controls) was carried out on the digit span scores. The two groups did not differ on this task [F(1, 59) = .003, p> .10]. A one-way ANOVA comparing groups (Poor vs RA controls) likewise showed no differences for auditory word span [F(1, 59) = .142, p> .10].

Importantly, although the poor readers did not differ from reading age controls in terms of the total number of digits recalled, it should be noted that when the scores are adjusted (i.e., converted to scaled scores) to account for differences in chronological age, the controls are at an advantage. The digit span scaled scores for normal and poor readers were 10.5 (SD 2.05), and 7.17 (SD 2.55), respectively. This whole notion of using adjusted scores to permit matching of different aged samples is somewhat problematical. This is because the younger child need only attain a fraction of the older poor reader's total raw score in order to become equated in ability or intelligence.

For example, on the block design subtest of the WISC-R, the poor readers' raw score of 35.67 (SD 11.16) produces a scaled score of 11.7 (SD 2.90), whereas the reading age controls' raw score of 20.93 (SD 10.09) produces a scaled score of 12.6 (SD 2.91). Therefore, it can be seen from viewing raw scores on the intelligence subtests that the poor readers are at a developmental advantage (see Table 3). However, the two groups are equated for reading ability and actual memory performance as participants have not been matched by means of adjusted scores. In contrast the children's test of embedded figures does not translate raw score performances to scaled scores, but instead provides normative data against which a child's visual skills can be compared to others of the same chronological age. In this sense it can be seen that the poor readers visual skills are far superior to that of the RA controls, (however, for both groups at a normal level for their chronological age). Thus, if one also takes into account the raw score performances on the WISC subtests, it can be seen how the poor readers verbal and visual skills are more advanced, as their scaled scores place them in a normal range for chronological age.

Table 3

Raw score (RS) and scaled-score (SS) equivalents for WISC-R subtests (vocabulary, similarities, block design, object assembly)

Group		Vocabulary	Similarities	Block Design	Object Assembly
Poor	RS	32.77 (6.37)	17.70 (3.00)	35.67 (11.16)	23.17 (5.05)
	SS	10.13 (2.29)	12.43 (2.49)	11.70 (2.90)	11.17 (3.38)
Normal	RS	21.97 (5.39)	10.40 (4.12)	20.93 (10.09)	16.33 (4.69)
	SS	11.63 (2.99)	12.03 (3.18)	12.60 (2.91)	10.90 (2.41)

Note. (Standard deviations), RS. raw score, SS. scaled score.

Tasks, Materials, and Procedures

Participants were individually tested and the order of presentation of the tasks was randomised. One experimental task was assigned to each session.

Auditory Discrimination (Input Phonology)

Auditory discrimination has to do with the ability to hear similarities and differences among the sounds in words and is generally considered to be a prerequisite for the acquisition of visual decoding skills. Thirty-six word pairs with consonant sounds represented by 6 single consonant letters (e.g., dish / desk, fun / ran), 6 consonant clusters (e.g., step / store, crash / flesh), 6 consonant digraphs (e.g., thing / thumb, song / ring), 6 short vowel sounds (e.g., ankle / angry, trap / splash), 6 long vowel sounds (e.g., item / island, away / obey), and 6 other vowel sounds (e.g., artist / argue, loner / fever) were read out to each child. The child repeated each word pair in order to ensure that these had been heard correctly. The first twelve items required judgment being made on whether the two spoken words began or ended with the same sound. Thus, the experimenter would say "dress / place". "Do these two words begin or end with the same sound, dress / place?" The child then repeated the word pair prior to responding beginning or end. (The experimenter's lip movements were shielded from participants' view.) The remaining twenty-four items required judgment being made on whether the two spoken words had similar sounds at the beginning, middle, or end (e.g., 'stop / lock' = middle). There were two practice items administered prior to each set of test items. Corrective feedback was provided on practice items, but not on the test trials. The stimuli are presented in Appendix A.

Phoneme Deletion

The phoneme deletion task used in this study (Duncan & Johnston, 1999) comprised 24 one syllable words, and 24 one syllable nonwords. Viewed to be the best measure of compound phonemic awareness skills in young children (Yopp, 1988), this measure was included as a means of assessing segmentation ability in addition to overall phonemic awareness. The test items were counterbalanced for the deletion of initial and final phonemes, and for single consonants and consonants as part of a blend. There were four different stimulus sets in total, which varied in the ordering of test items; the order of presentation being counterbalanced across participants. The experimenter first read each word or nonword. The child was required to pronounce each item in order to ensure that it had been heard correctly. Thus, the experimenter would say, “say desk”. The child would then be asked, “what would be left if we took away the ‘kuh’ sound?” Prior to the administration of test items each child was given 8 practice items (four words and four nonwords covering the range of segmentation types), the first of which was segmented by the experimenter. Corrective feedback was provided on these practice items. No feedback was given on the test trials. The stimuli are presented in Appendix B.

Syllable, Onset-Rime and Phoneme Segmentation

Four phonological awareness tasks were adopted from a study conducted by Swan & Goswami (1997). The tasks were used to test phonological awareness at three different linguistic levels (syllable, onset-rime, and phoneme), moreover, to assess whether children would demonstrate better awareness of larger speech segments (e.g., syllable, onset-rime) relative to smaller units (e.g., at the phoneme level). Line drawings depicting the target stimuli (words) were used to assess the children’s underlying phonological representations for words prior to segmentation. These comprised pictures from existing (British Picture

Vocabulary Scale, Dunn, Dunn, Whetton, & Pintilie, 1982) and hand-drawn sources.

In order to assess the degree to which underlying phonological representations were intact, in each task the child was first asked to name the pictured object or pair of objects. The experimenter provided the name for the object if an incorrect or null response was given. The experimenter then pronounced the name/s of the test object/s prior to the child being asked to carry out the required segmentation. The order of presentation of tasks was counterbalanced across participants.

A) Syllable tapping.

The syllable tapping task comprised 24 drawings depicting 8 monosyllabic words (clock, queen, belt, track, quill, claw, harp, wick), 8 three-syllable words (alphabet, telescope, hospital, potatoes, dominoes, acrobat, banister, boomerang), and 8 four/five syllable words (television, electricity, arithmetic, refrigerator, binoculars, harmonica, escalator, rhinoceros). Within each of these conditions half of the items were high-frequency words (i.e., occurring 20 or more times per million), and the remaining half were low frequency words (occurring 3 or less times per million), as determined by the Caroll, Davies, and Richman (1971) word frequency book.

Pictures depicting the words were presented in a random order. Children were first asked to name the pictured object. The experimenter provided the name for the pictured object if an incorrect or null response was given. The experimenter then pronounced the name of the test item prior to asking the child to tap out the number of beats/syllables (with a pencil) that could be heard in the word.

B) Onset-rime judgment task.

The onset-rime judgment task comprised 24 drawings depicting 6 consonant-cluster onset pairs (crust/cross, brush/brick, stop/stick, prong/prawn, sling/slot, brooch/braid) and 6 rime pairs (coat/goat, cake/snake, flood/blood, drill/frill, cork/stork, dart/tart). In each of these conditions half of the word pairs were high frequency words (occurring 20 or more times per million) and the remaining half, low frequency words (occurring 7 or less times per million).

Children were first asked to name the pair of pictures. The experimenter pronounced the correct name/s for the test item/s, if an incorrect or a null response was given. The experimenter then pronounced the items prior to asking the child to decide if the words had any sounds in common. The children were then asked to state the sound that was common to each word (e.g., crust - cross = 'kruh').

C1) Initial - final phoneme judgment task.

The initial – final phoneme judgment task comprised 24 drawings depicting 6 initial phoneme word pairs (crust/cloud, brush/block, stop/swing, prong/plait, sling/stump, brooch/blush) and 6 final phoneme word pairs (coat/bat, cake/duck, flood/shed, drill/skull, cork/yolk, dart/flute). Half of the items in each of these positions were high frequency words (occurring 20 or more times per million) and the remaining half, low frequency words (occurring 7 or less times per million).

Children were first asked to name the pair of pictures. The experimenter pronounced the correct name/s for the test item/s, if an incorrect or a null response was given. The experimenter then pronounced the items prior to asking the child to decide if the words had any sounds in common. The children were then asked to state the sound that was common to each word (e.g., sling/stump = 'suh', cake - duck = 'kuh').

C2) Initial - final phoneme judgment (additional task).

The word initial phoneme pairs in the Swan and Goswami (1997) study comprised CCVC structures in which identification of the common sound requires the segmentation of a single phoneme from a consonant cluster (e.g., s/ling - s/tump), whereas final phoneme pairs comprised single phonemes only (e.g., coa/t - ba/t). Thus, as the deletion of phonemes as part of a blend is more difficult than the deletion of a single phoneme, an additional task in which word initial (and final) phoneme pairs comprised single phonemes was also used. This task comprised 24 drawings depicting 6 initial phoneme word pairs (cap/cut, boot/back, sea/sit, paint/pick, sing/sand, ball/bear) and 6 final phoneme word pairs (boat/cat, peak/fork, head/read, bell/pull, rock/hook, tent/foot). The same procedure as that in the task above was used.

D) Phoneme tapping task.

The phoneme-tapping task comprised 12 drawings depicting 6 CVC words (gun, cup, box, bud, yak, cog), 2 CVCC words (dust, vest), and 4 CCVC words (flag, slip, clog, brim). Again half of the items in each condition were high frequency words (occurring 24 or more times per million), and the other half low frequency words (occurring 3 or less times per million).

Children were first asked to name the pictured object. The experimenter provided the name for the pictured object if an incorrect or null response was given. The experimenter then pronounced the name of the test item prior to asking the child to tap out the number of sounds (with a pencil) that could be heard in the word. The child was then asked to state the sounds contained within each word (e.g., dust = 'duh -uh - suh - tuh'); i.e., once the child tapped out the number of sounds, he/she was asked, "can you tell me what the sounds are?"

Output Phonology (word and nonword repetition tasks)

Nonword repetition.

The nonword repetition task was used as test of overall phonological ability and as a means of assessing phonological memory skill. The task (Gathercole & Baddeley, 1989) comprised 50 nonwords ranging from one to five syllables. There were ten items for each syllable length. These items were played on a tape recorder in a fixed random order. The stimuli are presented in Appendix C.

Word and nonword repetition.

The second measure of output comprised 12 real words and 12 nonwords that were played on a tape recorder in a randomised order (Snowling, Stackhouse, & Rack 1986). The nonwords were based on the real words, and thus shared a similar phonological structure (e.g., hazardous – bassarpus). These items are presented in Appendix D.

Reading Tasks

Letter name and letter sound knowledge.

The task was used to evaluate whether poor readers' difficulties in reading words can be traced to lack of knowledge of grapheme to phoneme correspondences, moreover to examine whether group differences would be shown for the provision of names versus sounds for the presented letters.

Twenty-six lower case letters presented in a random order on a single A4 sheet were presented to each child. The child's task was to first provide the letter name, and then state the corresponding sound.

Nonword reading.

The nonword reading task was used to assess the poor readers' ability to take a phonological approach to reading, and to examine whether poor readers would be slower in this application. It was expected that if deficits in accuracy were found, then this would account for difficulties in applying phonological information to print, such as in print word learning. In a similar sense, even if equated for accuracy, differences in identification speed might suggest that poor readers' approaches to print word learning may differ as a result of a slowness to integrate phonological information with corresponding visual forms.

One and two syllable nonwords were presented one at a time in the centre of a computer screen. There were twenty nonwords in each of the syllable conditions which were presented in a fixed order, with one syllable nonwords being presented before two syllable nonwords. Prior to the commencement of test trials for each syllable set, participants were given three practice items on which accuracy feedback was given. Children were instructed to read the nonwords as quickly and accurately as possible. A voice key was used to mark the amount of time (e.g., latency) taken to provide a reading response. Test items are presented in Appendix E.

Study 1

Results

Auditory Discrimination (Input Phonology)

The total number of correctly judged word pairs (sharing a common sound either at the beginning or the end) was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, position (beginning vs end sound judgment). The means and standard deviations are reported in Table 4.

Table 4

Auditory discrimination: Percentage of phoneme placement in words judged correctly (beginning and end sounds)

		Beginning	End	Totals
Poor	M	91.11	97.78	94.44
	SD	(17.36)	(5.76)	(9.38)
Normal	M	96.11	96.11	96.11
	SD	(8.40)	(8.40)	(5.68)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 58) = .69, p>.10]. Similarly, the main effect of position was not significant [F(1, 58) = 2.83,p >.05]. There was no significant group x position interaction, [F(1, 58) = 2.83, p>.05].

The total number of correctly judged word pairs (sharing a common sound at the beginning, middle or end) was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, position (beginning - middle - end sounds). The means and standard deviations are reported in Table 5.

Table 5

Auditory discrimination: Percentage of phoneme placement in words judged correctly (beginning, middle and end sounds)

		Beginning	Middle	End
Poor	M	77.41	87.14	70.42
	SD	(27.45)	(18.51)	(23.32)
Normal	M	82.59	75.83	67.08
	SD	(19.06)	(22.11)	(18.42)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 58) = .30, p>.10]. However, the analysis showed a main effect of position [F(1, 58) = 11.66, p< .001]. Newman-Keuls post hoc analysis showed that more correct responses were given for word pairs sharing beginning sounds than for those sharing end sounds (p<.05). Similarly, more correct responses were given for word pairs sharing middle sounds than for those sharing end sounds (p<.01). The group x position interaction was not significant, [F(1, 58) = 2.76, p> .05].

Phoneme Deletion

The total number of correct responses to word and nonword stimuli was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, wordtype (words and nonwords). The means and standard deviations are reported in Table 6.

Table 6

Phoneme deletion: Percentage of correct responses to word and nonword stimuli

		Word	Nonword	Total
Poor	M	72.21	67.35	69.85
	SD	(26.94)	(26.97)	(26.68)
Normal	M	75.69	71.53	73.61
	SD	(21.44)	(22.95)	(21.67)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant, [F(1, 58) = .37, p> .10]. However, the analysis showed a significant main effect of wordtype, [F(1, 58) = 16.33, p< .001]. This was due to children's deletion performance on word stimuli being better than on nonword items. The group by wordtype interaction was not significant, [F(1, 58) = .10, p> .10].

In order to further examine performance on the deletion task (e.g., which stimuli were most difficult to segment), word and nonword stimuli were analysed by separate 2-way repeated measures ANOVA's. Thus, for both word and nonword stimuli there was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, position (beginning

C/VCC, C/CVC, end CCV/C, CVC/C). The means and standard deviations for words are reported in Table 7, and for nonwords in Table 8.

Table 7

Phoneme deletion: Percentage of correctly deleted phonemes from CCVC & CVCC words

		C/CVC	C/VCC	CCV/C	CVC/C
Poor	M	66.11	86.67	66.67	74.44
	SD	(39.75)	(28.83)	(35.29)	(36.55)
Normal	M	66.67	87.78	67.22	83.33
	SD	(33.62)	(22.71)	(32.89)	(27.33)

Note. M Mean, SD (Standard Deviation).

The analysis involving word stimuli showed no significant main effect of group [F(1, 58) = .19, p> .10]. However, there was a significant main effect of position [F(3, 174) = 9.97, p< .001]. Post hoc Newman-Keuls tests (p<.01) showed that the deletion of initial phonemes in CCVC wordtypes (e.g., s/tep) proved more difficult than the deletion of initial phonemes in CVCC words (e.g., c/ost). The deletion of final phonemes in CVCC words (e.g., des/k), likewise proved more difficult than the deletion of initial phonemes in CCVC wordtypes (e.g., f/lat). The group x position interaction was not significant [F(1, 58) = .04, p> .10].

Table 8

Phoneme deletion: Percentage of correctly deleted phonemes from CCVC & CVCC nonwords

		C/CVC	C/VCC	CCV/C	CVC/C
Poor	M	51.11	83.89	63.33	71.11
	SD	(41.74)	(31.41)	(34.30)	(33.60)
Normal	M	62.22	87.22	60.0	78.33
	SD	(35.54)	(22.61)	(35.72)	(27.39)

Note. M Mean, SD (Standard Deviation).

There was no significant main effect of group in the analysis involving nonword stimuli [F(1, 58) = .50, p> .10]. However, again there was a significant main effect of position [F(3, 174) = 16.22, p< .001]. Post hoc Newman-Keuls tests (p<.01) showed that the deletion of initial phonemes in CCVC wordtypes (e.g., s/kep) proved more difficult than the deletion of initial phonemes in CVCC nonwords (e.g., n/ost). The deletion of initial phonemes in consonant cluster blends at the beginning of nonwords (e.g., s/kep) also proved more difficult than the deletion of final phonemes from consonant cluster blends at the end of CVCC nonwords (e.g., bes/k). Finally, the deletion of final phonemes in CVCC words (e.g., bes/k), likewise proved more difficult than the deletion of final phonemes in CCVC nonword types (e.g., sno/l). The group x position interaction was not significant [F(1, 58) = .04, p> .10].

Syllable, Onset-Rime and Phoneme Segmentation

A) Syllable tapping.

The total number of correct responses to one, three, and four/five syllable items was calculated and converted to percentage form. These data were analysed by a three way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and two within subjects factors, syllable (one, three, and four/five syllable words), and frequency (high vs low). The means and standard deviations are presented in Table 9.

Table 9

Percentage of one, three, and four / five syllable words tapped correctly

		Number of Syllables					
Group		1-HF	1-LF	3-HF	3-LF	4/5-HF	4/5-LF
Poor	M	74.17	78.33	98.33	93.33	86.67	93.33
	SD	(36.84)	(33.30)	(6.34)	(15.99)	(19.40)	(15.99)
Normal	M	47.50	51.67	93.33	92.50	75.83	82.50
	SD	(41.18)	(38.24)	(19.62)	(14.90)	(28.23)	(23.81)

Note. M Mean, SD (Standard Deviation), HF high frequency, LF low frequency.

There was a main effect of group [F(1, 58) = 9.33, p< .01], as a result of poor readers performing better than RA controls. The analysis also showed a main effect of syllable [F(2, 116) = 34.13, p< .001], as more correct responses were given for 3, 4-5 syllable words than for one syllable items

(Newman- Keuls, $p<.01$). Interactions were found between the factors of groups and syllable [F (2, 116) = 4.81, $p< .05$], and syllable and frequency [F(2, 116) = 3.21, $p< .05$]. Newman-Keuls post hoc analysis of the groups x syllable interaction showed that RA controls had greater accuracy in tapping 3, 4-5 syllable words than for one syllable items ($p<.01$). Additionally, poor readers gave more correct responses than RA controls in the identification of one syllable items ($p<.01$). Post hoc analysis of the syllable x frequency interaction showed that more correct responses were given for 3, 4-5 syllable high frequency words than for one syllable high frequency words ($p<.01$). The same pattern was noted for low frequency words ($p<.01$). Accuracy for 3 syllable high frequency words was better than for 4-5 syllable high frequency words ($p<.01$), however, this difference was not found for low frequency stimuli. The group x syllable x frequency interaction was not significant [F(2, 116) = .19, $p> .10$].

Although overall accuracy was better for 3, 4-5 syllable items than for the one syllable words, reading age controls were less accurate than poor readers in their identification of one syllable items. This seemed to be a result of the reading age controls having a tendency to further break these items down into phonemes, e.g., 'queen' = 'quah - ee - nuh'. A second analysis was therefore carried out on 3, 4-5 syllable items only. There was one between subjects factor, groups (Poor vs RA controls), and two within subjects factors, syllable (three, and four/five syllable words), and frequency (high vs low).

The main effect of group was marginally non significant [F(1, 58) = 3.86, p= .054]. However, the analysis showed a main effect of syllable as more correct responses were given in tapping 3 syllable words than the tapping of 4/5 syllable items [F(1, 58) = 18.70, p< .001]. The interactions between groups and syllable [F(1, 58) = 3.06, p> .05], and between groups and frequency [F(1, 58) = .34, p> .10] were not significant. However, the factors of syllable length and frequency interacted [F(1, 58) = 6.41, p< .05]. Newman-Keuls post hoc analysis showed that 3 syllable high and low frequency words were tapped more accurately than 4/5 syllable high frequency words (p<.01). However, there were no differences in accuracy for 3 syllable low frequency over 4-5 syllable low frequency items, thus producing the interaction.

B) Onset-rime judgment task.

The total number of correct responses to onset and rime items was calculated and converted to percentage form. These data were analysed by a three way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and two within subjects factors, condition (onset vs rime), and frequency (high vs low). The means and standard deviations are presented in Table 10.

Table 10

Mean Percentage of Correctly Identified Common Sounds in Onset-Rime Judgment Task

Group		Onset-HF	Onset-LF	Rime-HF	Rime-LF
Poor	M	84.44	76.67	66.67	60.00
	SD	(27.31)	(32.93)	(33.90)	(34.35)
Normal	M	74.44	72.22	63.33	56.67
	SD	(34.67)	(36.18)	(38.51)	(38.31)

Note. M Mean, SD (Standard Deviation). HF high frequency. LF low frequency.

The main effect of group was not significant [F(1, 58) = .56, p> .10]. However, there was a significant main effect of condition as more correct responses were given for onset pairs than for rime pairs [F(1, 58) = 15.91, p< .001]. There was also a significant main effect of frequency [F(1, 58) = 5.38, p< .05], as more correct responses were given for high frequency than for low frequency items. The group by condition, [F(1, 58) = .26, p> .10], and group by frequency interactions, [F(1, 58) = .30, p> .10] were not significant. Similarly, the interactions between condition and frequency [F(1, 58) = .07, p> .10], and group by condition by frequency, [F(1, 58) = .20, p> .10] were not significant.

C1) Initial-final phoneme judgment task.

The total number of correct responses was calculated and converted to percentage form. These data were analysed by a three way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and two within subjects factors, position (initial phoneme vs final phoneme), and frequency (high vs low). The means and standard deviations are presented in Table 11.

Table 11

Mean percentage of initial-final phoneme placement judged correctly

		Initial Phoneme-HF	Initial Phoneme-LF	Final Phoneme-HF	Final Phoneme-LF
Poor	M	68.89	73.33	90.00	81.11
	SD	(32.68)	(34.35)	(21.71)	(28.61)
Normal	M	91.11	92.22	96.67	92.22
	SD	(19.44)	(18.94)	(10.17)	(16.80)

Note. M Mean, SD (Standard Deviation), HF high frequency. LF low frequency.

There was a significant main effect of group as a result of RA controls having more accurate judgment than the poor readers [$F(1, 58) = 10.23$, $p < .01$]. The analysis also showed a main effect of position as more correct responses were given for final than for initial phoneme pairs [$F(1, 58) = 10.85$, $p < .01$]. Interactions were found between the factors of groups and position [$F(1, 58) = 4.98$, $p < .05$], and position and frequency [$F(1, 58) = 4.15$, $p < .05$].

The group x frequency interaction was not significant [F(1, 58) = .01, p> .10]. Post hoc (Newman-Keuls) tests showed that the group x position interaction was due to the poor readers giving more correct responses for final phoneme than for initial phoneme word pairs, in addition to the RA controls having greater accuracy than poor readers in judging initial phoneme pairs (p's<.01). Newman-Keuls post hoc tests of the position x frequency interaction showed that final phoneme high frequency items were better judged than initial phoneme high frequency items (p<.05), however, the same trend was not observed for low frequency pairs. The group x condition x frequency interaction was not significant [F(1, 58) = .70, p> .10].

C2) Initial - final phoneme judgment task.

The total number of correct responses to initial and final phoneme word pairs was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, position (initial vs final). The means and standard deviations are presented in Table 12.

The main effect of group was significant [F(1, 58) = 4.87, p< .05], as RA controls gave more correct responses than the poor readers. However, there was no significant main effect of position [F(1, 58) = 3.28, p> .05], and no interaction between these two factors [F(1, 58) = .49, p> .10].

Table 12

Mean percentage of initial-final phoneme placement judged correctly

Group		Initial Phoneme	Final Phoneme
Poor	M	88.33	83.33
	SD	(25.20)	(28.36)
Normal	M	97.22	94.10
	SD	(6.32)	(7.77)

Note. M Mean, SD (Standard Deviation).

D) Phoneme tapping.

The total number of correctly tapped items was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, frequency (high vs low).

There was a significant main effect of group as a result of RA controls performing better than poor readers [$F(1, 58) = 7.01$, $p < .05$]. The main effect for frequency was not significant [$F(1, 58) = .08$, $p > .10$], and no significant groups x frequency interaction [$F(1, 58) = .08$, $p > .10$].

Sounds: The total number of words for which the contained phonemes were correctly identified was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, frequency (high vs low). There was no significant main effect of group [F(1, 58) = 1.53, p> .10], or frequency [F(1, 58) = .98, p> .10], and no interaction between these factors [F(1, 58) = .02, p> .10]. Thus, although group differences were observed on the phoneme tapping task, the poor readers were as accurate as controls in stating the sounds comprising these stimulus items. The means and standard deviations for the phoneme tapping and phoneme production tasks are presented in Table 13.

Table 13

Percentage of correctly tapped number of phonemes in words, and the percentage of sounds in words correctly produced

		Tapping		Sounds	
		HF	LF	HF	LF
Poor	M	81.67	80.56	84.44	82.22
	SD	(23.30)	(23.60)	(18.53)	(20.03)
Normal	M	93.89	93.89	89.10	88.33
	SD	(15.46)	(16.66)	(21.26)	(19.15)

Note. M Mean, SD (Standard Deviation), HF high frequency. LF low frequency.

Levels of Segmentation Compared

Finally, an examination of the children's performances on the syllable, onset-rime and phoneme segmentation tasks was made. The purpose of this was to investigate the nature of the relationships between these three levels of awareness and to see whether children had indeed demonstrated a better awareness of onset and rime structures than phonemes as claimed by large unit theorists (e.g., Swan & Goswami, 1997).

Data from one syllable items in the syllable tapping task were not included in the overall calculations for reasons previously noted. The total number of correctly segmented items from the syllable tapping, onset-rime, and phoneme identification measures was calculated and converted to percentage form. (Items were collapsed across frequencies.) These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls) and one within subjects factor, linguistic level (syllable, onset-rime, and phoneme). The means and standard deviations are presented in Table 14.

Table 14

Percentage of correctly segmented items at the three linguistic levels

		Syllables (3, 4 & 5)	Onset-Rime	Phoneme
Poor	M	93.13	71.95	82.22
	SD	(11.05)	(24.12)	(16.48)
Normal	M	86.04	66.67	89.17
	SD	(15.63)	(30.01)	(19.35)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 58) = .35, p> .10]. However, the analysis showed a significant main effect for linguistic level [F(2, 116) = 16.79, p< .001]. As would be predicted by large unit theory, post hoc

Newman-Keuls tests showed that words were more easily segmented by syllable than by onsets and rimes ($p<.01$). However, it was also found that children were less capable of segmenting words according to their onsets and rimes than they were by individual phonemes ($p<.01$). This finding would suggest that onset-rime awareness may emerge at a later stage in children's development.

Output Phonology (Nonword and Word Repetition Tasks)

Nonword repetition.

The total number of correctly pronounced nonwords was calculated for each participant, and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one was between subjects factor, groups (Poor vs RA controls) and one within subjects factor, syllable length (one, two, three, four, and five syllable nonwords).

The main effect of group was not significant, [$F(1, 57) = .40$, $p > .10$]. However, the analysis showed a significant main effect of syllable length, [$F(4, 228) = 59.93$, $p < .001$]. The group by word length interaction was not significant, [$F(4, 228) = 1.35$, $p > .10$]. Post hoc (Newman-Keuls) tests of the main effect of word length showed that more correct responses were given in the repetition of one, two, three, and four syllable nonwords than for five syllable items (p's $< .01$). Similarly, more correct responses were given for one, two, and three syllable nonwords than for four syllable items (p's $< .01$). Finally, more correct responses were given for two syllable nonwords than for three syllable items (p<.05). Performances for one syllable items did not differ from two syllable nonwords. The means and standard deviations are presented in Table 15.

Table 15

Output phonology: Percentage of one-five syllable nonwords repeated correctly

		Number of Syllables					
		1	2	3	4	5	Total
Poor	M	81.0	79.67	68.0	56.0	46.33	66.20
	SD	(19.36)	(18.47)	(20.57)	(19.58)	(23.85)	(16.15)
Normal	M	76.90	82.07	75.86	60.0	47.93	68.07
	SD	(15.61)	(14.97)	(14.27)	(21.04)	(21.27)	(12.64)

Note. M Mean, SD (Standard Deviation).

Word and nonword repetition.

One child in the reading age control group did not complete the task. The total number of correctly repeated words and nonwords was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls) and one within subjects factor, wordtype (words and nonwords).

There was a significant main effect of group as a result of poor readers performing better than RA controls [F(1, 57) = .23, p<.05]. The analysis also showed a significant main effect of wordtype as more correct responses were given for word than for nonword stimuli [F(1, 57) = 57.61, p<.001]. There was no significant interaction between these two factors [F(1, 57) = .67, p>.10]. The means and standard deviations are reported in Table 16.

Table 16

Output phonology: Percentage of real and nonword stimuli repeated correctly

		Words	Nonwords
Poor	M	80.0	63.33
	SD	(8.92)	(19.40)
Normal	M	75.86	55.17
	SD	(8.43)	(17.59)

Note. M Mean, SD (Standard Deviation).

Reading Tasks

Letter name / letter sound knowledge.

The total number of correctly named letters and letter sounds was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, task (identification of letter names vs letter sounds).

There was a significant main effect of group as a result of poor readers performing better than RA controls [F(1, 58) = 6.92, p< .05]. The analysis also showed a main effect of task as more correct responses were given for letter names than for letter sounds [F(1, 58) = 7.05, p<.05]. The interaction between groups and task was not significant [F(1, 58) = .04, p>.10]. The means and standard deviations are reported in Table 17.

Table 17

Percentage of correctly identified letter names and their corresponding sounds

		Letter Names	Letter Sounds
Poor	M	97.05	94.06
	SD	(6.12)	(5.40)
Normal	M	93.20	89.74
	SD	(8.00)	(10.11)

Note. M Mean, SD Standard Deviation.

Nonword reading.

Accuracy: The total number of correctly read nonwords from each syllable length was calculated and converted to a percentage form. These data were analysed by a 2-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, syllable (one and two syllable nonwords).

The main effect of group was not significant, [F(1, 58) = 1.02, p> .10]. However, the analysis showed a significant main effect of syllable as a result of more correct responses being given for one syllable nonwords than for two syllable nonwords, [F(1, 58) = 88.35, p< .001]. The group by syllable interaction was not significant, [F(1, 57) = 2.11, p> .10]. The means and standard deviations are reported in Table 18.

Table 18

Nonword reading: Percentage of one and two syllable nonwords read correctly

		One Syllable	Two Syllable
Poor	M	83.97	52.93
	SD	(12.12)	(27.41)
Normal	M	84.72	61.99
	SD	(16.41)	(27.17)

Note. M Mean, SD (Standard Deviation).

Latency: An analysis was also carried out on response time (RT) data. Due to missing cells for two syllable response times the group numbers for this analysis were reduced to 25 and 28 for the poor readers and reading age controls respectively. The mean response times for correctly read items from each syllable length comprised the data. A two-way repeated measures ANOVA was carried out. There was one between subjects factor, groups (Poor vs RA controls) and two within subjects factors, syllable (one vs two). The means and standard deviations are reported in Table 19.

Table 19

Nonword reading: Response times (ms) for one and two syllable nonwords read correctly

		One Syllable	Two Syllable
Poor	M	2618.98	4010.61
	SD	(1179.78)	(2156.89)
Normal	M	2014.99	2828.66
	SD	(1126.31)	(1536.27)

Note. M Mean, SD (Standard Deviation), (ms) millseconds.

The main effect of group was significant as a result of RA controls being faster than the poor readers [F(1, 51) = 4.42, $p < .05$]. The analysis also showed a main effect of syllable as a result of response times being faster for one syllable than for two syllable nonwords [F(1, 51) = 49.31, $p < .001$]. There was also an interaction between the factors of groups and syllable [F(1, 51) = 4.60, $p < .05$]. Post hoc Newman-Keuls showed that one syllable nonwords were read faster than two syllable items in both the poor and RA control groups (p's<.01). However, although RA controls were faster than the poor readers in the identification of both one syllable (p<.05) and two syllable (p<.01) items, the difference between these two ability groups was more marked on two syllable nonwords, thus producing the interaction.

Discussion

The results of the phonological awareness battery are important for a number of reasons. First, as poor readers' difficulties in reading in some studies are more clearly linked to phonological impairment, it is less likely to be the case for the poor readers in this investigation as they performed as well as reading age controls on the measures of auditory discrimination, phoneme deletion, syllable, onset-rime, and phoneme segmentation, and nonword repetition. Additionally, equal performance on the nonword repetition measure would suggest that the poor readers' difficulties in reading are not connected to inefficient phonological memory skill for reading age. However, the poor readers were found to show deficits with the tapping of phonemes in spoken words, but not in giving the phoneme sounds. They also had difficulty with the judgment of initial and final sounds common to spoken word pairs. This aside, overall it would appear that these poor readers' difficulties with the use of phonological codes might largely be specific to reading tasks (e.g., print word learning). Two further tasks were carried out to examine whether poor readers had impaired knowledge of grapheme-phoneme relationships, and to examine whether they had reading age appropriate skills in reading unfamiliar words. On these measures, no differences in accuracy were found, however, the poor readers were slower than the controls in the speeded nonword reading task.

Phonological reading deficits have traditionally been sought in terms of nonword reading problems. The poor readers in the present study did not show a nonword reading deficit, however, the slower identification times might be taken as a residual phonological impairment. Seymour and Porpodas (1980) noted that their poor readers were also as accurate as RA controls in tests of nonword reading, but were slower. The authors concluded that although the grapheme-phoneme translation channel appeared to be intact, it might be impaired in terms of its speed of functioning. Therefore, the poor readers' decoding difficulties might be accounted for in terms of the time taken to make use of phonological information in print-based tasks.

Nevertheless, if differences in nonword naming speed are not taken as indication of a phonological impairment then some explanation for this interpretation must be given. For example, one might contend that the poor readers' slowness in nonword reading is simply a result of trading accuracy for speed. However, in terms of the reading process, if longer response times are to be interpreted as a slowness to process phonological information, then the outcome would be a slowness to generate verbal labels for new reading words, which may impair the learning of the items. Taken together these inefficiencies would impact on the poor readers' ability to establish and retrieve phonological representations from long-term memory, and thus account for their word recognition difficulties. This could also in part explain the poor readers' reliance on orthographic codes as suggested by their production of letter names rather than sounds in the phoneme tapping task. It would, therefore, appear fruitful to examine whether poor readers would demonstrate similar levels of accuracy in phonological tasks employing nonword stimuli. In this way, the degree to which poor readers make use of orthographic knowledge in making phonological judgments could be better controlled, given the non-lexicality of nonword structures. It is indeed believed that poor readers perform less well than controls in tasks involving nonword stimuli (Swan & Goswami, 1997).

On the subject of the children's segmentation abilities at different linguistic levels, results appear to favour the view held by large unit theorists. Although the comparison of children's performances across the various linguistic levels (e.g., syllable, onset-rime, and phoneme) showed that performance on syllables was better than on onsets and rimes (as a large unit theory would predict), the children's performances at the phoneme level were significantly better than at the levels of onset and rime. In this sense, the arguments put forth by small unit theorists appear to prevail. Nevertheless, there are a few important considerations to be given to this pattern of results.

In the absence of reading skill (e.g., at the pre-reader stage) children may well demonstrate a better awareness of larger phonological structures (e.g., rhyming words, odd word out) relative to smaller units. Gombert (1992) suggests that syllables are particularly salient very early in development and may indeed become objects of meta-awareness prior to the beginning of reading. Thus, syllables would be the first to be represented, followed by an onset-rime subdivision, and finally a phonemic structure. However, the point must be made that the act of learning to read may influence how children approach these phonological tasks at various linguistic levels. Thus, once formal reading instruction has begun, children's awareness of these structures may reflect the same pathway taken from applications in their reading instruction, i.e., from the phoneme upward. Consequently, although children may emerge from the pre-school stage with an awareness of rhyme, their first experiences with formal literacy will likely focus on small units, which would understandably result in the emergence of an explicit awareness of the phoneme prior to the units of onset and rime. Some attention is now given to the finer points of the poor readers' performance on the phonological processing / segmentation measures.

At the most basic phonological level, it was stated that the poor readers' difficulty in applying verbal information to visual stimuli could be connected to poorly established auditory representations for words (Perfetti, 1985). Difficulties in processing phonological information at input could mean that it would take longer to form auditory representations for visual stimuli, and would therefore point to the possibility that lexical entries may not always be complete. However, the poor readers were as accurate as controls in detecting the placement of common sounds within spoken words. This would suggest that they are free from impairments at the level of auditory input processing. However, because this task did not require that the common sound be articulated it should be noted that equal performance on this measure does not entirely rule out the possibility that low-level perceptual deficits may exist; however, this would apply to both groups of readers. In this sense, it has been suggested that individuals whose phonological deficit resides at an abstract level of representation might not present as having a perceptual deficit, but will encounter difficulty in tasks requiring manipulation of phonological codes, particularly in verbal memory tasks (Snowling et al., 1986; Adlard & Hazan, 1998).

However, in terms of the segmentation tasks the poor readers performed better than controls on a measure of syllable tapping, were as able as controls in identifying onsets and rimes, and individual phonemes in spoken words. In syllable tapping, given that performances should be better on words containing fewer syllables, one-syllable items should have been easier to identify than three- and four/five syllable words respectively. The normal readers therefore, may have had a tendency to segment one syllable items into individual phonemes, e.g., 'queen' = 'quah' -'ee' - 'nuh'. In this sense, it might be argued that the controls' treatment of one-syllable words stems from a more developed phonologically rooted mindset in comparison to the poor readers.

Onset items were more readily segmented than rime items by both groups, which is consistent with previous findings. However, at the phoneme level, poor readers were impaired at tapping out the number of phonemes in words (e.g., 'vest' = 1, 2, 3, 4). Still, no impairment was noted when they were asked to provide the sounds contained within these words (e.g., 'vest' = 'vuh'–'eh'-'suh'-'tuh'). This result might therefore, suggest that phoneme tapping tasks are not suitable measures of phonemic awareness, moreover that phonemic awareness deficits in previous studies using tapping tasks may not accurately reflect the poor readers' actual difficulties. Accordingly, the poor readers' difficulty in this task could be connected to inefficiencies in co-ordinating phonological retrieval processes with those in the psychomotor domain. However, it should also be stated that in the production of the contained sounds, poor readers had a tendency to state the spellings of words. When reminded that they were being asked to give the contained sounds and not the spellings, errors were made in their ability to separate single phonemes from consonant clusters (e.g., 'dust' = 'duh – uh – stuh'). Accordingly, in the tapping component items may have been addressed using similar means.

This type of segmentation difficulty might also explain the poor readers' lowered performance on the initial-final phoneme judgment measure in which they were less able than controls in identifying phonemes that word pairs had in common. Their difficulty with this task could stem from initial phoneme pairs containing consonant clusters (e.g., crust/cloud), which are known to be more difficult to segment for both poor and normal readers (Bruck & Treiman, 1990). (These word types were also shown to be the most difficult in the phoneme deletion task.) Alternatively, it could be that poor readers approach the task orthographically, as appears to have been the case with the phoneme identification and to some degree the phoneme deletion measure (e.g., a poor reader reporting that '*class*' take away 'suh' still leaves '*class*' as there are two S's in the word). In the initial-final phoneme judgment task a main effect of condition showed that final phonemes were more readily segmented than initial phonemes, which on the whole is not consistent with the literature. However, it could also be that the poor readers' difficulty in this task stems from a more general problem with stimulus comparison, rather than from a phonological deficit per se. Thus, it could be concluded that the specific difficulty with this task stems from the requirement of having to retain two words in short-term memory, or occurs in the process of making comparisons between the two words.

The latter conclusion appears more likely as deficits in phonemic processing should be more readily shown in deletion tasks. This is because the deletion of an individual sound from a spoken word requires the retention of the word's phonological form, and an awareness of the phonemic structure in order for segmentation to be carried out. Although the demands on memory would therefore, appear equally high in deletion tasks, the child must work with one word only. Thus, in terms of stimulus comparison tasks it could be that the poor readers' difficulty is connected to maintaining the phonological structure of two spoken words, performing segmentation for each, comparing the remaining segments and providing the spoken similarity. One additional possibility is that to hold two words, which share common attributes means having to deal with somewhat conflicting representations. Indeed it was noted that some poor readers engaging in overt rehearsal went from saying 'brush-block' to 'blush-block'.

Therefore, if taking the position that these difficulties are connected to a phonological disorder, one would expect differences to have emerged in the phoneme deletion measure. In this sense, although items in both the deletion and phoneme position judgment tasks were of similar complexity (e.g., f/lat and s/lot respectively), the latter measure required a comparison of two words (e.g., s/ling-s/tump), prior to segmentation and the articulation of the remaining sound being made. Moreover, whereas word initial pairs in the judgment task required the deletion of single phonemes from initial consonant blends final phoneme pairs involved single phonemes in V/C endings (e.g, coa/t-ba/t). The fact that more correct responses were given for final phoneme pairs than for initial phoneme pairs is not consistent with the literature. Thus, although the poor readers were also impaired on a second measure of initial-final phoneme judgment, which controlled for the deletion of initial and final phonemes pairs (e.g., c/ap-c/ut and roc/k-hoo/k), word-initial phonemes in this second task were more easily identified than word-final phonemes. This finding is consistent with the literature (Stanovich et al., 1984; Trieman, 1988). The phoneme deletion task controlled for the deletion of initial and final phonemes, and for single consonants and consonants as part of a blend in both initial (e.g., C/VCC, C/CVC) and final (e.g., CCV/C, CVC/C) positions. Yet, both groups of readers showed that initial phonemes were better segmented than final phonemes, and that the deletion of single phonemes from a consonant blend in both positions was more difficult. As a corollary, the deletion task comprised 36 more items in both word and nonword form. It is therefore argued that the poor readers difficulties in the initial-final phoneme judgment tasks stem from the requirement of holding not one, but two words in memory while being asked to perform the required segmentation. Therefore, overall this may be more demanding than performing the same set of operations on a single word, such as in the phoneme deletion task, and in the explication of individual phonemes stated serially for spoken words.

The specific difficulty with the non-lexical procedures involved in speech processing is said to amount to a difficulty with procedures involving phoneme segmentation and phoneme synthesis. In order for a nonword to be successfully repeated, the word's phonological form must first be segmented prior to being assembled for articulation. It therefore follows that inefficiency in segmentation ability at various linguistic levels (e.g., syllable, onset-rime, or phoneme) will inadvertently reflect in one's ability to accurately reproduce phonological representations as speech segments, i.e., at the level of output phonology. Because the poor readers in this study had performances that were equal to reading age controls on the nonword repetition measure, it is difficult to attribute performance differences in the initial-final phoneme measures to segmentation deficits.

Nevertheless, from a developmental perspective, findings suggest that the underlying cognitive deficit in dyslexia is at the level of phonology. This deficit is believed to compromise the acquisition of alphabetic literacy skills. Of course, the development of a variety of phonological skills is dependent upon access to phonological representations including output phonological codes (Hulme & Snowling, 1992). The Swan and Goswami (1997) results suggest that the accuracy of phonological representations in the mental lexicon accounted for a group of dyslexic children's segmentation difficulties at two linguistic levels (syllable and onset-rime). Prior to adjustment for picture naming proficiency the dyslexic children had shown deficits for chronological age at the levels of syllable, onset-rime and phoneme, as well as for reading age at the phoneme level. When adjustments were made for picture naming errors (i.e., where analyses were based on proficient picture naming), the dyslexic children performed at similar levels to both control groups at the levels of syllable and onset-rime, but differed at the phoneme level.

Although a statistical analysis was not carried out on picture naming data in the Swan and Goswami (1997) study, the dyslexic children's performance was in general much poorer than the normally developing control children, and especially so for low frequency and larger syllable items. The point however, should be made that Swan and Goswami's (1997) dyslexic children had reading ages that were on average 5 months below that of their RA controls. This might therefore account for the reported differences in picture naming proficiency.

A review of the picture naming errors in the current investigation showed no differences in general levels of accuracy by frequency, which is not surprising given that effects for frequency were not found in the syllable tapping, initial-final phoneme judgment, or phoneme tapping measures (although a main effect for frequency was noted in the onset-rime judgment task). More to the point, controls generally displayed more difficulties with pronunciations in picture naming (e.g., 7 of 30 controls pronounced 'dominoes' as *donimoes* compared to only 3 of the poor readers). Thus, given the sophistication of the older poor readers' articulatory motor skills and programmes for speech output relative to controls, the Swan and Goswami (1997) results appear inconsistent. In other words there are a minority of studies showing naming deficits in dyslexic children for reading age (Wolf & Obregon, 1992). To illustrate this, one only has to consider the fact that the children in the current investigation did not differ in tests of nonword repetition. In fact, the poor readers were shown to perform better than controls in the test of word / nonword repetition. The likely explanation is that with time words become more familiar and motor programmes are more developed. Thus, it is not surprising that the poor readers made fewer naming errors than controls. As a corollary these errors were confined to longer syllable items for both groups (e.g., '*hostiple*' for 'hospital' in a RA child, '*esqulator*' for 'escalator' in a poor reader, '*elestricity*' for 'electricity' in a RA child whereas there was no single case of mispronunciation for this word in the poor reader group).

Conclusion

The results of this investigation showed that poor readers were impaired on only one of four phonemic segmentation processing tasks (e.g., on measures of initial - final phoneme judgment). The poor readers did not show deficits in auditory discrimination, phoneme deletion, syllable, onset-rime or phoneme segmentation, and were generally better in tests of word and nonword repetition. Accordingly, it would seem that inadequate facility in phonological processing cannot be said to account for their specific reading impairment.

The reason is that if phonological awareness plays a critical role in the acquisition of skilled reading development, one would expect a close connection between inadequate facility in phonological processing and failure in reading. The central purpose of this study was to examine where potential deficiencies in phonological processes lie, and to see if the overall pattern of performance was developmentally similar to that of younger normal reading age controls. Not only do these groups demonstrate similar patterns of performance, but also similar levels of accuracy in these measures. It is therefore difficult to account for these poor readers' significant delays in reading development in terms of a phonological processing deficit, as this deficit is best described as mild. The performance of these poor readers is consistent with the developmental lag hypothesis, which suggests that processes between these two groups are developmentally similar, yet lag in terms of the time required reaching a similar level of attainment. Clearly, for some groups of children it is their specific phonological deficits that can be held accountable for their failure in reading. However, for this group of poor readers such a connection is difficult to make.

Nevertheless, overall consideration must be given to the remedial tuition received by these children both as part of their regular and specialised schooling, which was phonemic in nature. However, even if this can account for their ability to demonstrate adequate facility in phonological awareness tasks, it does not speak to the issue of why these children's development in reading is not advancing. After all, these are not individuals at the lower end of the distribution who are subsequently tested in a year or two and shown to have made progress in reading. This puts to question the relationship that is seen to exist between teaching phonemic awareness and advancements made in reading skill. The tuition that these readers receive is highly intensive, given in groups of four by practitioners with specialised training, yet if it does improve phonemic awareness, it alone does not appear to be sufficient enough for the amelioration of their reading difficulties.

STUDY TWO: PHONOLOGICAL AWARENESS

EXAMINATION OF POOR READERS' ABILITY IN NONWORD DISCRIMINATION AND SEGMENTATION TASKS

It was concluded in study one that poor readers presented with a relatively mild phonological weakness for reading age. However, it was also observed that they exhibited slower response rates in a speeded nonword reading task. It was suggested that a slowness to generate pronunciations for novel words could indicate impairments in automaticity in extracting phonological information from print. This slowness could therefore suggest that phonological assembly procedures would be more effortful than trying to read words visually. Accordingly, in terms of printed word learning the poor reader might attempt to remember words as a visual whole, forming partial visual and / or phonological cues (see Ehri, 1992). One possible outcome therefore, would be a tendency to visualise the spelling of a word in phonological tasks. It was indeed noted that the poor readers often provided letter names rather than letter sounds in phoneme identification.

One way in which researchers have attempted to experimentally control for the influence of lexical knowledge in phonological tasks is through the use of nonword stimuli. As these items have not previously been heard the argument follows that there is no lexical equivalent from which to derive information. The possibility that the poor readers' performance in the first study was assisted by their use of orthographic information led to the development of nonword auditory discrimination and segmentation tasks in this next study. In this way the extent to which poor readers' phonological difficulties may be masked by their use of orthographic knowledge in phonological tasks might be determined, and the severity of their phonological difficulties better illuminated.

With this view in mind it appeared fruitful to continue with the same samples of children. Eighteen poor readers and nineteen reading age (RA) controls were available for further study. The participant characteristics are presented in Table 20.

Study 2

Method

Embedded Figures Task

Scores for the Children's Embedded Figures Test (Witkin et al., 1971) used in the previous study were re-calculated for the participants who carried on in this investigation. The test was used as a measure of visual perceptual disembedding, where the child has to detect and trace out either a triangle or a house shape embedded within coloured pictures of varying complexity. The task explicitly measures visual segmentation skills. The task was carried out to determine whether the poor readers had superior visual skills for reading age in a non-reading task. The Children's Embedded Figures test was also selected as it has been shown to be associated with word reading skill (Johnston, Anderson & Duncan, 1991). Only accuracy is recorded in the children's version.

Results

(One child from each of the two groups was unavailable on the date of testing.) The total number of correctly identified embedded figures was calculated and converted to percentage form. A one-way ANOVA was conducted for these scores with one between subjects factor, groups (Poor vs RA controls). The main effect of group was significant as a result of poor readers performing better than reading age controls [F(1, 34) = 13.32, $p <$ .001].

Table 20

Participant characteristics

		CA	RA	SA	IQ	V.IQ	P.IQ	EF-test
Poor	M	11.03	7.64	7.63	109.25	109.6	107.21	70.35
	SD	(.583)	(.776)	(.833)	(11.94)	(11.61)	(14.26)	(14.08)
Normal	M	7.17	7.50	7.11	106.17	103.36	106.52	52.0
	SD	(.366)	(.481)	(.610)	(9.30)	(11.65)	(11.69)	(15.58)

Note: M Mean, SD (Standard Deviation), CA = chronological age, RA = reading age, SA = spelling age, V.IQ = verbal IQ, P.IQ = performance IQ, EF-Test = Embedded Figures test.

A one-way ANOVA comparing groups (Poor vs RA controls) was carried out on the reading age scores. The two groups did not differ for reading age [F(1, 35) = .391, p> .10]. A one-way ANOVA comparing groups, (Poor vs RA controls) likewise showed no differences for IQ [F(1, 35) = .770, p> .10].

An examination of memory span performance was again made for the digit span (WISC-R) and auditory word span scores. These data were analysed by one-way ANOVA's (Poor vs RA controls). No differences were found for the digit span [F(1, 35) = .391, p> .10] or auditory word span measure [F(1, 35) = .005, p> .10]. These means and standard deviations are shown in Table 21.

Table 21

Raw scores on WISC-R digit span, and auditory word span task

		Digit	Word
Poor	M	9.50	4.33
	SD	(2.33)	(0.69)
Normal	M	8.58	4.32
	SD	(1.30)	(0.75)

Note. M Mean, SD (Standard Deviation).

Tasks, Materials, and Procedures

The nonword stimuli were based on the words used in the first study. Participants were individually tested and the order of presentation of the tasks was randomised. One experimental task was assigned to each session.

Nonword Auditory Discrimination (Input Phonology)

Thirty-six nonword pairs with consonant sounds represented by 6 single consonant letters (bĭsh / bĕsk, jŭm / făm), 6 consonant clusters (stŭp / stōme, flōsh / crĭsh), 6 consonant digraphs (thĕrb / thŭnd, cŏng / lĭng), 6 short vowel sounds (ănsle / ănfry, frăp / plăsh), 6 long vowel sounds (īlem / ītland, ănæ / ōræ), and 6 other vowel sounds (arnist / arlue, vōner / kēver) were read out to the child. The child repeated each set of nonword items in order to ensure that these had been heard correctly. The first twelve items required the child's judgment as to whether the two spoken nonwords began or ended with the same sound. For example, the experimenter would say "vŏt / yĭt". "Do these two words begin with the same sound or end with the same sound, vot / yit?" (Thus, each child heard each nonword pair twice.) The child would then repeat the word pair prior to responding beginning or end. The remaining twenty-four items required that the child listen for beginning, middle, and end sounds, such that s/he would have to determine where nonword pairs (e.g., 'stŏb / yŏck') sounded the same, i.e., at the beginning, middle, or end. There were two practice items administered prior to each set of test items. Corrective feedback was provided on the practice items, but not on the test trials. The stimuli are presented in Appendix F.

Nonword Syllable, Onset-Rime, and Phoneme Segmentation

Three nonword phonological awareness tasks were administered in the present investigation. The tasks were designed to test phonological awareness at three different linguistic levels: syllable, onset-rime, and phoneme. (These nonwords and the words on which they are based are presented in Appendices G, H, and I.)

The children were asked to repeat each nonword or nonword pair prior to performing the required segmentation. This was done to ensure that the stimuli were heard correctly, and that the children could pronounce the items. The stimuli were pronounced a second time if an incorrect or null response was given. The experimenter then pronounced the name/s of the test item/s prior to the child's segmentation of these. The three tasks measuring phonological awareness at the linguistic levels of syllable, onset-rime, and phoneme are outlined below.

A) Nonword syllable tapping.

The syllable tapping task comprised 24 nonwords. In each of these conditions half of the word pairs were based on high frequency words (occurring 20 or more times per million) and the remaining half on low frequency words (occurring 7 or less times per million). (See appendix G for comparisons of word and nonword structures.) Of these, there were 8 monosyllabic nonwords (slock, queef, gelt, brack, quiss, blaw, darp, jick), 8 three-syllable nonwords (ulsajet, delistoke, losrikal, dofamoes, roniloes, atmobaf, fenisker, goomerand), and 8 four/five syllable nonwords (renekision, alarpricipy, ajithnemic, negriberafor, jimopudars, garkonima, azdelafor, whinocilos). The nonword items (one, three, and four/five syllable) were presented in a randomised order. The experimenter pronounced each nonword. This was followed by the child's repetition of the presented item. The experimenter pronounced the test item again if an incorrect or a null response was given. The experimenter then repeated the test item prior to asking the child to tap out the number of beats/syllables (with a pencil) that could be heard in the nonword.

B) Nonword onset-rime judgment task.

The onset-rime judgment task comprised 24 nonwords. In each of these conditions half of the word pairs were based on high frequency words (occurring 20 or more times per million) and the remaining half on low frequency words (occurring 7 or less times per million). (See appendix H for comparisons of word and nonword structures.) There were 6 consonant-cluster onset pairs (prust/pross, grush/grick, stob/stip, crong/crawn, slork/sloat, brimf/brack) and 6 rime pairs (soat/loat, dake/frake, slud/klud, trill/prill, gork/lork, nart/zart).

The experimenter pronounced each nonword pair. This was followed by the child's repetition of these items. The experimenter pronounced the test items again if an incorrect or a null response was given. The experimenter then repeated the nonword items prior to asking the child to decide if the nonwords had any sounds in common, and if so, to state the common sound.

C) Nonword phoneme tapping task.

The phoneme-tapping task comprised 12 nonwords, of which 6 were CVC constructs (lan, fup, mox, yud, gak, nog), 2 CVCC (nust, kest), and 4 CCVC (flig, slup, clom, brip). Again half of the items in each condition were based on high frequency words (occurring 24 or more times per million), and the other half based on low frequency words (occurring 3 or less times per million). (See appendix I for comparisons of word and nonword structures.)

The experimenter pronounced each nonword. This was followed by the child's repetition of the presented item. The experimenter repeated the nonword if an incorrect or null response was given. The experimenter then repeated the test item prior to asking the child to tap out the number of sounds (with a pencil) that could be heard in the nonword. The child was asked to state the contained sounds once the tapping exercise had been completed. Thus, once the children tapped out the number of sounds that they detected in a word, they were asked, "can you tell me what the sounds are?"

Results

Nonword Auditory Discrimination (Input Phonology)

The total number of correct responses to the12 nonword pairs sharing a common sound at either the beginning or the end was calculated and converted to percentage form. These data were analysed by a two way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, position (beginning vs end sound judgment). The means and standard deviations are reported in Table 22.

Table 22

Auditory discrimination: Percentage of beginning and end phoneme placement in nonwords judged correctly

		Beginning	End	Total
Poor	M	90.20	93.62	91.91
	SD	(19.60)	(13.02)	(14.62)
Normal	M	94.74	92.98	93.86
	SD	(13.67)	(12.81)	(9.56)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 34) = .23, p>.10]. Similarly, the main effect of position was not significant [F(1, 34) = .08,p >.10]. There was no significant group by position interaction, [F(1, 34) = .81, p>.10].

Auditory Discrimination (beginning, middle, end sound judgment)

The total number of correct responses to the 24 nonword items sharing a common sound at either the beginning, middle or end positions of the two spoken word forms was calculated and converted to percentage form. These data were analysed by a two way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, position (beginning vs middle vs end sound judgment). The means and standard deviations are reported in Table 23.

Table 23

Auditory discrimination: Percentage of beginning, middle and end phoneme placement in nonwords judged correctly

		Beginning	Middle	End	Total
Poor	M	71.32	79.41	66.91	72.55
	SD	(19.14)	(22.07)	(17.08)	(15.53)
Normal	M	75.0	73.68	67.76	72.15
	SD	(23.57)	(19.50)	(25.79)	(16.14)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 34) = .01, p>.10]. There was no significant main effect of position [F(2, 68) = 2.46, p> .05]. There was no significant group by position interaction [F(2, 68) = .66, p> .10].

Nonword Syllable, Onset-Rime, and Phoneme Segmentation

A) Syllable tapping task.

The total number of correct responses to one, three, and four/five syllable nonwords was calculated and converted to a percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, length (one, three, and four/five syllable nonwords). The means and standard deviations are presented in Table 24.

Table 24

Percentage of one, three, and four / five syllable nonwords tapped correctly

		1 syllable	3 syllable	4/5 syllable	Total
Poor	M	63.89	94.44	88.89	82.41
	SD	(45.35)	(10.69)	(16.53)	(17.48)
Normal	M	65.63	88.75	81.25	78.75
	SD	(38.45)	(16.67)	(28.24)	(22.50)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 36) = .35, p> .10]. However, the analysis showed a significant main effect of length [F(2, 72) = 11.64, p< .001]. Post hoc Newman-Keuls tests showed that performance for 3 syllable nonwords was better than that for 1 syllable items (p<.01). Performances for 4 and 5 syllable nonwords was similarly better than for 1 syllable items (p<.05). The group x syllable length interaction was not significant [F(2, 72) = .36, p> .10].

B) Nonword onset-rime judgment task.

The total number of correct responses to nonword onset and rime items was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, condition (onset vs rime). The means and standard deviations are presented in Table 25.

Table 25

Mean Percentage of Correctly Identified Sounds in Nonword Onset-Rime Judgment Task

		Onset	Rime	Total
Poor	M	60.19	55.02	57.60
	SD	(32.91)	(42.21)	(26.0)
Normal	M	69.17	62.50	65.83
	SD	(31.19)	(35.82)	(31.29)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 36) = .77, p> .10]. Similarly, there was no significant main effect of condition [F(1, 36) = .76, p> .10]. The group by condition interaction was not significant [F(1, 36) = .01, p> .10].

C) Phoneme tapping (number of sounds).

The total number of correctly tapped items was calculated and converted to percentage form. These data were analysed by a one-way ANOVA. There was one between subjects factor, groups (Poor vs RA controls). The analysis showed a significant main effect of group [F(1, 36) =

7.69, p< .01], a result of RA controls performing better than poor readers. The means and standard deviations are presented in Table 26.

Sounds: The total number of words for which each individual phoneme was correctly identified was calculated and converted to percentage form. These data were analysed by a one-way ANOVA. There was one between subjects factor, groups (Poor vs RA controls). The analysis showed a significant main effect of group [F(1, 36) = 9.82, p< .01], a result of RA controls performing better than poor readers. The means and standard deviations are presented in Table 26.

Table 26

Percentage of correctly tapped number of phonemes, and the percentage of sounds in nonwords correctly produced (e.g., 'kest' = 'kuh', 'eh', 'suh', 'tuh')

		Tapping	Sounds
Poor	M	78.70	75.0
	SD	(16.96)	(20.0)
Normal	M	94.17	93.42
	SD	(17.33)	(17.25)

Note. M Mean, SD (Standard Deviation).

Levels of Segmentation Compared

In keeping with the assignment of examining children's performances at various linguistic levels, an analysis was carried out incorporating the nonword syllable, onset-rime, and phoneme segmentation data. Due to the apparent unreliability of one syllable items, these were again excluded from the analysis. The total number of correctly segmented nonwords from the syllable tapping, onset-rime, and phoneme identification measures was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls) and one within subjects factor, linguistic level (syllable, onset-rime, and phoneme). The means and standard deviations are presented in Table 27.

Table 27

Levels of Segmentation: Percentage of correctly segmented nonword items at the three linguistic levels of syllable, onset-rime, and phoneme

		Syllables (3, 4 & 5)	Onset-Rime	Phoneme
Poor	M	91.67	57.60	75.0
	SD	(10.50)	(26.00)	(20.00)
Normal	M	87.28	65.35	93.42
	SD	(16.75)	(32.07)	(17.25)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 35) = 2.23, p> .10]. However, the analysis showed a significant main effect for level of segmentation [F(2, 70) = 21.96, p< .001]. There was also a significant interaction between these two factors [F(2, 70) = 3.23, p< .05]. In terms of performances at the different levels of segmentation, post hoc Newman-Keuls tests again showed that the children were better at identifying the contained number of syllables in nonwords than they were at identifying onsets and rimes in spoken nonword pairs ($p<.01$). However, inconsistent with large unit theory, it was again found that children had more difficulty segmenting and identifying common onsets and rimes than they did segmenting nonwords into individual phonemes ($p<.01$). Analysis of the group x level of segmentation interaction showed that syllable segmentation was better than onset and rime identification for both poor and reading age control groups (p's <.01). Poor readers were similarly better at identifying phonemes in nonwords than shared onsets and rimes in the nonword pairs ($p<.05$). This was also true for the reading age control children ($p<.01$). Finally, reading age controls were better than poor readers at phoneme segmentation ($p<.05$). Differences were also noted in the poor readers' better awareness of syllables than phonemes ($p<.05$), which was not the case for the reading age controls, thus, producing the interaction.

Discussion

With the use of nonword stimuli children again demonstrated a better awareness at the phoneme level than at the levels of onset and rime. This contradicts the contentions of large unit theory which supports the idea of a linguistic pathway in which development is said to proceed from an awareness of larger phonological structures (e.g., syllable) through intrasyllabic units (e.g., onsets and rimes) to the serial phoneme. However, as both groups of readers identified individual phonemes more easily than they did common onsets and rimes in spoken nonword pairs, it would appear that the former skill is an earlier developing one. Nevertheless, in Scottish schools it may be that the phonic method of instruction promotes an earlier development of the awareness for smaller constructs, although it must be said that both groups of children were learning by a mixed method in which they also received tuition in noting similarities in word family groupings sharing common onsets and rimes in addition to their standard phonics curriculum. (Additional interpretation of this result was offered in Study 1, pp. 127-128.)

However, other findings from the first study were also replicated by the second investigation. These concern the children's awareness at the levels of syllable and onset and rime. In the syllable tapping task performances were again shown to be better for 3, 4, and 5 syllable items than for 1 syllable nonword structures. This finding could suggest a tendency for children to analyse single syllable items more completely, and possibly think that these are to be broken down into sub-phonemic components (e.g., 'slock' = /sl/ /o/ /kuh/). Another possibility is that some children believe that as other items have more than one division, a single tap cannot be a correct response. Thus, it might be that this perception is generated by the task of dividing the 3, 4 and 5 syllable items.

The poor readers were again as able as controls in identifying common onsets and rimes in spoken nonword pairs. However, whereas onsets were better identified than rimes in the first study, in this investigation they were identified equally well. However, although the results of this study in many ways mirror those of the first investigation, they differ in one rather important way. This concerns the poor readers' deficit in the explicit identification of phonemes following the tapping procedure. Thus, although difficulties in tapping were noted in both investigations, in the present study poor readers were less able than their controls when the contained phonemes in nonwords were to be identified. In the first study performances were quite closely matched in this regard (see Table 13, p.117). Thus, it would appear that the poor readers' difficulty in naming serial phonemes is more pronounced for nonword stimuli than for words. Equally so, it would seem that to describe these poor readers' phonological difficulties as 'mild' would be misleading, as the use of nonwords resulted in a clear segmentation deficit.

In this sense, if children are relying on a phonological approach to carry out the task then equal performance on similar items (e.g., words) should result in no group differences for nonword items. Moreover, the two types of stimuli differed only by a single altered phoneme or consonant. In CVC and CVCC words the initial consonant was substituted to create the nonwords (e.g., 'cup' became '*fup*', 'vest' became *'kest'* respectively). In two of the CCVC structures the vowel was substituted (e.g., 'flag' – *'flig'*), and in the remaining two the final consonant (e.g., 'brim' – *'brip'*). Therefore, one explanation for the poor readers' difficulty is that the use of nonwords limited the degree to which orthographic knowledge could be relied upon for making these judgments. It was earlier contended that the poor readers may make use of orthographic information, which when combined with their working knowledge of phonemes permits the 'naming' of sounds translated from stored representations of spellings. In this way, the lack of a lexical equivalent for the spoken nonwords might have limited the poor readers' use of similar strategies used in identifying phonemes in known words (e.g., '*vest*' versus *kest*). Thus, as the normal readers' levels of accuracy across the three tasks differed little for word and nonword stimuli, it could be that they are relying primarily on phonological skill. Conversely, poor readers seemed to suffer greater decrements in accuracy performance in the nonword onset-rime task, in addition to their noted drop in performance in the nonword phoneme identification task. (see Tables 14, p. 118 and 27, p. 150).

Nevertheless, although the poor readers' phonological difficulties are well documented, few investigations have endeavoured to capture what type of approach is being taken where there is evidence that a phonological strategy is not adopted. Thus, the extent to which poor readers may take a visual / orthographic approach to reading is not easily discerned. Importantly, the many reported phonological deficits for poor readers could in part stem from their application of different strategies in reading and memory tasks. For example, the poor reader might learn to recognise words on the basis of 'visual' appearance, and accordingly do not spontaneously abstract the inherent grapheme-phoneme correspondences In itself, the adoption of a more visual or orthographic approach to reading may therefore be enough to undermine the poor readers' efficiency in establishing visual-phonological connections for print in memory, which in turn could contribute to a phonological processing deficit in phonological awareness tasks. Therefore, one possibility is that the process of translating graphemes to phonemes is time consuming for poor readers and results in a loss of information as recoded forms decay. Given the poor readers' impairment in phonemic segmentation with nonwords it seemed important to establish whether such difficulties could be discerned and traced back to a slowness to apply grapheme-phoneme correspondence knowledge, moreover, whether qualitatively different approaches to reading might be taken as a result of a slowness in carrying out grapheme-phoneme correspondence translations. The idea that a slowness to generate phonological information from print might result in a visual processing bias led to the selection of a number of tasks aimed to encapsulate the use of orthographic coding strategies in printed word learning, word reading as well as in phonemic processing tasks.

CHAPTER THREE

POOR READERS' USE OF ORTHOGRAPHIC INFORMATION IN LEARNING TO READ NEW WORDS

It has already been stated that the issue of whether phonemic awareness training is causally related to the development of reading skill is unresolved (e.g., Bradley & Bryant, 1983; Fox & Routh, 1980). However, in spite of the criticisms of investigations that have attempted to address this issue, there is little dispute regarding the role played by instructional approaches which include relating sounds in words with their spelling patterns (Bradley & Bryant, 1983; Fox & Routh, 1980; Lundberg et al., 1980). In this regard, tuition that involves making links between children's phonological awareness and their experience of learning to read appears to be far more effective than training phonological skills in isolation.

Nevertheless, a number of questions about intervention programmes aimed at assisting the dyslexic child still remain. As mentioned elsewhere, some of these questions concern whether there is a reason for teaching dyslexic children differently from those who do not appear to show signs of reading difficulty; at what age the specialised tuition should commence; and at what linguistic level should the instruction be aimed (e.g., rime versus phoneme). However, although these questions are of both practical and theoretical importance, it has to be noted that the majority of intervention studies have centred on evaluating the efficacy of different training programmes on large groups of children and subsequent reading skill.

Consequently, the effectiveness of these interventions for the percentage of children within this group who do develop a reading disorder is less well known, the idea being that what appears to be significant progress for the group as a whole, is not necessarily the case for each individual. Thus, it is said that the success of an intervention on a large group may in fact mask the delayed progress of others (Snowling, 2000). Nevertheless, these types of studies are critical to the development of instructional programmes aimed at assisting the reading process for 'at risk' children before the deficit becomes too marked.

Hatcher, Hulme, and Ellis (1994) examined the effectiveness of structured interventions in improving the reading performances of a large group of 7-year-old readers who were experiencing difficulties in learning to read. The aim of the study was to examine whether an intervention that involved a combination of phonological awareness training and reading instruction would be more effective than reading instruction or phonological training alone. The three different structured teaching methods included reading with phonology, phonology alone, reading alone, (and a control condition in which the children received their regular classroom teaching without any special form of additional provision from the study). The 'reading with phonology' condition covered reading and writing in context, reading and writing words, and looking at and writing letters, in addition to phonological activities received by the 'phonological training alone' group; whose programme involved no reading, and remained purely phonological. Examples of activities for this group included the identification and supply of rhyming words, the identification of words as units within sentences, the identification and manipulation of syllables, the identification and discrimination of sounds within words, sound synthesis to form words, segmentation of words into sounds, etc. The 'reading alone' group received the same reading programme as the 'reading and phonology' group, however, without any explicit reference being made to phonology (e.g., sounds in words, letter-sound relationships). Instruction for this group was devoted to the teaching of letter names (not sounds), the usefulness of context and meaning in reading, self-checking for accuracy in reading unknown words, etc.

Each of the programmes involved the children being taught individually for forty 30-minute sessions over 20 weeks. The children's levels of phonological awareness were measured prior to the commencement of teaching, and seven months after the teaching programme was completed. The children were assessed nine months after the interventions ceased in order to evaluate any lasting effects of the intervention on reading and spelling skills. (Although the children were given general tests of intellectual ability, arithmetic and memory, only the tests of reading, spelling and phonological awareness are reported here.) Reading tests comprised word and nonword pronunciation, text reading accuracy, and comprehension in addition to standardised measures (e.g., BAS, NEALE) as a means of assessing subsequent progress. Sound deletion, sound blending, nonword segmentation, and sound categorisation tasks measured phonological skills.

The results of the analyses (at time 2) after the intervention showed that although the groups remained closely matched in single word identification (on the BAS test of word reading), the 'reading with phonology' group differed significantly from the control group, whereas the 'reading alone', and 'phonology alone' groups did not. Performance on the literacy measures proved to be even more variable. The improvements following the intervention were on the whole larger in the 'reading with phonology' group with one exception. This concerned a word recognition test, on which the 'reading alone' group also differed from the control group. Otherwise, there was no other task on which the 'phonology alone', or 'reading alone' groups were shown to make significantly more progress than the control group. The same pattern of findings was noted for spelling performance at time 2. As a corollary, all groups were equal on the test of arithmetic ability at time 2, thus demonstrating that the progress made by the 'reading with phonology' group was specific to literacy skills, and not a result of general improvement being made. Most striking, however, is that at time 3 (nine months after intervention had ceased) the 'reading with phonology' group maintained their advantage over the other experimental and control groups on the reading and literacy skills tests. Spelling skill however, was shown to be similar for all groups.

Therefore, these results demonstrate how the greatest improvements in reading appear to be made when phonological awareness training and reading are jointly approached. The 'reading alone' group did make some gains, but these were not as large as the 'reading with phonology' group. Thus, in terms of the poor reader, if more emphasis is given to the construction of a visual code in reading, then links to the word's phonology will be less well established in memory. It may therefore, be advantageous to explicitly 'draw' poor readers' attention to the relationships between individual letters and groupings in words and the corresponding sounds in acquisition training. In this way better links between orthography and phonology might be established.

Nevertheless, although studies have shown that greater gains in reading occur where phonological awareness and reading are jointly approached, it is not to say that the teaching of phonology alone will not be of benefit to 'at risk' children in the earliest stages of their reading development. Thus, although an empirical question, it is unknown whether early intervention programmes might prevent the development of what otherwise could become a developmental 'surface' or 'phonological' dyslexic type characteristic. The point is an important one as far as the poor reader is concerned because in the early developing stages a child's reliance on the visual 'whole' in printed word learning may stem from poor phonological awareness. Intervention could improve this understanding to the point that discovery of the alphabetic principle occurs, thereby altering the direction of development towards the use of visual strategies in word acquisition and in reading. The results of a longitudinal study of pre-school children conducted by Lundberg, Frost, and Petersen (1988) might serve to illustrate this point.

These children, whose curriculum at the pre-school stage included various games involving rhymes and phonemes performed better than a control group on tests of phonemic awareness one year later. This however, should not be surprising, as it has already been shown how training in 'phonology alone' can result in gains in phonemic awareness being made (e.g., Hatcher et al., 1994). This aside, what is noteworthy in the Lundberg et al. (1988) study is that the children who received the pre-school phonemic awareness training had better reading performances than the untrained group over the first three years of their schooling (as measured in seven-month intervals). Moreover, the children identified to be 'at risk' for reading failure from the pre-school training group were reported to have reached normal levels of reading in a follow up study conducted three years later (Lundberg, 1994). Thus, it would appear that 'early' phonemic awareness training alone, can impact positively on subsequent reading performance. However, this appears to be less effective than an approach in which letter-sound correspondences are emphasised in such a way that links between orthography and phonology are established.

This idea is reinforced by the results of Bradley and Bryant's (1983) study in which 'at risk' children identified at age 4 and 5 (according to their performances on a sound categorisation task) were given a two-year intervention programme at age six. Children in one group received sound categorisation training in which they learnt (through the use of pictures) how words sounded the same at the beginning (hen, hat), middle (hen, pet), or end (hen, man). The second experimental group also received this instruction, but in addition was taught with the use of plastic letters (how each of the common sounds is represented by a letter of the alphabet). The third group (a control) received semantic categorisation training with the same pictures to show how the same word could be grouped in different ways (e.g., *hen, bat* are animals, but *hen, pig* are farm animals). The fourth group did not receive any training.

Not surprisingly, the most progress was made by the alphabetic letter / sound categorisation group, again suggesting that phonological awareness training is more effective when combined with making explicit connections with the alphabet (e.g., print) than training in phonological awareness only.

The studies reviewed thus far have considered 'general' populations in which 'at risk' children have been identified prior to intervention. However, the point must be made that not all children considered 'at risk' for reading failure (because of poor performance on letter naming, phoneme identification or sound categorisation tasks) necessarily become poor readers. Quite simply, without intervention many of these children improve as these systems develop. Therefore, it is important to know what types of training procedures will promote reading skill in the slightly older child whose problems are more pronounced. One important note in this regard however, is that the skills acquired by dyslexic children in training procedures are often not transferred to new learning situations.

Lovett, Warren-Chaplin, Ransby, and Borden (1990) noted dramatic increases in the sight word vocabulary of dyslexic children following an intervention which placed a great deal of emphasis on single word recognition. However, the children did not show a similar development in their ability to abstract letter-sound correspondences, and were also unable to read words that were not part of the training programme. The results do suggest that a sight word vocabulary can develop, although this process will prove laborious and lengthy in the absence of support from phonological skills, and will require substantial exposure to printed words and feedback for pronunciations and meanings.

Nevertheless, some transfer of learning has been noted in other investigations where the focus of the instruction has also been on sub-syllabic as well as whole word levels. Lovett, Borden, DeLuca, Lacrerenza, Benson, and Brackstone (1994) examined the efficacy of two separate interventions relative to the performance of a control group who received tuition in a variety of study skills. One experimental group was given phonological analysis, synthesis of printed words, and letter-sound correspondence training. The other experimental group's programme focused on the acquisition of word recognition through reading by analogy, decomposing words into known and unknown components, removing prefixes and suffixes, and attempting different enunciations for contained vowels. Instruction was delivered to pairs of children over 35 one-hour sessions.

The results of this investigation showed that both of the experimental groups made better progress than the control group in letter and word recognition for trained words. Notably, transfer of learning occurred in the two experimental groups' reading of new words that had been based on the training words. Transfer was also shown in the reading of various regular words. However, differences between the two experimental groups were noted in tests of nonword and irregular word reading, in which the phonological analysis group performed better on nonwords, and the larger unit group on irregular words. Thus, these interventions effected very specific changes in these two groups' abilities for reading regular words and nonwords versus irregular words relative to the type of instruction that each group received.

Lovett, Ransby, Hardwick, Johns, and Donaldson (1989) reported similar results in an earlier study in which training in word recognition and decoding skills was given to one group, and oral and written language skills training to another. The control treatment condition consisted of training in social skills, classroom etiquette, life skills, etc. The results showed that the 'decoding skills' treated children made significant gains in both regular and irregular word reading, and that this growth was greater for irregular words. Given that instruction for regular words in this group involved the use of word family groupings (e.g., jade, fade, made) in which letter sound mappings were emphasised, and irregular words taught by 'sight' methods alone (rehearsed individually), it would appear that the reduced attention given to the 'lexical' whole in the former word types resulted in these regular words being less well learnt than the exception words. Therefore, in terms of the poor reader, perhaps a programme that focuses on repeated attention being given to individual words is necessary for the acquisition of both regular and exception words alike. It has already been mentioned how poor readers might learn to recognise words visually, and therein fail to abstract grapheme-phoneme relationships.

These types of results therefore, have important implications for understanding how methods of instruction can influence behavioural reading patterns. On the one hand, a large unit approach which places little emphasis on letter correspondences at the phoneme level might result in a pattern of reading performance that fits the phonological dyslexic profile. Conversely, it would appear that finer grained instruction in phonetic analysis can influence nonword reading, but might be less effective for the identification of irregular words, thus producing a surface dyslexic type profile. A whole word reader may therefore, adopt this strategy because they have not been alerted to the alphabetic nature of the English spelling system. This would lead to weaknesses in nonword reading. Thompson and Johnston (2000) noted that children from New Zealand exhibited this very pattern in reading, i.e., they were weaker in nonword reading than phonics taught Scottish children because in New Zealand children are taught by a whole word method. The poor readers in this study were found to have deficient nonword reading skills relative to phonics taught reading age controls, but not when compared with the non-phonics controls. In this sense dyslexia can almost be spoken about in terms of being a product of instruction or 'learnt' disorder. Indeed the suggestion has been made elsewhere (Snowling, 2000).

Accordingly, a child's reading profile might be shaped by the method of tuition in the early stages of formal reading instruction (e.g., whole word or phonics-based curriculum), which for some children results in a reading problem. Therefore, because intervention may not occur at an early enough stage it is conceivable that a child will continue to read words visually. As this visual approach comes to predominate in the poor reader's word acquisition and identification strategies, any formerly existing phonological skill is likely to deteriorate and the phonological deficit will become more marked.

Importantly, the Lovett et al (1989, 1994) interventions demonstrate how change was effected in selected skill areas (e.g., letter-sound correspondence knowledge and whole word reading) relative to the type of intervention that was given (e.g., phonological analysis and larger units respectively). However, a particular problem with these approaches is that they involve group studies, aimed at examining the effectiveness of different interventions. Thus, it is not known how effective these interventions have been for each of the children within the given groups. As such, the individual differences hypothesis (Stanovich, 1988) should not be overlooked, as no specific single treatment will generalise to all dyslexic children for whom different cognitive profiles are known to exist. Even where the specific areas of difficulty have been isolated in individual cases, and highly specific intervention treatment programmes applied, it has been noted that improvements were made only in the reading of treated words (e.g., Broom & Doctor, 1985; Seymour & Bunce, 1992).

Broom and Doctor (1995) investigated the effects of a remedial training programme in an 11 year-old boy (DF) with a surface dyslexic profile who had failed to develop orthographic reading skills. Assessing DF on various tasks including word and nonword reading, regular versus irregular words, and homophone matching established this profile. For example, words and nonwords (derived from the words) were read equally well, thus suggesting a phonological strategy in reading. DF was similarly better at reading regular than irregular words, and made a number of regularisation errors in the reading of the latter type words (e.g., 'steak' read as '*steek*').

Together these results provided evidence for the efficiency of the sublexical channel relative to the lexical route. The use of phonological strategies in reading was further exemplified in a homophone definition task (in which subjects are required to define regular and irregular visually distinct words which share the same phonological code, e.g., write / right). In this task DF's definitions matched his given pronunciations irrespective of whether the word was identified correctly, for example, in reading 'SOUL' as 'soil' defining it as something in the garden. This result provided evidence that word meanings were derived from DF's phonological interpretation of what the word was rather than from a direct association with representations in the visual lexicon. A spelling test showed a similar pattern of reliance on phonological strategies, where DF had a preponderance of phonetically appropriate errors for words that he was able to read (e.g., 'clok' for 'CLOCK'). According to Frith (1985), this is typical of children who have failed to develop orthographic representations but make use of their alphabetic knowledge in spelling tasks.

Given this type of information the aim of the intervention programme was not only to facilitate DF's acquisition of a visual reading strategy (e.g., in order to establish visual representations in the lexicon), but also to foster direct connections between a word's visual form and corresponding meaning. A pre-therapy stage in DF's intervention programme focused on 144 'mildly' irregular (e.g., villain) and 'very' irregular (e.g., sword) words that were presented to him on three occasions in one-week intervals. The homophone definition task was used alongside various other standardised (unrelated processing) tests (e.g., receptive language, reading comprehension and arithmetic) as control materials in the pre-therapy stage. The set of words on which DF would be trained (in the remediation phase) was constructed by eliminating words that he had correctly identified (in the pre-therapy stage) more than once in the three presentations, words that he could spell correctly, and words that he could not define. This left 66 words, which were separated according to matched frequencies into six lists to be used in the remediation programme. This programme involved a series of stages in which practise was undertaken in naming, defining, writing while naming the contained letters, re-naming using the word in a sentence, etc. (See Broom & Doctor, 1985 for procedural description.)

The first phase of therapy was spread over three sessions and involved working with one set of training lists (e.g., 1, 2, 3), but not the other (e.g., 4, 5, 6). Each of the three sessions therefore included working on a single list only (e.g., 1, 2, or 3). In the second phase the reverse was done, i.e., lists 4, 5, and 6 became the treated lists and 1, 2, and 3 were untreated. Between these two phases of therapy the reading of the 144 words from the pre-therapy stage was given, in addition to the control tasks. Post therapy involved re-testing on the 144 irregular words and the control tasks.

The effect of therapy on the training sets of irregular words was examined on treated and untreated lists at the end of each session of therapy. This showed a significant improvement for trained words relative to untreated lists in the first phase of therapy (i.e., performance on lists 1, 2, and 3 was better than on lists 4, 5, and 6). This improvement was also noted in the second phase of therapy in which lists 4, 5, and 6 became the treated sets of items. Importantly, at this stage there was no difference in DF's performance for the two sets of lists, thus demonstrating that his performance for the earlier treated lists (1, 2, and 3) had been maintained. Examination of performance on the total list of irregular words (144 items) also showed improvement between the pre-therapy and post-therapy phases, however, this was due to the increased performance for treated items only. Thus, although this training programme demonstrated the extent to which an individual's ability to read treated words can improve, it did little to effect changes in processing strategy. The authors claim that this was most evident in the lack of change in DF's performance on the homophone definition task, where one would expect to see fewer homophone decision errors being made if changes in processing strategy had occurred. The fact that these errors did not change implies that there was no alteration of strategy for accessing word meanings (i.e., semantic information) by virtue of a phonological code.

Thus, although therapy was shown to cause a quantitative change in DF's performance on treated irregular words, there was no qualitative change in the approach taken to untreated items since these effects were specific to trained items only, and did not generalise to untreated words. The authors add that it is not even known whether orthographic representations for the treated items had been formed (Broom & Doctor, 1985). They also suggest the possibility that the treated items became a 'response set' similar to the early reading vocabulary of beginning readers in the logographic stage of their development. Thus, the words could have been recognised on the basis of salient visual features and some alphabetic information as opposed to being recognised at the orthographic level.

Similar results are reported in Seymour and Bunce's (1994) case studies of two 8 year-old boys, one of whom demonstrated a phonological dyslexic profile (DK), and the other a surface dyslexic pattern (RC). Interestingly, although the two boys limitations in reading would appear to require different approaches to remediation, similar programmes were prescribed. The boys' profiles were largely determined by virtue of a word and nonword reading contrast, in which DK showed substantially poorer performance in the reading and spelling of nonwords relative to words, whereas RC showed a smaller word / nonword difference in reading and better spelling of nonwords relative to words. Other indication of contrast between the two boys' profiles was noted in reaction time data for word and nonword length, in which RC showed very high values compared to DK, thus suggestive of RC's use of a phonological reading strategy in contrast to DK's visual approach and resulting reduced effect of length on reaction time. RC had higher error rates on irregular words, was prone to using letter-sound knowledge to pronounce these, and produced a large number of phonetically appropriate errors in spelling. In contrast, DK's spelling errors were dysphonetic, and his reading responses for unknown words included word substitutions rather than evidence of a phonological strategy (e.g., attempts at sounding out).

Although at first glance it would seem that a programme for DK should include sound, letter and phonological awareness training to treat the underlying causes of his difficulties, and conversely a programme of rapid whole word recognition for RC, the authors point out that this type of approach is less appropriate for older children who already possess a basic knowledge of letter-sound correspondences and a partial sight vocabulary. Accordingly, the intervention adopted a direct approach (to treat the problem rather than the causes) by attempting to establish an orthographic structure through a variety of standard teaching techniques, which included specific controls on cognitive areas (reading / spelling, lexical / nonlexical) and organisation (syllabic forms as initial consonants, vowels, and terminal consonant structures). (See Seymour & Bunce, 1995 for a detailed review of this structure, and for reference to pedagogic techniques.)

Large gains in nonword reading and spelling were noted for DK (phonological dyslexic profile) following two teaching phases. Gains were also made in word reading and spelling in spite of DK's programme having a nonlexical (nonword examples) focus. Improvements in spelling were greater than for reading, however, the word/nonword contrast remained across tasks, thus suggesting that although the intervention impacted significantly on DK's spelling ability the word / nonword reading discrepancy was unchanged. In contrast, RC (surface dyslexic profile) showed improvements in the number of errors for word and nonword scores in both reading and spelling. The word / nonword discrepancy that was apparent at the beginning of instruction was no longer significant at the end of the intervention.

Subsequent tests on the word and nonword lists used in the original assessment were again administered on two occasions with a four-week separation following the intervention. DK's performance on nonwords was greatly improved with larger effects noted for spelling over reading. However, the contrast between words and nonwords in reading remained large. However, although word reading appeared to involve the same approaches in the post-test stage, the same could not be said for nonword reading as accuracy improved alongside of an increase in response times for nonwords. Thus, although treatment did not effect changes in RC's processing strategy, improvement was noted in his performance for untreated items. In contrast, DK did show a change in his reading strategy. The authors concluded that although RC already possessed an orthographic framework, correction of deviant lexical forms needed to take place. DK did not possess such a framework, but developed a system for spelling when assisted with orthographic structure. Thus, it appears that the direction of intervention along similar lines for both of these contrasting cases was justified.

It has been discussed how the greatest gains in intervention studies have most notably been made when phonological awareness training and reading are jointly approached. It has also been noted how this type of intervention has been beneficial to readers identified to be 'at risk' in their early stages of reading development. However, for older children whose problems have become more defined the nature of the intervention that is to be applied is less clearly defined. Part of the reason might be that as compensatory strategies are developed the phonological deficit becomes more marked, and consequently, less responsive to a programme that is phonics intensive. On the one hand, it appears that fine-grained instruction in phonetic analysis can influence nonword reading, but might be less effective for the identification of whole or irregular words. In contrast the Lovett et al. (1990) study in which a great deal of emphasis was placed on single word recognition suggested that a sight word vocabulary can develop, but often requires substantial exposure to printed words and feedback for pronunciations and meanings. Similarly, a focus on larger word parts might not facilitate the ability to abstract letter-sound correspondences. Nevertheless, the Lovett et al. (1989) results suggest that a programme which involves repeated attention being given to individual words might be necessary for the acquisition of both regular and exception words.

Either way, it is likely that a preferred visual strategy of the older poor reader will predominate over phonological approaches to reading unless highly specific measures are taken to improve skill in the affected area. As mentioned elsewhere, 'whole' word readers may adopt this strategy because they have not been alerted to the alphabetic nature of the English spelling system. This would lead to weaknesses in nonword reading. Therefore, if the poor reader does in fact give more emphasis to the construction of a visual code in reading, then links to the word's phonology will be less well established in memory. It may therefore, be advantageous to 'draw' poor readers' explicit attention to the relationship between individual letters and groupings in words and the corresponding sounds, especially in the acquisition stage. In this way better links between orthography and phonology might be established.

Overall, as poor readers are known to display qualitatively different patterns in reading (e.g., phonological versus surface characteristics), it follows that there will also be variation in their individual strengths and weaknesses. The underlying cognitive deficit in dyslexia is said to reside at the level of the phoneme. Consequently, the poor reader will make use of various strategies to compensate for their phonological difficulties. Thus, even though poor readers might demonstrate adequate facility in phonological tasks for reading age, it is believed that residual deficits will be seen on certain phonological processing measures (Morton & Frith, 1995). For example, the case might be that they exhibit slower rates of processing for phonological materials in spite of their general levels of accuracy for reading age. The implications of this are that a slowness to generate pronunciations for letters, words and nonwords would indicate impairments in automaticity in generating phonological information from print. This slowness would suggest that sub-lexical approaches, such as recoding letters to sounds to pronounce the items would be more laborious than trying to read words visually.

Thus, the evidence which suggests that poor and normal readers' learning processes as a whole may be qualitatively different appears sufficient enough to warrant further investigation. Moreover, with indication of the poor readers' preference for the use of orthographic rather than phonologic coding strategies in other reading-based tasks (Holligan & Johnston, 1988; Rack, 1985), it seems likely that the word recognition strategies of these readers must somehow differ, similarly, their development of codes and acquisition in general. Additionally, although there is a certain amount of information regarding the role of visual and verbal processes in identification or recognition tasks, little is known about the contributions made by these two processes in acquisition. Consequently, there is little, if any evidence to suggest what the learning curves resemble for poor and normal readers in acquisition. It therefore, appears fruitful to consider the possible differences in the reading strategies of poor and normal readers in acquisition tasks, from which a theory of acquisition or an account of failure in reading can be postulated.

Another reason for such an investigation stems from the need to examine the issue of applied strategies and possible processes involved in acquisition for children arrested at various stages of development. Thus, beyond the implications of a reader's arrestment at a particular stage, there is little account of how older poor readers (who have been afforded schooling of longer duration, and in most instances increased remedial tuition), approach the learning of words relative to reading age controls. In short, given the poor readers' developmental advantage it cannot be assumed that their progression would resemble that of the younger early beginning reader. In this sense it has been asked whether the poor readers' codes applied in acquisition and recognition qualitatively differ for reading age.

This study examines the approach poor readers take to learning new print vocabulary, to see if it differs qualitatively from that of reading age controls. It is possible that in the initial stages of acquisition, poor readers' emphasis may be on the visual form of words, whereas reading age controls might be better at developing phonological representations for the new items, and developing connections between the visual and phonological forms. This leads to the prediction that poor readers will be better able than controls to identify the unfamiliar words being learnt in a visual recognition task, but to have impaired auditory memory for the items. They should also show slower improvement in their ability to learn to pronounce the unfamiliar words accurately.

A battery of tasks was administered to examine whether poor readers show phonological deficits on a range of reading and reading related tasks, i.e., in regularity, nonword reading, and phonemic awareness tasks. A speeded letter name / letter sound recognition task was used to see whether difficulties in novel word reading could be traced to a fundamental slowness in extracting phonemic information from print. Visual segmentation skills were assessed to examine whether poor readers showed superior visuo-spatial skills for reading age. A nonword repetition task was given as a measure of phonological working memory.

Study 3(a)

Method

Study three carried on with the same participants from the previous examination reported in Chapter Two (for Participant characteristics see Table 20, p. 137). Participants were individually tested and the order of presentation of the tasks was randomised. One experimental task was assigned to each session.

Nonword Acquisition Task

The stimuli comprised six nonwords presented (individually) in 18pt font on index cards. Three of the six nonwords shared a common orthographic pattern (e.g., 'oa' in gaboatok, gapoatok, ganoatok), and three were individually unique (e.g., 'ou', 'oi', and 'ai' in renoudel, yamoiter, and nuraipog, respectively). The purpose of having one of the four vowel digraphs repeated in three of the nonwords was to examine whether there would be faster rates of word learning for these stimuli due to the common orthographic (i.e., repeated spelling) pattern. There were four different stimulus sets, allowing each of the four vowel digraphs (i.e. oa, ou, oi, ai) to comprise the orthographically similar nonwords, and thus control for possible vowel digraph effects (e.g. 'oa' being better known that 'oi'). Pilot work showed that children of this reading level have some difficulty in accurately reading vowel digraphs, so both groups had their attention drawn to the vowel digraphs during the training procedure, and corrective feedback was given. The order of presentation of these sets was counterbalanced across participants. The stimulus sets are shown in Appendix J.

1). Pre-test (vowel digraph reading ability).

a) The child was shown one of four randomly selected vowel digraph cards, e.g., *ai* and asked, "what sound do you think is made by these two letters?" (No corrective feedback was given for this reading.) The same was then done for cards bearing digraphs ou, oi, and oa.

2). Pre-test: (nonword reading).

a) The child was then shown one of the six nonwords, e.g., **gaboatok** and asked, "how do you think this word might sound"? As an example, a child's response might have been "gab-ŏ-tok" (an incorrect reading). In this case the child was given the correct reading, "gab-ō-tok", and then asked, "can you say that word?" The child repeated the word correctly before being asked:

b) "what sound do you think is made by these two letters?" (with *gab*, and *tok* being covered by the experimenter's fingers,) e.g., ~~gab~~ **oa** ~~*tok*~~ Any necessary corrective feedback was provided for the vowel reading. Then the second of the six nonwords was shown to the child to be read, followed by his/her reading of the vowel digraph, and so on. The same was then done for the remaining nonwords and their digraphs, following the procedure above. (The nonwords were randomly selected.)

3). Training (in nonword reading)

The purpose of the training stage was to examine the effects of practice on the children's reading of the six nonwords. Thus, as in 2(a) (see above) the child was shown one of the six nonwords (selected randomly, e.g., gapoatok) and asked to read it. If the reading was correct, the child was simply asked to read the word again for practice. If the reading was incorrect the child was given the correct pronunciation and asked to read it again for practice. After the second reading the child was asked to state what sound was made by the vowel digraph (as in 2(b) above), receiving corrective feedback if incorrectly read. This training format was then applied to each of the remaining 5 nonwords. The child then rested for three minutes before proceeding to the next stage ('testing') in order to ensure that responses to test stimuli were not based on immediate recall from short-term memory recall. (This rest period generally involved discussion of an unrelated activity, e.g., sport, hobby, school event.)

4). Testing (at the end of each learning trial).

a) Auditory Memory: Following the three minute rest, the child was asked if he/she could remember any of the words being learnt. This free recall measure served as an indication of the degree to which children were forming phonological representations for the words that they were being taught.

b) Visual Recognition Memory: The child was then presented with 5 cards (see below), one of which was the target stimulus (e.g., gaboatok), the remaining 4 being distractor items (e.g., gabaotok, gabowtok, faboatok, gaboatof). The cards were placed face up in front of the child in a random arrangement. The child was then asked to "look at the words, and try to pick the one that you read earlier". (Target and distractor items are shown in Appendix K.)

gaboatok
faboatok
gabaotok
gaboatof
gabowtok

c) Nonword Reading: The child was then asked to read his/her recognition memory choice. However, if the child selected a distractor on the recognition memory component, the five cards were shuffled and the 'target' item presented to be read. This was done in order to create an equal number of readings for target stimuli for all participants. A two-minute rest period followed before returning to the training stage (3 above) to start the *second* trial. The six nonwords were read as for Trial 1 with feedback being given. They were also asked to read the vowel digraph in isolation, with corrective feedback as before. This training 3) and testing format 4) was repeated for a total of six trials, or until criterion had been reached. Criterion was set at the correct selection of all six nonwords in the visual recognition task, and the child's correct reading of these six nonwords for two consecutive trials.

Results

Nonword Acquisition

1). Pre-test (vowel digraph reading ability).

The total number of correctly read vowel digraphs (e.g., ou, ai, oa, oi) was calculated. A one-way ANOVA was conducted on these data with one between subjects factor, groups (Poor vs RA Controls). The analysis showed no between group differences [$F(1, 36) = 1.83$, $p > .10$]. The means and standard deviations are presented in Table 28.

2. Pre-test: (nonword reading).

The total number of correctly read nonwords was calculated. These data were analysed by a 2-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA Controls), and one within subjects factor, wordtype (orthographically similar vs orthographically dissimilar stimuli). The means and standard deviations are presented in Table 28.

The main effect of group was significant [F(1, 35) = 4.25, p< .05]. This was a result of RA controls' first reading of the nonwords (at introduction) being more accurate than the poor readers'. There were no differences in accuracy for the reading of orthographically similar stimuli over orthographically dissimilar items [F(1, 35) = 0.74, p> .10]. The group by wordtype interaction was not significant [F(1, 35) = 0.74, p> .10].

Table 28

Mean number of correctly identified vowel digraphs (VD) and orthographically similar (OS) versus orthographically dissimilar (OD) nonwords in the pre-test (introductory) stage

		Vowel Digraph	OS nonwords	OD nonwords
Poor	M	1.33	.556	.278
	SD	(1.19)	(.856)	(.575)
Normal	M	1.89	.895	.895
	SD	(1.33)	(.994)	(.937)

Note:OS = Orthographically similar, OD = Orthographically dissimilar, M Mean, SD (Standard Deviation).

3). Training (in nonword reading).

The children received a maximum of six training sessions unless criterion on the visual recognition and nonword reading tasks was reached in testing (section 4 in procedure). Two poor readers and two RA controls reached criterion by the fourth trial in testing; thus, all of the remaining children had to carry out six training and testing trials. The number of trials to criterion on individual tasks was calculated for the subsequent analyses.

First reading: The total number of trials needed to reach criterion reading the two types of nonwords (orthographically similar vs orthographically dissimilar) was calculated for each participant, using their scores from their first attempt at the start of each training session. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, wordtype (orthographically similar vs orthographically dissimilar stimuli). The means and standard deviations are presented in Table 29.

The analysis showed a significant main effect of group, poor readers taking more trials to criterion than controls [$F(1, 35) = 11.87$, $p < .01$]. There was also a significant main effect of wordtype as orthographically similar items were learnt in fewer trials than orthographically dissimilar items, [$F(1, 35) = 11.72$, $p < .01$]. The interaction between groups and wordtype was not significant [$F(1, 35) = .11$, $p > .10$].

Second reading: The total number of trials needed to reach criterion in the second (e.g., practice) reading of the two types of nonwords (orthographically similar vs orthographically dissimilar) was calculated. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, wordtype (orthographically similar vs orthographically dissimilar stimuli). There was no significant main effect of group [F(1, 35) = 1.97, p> .10], or wordtype [F(1, 35) = 1.58, p> .10], and no interaction between these factors [F(1, 35) = 0.52, p> .10]. The means and standard deviations are presented in Table 29.

Vowel digraph reading: An analysis was also made of how long it took the children to learn to read the vowel digraphs in isolation accurately, comparing the trials to criterion for orthographically similar vs orthographically dissimilar items. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, digraph (orthographically similar vs orthographically dissimilar stimuli). The means and standard deviations are presented in Table 29.

Table 29

Mean number of trials to criterion in the first reading, second (practice) reading, and reading of isolated vowel digraphs for orthographically similar (OS) and orthographically dissimilar (OD) nonwords in training trials

		1st Reading		2nd Reading		Vowel Digraph	
		OS	OD	OS	OD	OS	OD
Poor	M	8.83	12.28	1.78	1.38	1.44	4.22
	SD	(6.75)	(6.31)	(4.23)	(4.38)	(4.37)	(6.05)
Normal	M	4.05	6.89	.263	.158	.211	1.63
	SD	(4.68)	(2.42)	(.653)	(.502)	(.535)	(2.34)

Note:OS = Orthographically similar, OD = Orthographically dissimilar, M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 35) = 3.09, p> .05]. However, the analysis showed a significant main effect of digraph as the repeated vowel digraphs (e.g., orthographically similar set) were read more accurately (and therefore learnt in fewer trials) than dissimilar digraphs [F(1, 35) = 10.01, p< .01]. There was no significant interaction between groups and wordtype [F(1, 35) = 1.05, p> .10].

4). Testing.

a) Auditory Memory: The total number of trials to criterion for each category of nonword (orthographically similar vs orthographically dissimilar) was calculated. These data were analysed by a 2 way repeated measures

ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, wordtype (orthographically similar vs orthographically dissimilar stimuli). The means and standard deviations are presented in Table 30. (The auditory memory performance of these two groups over the six trials is shown in figure 1.)

The main effect of group was significant [$F(1, 35) = 5.32$, $p < .05$]. This was a result of RA controls overall having fewer trials to criterion than poor readers. Thus, controls would appear to have faster rates of learning in terms of establishing phonological codes for words being learnt. The analysis also showed a main effect of wordtype as a result of fewer trials to criterion being required for the recall of orthographically similar nonwords than for orthographically dissimilar items [$F(1, 35) = 5.45$, $p < .05$]. The interaction between groups and wordtype was not significant [$F(1, 35) = 0.20$, $p > .10$].

b) Visual Recognition Memory: The total number of trials to criterion for each category of nonword (orthographically similar vs orthographically dissimilar) selected on the visual recognition memory task was calculated. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, wordtype (orthographically similar vs orthographically dissimilar stimuli). The means and standard deviations are presented in Table 30. (The visual recognition memory performance of these two groups over the six trials is shown in figure 2.)

The main effect of group was significant as a result of poor readers having fewer trials to criterion than controls in the selection of target stimuli in the visual recognition memory task [F(1, 35) = 26.72, p< .001]. There was no significant main effect of wordtype [F(1, 35) = .042, p> .10]. The interaction between groups and wordtype was not significant [F(1, 35) = .016, p>.10].

c) Reading of Target Stimuli: The total number of trials to criterion for each category of correctly read nonword (orthographically similar vs orthographically dissimilar) was calculated. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, wordtype (orthographically similar vs orthographically dissimilar stimuli). The means and standard deviations are presented in Table 30. (The nonword reading performance of these two groups over the six trials is shown in figure 3.)

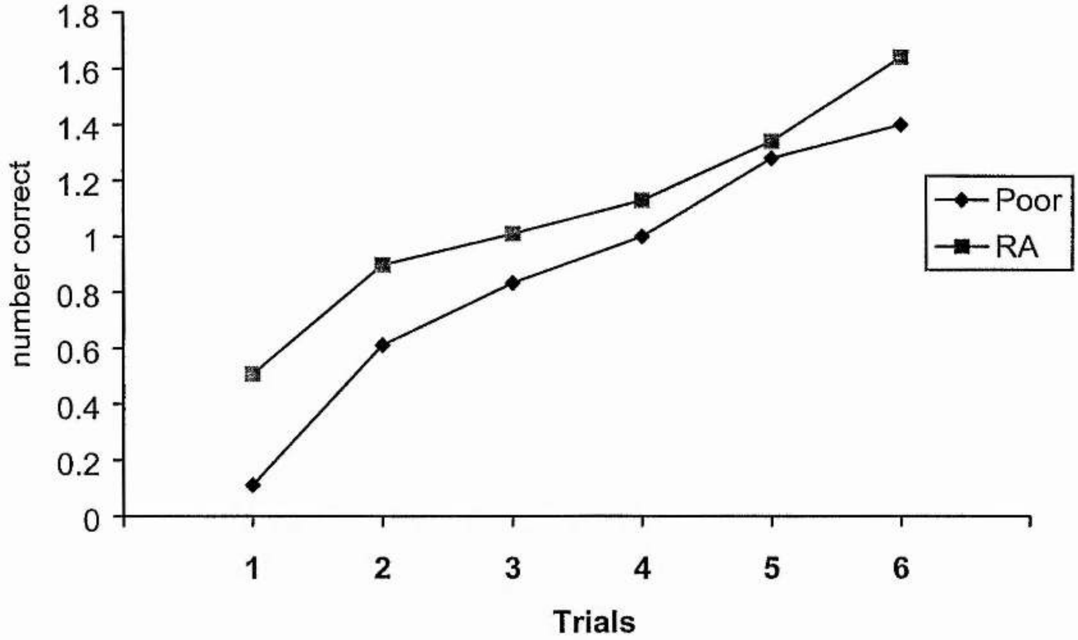
The main effect of group was significant as a result of controls having fewer trials to criterion than poor readers in the reading of nonword target stimuli [F(1, 35) = 11.22, p< .01]. The analysis also showed a significant main effect of wordtype as a result of orthographically similar nonwords being learnt in fewer trials than orthographically dissimilar nonword stimuli [F(1, 35) = 7.72, p< .01]. The interaction between groups and wordtype was not significant [F(1, 35) = .281, p>.10].

Table 30

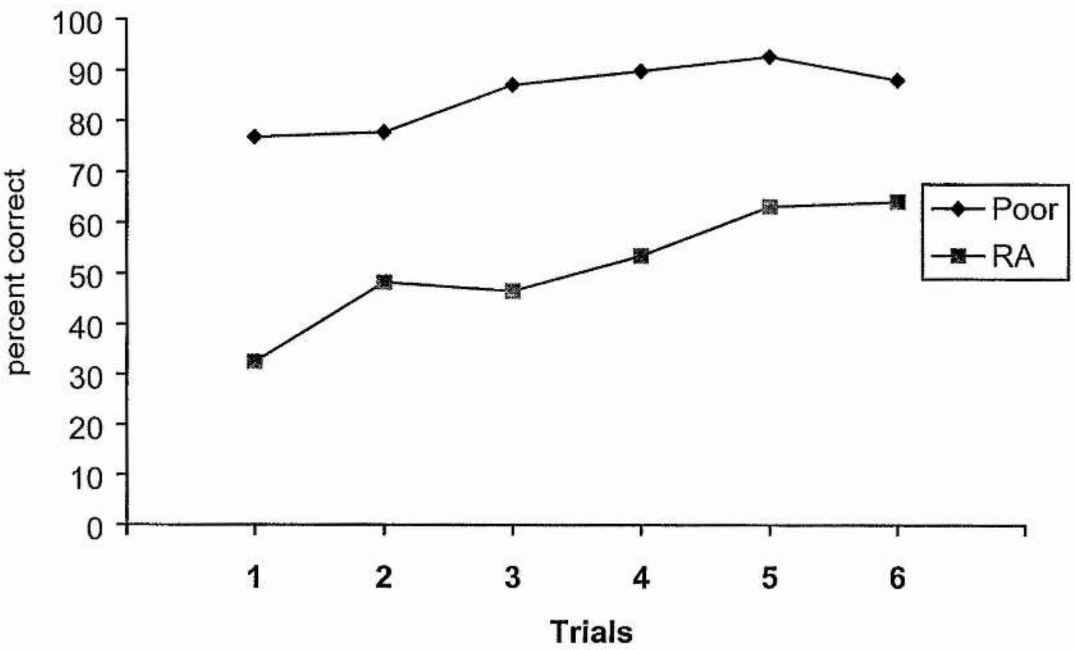
Mean (M) number of trials to criterion (from a possible 18) in the auditory recall (AR), selection of target stimuli on the visual recognition memory (VRM) task, and the reading of target stimuli (RTS): SD (standard deviation)

		AR		VRM		RTS	
		OS	OD	OS	OD	OS	OD
Poor	M	15.50	16.61	3.11	3.33	7.89	10.44
	SD	(4.25)	(1.94)	(4.97)	(5.15)	(7.14)	(5.84)
Normal	M	13.16	14.79	11.26	11.32	3.05	4.79
	SD	(3.72)	(2.70)	(5.23)	(5.29)	(4.86)	(2.35)

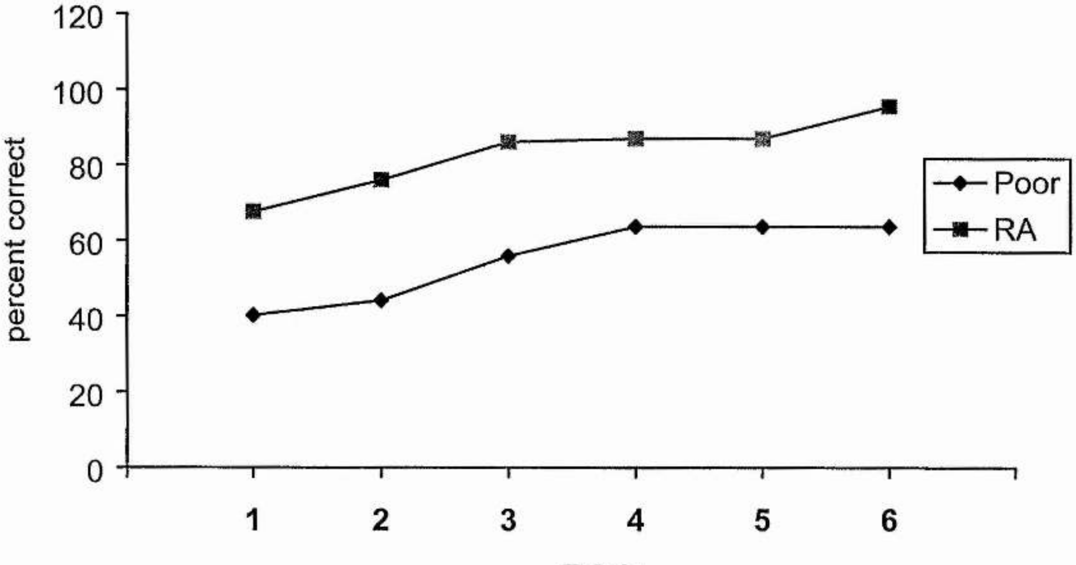
Note:OS = Orthographically similar, OD = Orthographically dissimilar



~~Figure 1.~~ Mean number of correctly recalled nonwords (from a possible total of six) in auditory (free) recall component of nonword acquisition task over six trials.



~~Figure 2.~~ Mean percentage of correctly selected nonwords in visual recognition component of nonword acquisition task over six trials.



~~Figure 3.~~ Mean percentage of correctly read target nonwords in nonword acquisition task over six trials.

Summary

Although it was found that the poor readers were slower than controls to learn to read the set of nonwords accurately, and had poorer auditory memory for the items, they were much better at identifying these items in the visual recognition task. It seems therefore that the poor readers developed a visual representation of the items more quickly than their controls, but established phonological representations more slowly. The auditory memory impairment, however, may be a direct consequence of being less competent at generating a correct reading of the nonwords.

Given that the poor readers showed better visual recognition of the nonwords than controls, the question arises whether a preference for the use of visual codes is a default outcome of the poor readers' inability or inefficiency in their use of phonological codes. The following tasks were selected in order to establish whether the poor readers' word reading skills might show evidence of a more visual or orthographic approach to reading than that of reading age controls. Furthermore, it was necessary to establish whether there was evidence of their difficulties stemming from an underlying phonological deficit, either in terms of accuracy and/or speed.

Study 3(b)

Method

Regularity Task

The regularity task was used to assess whether poor readers take a phonological approach to reading, i.e., would the size of their advantage in reading regular versus irregular words be similar to that of reading age controls? The stimuli were selected from a list devised by Holligan and Johnston (1988), based on the items used by Waters et al (1984). It consisted of 56 monosyllabic words, which were divided into four categories: (1) high frequency regular words; (2) low frequency regular words; (3) high frequency irregular words, and (4) low frequency irregular words. Frequencies were gauged according to the Carroll, Davies, and Richman (1971) norms, as appropriate for reading age. Test items are presented in Appendix L.

The words were presented one at a time in the centre of a computer screen in large lower case letters. The order of presentation of the words was varied, with no more than three items of the same type appearing in sequence. Six practice items (consisting of three regular and three irregular words) were given prior to the commencement of the test trials. Corrective feedback was only given on practice items. Children were instructed to read the words as quickly and accurately as possible. A voice key was used to measure latencies.

Auditory Rhyme Judgment

While the auditory rhyme judgment task was used to assess overall rhyme ability, there was an additional interest in examining the degree to which rhyme judgment skill would be affected by orthographic similarity, as has been the case with print (Holligan & Johnston, 1988; Rack, 1985). The stimuli were adopted from Duncan and Johnston (1999) and consisted of 60 rhyming and non-rhyming monosyllabic word pairs categorised according to the following four structural properties: 1) orthographically similar rhyming word pairs, e.g., town-down; 2) orthographically dissimilar rhyming word pairs, e.g., food-rude; 3) orthographically similar nonrhyming word pairs, e.g., lost-post; 4) orthographically dissimilar non-rhyming word pairs, e.g., boil-safe. The experimenter read out each word pair and the child's task was to state whether or not the words rhymed. Four practice trials were given prior to the test trials. Corrective feedback was provided only on practice items. The word pairs were presented in a fixed random order from one of four lists that were counterbalanced across participants. Test items are presented in Appendix M.

Phoneme Deletion

The phoneme deletion task used in this study is the same as that presented in Chapter Two, p. 96 (Duncan and Johnston, 1999). The stimuli are presented in Appendix B.

Nonword Repetition

The nonword repetition task was used as a test of immediate phonological memory. The task is the same as that used in the initial investigation presented in Chapter Two, p. 102 (Gathercole & Baddeley, 1989). The stimuli are presented in Appendix C.

Results

Regularity Task

Accuracy: (Two children from the poor reader group were not available for testing.) The total number of correctly read words from each of the four categories was calculated and converted to percentage form. These data were analysed by a three-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA age controls), and two within subjects factors, regularity (regular vs irregular words) and frequency (high vs low frequency words). The means and standard deviations are presented in Table 31.

Table 31

Poor and reading age controls' mean percentage correct reading responses for regular and irregular high and low frequency words

		Regular Words		Irregular Words	
% correct		High	Low	High	Low
Poor	M	92.21	75.77	83.81	63.03
	SD	(7.86)	(21.91)	(16.63)	(14.43)
Normal	M	93.18	73.19	79.32	48.54
	SD	(8.47)	(22.88)	(16.48)	(16.33)

Note: M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 33) = 1.31, p> .10]. However, there was a main effect of regularity, as more correct responses were given for regular than for irregular words [F(1, 33) = 92.37, p< .001] and an interaction between these two factors [F(1, 33) = 7.83, p< .01]. Newman-Keuls post hoc analysis of the group x regularity interaction showed that regular words were read better than irregular words by both the poor reader and reading age control groups (p<.01). However, poor readers were more accurate than controls in the reading of irregular words (p<.01).

There was a main effect of frequency, with high frequency words being read better than low frequency words [F(1, 33) = 156.12, p< .001]. The group by frequency interaction approached significance [F(1, 33) = 3.70, p= .063]. None of the other effects was significant (F > .10).

Latency: (One RA control case was rejected because of missing data due to incorrect and early triggered responses.) The total number of response times for correctly read items from each of the four categories was calculated and converted to a percentage form. These data were analysed by a three way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and two within subjects factors, regularity (regular vs irregular words), and frequency (high vs low frequency words). The means and standard deviations are presented in Table 32.

Table 32

Poor and reading age controls' mean reaction times to regular and irregular high and low frequency words

		Regular Words		Irregular Words	
% correct		High	Low	High	Low
Poor	M	1830.81	2344.47	1800.16	2595.29
	SD	(928.78)	(1158.00)	(721.32)	(1587.12)
Normal	M	1275.78	1657.62	1313.16	1769.38
	SD	(541.59)	(946.18)	(549.72)	(949.42)

Note: M Mean, SD (Standard Deviation).

The main effect of group was significant as the reading age controls were faster than the poor readers in reading the presented words [F(1, 32) = 4.67, $p < .05$]. There was no significant main effect of regularity [F(1, 32) = 0.78, $p > .10$], and no interaction between these factors [F(1, 32) = .03, $p > .10$]. However, the analysis did show a significant main effect of frequency as a result of high frequency words being read faster than low frequency words [F(1, 32) = 32.55, $p < .001$]. The interaction between groups and frequency was not significant [F(1, 32) = 1.57, $p > .10$]. There were no other significant effects (F > 1).

Finally, in order to examine the extent to which these groups of readers were relying on sublexical procedures (letter-sound conversion) in reading words aloud, an analysis of the types of reading errors for regular and irregular words was carried out. As discussed earlier, a reliance on letter-sound information when attempting to read irregular words would result in regularisation errors (e.g., reading 'steak' as '*steek'*). In contrast a reliance on word-specific (whole word) information would result in fewer regularisation errors, but also in proportionately more word substitutions or what some researchers have termed visual errors (where the response contains 50% or more of the target word's letters, e.g., 'bread' for *'broad'*). These types of 'visual' errors in regular word reading are not only interpreted to mean that the word is viewed more as a whole, but that a sequential letter by letter approach is not undertaken. Accordingly, a visual approach taken in the reading of unfamiliar regular words would also be signaled by the presence of proportionately more word substitutions (e.g., 'stale' for *'slate'*), relative to nonword substitutions where a phonological approach has been taken and sounding out attempts have been made (e.g., 'stal-ee' for *'stale'*). Two types of error categories were therefore used for regular words (whole word (visual) substitutions and sounding out strategies), and two categories for irregular words (regularisation and whole word (visual) substitutions). Only items for which responses had been given were included in the analysis. The number of items for each category was calculated and converted to a percentage form. One-way ANOVA's comparing groups (Poor vs RA controls) were conducted on the proportion of (error) responses to regular words that were either regularisations or whole word substitutions, and on the proportion of (error) responses to irregular words that were either whole word substitutions or showed evidence of a phonological approach. The means and standard deviations are reported in Table 33.

Table 33

Poor and normal readers' proportion of whole word (W-W) and sounding out (S-Out) responses in errors for regular words, and regularisation and whole word (W-W) responses in errors for irregular words

		Regular		Irregular	
		W-W	S-Out	Reg	W-W
Poor	M	70.16	17.34	54.74	45.27
	SD	(33.97)	(21.20)	(19.81)	(19.81)
Normal	M	32.32	41.37	62.73	36.89
	SD	(36.08)	(39.41)	(27.28)	(27.35)

M Mean, SD (Standard Deviation).

The analyses showed that for regular word reading poor readers had proportionately more word substitution (visual) errors than controls [F(1, 34) = 10.08, p< .05)]. In contrast, the RA controls showed more evidence of a phonological approach being taken in the reading of unfamiliar regular words [F(1, 34) = 4.77, p< .05]. The examination of irregular word reading showed no between group differences for either the proportion of regularisation errors [F(1, 34) = .951, p> .10] or whole word (visual) substitutions [F(1, 34) = 1.04, p> 1.0]. Thus, although the poor readers were more likely to provide another word sharing similar features for unfamiliar regular words rather than attempt to sound the word out, there was some evidence of them taking a phonological approach to irregular words as they did not differ from the controls in terms of the proportion of regularisation errors that were made.

Auditory Rhyme Judgment

Although in their written form the orthography of some rhyming (e.g., bear-hare) and non-rhyming (e.g., wear-deer) word pairs used in this investigation would not appear to be ambiguous, with auditory presentation it is possible that alternative visual representations might have been retrieved (e.g., bare-hare and wear-dear respectively). These homophones (words for which there are other same sounding words, but differ in meaning and spelling, e.g., pare, pair, pear) were therefore removed prior to analysis. This involved the elimination of four word pairs from the orthographically dissimilar rhyming subset (e.g., pain-lane, tail-pale, bear-hare, pour-sore), and three word pairs from the orthographically similar non-rhyming subset (e.g., wear-dear, gone-lone, pear-year). One child from each of the two groups was unavailable on the date of testing.

The total number of correctly judged word pairs from each of the four classifications was calculated and converted to percentage form. These data were analysed by a three-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and two within subjects factors, rhyme (rhyming vs non-rhyming) and similarity (orthographically similar vs orthographically dissimilar). The means and standard deviations are presented in Table 34.

Table 34

Poor and normal readers' mean percentage correctly judged orthographically similar and orthographically dissimilar rhyming and non-rhyming word pairs

		Rhyming		Non-Rhyming	
		OS	OD	OS	OD
Poor	M	96.86	99.07	62.35	96.47
	SD	(4.78)	(2.65)	(32.55)	(6.29)
Normal	M	98.52	96.97	82.87	98.52
	SD	(2.85)	(5.40)	(25.48)	(2.85)

Note: OS = orthographically similar, OD = orthographically dissimilar, M Mean, SD (Standard Deviation).

There was a significant main effect of group as a result of the reading age controls performing better than the poor readers [F(1, 33) = 4.56, $p < .05$]. The analysis also showed a main effect of rhyme as more correct responses were given for rhyming than for non-rhyming word pairs [F(1, 33) = 23.86, $p < .001$]. A main effect of similarity was also noted as a result of performance judgment on orthographically dissimilar (rhyming and non-rhyming) pairs being better than on orthographically similar (rhyming and non-rhyming) pairs [F(1, 33) = 24.49, $p < .001$]. Interactions were found between the factors of groups and rhyme [F(1, 33) = 4.82, $p < .05$], groups and similarity [F(1, 33) = 4.76, $p < .05$], and rhyme and similarity [F(1, 33) = 25.89, $p < .001$]. There was no interaction between groups, condition, and similarity [F(1, 33) = 2.33, $p > .10$].

Newman-Keuls post hoc analysis of the group x rhyme interaction showed that RA controls performed equally well on rhyming, and non-rhyming pairs. The poor readers were as good as controls at correctly accepting rhyming word pairs, but were much poorer at saying that word pairs did not rhyme. Analysis of the group x similarity interaction showed that the two groups were equally good at making correct decisions on orthographically dissimilar pairs, but differed in their performances for orthographically similar pairs.

Newman-Keuls post hoc analysis of the rhyme x similarity interaction showed that orthographically dissimilar word pairs were judged equally well in the rhyming and non-rhyming conditions, however, proportionately more orthographically similar pairs were judged as rhyming in the non-rhyming condition. Thus, although there was no 3-way interaction between groups, rhyme and similarity, it can be seen from the means that the poor readers' problems with orthographically similar word pairs lie in a difficulty in determining that orthographically similar non-rhyming pairs do not rhyme. That is, they are prone to say that pairs of words such as 'post - lost' do rhyme.

As it was predicted from previous research that poor readers would have difficulty with orthographically similar non-rhyming word pairs, a planned t-test was carried out. This showed that the poor readers did make more errors than controls on orthographically similar non-rhyming word pairs [$t(33) = 2.8$, $p < .05$]. None of the other factors from the categories of orthographically similar rhyming [$t(33) = 0.23$, $p > .05$], orthographically dissimilar rhyming [t(33) = 0.3, p> .05], or orthographically dissimilar non-rhyming word pairs [t(33) = .03, p> .05] was significant.

Phoneme Deletion

The total number of correct responses to word and nonword stimuli was calculated and converted to percentage form. These data were analysed by a two way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, wordtype (words and nonwords). The means and standard deviations are reported in Table 35.

Table 35

Phoneme deletion: Percentage of correct responses to word and nonword stimuli

		Word	Nonword	Total
Poor	M	64.35	59.49	62.03
	SD	(29.85)	(28.25)	(28.74)
Normal	M	73.90	68.86	71.38
	SD	(15.52)	(19.76)	(16.99)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant, [F(1, 35) = 1.56, p> .10]. However, the analysis showed a significant main effect of wordtype, [F(3, 105) = 10.18, p< .01]. This was due to children's deletion performance on word stimuli being better than on nonword items. The group by wordtype interaction was not significant, [F(3, 105) = .00, p> .10].

Nonword Repetition (Output Phonology)

The total number of correctly repeated (one - five syllable) nonwords was calculated and converted to percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls) and one within subjects factor, condition (one, two, three, four, five). The means and standard deviations are shown in Table 36.

Table 36

Output phonology: Percentage of one-five syllable nonwords repeated correctly

		One	Two	Three	Four	Five	Total
Poor	M	92.78	90.0	73.33	68.89	62.22	77.56
	SD	(15.26)	(10.29)	(20.29)	(16.76)	(22.64)	(12.86)
Normal	M	80.0	88.42	73.68	71.05	50.53	72.74
	SD	(13.74)	(11.67)	(15.35)	(22.08)	(22.97)	(13.37)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 35) = 1.22, p> .10]. However, there was a significant main effect of condition [F(4, 140) = 36.35, p< .001], and an interaction between these two factors [F(4, 140) = 2.53, p<

.05]. Post hoc Newman-Keuls tests showed that performance on one, two, three and four syllable nonwords was better than on five syllable items. Performance on one and two syllable stimuli was similarly better than on three, and four syllable nonwords respectively (p's <.01). In terms of the group by syllable interaction, it appears that this was due to poor readers' having performed better than RA controls in the repetition of one syllable ($p<.05$) and five syllable ($p<.01$) nonword items. However, the point should be made that RA controls were rather prone to making word substitutions for one syllable nonwords (e.g., '*snip*' for 'smip', '*growl*' for 'grall', '*hand*' for 'hond' etc.)

Study 3(c)

Method

The following speeded reading tasks examined whether the poor readers' preference for the use of visual codes could be traced to a fundamental deficit in accuracy and/or speed in applying letter-sound knowledge.

Letter Name and Letter Sound Knowledge

The task was designed to assess the speed of application of letter name and letter sound knowledge, and further to examine whether the two ability groups would show similar patterns of performance in their knowledge of letter names versus sounds.

Twenty-six lower case letters were presented individually in the centre of a computer screen. The child's task in the letter name condition was to provide the name (e.g., b=bē) associated with each of the 26 presented letters. In the letter sound condition the child was required to provide the sound (e.g., b=buh) associated with each of the 26 presented letters. Children were instructed to say the letter names / sounds as quickly and accurately as possible. A voice key was used to mark the amount of time (e.g., latency) taken to provide a 'reading' response. Letters in each of the two conditions were presented in a fixed random order. The order of presentation of conditions was counterbalanced across participants.

Nonword Reading

As the use of the indirect or phonological route in reading is said to be indexed by the ability to read nonwords, the nonword reading task was employed to this end, as well as to assess children's application of phonological skill to reading. It was expected that if a nonword naming deficit was found, then this would account for possible differences in terms of the poor readers' approaches in acquisition. There was a secondary interest in investigating whether the poor readers would be slower than reading age controls in naming the nonwords. In this way, even if equated for accuracy, differences in response times might suggest that poor readers' approaches in acquisition may similarly differ as a result of their slowness to integrate phonological information with corresponding visual forms.

One, two, and three syllable nonwords were presented one at a time in the centre of a computer screen. There were twenty nonwords in each of the syllable conditions which were presented in a fixed order, with one syllable nonwords being presented before two syllable nonwords, followed by three syllable nonwords. Prior to the commencement of test trials for each syllable set, participants were given three practice items on which accuracy feedback was given. Children were instructed to read the nonwords as quickly and accurately as possible. A voice key was used to mark the amount of time (e.g., latency) taken to provide a reading response. Test items are presented in Appendix N.

Results

Letter Name / Letter Sound Knowledge

Accuracy: The total number of correct responses to the letter name and letter sound conditions was calculated and converted to a percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, group (Poor vs RA controls), and one within subjects factor, condition (letter names vs letter sounds).

The main effect of group was not significant [$F(1, 32) = .02$, $p > .10$]. The main effect of condition was marginally non significant [$F(1, 32) = 3.62$, $p = .066$]. There was no significant group by condition interaction [$F(1, 32) = 2.31$, $p > .10$]. The means and standard deviations are presented in Table 37.

Latency: The total number of response times for correctly identified letter names and letter sounds was calculated and converted to a percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, condition (letter names vs letter sounds). The means and standard deviations are presented in Table 37.

Table 37

Poor and reading age controls' mean percentage correct letter name and letter sound identification, and mean response times (in milliseconds)

		Identification		Response Times	
		Names	Sounds	Names	Sounds
Poor	M	93.21	87.56	1246.71	1139.08
	SD	(10.49)	(12.20)	(615.11)	(386.89)
Normal	M	90.27	89.79	1222.62	1473.47
	SD	(8.50)	(8.36)	(397.76)	(472.06)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 33) = 1.12, $p > .10$]. Similarly, there was no significant main effect of condition [F(1, 33) = 1.18, $p > .05$]. However, there was a significant group by condition interaction [F(1, 33) = 7.38, $p < .05$]. Newman-Keuls post hoc analysis showed that poor readers had faster response times than RA controls in the identification of letter sounds (p<.01). RA controls were faster at providing names for letters than they were at providing sounds (p<.05).

Nonword Reading (one, two, and three syllable)

Accuracy: The total number of correct responses to one, two, and three syllable nonwords was calculated and converted to a percentage form. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, word length (one, two, and three syllables). The means and standard deviations are presented in Table 38.

Table 38

Poor and reading age controls' mean percentage correct readings for one, two, and three syllable nonwords

		One	Two	Three
Poor	M	82.51	52.38	15.79
	SD	(12.44)	(31.12)	(16.31)
Normal	M	86.32	65.00	24.39
	SD	(16.90)	(24.66)	(24.64)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 35) = 1.92, p> .10]. However, the analysis showed a main effect of word length [F(2, 70) = 174.54, p< .001]. Newman-Keuls post hoc analysis showed that performance for one syllable nonwords was better than for two syllable, and three syllable nonwords (p<.01). Similarly, two syllable nonwords were read better than three syllable nonwords (p<.01). The group by word length interaction was not significant [F(2, 70) = .81, p> .10].

Latency: With many participants scoring at floor or close to floor levels on three syllable nonword stimuli, missing data precluded response times from this condition being entered into an analysis with the one and two syllable response time data. The mean response times for correctly read one and two syllable nonwords were calculated. These data were analysed by a two-way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, condition (one and two syllable response times). The means and standard deviations are presented in Table 39.

Table 39

Poor and reading age controls' mean response times (in milliseconds) for correctly read one and two syllable nonwords

		One	Two
Poor	M	2511.68	3608.57
	SD	(1298.77)	(1248.12)
Normal	M	1808.35	2635.99
	SD	(1275.38)	(1648.44)

Note. M Mean, SD (Standard Deviation).

There was a significant main effect of group as a result of reading age controls having faster response times [F(1, 35) = 4.22, p< .001]. The analysis also showed a significant main effect of condition as a result of response times for one syllable stimuli being faster than for two syllable items [F(1, 35) = 23.27, p< .001]. There was no significant interaction between groups and condition [F(1, 35) = .456, p> .10].

An analysis was also carried out on the proportion of nonwords for which a real word response was given for the whole (e.g., 'dep' read as 'deep', 'renbok' as *'rebok'*) or partial form (e.g., 'renbok' as *'rainbok'* or '*renbook*'). In this sense some indication of the degree to which children were approaching nonwords either at a 'whole' word level, or by systematic letter by letter (sound correspondence) reading could be gauged. Only nonwords for which a response was given were included in this analysis for one and two syllable items. These scores were converted to a percentage form.

A one way ANOVA comparing groups (poor vs RA controls) showed no differences in the proportion of nonwords read as real words or as nonwords containing (whole) word components F(1, 35) = 1.46, p>.10]. The means for poor and normal readers were 2.72 (SD 2.14) and 1.89 (SD 2.02) respectively.

Summary of Studies 3(a), (b), (c)

The poor readers identified letter names and letter sounds as quickly and as accurately as the reading age controls. This result would suggest that they possess the basic skills requisite for decoding the nonwords in the speeded nonword task, which unlike the acquisition task did not contain vowel digraphs. Nevertheless, despite the lack of significant group differences on the speeded nonword task, the poor readers tended to be slower and generally less accurate in the reading of these items than their controls. This decrement in accuracy performance is most markedly shown for the poor readers in a review across increasing syllable length (see Table 38, p. 204). The fact that this decline appears to be much greater for poor readers than for controls is important to understanding the poor readers' difficulties in reading more complex three syllable nonwords in the acquisition task. A review of the performances in the regularity task showed that both groups demonstrated more accurate reading of regular over irregular words, however, poor readers reading of irregular words was better than that of the controls. This result would therefore, suggest that the poor readers were less sensitive to effects of regularity, but were not impaired for reading age in regular word reading.

The poor readers were better at visual recognition of nonwords, were prone to making more errors on visually similar non-rhyming words (e.g., post-lost), and demonstrated better reading of irregular words. Taken together it would appear that poor readers take a more visual approach to both reading and reading related tasks. The question arises as to why their approach was more visual than that of their controls in these various measures. The Children's Embedded Figures test (Witkin et al., 1971) had shown that the poor readers had superior visual skills for reading age. Although this is a non-reading task it has been shown to be associated with word reading skill (Johnston et al., 1991).

General Discussion

It was found that poor readers were better than reading age controls at identifying printed nonwords in a visual recognition task, but they read them less well and had impaired auditory memory for these items. There were other indications of taking a more visual approach with print than controls, as they showed a less marked regularity effect and were more influenced by the visual appearance of words in an auditory rhyme judgment task. Although the groups did not differ in their ability to carry out a test of phoneme deletion, it can be seen that the poor readers were generally less accurate than controls in this task (see Table 35, p. 198). Furthermore, they exhibited segmentation deficits with nonword stimuli in the previous investigation in Chapter Two.

Nevertheless, their pattern of performance in the acquisition task cannot be ascribed entirely to a phonological deficit as they had reading age appropriate phonological working memory skills. The results of this study suggest that poor readers use a qualitatively different form of memory coding to reading age controls when learning new print vocabulary. Consequently their word recognition may be less well underpinned by connections in memory between the letters in the spelling and the phonemes in the pronunciation (Ehri, 1992).

Phonological reading deficits have traditionally been sought in terms of nonword reading deficits and small or non-existent regularity effects. The poor readers in the present study showed a nonword reading deficit both in speed and accuracy, and they also required more training in reading the nonwords in order to reach criterion. They also showed a smaller regularity effect than the controls, whereas in the vast majority of studies poor readers show normal regularity effects (Metsala et al, 1998). Although Metsala et al's (1998) meta-analysis identifies a few studies showing smaller or non-existent regularity effects (e.g., Beech & Awaida, 1992; Johnston et al., 1990) these results seem to be due to poor readers reading regular words less well than controls. In the current study, however, the poor readers showed superior reading of irregular words compared to reading age controls and only the study by Siegal and Ryan (1988) follows the same pattern.

A number of tentative conclusions can be drawn regarding the nature of the impaired reading process by making reference to the dual route model and the phonological / surface dyslexic contrast. According to the dual route model the regular-irregular word difference should be greater for low frequency words than for high frequency words. The poor readers in this study read proportionately more irregular words than controls, and an examination of these means would suggest that it was their performance on low frequency items which lessened the magnitude of this effect for poor readers (see Table 31, p. 190).

Therefore, because the two groups are matched for reading age then this is some indication that the poor readers' level of attainment in reading has been acquired by virtue of qualitatively different approaches in reading (e.g., word-specific associations). The dual route model posits that these irregular words (which do not conform to spelling-sound rules) have to be recognised directly. Regular words, on the other hand, can be read by using either phonological or direct recognition processes. The point of interest in this regard is that the error analysis for regular words showed that the poor readers responded with proportionately more whole word (visual) substitutions than phonological strategies compared with controls, for whom the reverse pattern was shown.

Referred to in neuropsychological accounts as visual paralexias, these word substitution errors (e.g., 'drive' for 'dive') are considered to be a characteristic symptom of an acquired phonological dyslexic (e.g., Temple & Marshall, 1983). These readers read irregular words relatively well in spite of their weaknesses in decoding. They similarly do not show distinct advantages for regular over irregular words, and word reading errors most often indicate the inclusion of other word components, which implies an attempt at reading by analogy.

However, to classify the poor readers in this study as developmental phonological dyslexics is not appropriate in the absence of conducting an analysis of their individual performances relative to chronological and reading age controls (perhaps by the use of regression techniques, e.g., Castles & Coltheart, 1983). Nevertheless, an appraisal of their general profile can be made by considering whether there is a discrepancy between these poor readers' word and nonword reading skills. Currently, there is strong agreement that this contrast is fundamental to the identification of surface and phonological dyslexic subtypes. Certainly, their word reading performance would be viewed to be better than their nonword reading.

In recalling the case of RE (Campbell & Butterworth, 1985) one can draw a number of parallels between her performance and the poor readers in this investigation. RE had poor nonword reading skill relative to her word reading ability. The poor readers in the current investigation were more or less poorer than controls in nonword reading although this was not statistically proven. Nevertheless, it is possible that the nonwords were of insufficient complexity and could therefore be read by virtue of the poor readers' acquired, yet limited phonological knowledge. Certainly, the three syllable nonwords (with more complex vowel digraph structures) were not acquired by the poor readers, however, this may have resulted from their stricter reliance on the visual features of the to-be-learnt items. The examination of RE's nonword reading skills showed that reading was slow and laborious in spite of the nonwords being simple three-letter items (e.g., oan, owt). The poor readers in this investigation were also slow in reading simple CVC nonword constructs. Similarly, RE's difficulties were more marked with complex nonwords, a result also found for the nonword acquisition task in the current investigation.

Beyond the acquisition task, there have been other indications of the poor readers' reliance on orthographic rather than phonological codes in the earlier investigations. In phoneme tapping they made a number of errors on nonwords (e.g., where they reported 'flig' to have three sounds, 'gak' to have four, possibly from 'gack'), whereas they often accurately reported the contained number of sounds in the words on which these nonwords were based (e.g., 'flag' = 4, 'yak' = 3). This same type of pattern was noted in the performance of RE where it appears that her knowledge for the contained number of sounds in words might have been supported by her memory for spellings.

The other striking similarity between these poor readers and RE is the difficulty encountered in judging orthographically similar word pairs (e.g., saying that *post* and *lost* rhyme. The phonemic segmentation deficit is yet another common feature, and there is no question about these poor readers' difficulty on this task. Although RE's auditory discrimination was reported as normal, her memory span for digits was significantly impaired for chronological age. However, again in the case of RE, her performance for rare and irregular word forms (e.g., idyll) appeared unimpaired.

Nevertheless, although RE's profile is seen within a phonological dyslexic context, (i.e., she has a distinctive impairment in nonword compared with word reading) it must be borne in mind that evidence has at least suggested that whole word instructional programmes might contribute to this profile (Lovett et al., 1990; Thompson & Johnston, 2000). Thus, in a similar regard these poor readers' ability in simple nonword reading might stem from the Scottish based phonics tuition that they have received, i.e., because they have learnt to read by a phonic method certain phonological difficulties might have been resolved by virtue of letter-sound associations making sounds easier to identify in speech. As RE on the other hand is English, she may have learnt to read by a whole word approach.

Nevertheless, the point is made that in the absence of adequate phonological skills some individuals become literate by way of compensatory factors. The Campbell and Butterworth (1985) results showed how individuals with good visual memory use these skills to compensate for a phonological weakness. Connectionist models have given some indication of how visual memory and speed of processing relate to the effects of a phonological deficit on reading development. Harm and Seidenberg (1999) simulated phonological dyslexia by reducing the system's capacity to represent phonological information in the training stage. With this manipulation it was shown that the greater the phonological deficit, the more the system had to make use of general processing resources. In this sense visual memory can be thought of as such a resource. Accordingly, a child with strong visual memory skills and a severe phonological deficit might develop the 'phonological' dyslexic profile. In contrast, if a child's visual memory is poor or his speed of processing slow, it is likely that he will be capable of reading novel words, however, by slow and laborious means (e.g., surface dyslexic). Thus, the type of profile that develops is not determined solely by a phonological deficit. In these examples, visual memory and speed of processing are seen as other contributing skills.

These issues aside, in the absence of a case-by-case analysis it cannot be stated that these poor readers completely fit the phonological dyslexic profile. On the one hand, the results of the acquisition task would suggest that the poor readers' word reading has involved a reliance on visual processes. However, the poor readers in this investigation did show some ability in the reading of simple nonwords, and this does not entirely fit the profile of the phonological dyslexic. Nevertheless, connectionist models also provide some corroboration for this pattern. Seidenberg and McClelland (1989) found that alterations to their learning algorithm produced differential patterns of reading performance for nonword and irregular words. Therefore, in this sense, whether the sublexical procedure is a separate route, or simply a type of structure capable of manipulating more fine-grained components within a larger system, it has nevertheless been shown that word specific knowledge might assist the reading of unfamiliar regular words or nonwords.

There is evidence therefore, of the poor readers in some respects taking a more visual approach to reading than controls. The smaller regularity effect was the product of good visual recognition of words, and there was evidence of better visual recognition of print in the nonword acquisition task. Although the poor readers appeared to have deficient auditory rhyme judgment skills, their problems lay with orthographically similar words that did not rhyme; their preponderance of errors of this type suggests that they visualised the spoken words, and so incorrectly identified pairs of words such as 'post-lost' as rhyming. A number of other studies have also found poor readers to be better on tests of orthographic processing (e.g., Frith & Snowling, 1983; Holligan & Johnston, 1988; Olson, Kliegl, Davidson, & Foltz, 1985; Olson, Wise, Connors, Rack, & Fulker, 1989; Rack, 1985; Siegal, Share, & Geva, 1995; Stanovich & Siegel, 1994).

The question arises as to whether poor readers take a more visual approach to reading because they do not have sufficient phonological skill appropriate for reading age, or whether their visual skills are relatively strong. The poor readers' performance on the embedded figures task showed that their skills in this domain are superior to that of their reading age controls. Interestingly this task appears to be correlated with reading (Johnston et al., 1990). Similarly, there was incomplete support for an underlying phonological deficit (as mentioned above) and they also performed as well as controls in the measure of phonological working memory.

The findings from this study may have direct implications for understanding the nature of the poor readers' slowness in learning to recognise new words. In normal readers, repeated exposure to words or other printed stimuli that have verbal labels usually leads to the development of interconnections between the visual and verbal modalities (Swanson, 1987). The findings suggest that the poor readers' visual and verbal coding systems were poorly linked or functionally independent (Nelson & Brooks, 1973). Thus when visual stimuli were presented for recognition or recall, this was less likely to evoke an interdependent network of visual and verbal associations in the poor readers. Their pattern of performance in the acquisition task, where they showed a lack of phonological coding when asked to read the visual recognition memory choices, may therefore stem from fewer or degraded interconnections between the visual and verbal representations as a result of these systems being poorly co-ordinated. It may be that poor readers rely on intact visual processes because they need to compensate for inefficient or poorly connected visual and verbal systems, rather than because they have inefficient phonological processing skills as such.

When learning to read new words poor readers may prefer to use visual coding, working out what the word is from context or getting the pronunciation of the word from the teacher. Poor readers' phonological representations for printed words in long-term memory may therefore be incomplete, hence the difficulty in accessing this information. Thus the failure to develop visual-phonological linkages in acquisition may stem from a bias towards a visual approach to reading. In the early stages of acquisition, normal readers to some degree similarly fail to use visual and verbal codes in integrative fashion, reading logographically or by an incomplete alphabetic approach (Ehri, 1992). Poor readers may initially be very successful with such an approach because their visual skills are good, and may not feel the need to develop a form of word recognition heavily underpinned by phonological information.

In conclusion, it appears that although poor readers are capable of taking a phonological approach to reading, they nonetheless appear to demonstrate a bias toward establishing visual memory connections for printed words, and fail to integrate these with the corresponding phonological forms. The result is that poor readers have good visual recognition of nonwords, but this is not matched by equivalent ability to read the items. Even when they are taught to read the items, with explicit training in the pronunciation of the vowel digraph, they are much slower than reading age controls to set up connections between the printed form and its pronunciation.

CHAPTER FOUR

WORD LENGTH, PHONEMIC, AND VISUAL SIMILARITY EFFECTS IN POOR AND NORMAL READERS

This thesis has been examining the contributions made by phonological awareness and the relationship to skilled reading development. However, what should not be overlooked in this examination is the role played by memory processes and their overall involvement in each individual part of the reading process. This is why any interpretation of reading performance must include an account of the relative contributions made by memory processes, and the resources required to perform in different types of tasks. For example, many of the impairments in phonological processing ability may in part result from deficient phonological verbal working memory skills. Thus, a failure to set up adequate representations in memory would mean that representations were incomplete, which would lead to difficulties in analysis. Therefore, the relationship is complex as difficulties with phonological coding might be contributing to the poor readers' noted impairments in phonological memory, as well as in the reported deficiencies in phonological analysis, and word reading skills. Nevertheless, although memory impairments are largely implicated in accounts of the poor readers' difficulties in learning to read unfamiliar words (Baddeley, 1986), investigations of the poor readers' use of phonological memory processes in reading tasks are comparatively few. Thus, although many current investigations of reading disability will include some index of working memory ability (digit span, word span, nonword repetition), the more cognitively taxing memory measures appear to be restricted to studies of memory function alone. Moreover, these investigations are seldom extended to the examination of developmental reading disorders. Consequently, the reading and memory literatures are not well connected.

In terms of the reported memory deficits in poor readers, the issue arises as to whether these difficulties are a result of reduced memory capacity for verbal information, or whether these are more managerial in nature. With respect to the latter, it is known that poor readers are less adept in their application and/or maintenance of phonological information in short and long-term memory tasks (Hulme & Mackenzie, 1992; Vellutino, 1979). However, it is also known that poor readers' memory spans are significantly lower than that of their chronological age counterparts (Holligan & Johnston, 1988; Johnston, Rugg, & Scott, 1987; Jorm, 1983; Rugel, 1974; Torgesen, 1978). Thus, the poor reader's reduced memory performance could stem from difficulties encountered in applying, maintaining, or retrieving phonological information in serial order recall tasks, therein producing the widely reported memory difficulties noted for chronological age.

One possibility is that poor readers show immaturity in the development of their working memories; this proposition has been examined by studying whether they show normal phonemic similarity and word length effects. The phonemic similarity effect, found in adults and older children, has been theoretically attributed to a passive phonological store (Figure 4) contained within the phonological loop component of working memory (Baddeley, 1986).

The Phonological Loop Model (Baddeley, 1986)

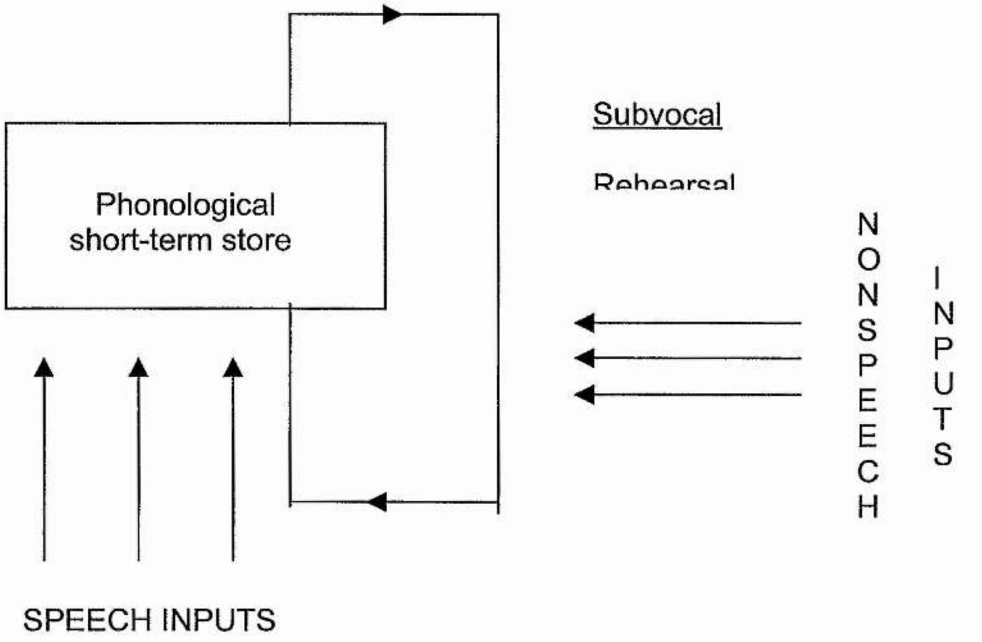


Figure 4. The phonological loop model of working memory

The poorer recall of similar sounding items (e.g., B C D G P T V) over dissimilar items is said to be due to the nature of the phonological store; because information is stored phonologically, similar sounding items become confused as the distinctive phonological information decays. Another effect attributed to the functioning of the phonological loop is that of word length, which refers to the finding that memory span for words of short spoken duration (e.g., tent, rope, cake) is greater than for words of longer duration (e.g., policeman, elephant, strawberry). A linear relationship has been found between the number of items that can be recalled and the rate at which these can be articulated (Baddeley, Thomson, & Buchanan, 1975; Nicholson, 1981); faster rates of articulation would result in more items being rehearsed and recalled. Items of long spoken duration take longer to articulate and therefore receive less rehearsal in the phonological loop, and are more likely to be forgotten. Phonemic similarity and word length effects are found with both visual and auditory presentation; auditorily presented materials gain direct access to the phonological store, whereas visually presented items must be phonologically recoded in order to gain entry as a verbal form (Baddeley, 1986). With visual presentation in adult subjects, when articulation is suppressed the effects of word length and phonemic similarity are abolished, thus, supporting the attribution of these effects to rehearsal processes (Murray, 1968; Baddeley et al., 1975; Baddeley, 1986). The same results have been found with articulatory suppression in 11 year old children, but not in 5 year olds, thus suggesting that older children, like adults, encode pictorial information in a verbal form, whereas young children do not (Halliday, Hitch, Lennon, & Pettipher, 1990).

However, the use of the phonological loop may not be automatic for all individuals. It has been found that as children become older their ability to recall longer sequences of letters, numbers, or words improves. This increase in performance is attributed in part to the development of rehearsal strategies (i.e., the use of the phonological loop) to maintain serial order information. However, it is well established that children below the age of around 7 to 8 children do not actively rehearse information in serial order recall tasks (Kail, 1984). One way of testing for the use of rehearsal processes is to establish whether or not effects of word length are present. Hitch and Halliday (1983) found that pictorial word length effects were absent in six year-olds, yet the effect was nearly significant in eight year-olds, and in ten year-olds the effect was fully present. Hulme, Thomson, Muir, and Lawrence (1984) have also found that children under the age of seven fail to show these effects. However, effects of word length have been found in children as young as four years of age with spoken materials (Hulme et al., 1984).

A similar picture is found with the phonological similarity effect, which is indicative of the functioning of the phonological store. Studies of auditory presentation find that children as young as 4 show a phonemic similarity effect (Hulme,1987). Henry (1991) also found clear effects with auditory presentation in children aged 5 to 6, and 8 to 9 years. However, as far as pictorial presentation is concerned, Halliday et al (1990) found that 5 year olds did not show a phonemic similarity effect, but 11 year olds did. Thus, word length and phonological similarity effects show similar patterns of emergence developmentally. It would appear then that with pictorial presentation very young children do not use the phonological loop to remember the names of the pictures.

The developmental studies of word length and phonemic similarity are consistent in showing that with visual presentation these effects only appear in middle childhood. This indicates that it is around the ages of 7-8 that children start to use both the passive phonological store and the rehearsal component of the phonological loop. However, this means that the appearance of auditory word length and phonological similarity effects in 4 and 5 year olds who are too young to carry out verbal rehearsal needs explanation. The phonemic similarity effect is the least problematical to explain, as it might emerge due to direct entry of auditorily presented items into the phonological store. However, a word length effect in 4 year olds should indicate the use of active verbal rehearsal. Gathercole and Hitch (1993) propose that children of this age repeat each word subvocally as it is heard and that at recall they sequentially 'read out' the contents of the phonological store. This process would be slower for words of long spoken duration as they contain more phonological information and so fewer items would be recalled.

Investigations have been carried out to examine what form of coding is used by children too young to be able to rehearse. Using a fixed length procedure, Hitch, Halliday, Schaafstal, and Schraagen (1988) presented 5 and 10-year-old children with one syllable visually similar, and one and three syllable visually dissimilar items for recall. It was predicted that the use of visual memory codes by five year olds would cause disruption of recall for visually similar stimuli, in the absence of a word length effect. Conversely, eleven year olds were expected to show effects of word length, but not of visual similarity. The results overall confirmed these predictions, however, the five year-olds unexpectedly showed a word length effect, suggesting both forms of coding were available to them. On the other hand, when Hitch, Halliday, Dodd, and Littler (1989) studied 4, 5, 7, and 11 year olds using a memory span procedure, pictorial word length effects were shown only by the 11 year old children, and no evidence of a visual similarity effect was found in any of the age groups. However, it has been noted that incremental memory span procedures are generally less sensitive than a fixed list length procedure in showing effects of visual similarity (Hayes & Schulze, 1977; Hitch et al., 1988; Hitch, Woodin, & Baker, 1989).

Poor readers may show immature development of the phonological loop, which might be reflected in showing small or non-significant phonemic similarity and word length effects. Such a conclusion would be reinforced by evidence that they used visual coding instead (i.e., if they demonstrated visual similarity effects). It has indeed been proposed that poor readers fail to show phonemic similarity effects, which has been taken to indicate inefficient use or deficient functioning of the phonological loop (Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979). Shankweiler et al (1979) reported reduced phonological similarity effects in eight year-old poor readers' recall of rhyming versus non-rhyming letter strings with both visual and auditory presentation. The same pattern of results emerged in Mann, Liberman, and Shankweiler's (1980) study of eight-year-old poor readers recalling strings of rhyming sentences and words. It was thus believed that poor readers had access to degraded phonological representations or poorer access to a phonological code with both visual and auditory presentation (Shankweiler et al., 1979). However, normal effects of phonemic similarity with visual and auditory presentation have been shown in 8-14 year old poor readers (Johnston, 1982; Johnston et al., 1987; Hall, Wilson, Humphreys, Tinzmann, & Bower, 1983). Given that poor readers' memory spans are markedly reduced for chronological age (Holligan & Johnston, 1988; Johnston et al., 1987; Jorm, 1983; Rugel, 1974; Torgesen, 1978), it would appear that the lack of phonological similarity effects in many investigations can be explained by poor readers being given as many items to recall as their chronological age controls. Holligan and Johnston's (1988) examination of these very issues found that 8 year old poor readers and their reading age controls showed normal phonological similarity effects with visual presentation of letters when the task was set at an appropriate level of difficulty, but no effects were found in either group when the number of presented items exceeded their memory spans. Therefore, there is evidence to suggest that poor readers can make use of the passive phonological store, although given their impaired memory spans for chronological age, its capacity may be reduced.

Another possibility is that poor readers' impaired memory spans are due to difficulties in using verbal rehearsal, which might be reflected in small or non-existent word length effects. However, poor readers show normal word length effects with auditory presentation (Avons & Hanna, 1995; Johnston & Anderson, 1998; McDougall, Hulme, Ellis, & Monk, 1994). Although McDougall et al (1994) found that rate of articulation accounted for the auditory memory span differences between groups of poor, average, and above average ability readers all of the same age, this has not been replicated (Johnston & Anderson, 1998). With respect to pictorial presentation, Johnston and Anderson (1998) found that 11-year-old poor readers failed to show word length effects, which suggests a reliance on visual memory codes in situations where the use of a phonological code is not obligatory. Under most circumstances poor readers therefore seem to exhibit normal effects of both phonological similarity and word length, but with highly codable visual stimuli it would seem that they do not retrieve information from the phonological store at recall. There are no studies of word length effects with printed word presentation in poor readers, but as words are very visually similar it can be predicted that they would use phonological coding in this situation.

Thus, although differences in the poor readers' application and maintenance of phonological information in short and long-term memory tasks are well documented (Hulme & Mackenzie, 1992; Vellutino, 1979), investigations of the poor readers' use of phonological memory processes in reading tasks are comparatively few. However, where these investigations have been conducted similar atypical patterns of performance can be seen. In a visual recognition memory task, Holligan & Johnston (1988) noted that poor readers demonstrated a bias towards the selection of orthographically similar word pairs (post-lost), whereas normal readers made proportionately more choices based on the shared phonological properties of rhyming words (food-rude). A similar bias was captured in a study in which cued recall tasks followed both visual and auditory presentation of rhyming and non-rhyming word pairs (Rack, 1985). In this study, the poor readers had better recall of orthographically similar pairs than orthographically dissimilar pairs even when the mode of presentation was auditory, which was not the case for the normal readers. However, as these two studies involved print it is not known if a similar bias favouring classification of words based on orthographic rather than phonologic properties would emerge with auditory presentation alone.

Nevertheless, with respect to those studies involving print, although words are automatically recoded into a phonological form when read, it appears that in tasks where words have been paired together on the basis of visual similarity (e.g., post - lost), and subsequently involve showing one item of the pair to cue recall of the other item, then it is feasible to use visual coding because of the connections formed between the word pairs at presentation. However, in immediate memory tasks where lists of printed words have to be recalled in serial order, visual coding would not be a good strategy because words are not very visually distinctive. Poor readers therefore, seem to be prone to adopting a visual approach in memory tasks involving printed words where this form of coding is feasible (Holligan & Johnston, 1988; Rack, 1985). Accordingly, it appears that poor readers will resort to using phonological codes in task situations where the necessity to do so is inherently greater, i.e., where the demands are high and the use of verbal codes called into play. Verbal naming and rehearsal is the most efficient form of encoding and retrieving sequentially presented information. Consequently, poor readers will make use of verbal codes to store and recall serially presented letters with visual and auditory presentation, however, in task situations where it is less apparent that verbal labels will be the most efficient coding strategy, (for example in learning to read new words presently individually) poor readers might naturally engage their use of visual codes, as they have been shown to do with the visual presentation of pictorial images

(Johnston & Anderson, 1998), and in the categorisation of printed words with similar orthographic structures (Holligan & Johnston, 1988; Rack, 1985).

Study 4

It was concluded in study three that poor readers may make use of a different form of memory coding in print acquisition tasks. The fact that poor readers were shown to make use of visual rather than phonological codes in printed word reading would suggest that the representations that they form could be more orthographic in nature. This would account for the earlier evidence of their reliance on visual information in phonological, word reading, and nonword learning tasks. However, the question is whether this bias can be ascribed to a phonological processing deficit, a general slowness to generate phonological information from print, or the application of different coding strategies. Although the poor readers had performed at comparable levels on a number of phonological tasks, they demonstrated a segmentation deficit, a slowness to read words and nonwords, and had qualitatively different approaches in phonological and print word reading / learning tasks (in each favouring the use of visual codes). It therefore appeared fruitful to examine whether different forms of memory coding would also be seen in tasks commonly applied in investigations of memory performance in normally developing children at different developmental stages. A speeded auditory task was used to examine whether the poor readers' prior response time deficits were specific to print, or stemmed from a more general slowness in processing phonological information.

Thus, the principal interest of the final investigation was to examine what type of memory coding would be used to remember other types of visually presented stimuli. For example, it is well established that verbal codes are viewed to be the most efficient for recalling serially presented items. However, given the understanding that some poor readers are said to encounter difficulty in applying verbal information to visual stimuli, they might simply attempt to code items visually. In this way, the degree to which poor readers' working memories are developmentally immature could be examined. The same samples of children as in Chapter Three participated in the present investigation in the following school year.

Study 4

Method

Participants

Thirty-seven children in total were studied. Eighteen of these were poor readers identified as having specific reading disability (SRD). Ten of the poor reader participants were still attending a reading unit twice weekly for half day periods. The remainder of the poor reader sample had completed their two-year program, and were attending their first year of Secondary School. The nineteen normal reading age (RA) controls were as before, from two separate Primary 3 classes. The group characteristics are presented in Table 40.

Phonological Working Memory (speeded task)

A speeded test of phonological working memory was used to examine whether the poor readers would be slower or less accurate than controls in making phonological judgments for auditorily presented stimuli. Although typically used as a measure of phonological memory skill, the nonword repetition task is one which requires an amalgam of phonological abilities at various levels (e.g., input, segmentation, synthesis, and output). Difficulties at any of these levels would result in a slowness and/or an inability to carry out the task. Therefore, the argument that poor readers have difficulty integrating visual and verbal codes would be strengthened by showing equivalent response times in a comparison with reading age controls. Other details of this task are given in Chapter 2, page 100. (See appendix C for test items.)

The task used digitally recorded stimuli that were converted to wav.files and used in conjunction with a voice key response system as with the previous speeded (visual presentation) reading tasks. The items were presented through stereo headphones.

Table 40

Participant characteristics

		CA	RA	IQ	Accuracy	RT
Poor	M	12.01	8.12	109.25	82.29	402.75
	SD	(.729)	(1.04)	(11.94)	(7.38)	(134.69)
Normal	M	7.82	8.14	106.17	81.37	467.38
	SD	(.328)	(.509)	(9.30)	(8.11)	(145.32)

Note. CA = chronological age, RA = reading age, accuracy and response time (RT) for speeded phonological working memory task.

Accuracy: The total number of correctly repeated nonwords was calculated. A one-way ANOVA comparing groups (Poor vs RA controls) was carried out on the nonword repetition scores. The two groups did not differ [F(1, 35) = 0.13, p> .10]. The means and standard deviations are presented in Table 40.

Latency: Mean response times for correctly repeated nonwords were calculated for each participant. A one-way ANOVA comparing groups (Poor vs RA controls) was carried out on the response time data. The two groups did not differ in the time taken to repeat the one - five syllable nonwords [F(1, 35) = 1.96, p> .10]. The means and standard deviations are presented in Table 40.

Experiment 1

Pictorial Working Memory

The following tasks were used to examine memory performance and to see if there was evidence of poor readers taking a more visual approach in their effort to recall various types of information presented serially in immediate memory tasks. The study's aim was to examine whether poor readers would demonstrate normal effects of word length and phonemic similarity with pictorial, printed word, and auditory presentation. It was predicted that poor readers would show non-significant or small phonemic similarity and word length effects with pictorial presentation, but normal effects with printed word and auditory presentation. It was further predicted that if poor readers showed reduced phonemic similarity and word length effects with pictorial presentation that they would also show sensitivity to visual similarity, indicating the use of visual coding in these tasks.

Method

Materials

The stimuli that were used for each of the four conditions in Experiment 1 comprised 8 common nouns that were matched for word frequency (Carroll et al., 1971), and where possible for age of acquisition (Carroll & White, 1973). The four lists for phonemically similar, visually similar, one, and three syllable items respectively, were as follows: phonemically similar items (cat, cap, mat, bat, map, tap, hat, rat); visually similar items presented at 45 degree angles (bat, comb, spade, saw, fork, pen, key, nail); one syllable items (king, leaf, tent, rope, tree, snake, knife, horse); three syllable items (strawberry, umbrella, envelope, banana, ambulance, butterfly, policeman, elephant). One syllable items served as the control set against which the effects of word length, phonemic similarity, and visual similarity could be gauged. List length was set at four items. This was established on the basis of mean recall performance on the WISC-R Digit Span subtest. Similarly, it has been noted that floor effects have been present in investigations (albeit under the conditions of articulatory suppression), using older participants aged 24-70, where span length had been set at five items (Baddeley, Lewis, & Vallar, 1984).

Procedure

Pictures for each of the four conditions were presented immediately prior to the test trials for each condition in order to ensure correct naming of items. For the memory task, the pictures were presented one at a time on a computer screen, at the rate of one item per second, with one second intervals between each. In order to cue recall, an asterix appeared in the centre of the screen after the presentation of the four pictures, after which the participant was required to report what had been presented. Participants were presented with 8 trials for each of the four conditions, with list length set at four items. Two practice trials were presented prior to the 8 test trials; if the participant failed to report either of the two lists, or one of these in the correct serial order, two additional practice trials were given. The presentation of the test trials commenced if one of these was correctly recalled. Memory span performance was recorded as the total number of trials correctly reported in serial order. The order of presentation of list types (i.e., conditions), was counterbalanced across participants.

Results

The total number of four-picture sequences recalled in correct serial order was calculated for each condition, and converted to a percentage form. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, condition (phonemically similar, visually similar, one, and three syllable items). The means and standard deviations are presented in Table 41.

Table 41

Mean percentage correct for visually presented phonemically similar (PS), visually similar (VS), one-, and three - syllable pictorial stimuli

		PS	VS	One	Three
Poor	M	42.36	44.44	60.42	53.47
	SD	(21.50)	(25.08)	(16.18)	(20.92)
Normal	M	23.03	46.71	59.21	30.92
	SD	(22.15)	(22.76)	(30.86)	(29.07)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 35) = 2.94, p> .05]. However, the analysis showed a main effect of condition [F(3, 105) = 16.19, p < .001], and an interaction between group and condition [F(3, 105) = 5.04, p< .01]. Newman-Keuls post hoc analysis of the group x condition interaction showed that (in terms of phonemic similarity effects) the normal readers' performance for one syllable items was significantly better than their performance for phonemically similar items (p<.01). This was also true for the poor reader group (p<.05). As far as effects of word length were concerned, the normal readers recalled one syllable stimuli better than three syllable items (p<.01), but no such differences emerged for poor readers. However, the poor readers recall of one syllable stimuli was better than that of visually similar items (p<.05), thus demonstrating an effect of visual similarity; no such effect was found for RA controls. Finally, poor readers remembered phonemically similar items, and three syllable items better than RA controls (p<.01).

As the reading age controls showed a phonemic similarity effect twice the size of that of the poor readers, a Scheffé test comparing differences between pairs of means was carried out. It was found that the poor readers showed a significantly smaller phonological similarity effect compared with the reading age controls.

Discussion

Post hoc analysis of the group x condition interaction revealed that normal readers showed effects of both phonemic similarity and word length. The poor readers showed no word length effects and a phonemic similarity effect of smaller magnitude than that of reading age controls. On the other hand the poor readers demonstrated a visual similarity effect, whereas the normal readers did not. These results suggest that poor readers rely more on visual codes than on verbal labels to assist recall of pictorial stimuli. However, the poor readers, as well as the reading age controls were observed to make lip movements during the task, and sometimes reported saying the names of the pictures in order to remember them.

Experiment 2

Auditory Working Memory

It was predicted in Experiment 2 that with auditory presentation poor readers would show phonemic similarity and word length effects like those of their RA controls. It was further predicted that neither group would show a visual similarity effect.

Method

Materials

The items used in Experiment 2 were identical to those used in Experiment 1, but presentation was auditory.

Procedure

This experiment was carried out around 3 weeks after Experiment 1, with a minimum gap of 2 weeks. This order of presentation was adopted as prior presentation of an auditory condition might have evoked a verbal coding strategy in the poor readers in the pictorial presentation experiment, which would therefore not reveal their normal method of dealing with such stimuli.

In Experiment 2, items from each of the four conditions were read to each participant prior to the test trials in order to familiarise participants with the items that would be heard in the test trials. The additional purpose of presenting these prior to the commencement of each condition was to reduce the possibility of carry over of representation of the stimuli from the previous experiment. Words were read out at a rate of one word per second, with one second intervals between each. Timing was paced by the experimenter's use of the computer presentation of the same images used in Experiment 1 (which was not in view of the participant being tested). Upon the completion of presentation of the four items, the request for recall was cued by the experimenter's saying of the word "now". As in Experiment 1, participants were presented with 8 trials (of each of the four conditions) with list lengths of four items. Two practice trials were presented prior to the 8 test trials. If the subject failed to report either of the two lists, or one of these in the correct serial order, two additional practice trials were given. The presentation of the test trials commenced if one of these was correctly recalled. Auditory memory span performance was recorded as the total number of trials correctly reported in serial order. The order of presentation of list types (i.e., conditions), was counterbalanced across participants.

Results

The total number of four-word sequences recalled in correct serial order was calculated for each condition, and converted to percentage form. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, condition (phonemically similar, visually similar, one,-

and three syllable items). The means and standard deviations are presented in Table 42.

Table 42

Mean percentage correct for auditorily presented phonemically similar (PS), visually similar (VS), one-, and three- syllable stimuli

		PS	VS	One	Three
Poor	M	15.28	67.37	79.86	41.67
	SD	(12.54)	(17.75)	(17.75)	(23.48)
Normal	M	22.37	75.66	71.05	33.55
	SD	(16.45)	(24.46)	(19.12)	(20.43)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 35) = .01, p> .05]. However, the analysis showed a main effect of condition [F(3, 105) = 134.34, p< .01], and an interaction between groups and condition [F(3, 105) = 3.94, p< .05]. Post hoc analysis of the group x condition interaction showed that RA controls recalled one syllable items better than both phonemically similar items (p<.01), and three syllable items (p<.01). For the poor readers, one syllable items were similarly recalled better than phonemically similar items (p.<.01), and three syllable items (p<.01). However, the poor readers recalled significantly more one syllable items than visually similar items ($p<.05$), despite their presentation as an auditory form.

Discussion

Whereas poor readers failed to show a word length effect with the presentation of pictorial stimuli in Experiment 1, and showed a phonemic similarity effect of reduced magnitude, they showed normal effects of both word length and phonemic similarity with auditory presentation in Experiment 2. It would therefore appear that with pictorial presentation, readers may opt out of using a verbal code for remembering serially presented stimuli, although they are capable of using such codes with auditory presentation. The phonemic similarity and word length effects found in poor readers with auditory presentation suggest that when they are forced to make use of phonological information they demonstrate normal processing. However, the fact that they showed a visual similarity effect in the auditory experiment suggests that poor readers may also attempt to ‘picture’ spoken items as a means of remembering the presented information. Indeed there were self-reports of trying to ‘see’ what had been said. As the pictorial experiment preceded the auditory experiment, the children may have been making use of mental images generated from their memory of the stimuli presented two weeks earlier.

Experiment 3

Visual Presentation of Printed Words

Note. The order of presentation of Experiments 3 and 4 was counterbalanced across participants, and occurred after Experiments 1 and 2.

It was predicted that with visual presentation of printed words poor readers might make use of visual memory coding for the printed words, which would reduce their phonemic similarity and word length effects. However, as printed words are visually similar and are not as easily maintained in a visual store as pictures (Swanson 1984), it was alternatively predicted that the poor readers may be forced to rely on a phonological code, and thus demonstrate normal effects of both phonemic similarity and word length.

Method

Materials

The stimuli used in Experiment 3 were identical to those used in Experiments 1 & 2 with the exception of the 'visually' similar stimulus set, which was replaced by a two syllable stimulus condition (giraffe, hammer, iron, ladder, mountain, rabbit, table, window), matched to the other sets for both frequency and age of acquisition. Thus, the four respective conditions comprised phonemically similar, one-, two-, and three syllable printed words.

Procedure

Again, as in the previous experiments, the printed words from each of the four conditions were presented prior to the test trials for each condition in order to ensure correct naming of items. Any item wrongly identified was again shown upon the completion of each participant's reading of the list of 8 items. The words were presented one at a time on a computer screen, at the rate of one word per second, with one second intervals between each. In order to cue recall, an asterix appeared in the centre of the screen after the presentation of the four pictures, at which time the participant was required to report what had been presented. Participants were presented with 8 trials for each of the four conditions, with list lengths of four items. Two practice trials were presented prior to the 8 test trials. If the participant failed to report either of the two lists, or one of these in the correct serial order, two additional practice trials were given. The presentation of the test trials commenced if one of these was correctly recalled. Memory span performance was recorded as the total number of trials correctly reported in serial order. The order of presentation of list types (i.e., conditions), was counterbalanced across participants.

Results

(One poor reader participant was unable to read two,- and three syllable items quickly enough for the pre-set presentation rate, and was thus excluded from all four conditions in this particular analysis.) The total number of four-word sequences recalled in correct serial order was calculated for each condition, and converted to percentage form. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, condition (phonemically similar, one,-two, and -three syllable items). The means and standard deviations are presented in Table 43.

Table 43

Mean percentage correct for visually presented phonemically similar (PS), one-, two-, and three- syllable printed words

		PS	One	Two	Three
Poor	M	19.85	72.79	46.32	29.41
	SD	(17.71)	(19.88)	(21.09)	(14.62)
Normal	M	27.63	66.45	42.76	29.61
	SD	(15.91)	(24.31)	(23.32)	(26.09)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [$F(1, 34) = .01$, $p > .05$]. The analysis showed a main effect of condition [$F(3, 102) = 69.85$, $p < .001$]. In terms of phonemic similarity effects, Newman-Keuls showed that one syllable items were recalled better than phonemically similar items ($p<.01$). Overall effects of word length were found with one syllable items being better recalled than both two syllable ($p<.01$), and three syllable items ($p<.01$). Finally, two syllable items were recalled better than three syllable items ($p<.01$). There was no interaction between groups and condition [$F(3, 102)= 1.56$, $p > .10$].

Discussion

There were significant effects of both word length and phonemic similarity for poor readers and reading age controls when given visual presentation of printed words, the findings being similar to those with auditory presentation in Experiment 2. Although presentation was visual, the fact that the words were printed seemed to preclude the poor readers from being able to make use of a visual memory code, print not being as highly codable as pictures in terms of establishing visual memory forms.

Experiment 4

Visual and Auditory Presentation of Phonemically Similar and Phonemically Dissimilar Letter Strings

As printed word forms share similar visual attributes (e.g., flower - tower), there existed the possibility that in Experiment 3, recall for phonemically similar stimuli (e.g., cap, cat, map) could in part be disrupted by the shared visual properties of these words. Thus, in order to demonstrate the degree to which poor readers are truly susceptible to phonemic similarity errors, the fourth experiment used phonemically similar and phonemically dissimilar letter strings in both visual and auditory presentation conditions. It was predicted that the poor readers would resort to verbal recoding in both the visual and auditory conditions, demonstrating normal decrements in performance for phonemically similar strings compared with reading age controls.

Method

Materials

The phonemically similar letters used were g, c, t, d, p, v, b, and the phonemically dissimilar letters were r, y, l, s, z, h, and j. There were four conditions in total (e.g., visually presented: phonemically similar and phonemically dissimilar, and auditorily presented: phonemically similar, and phonemically dissimilar letter strings).

Procedure

Again list length was set at four items, with a total of 8 test trials for each condition. With visual presentation participants were shown the letters that they would be seeing prior to the commencement of each condition (i.e., either similar or dissimilar string condition). With auditory presentation the experimenter read the names of the letters that the participants would be hearing prior to the commencement of each condition (similar / dissimilar). Two practice trials were presented prior to the 8 test trials in each condition. If the participant failed to report either of the two practice lists, or one of these in the correct serial order, two additional practice trials were given. The presentation of the test trials commenced if one of these was correctly recalled. Memory span performance was recorded as the total number of trials correctly reported in serial order. Administered in a single test session, the order of presentation of visual and verbal conditions was counterbalanced across participants, as were similar versus dissimilar items. Thus, half of the participants received the visual presentation condition first, followed by auditory presentation in the second half of the session (whereas the remainder of participants received the reversed order of conditions). The order of presentation of letter types (similar / dissimilar), was counterbalanced across the visual and verbal presentation conditions such that no single ordering was received by more than one subject per group.

Results

One participant in the poor reader group was unable to complete the visual presentation condition, and was excluded from the complete analysis. The total number of four-letter sequences recalled in correct serial order was calculated for each condition, and converted to percentage form. These data were analysed by a 3-way repeated measures ANOVA. There was one between-subjects factor, groups (Poor vs RA Controls), and two within-subjects factors, modality (visual and auditory presentation) and letter type (phonemically similar and phonemically dissimilar letters). The means and standard deviations are presented in Table 44.

Table 44

Mean percentage correct for visually and auditorily presented phonemically similar (PS) and phonemically dissimilar (PD) letter strings

		Visually Presented		Auditorily Presented	
		PS	PD	PS	PD
Poor	M	35.29	63.24	31.62	74.26
	SD	(19.88)	(21.86)	(23.43)	(17.94)
Normal	M	44.08	65.79	46.05	78.95
	SD	(27.44)	(24.24)	(24.31)	(16.17)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 34) = 1.62, $p >$ .10]. However, the analysis showed a main effect of modality, a result of recall being better with auditory presentation [F(1, 34) = 4.86, $p < .05$]. Similarly, there was a significant main effect of letter type with phonemically dissimilar letters being better recalled than phonemically similar letters [F(1, 34) = 169.71, $p < .001$]. There was also an interaction between these two factors [F(1, 34) = 5.89, $p < .05$]. Newman-Keuls tests showed that phonemic similarity effects were shown with both visual and auditory presentation ($p < .01$). However, phonemically dissimilar letter strings were better recalled in the auditory presentation modality ($p < .05$), whereas there was no such difference for similar items. The groups x modality, groups x letter type, and groups x modality x letter type interactions were not significant (F's >.10).

Experiment 5

Articulation Rate

As it has been shown that differences in articulation rates account for variation in serial order recall tasks, it was necessary to investigate the degree to which the two groups differed on this measure. One important question was whether poor readers tend to rely on visual coding as a result of a slowness to articulate words. Avons and Hanna (1995) found 10 year old poor readers' memory spans and articulation rates to be impaired for chronological age, although these skills were appropriate for reading age.

Both groups showed word length effects, and rate of articulation accounted for the memory span differences between groups. The poor readers in Johnston & Anderson's (1998) study similarly showed word length effects with auditory presentation. However, the poor readers in the first experiment actually had faster rates of articulation than their reading age controls, whereas in the second experiment another group of poor readers were equal to reading age controls in the articulation of one syllable words, but were slower to articulate two and three syllable words. It was considered an open question as to whether the poor readers in this study would perform similarly to reading age controls on articulation rates.

Method

Materials

The stimuli used for measuring articulation rate were taken from the one and three syllable items used in Experiments 1, 2, and 3, and the two syllable items were taken from Experiment 3. The one syllable word pairs were 'tent rope', king snake', and 'knife horse'; the two syllable word pairs, 'hammer mountain', 'table rabbit', and 'window giraffe'; the three syllable word pairs, 'elephant banana', 'strawberry umbrella', and 'ambulance policeman'.

Procedure

Participants were asked to repeat each word pair as quickly as they could until they were told to stop. The duration of 10 repetitions for each word pair was measured from the beginning of the second repetition with a stopwatch. The order of presentation of word pairs between and within syllable length were counterbalanced across participants such that no given order of presentation was repeated by more than one participant per ability group. The mean time to articulate a word was calculated by dividing the ten repetitions (20 words) by the total time taken to complete these repetitions, thereby giving a measure of the number of words spoken per second (WPS), at each of the respective syllable lengths.

Results

The mean time taken to articulate one, two, and three syllable words was calculated for each participant. These data were analysed by a 2 way repeated measures ANOVA. There was one between subjects factor, groups (Poor vs RA controls), and one within subjects factor, word length (one, two, and three syllable words). The means and standard deviations are presented in Table 45.

Table 45

Mean rates of articulation for one, two, and three syllable words (number of words spoken per second)

		One	Two	Three
Poor	M	2.23	2.10	1.58
	SD	(.4370)	(.3265)	(.2717)
Normal	M	2.17	1.85	1.37
	SD	(.4371)	(.2803)	(.2616)

Note. M Mean, SD (Standard Deviation).

The main effect of group was not significant [F(1, 35) = 3.15, p> .05]. However, the analysis showed a main effect of word length [F(2, 70) = 115.23, p< .001]. Newman-Keuls showed that rate of articulation for one syllable words was faster than articulation rates for two syllable (p<.01), and three syllable words (p<.01). Articulation rate for two syllable words was similarly faster than the rate for three syllable words (p<.01). There was no significant interaction between groups and word length [F(2, 70) = 1.96, p> .10].

Discussion

As no differences were detected for the two groups' rates of articulation, the lack of a pictorial word length effect in Experiment 1 cannot be accounted for in terms of slow speech inhibiting the use of verbal rehearsal.

General Discussion

The poor readers did not show a general immaturity in the development of their working memories. First of all, there was evidence that they made normal use of the passive phonological store when words and letters were presented both auditorily and in print form, as they showed phonemic similarity effects in these conditions. Secondly, as they showed word length effects with both auditory and printed word presentation, there was also evidence of normal use of the active rehearsal element of the phonological loop. Furthermore, verbal rehearsal would not have been impeded by slow speech as they performed as well as the reading age controls on the articulation rate measure. What they did demonstrate was a bias towards using visual rather than verbal coding when presented with information that was easily codable in visual form. Thus they were developmentally immature compared with children of similar memory ability in that with pictorial presentation they showed no word length effect and they showed a phonemic similarity effect of reduced magnitude. The fact that they also showed a visual similarity effect suggests the retention of a strategy that generally falls into disuse when children become capable of verbal rehearsal.

It has been proposed that word length effects are in part due to processes operating during verbal output, as word length effects are smaller with probed recall (Avons, Wright, & Pammer, 1994). However, the poor readers in this study used full verbal recall and yet did not show any effect of word length. There was reason to think the poor readers encoded the words phonologically because of their lip movements and because they often reported doing so. However, they may not have attempted to carry out any verbal rehearsal. It is likely that when asked to recall the items they had seen, they visualised the pictures and then retrieved the names and verbalised them for recall. This process was apparently not a more time-consuming one for the long words; it may be that information has to be retrieved from the phonological store and rehearsed in order for word length effects to be shown at output. Even 5 year olds, who do not spontaneously rehearse and do not normally show word length effects, demonstrate better verbal recall of short than long words when they see pictures and are trained in covert verbal rehearsal (Johnston, Johnson, & Gray, 1987). It seems likely that an instruction to rehearse for 5 year olds encourages them to enter information into the phonological store, and to rehearse it prior to recall; the poor readers may have only carried out the first phase of this process.

The poor readers did show some susceptibility to phonemic similarity in the pictorial version of the task, although the effect was smaller than would be expected for their memory spans. There are several possible explanations of this finding. A simple explanation is that the poor readers visualised the pictures at recall, and when the verbal labels for them were retrieved there was some confusion between the similar sounding items. Although phonemic similarity effects are not thought to occur at output, support for this idea comes from a study by Henry (1991), who found 5 year olds did not show auditory phonemic similarity effects with probed recall, although they did with full verbal recall. However, Johnston and Conning (1990) found that 5 year olds who were not instructed to rehearse when presented with pictures failed to show a phonemic similarity effect with full verbal recall. Given the evidence that the poor readers in the present study labelled the items at presentation, an alternative explanation is that this information entered the phonological store, where it would have become confused as the traces decayed. At recall the children may then have visualised the pictures and labelled them, but in doing so decaying information from the phonological store might have been activated and so caused disruption. A full phonemic similarity effect might not be found because the pictorial information would inhibit the number of errors made in recalling the phonologically similar items. In contrast, disruptive effects would not occur in a word length task if pictures were visualised and then named at recall, and if information was also activated from the phonological store; the information retrieved from the store for the two word types would not have been differentially subjected to phonological confusion.

Although the poor readers were observed to label the pictures on presentation, they also sometimes reported attempting to remember the pictures, and even in some instances said that they attempted to 'picture' the spoken items when presentation was auditory. It is interesting therefore that in the auditory study in Experiment 2 the poor readers also showed a 'visual' similarity effect. This condition was carried out around 3 weeks after the pictorial condition, which may mean that when they visualised 'bat', 'comb', 'spade' etc this evoked images at a 45 degree orientation. Even if the earlier presentation of a pictorial condition triggered the use of a visual strategy in poor readers several weeks later, there was no evidence that it did so for the reading age controls. The findings therefore indicate a strong preference by poor readers for using visual coding. Given that the capacity to use verbal coding of visual stimuli is present in poor readers in certain circumstances, it would appear that the principal difference in their memory systems compared to controls is the conditions in which visual or verbal encoding of visual stimuli is called into play. This difference in the selection of type of coding may have direct implications for understanding the nature of the poor readers' slowness to learn to recognise new words.

For normal readers, repeated exposure to visual stimuli (including words) that have verbal labels leads to the development of interconnections between the two modalities. Verbal labels are activated by the presentation of a visual stimulus, and conversely the presentation of an auditory stimulus is said to elicit its corresponding visual form (Swanson, 1987). Swanson (1987) concludes from a series of studies that poor readers' verbal and visual codes may be independent, or at best poorly connected, and thus poor memory performance may be an outcome of fewer or degraded interconnections between the verbal and visual systems. When presented with visual images they may not have an interdependent network of visual and verbal associations to assist recognition or recall, and so rely on visual coding in memory tasks. In contrast, interdependency between these two coding systems has been shown to be more prevalent in skilled readers (Nelson & Brooks, 1973; Swanson, 1987). It may be that in the face of inefficient phonological processing skill poor readers are more or less forced to rely on intact visual processes to compensate for phonological impairments. Thus, given that skilled reading depends upon the transference of visual information into a verbal or symbolic system (Swanson, 1987), deficits in the phonological or verbal domain could produce a dependence on visual processes in reading. In consequence, poor readers may have underspecified phonological representations for printed words in long-term memory, and/or difficulty in accessing the information in long-term memory.

Although the poor readers in the present study showed normal use of phonological information in serial order recall tasks with printed words, this is not the case for poor readers carrying out long term memory tasks. When a visual recognition memory task followed a visually presented rhyme judgment task, Holligan & Johnston (1988) noted that poor readers demonstrated a bias towards the selection of orthographically-similar word pairs (post-lost), whereas normal readers made proportionately more choices based on the shared phonological properties of rhyming words (rude-food). A similar bias was captured in a study in which cued recall tasks followed both visual and auditory presentation of rhyming and non-rhyming word pairs (Rack, 1985). In this study, the poor readers had better recall of orthographically similar pairs than orthographically dissimilar pairs even when the mode of presentation was auditory, which was not the case for normal readers. A similar lack of regard for phonological information has also been noted in poor readers' bias towards the categorisation of words according to semantic, rather than phonological properties (Bryne & Shea, 1979; Vellutino & Scanlon, 1987).

Poor readers seem to be prone to adopting a visual approach in memory tasks involving printed words and pictures where this form of coding is feasible. In immediate memory tasks, where lists of printed words have to be recalled in serial order, visual coding would not be a good strategy. Words are not very visually distinctive, and furthermore when words are read they are automatically converted into phonological form. However, if words have been paired together on the basis of visual similarity, and then one item of the pair is shown to the child to cue the recall of the other item, then it is feasible to use visual coding because of the connections formed between the word pairs at presentation. Furthermore, if poor readers are prone to recognising words on the basis of their visual characteristics, then they may be better at forming visual rather than phonological connections when words are paired together. It has indeed been suggested that poor readers primarily use visual or orthographically based strategies in reading, rather than recode visual information into a corresponding phonological form (Foorman & Liberman, 1989; Seymour & Porpodas, 1980; Snowling, 1980).

In conclusion, it was found that poor readers showed evidence of a preference for the visual coding of stimuli in immediate memory tasks, which was demonstrated when a pictorial form of presentation was used. This preference may occur because poor readers have difficulty in forming visual-verbal connections, such that using pictorial representations is less effortful for them than verbal coding. However, in situations where visual coding was not feasible because of the stimuli being spoken or printed words, poor readers showed normal effects of word length and phonemic similarity.

CHAPTER FIVE

DISCUSSION

There has been considerable interest in recent years in determining what skills are important in early reading success, and why some children fail to progress at the normal rate. There have been many studies of poor readers investigating their phonological skills. However, we have less evidence of their strengths than of their weaknesses. For example, poor readers are known to perform as well as chronological age controls on a variety of visual processing tasks (Swanson, 1984; Vellutino et al., 1975; Vellutino; 1979). Therefore, it is surprising that little investigation has been made of the poor readers' use of visual information in reading and memory tasks. The current series of investigations sought to establish whether difficulties in the integration of visual and verbal codes could be discerned and accounted for in terms of deficient phonological skill, a slowness to generate phonological information from print, or merely from the application of different coding strategies.

The first investigation examined the extent to which poor readers' difficulties in reading could be ascribed to a fundamental impairment in processing phonological information. It further aimed to identify which aspects of phonological processing are most problematical for the poor reader, and to see if their overall pattern of reading performance was developmentally similar to that of younger reading age controls. The results showed that the poor readers were deficient in only one of four phonemic segmentation processing tasks. This concerned their difficulty with making initial - final phoneme judgments. Otherwise, the poor readers appeared to be as able as their controls at the level of input (auditory discrimination), in segmentation ability (phoneme deletion, syllable, onset-rime, phoneme), as well as with output procedures (word and nonword repetition). With a demonstrated adequacy in tasks considered to demand a greater awareness of phonological structures (e.g., in phoneme deletion and identification), it was concluded that the noted difficulties in making initial - final phoneme judgments were perhaps an artefact of the task itself, and therefore, not indicative of a phonological deficit per se. The conclusion was drawn that these poor readers' significant delays in reading development could not easily be described in terms of a severe phonological processing impairment.

However, the first study (Chapter Two) also examined the poor readers' ability to make use of phonological information in reading tasks. This examination sought to explore possible differences in the poor readers' application of phonological codes in a speeded nonword reading task. Although no differences in accuracy were found, nonword reading times were shown to be slower in the poor reader group. This result, alongside of the poor readers' tendency to identify letter names rather than sounds in the phoneme identification task, provided the impetus to consider how poor readers might make use of visual information as an overall means of compensating for a slowness to generate phonological information from print.

Thus, although a visual approach to reading is more likely to be detected in reading and memory based tasks, this type of coding bias might also be found in phonemic processing measures. For example, in phoneme deletion one poor reader responded that when the /suh/ sound is taken away from the word ‘class’ it still leaves ‘class’ as there are two s’s in the word. The next set of tasks therefore, aimed to examine phonemic awareness skills using nonword stimuli, the purpose of which was to reduce the possibility that orthographic properties are as readily consulted given the non-lexicality of nonword structures. In this way, existing deficits in phonemic processing were more likely to be found.

The results of this second investigation (in Chapter Two) showed that the poor readers were impaired in the identification of individual phonemes contained in simple CVC, CVCC, and CCVC nonword structures. Thus, it is of interest that the poor readers’ phonemic segmentation deficit was specific to nonwords, and not to the real words used in the initial study. After all, CVC and CVCC nonwords differed only in the initial consonant (e.g., cup –fup, vest – kest), and CCVC nonwords by an altered vowel (e.g., flag – flig) or consonant (e.g., brim – brip). One possible explanation therefore, is that what the poor readers have is a ‘working’ knowledge of phonemes, which enables them to retrieve phonological codes, not automatically from long-term memory, but from retrieved orthographic representations that can be visually segmented, and the contained phonological components named or read out from this temporary output store (i.e., the children hear the word ‘tent’, visualise the spelling, and then give the letter sounds). It is in this way that the poor readers in this thesis might primarily rely on orthographic knowledge, but will be able to demonstrate an ability to use their acquired phonics skill to perform in certain phonological tasks. Given the poor readers' slowness to read one and two syllable nonwords in the first investigation, response time differences for printed materials may therefore hold a key to outlining fundamental processing difficulties for poor readers where accuracy is otherwise demonstrated for reading age (e.g., in nonword reading).

To summarise, the poor readers' slowness in nonword reading raised the question as to the degree to which reading difficulties might be connected to a lack of automaticity in the application of letter-sound knowledge. It therefore, seemed important to examine whether response time differences would be noted at a more basic level in the identification of familiar stimuli (e.g., letter names). In this way a slowness to provide the names and / or sounds for individually presented letters could indicate an impairment in efficiently generating phonological information from print at a more basic level of the reading process. Therefore, in terms of impaired word learning letter-sound translation processes might not be efficient enough for the integration of visual and phonological information in memory. However, on this task no differences in naming speed were found (see Chapter 3).

Nevertheless, although it was important to examine whether these poor readers would be as fast as controls in the naming of individually presented letters, it should be noted that as these items appear in isolation and not as components of printed novel words, the poor readers' slowness to read nonwords could result from a difficulty in sequentially recoding each contained letter to be held in memory for blending and pronunciation. As this process would require greater effort than simply attempting to encode the word visually, it might be the case that the poor reader will take a more orthographic approach in acquisition, 'picking up' partial letter-sound information, but keeping the predominant memory trace visual. In this way, recognition processes for the poor reader might well resemble those described in Ehri's (1992) account of the procedures involved in early word recognition. Thus, although word specific associations will likely predominate in the poor readers' retrieval procedures, this visual information will be supported by a limited amount of letter-sound associations.

Nevertheless, even at the most rudimentary level, the poor readers' representations for individual letters might be more visually structured as more emphasis might have been given to letter shapes learned by sight, yet supplemented to a lesser degree by phonemic codes. Given this contention alongside of the poor readers' slowness to name nonwords, and their apparent reliance on orthographic information in the earlier phonemic awareness tasks, it seemed likely that poor readers might opt for the less cognitively demanding task of coding words visually in acquisition. Consequently, it would be this type of concentration on a word's visual form that could result in poorly co-ordinated visual and verbal codes and underspecified phonological representations in long-term memory. It is from this perspective that poor readers' ability to carry out phonological tasks may be impeded by the relative lack of strength of these representations not well underpinned by visual-phonological links in memory. Consequently, it might be that the representation on which segmentation, judgment, or manipulation is to be made is vague, and therefore prone to being confused with other entries in the lexicon. In this sense, it may be less of an issue that a phonological deficit characterises these poor readers' difficulties.

The next investigation (Chapter Three) attempted to encapsulate differences in strategy use in reading acquisition and phonological tasks, while retaining an interest in rates of response for printed materials.
In the acquisition study the poor readers demonstrated faster rates of visual print learning as reflected in their better identification of printed nonwords in a visual recognition task. However, in terms of their development of auditory and auditory-visual (i.e., phonological) codes poor readers had impaired auditory memory for the items, and read them less well than their controls.

The poor readers' apparent reliance on visual information in printed tasks was further noted in their demonstration of a smaller effect of regularity than that of reading age controls. A similar strategy bias was also noted in an auditory rhyme judgment task in which the poor readers seemed to rely on orthographic information incorrectly judging orthographically similar non-rhyming items as rhyming (e.g., post - lost). A re-examination of performances in phoneme deletion and nonword repetition tasks made the attribution of these atypical patterns of performance to a phonological deficit unlikely as accuracy on these tasks was as good as that of controls. However, the analysis of response time data in both the regularity and nonword reading tasks again showed poor readers to be slower than their controls.

However, it is possible that the poor readers' slowness in extracting phonological information from print stems from their preference for accuracy rather than for speed. In support of this, the examination of whether their difficulties in mapping visual and phonological aspects in reading could be accounted for in terms of a fundamental lack of knowledge of grapheme-phoneme correspondences, or in a slowness to retrieve these verbal labels revealed no differences in the speeded letter name and letter sound task. Nevertheless, in terms of the reading process if longer response times were to be interpreted as a slowness to process phonological information, then the outcome would be a slowness to learn verbal labels for new reading words. Taken together these inefficiencies would impact on the poor readers' ability to establish and retrieve phonological representations from long-term memory, and thus account for their word recognition difficulties. This could also in part explain the poor readers' reliance on orthographic codes as suggested by their production of letter names rather than sounds in the phoneme identification component in the phoneme tapping task.

Thus, it seemed that if this preference for the use of different coding strategies was applied to print, then atypical patterns of performance should also be demonstrated where stimuli are less readily coded as a verbal form.

The final series of investigations (Chapter Four) examining immediate memory for visually presented stimuli showed that with pictorial presentation the poor readers showed no word length effect and a phonemic similarity effect of reduced magnitude. They also showed a visual similarity effect, even with auditory presentation, which when viewed as a whole suggests the use of a visual strategy to remember pictures, rather than verbal coding. However, when words were presented either auditorily or in print form poor readers showed normal phonemic similarity and word length effects.

Overall, these results suggest that poor readers demonstrate a bias towards using visual rather than verbal coding when presented with information that is easily codable in visual form. Furthermore, given that poor readers have the capacity to use verbal coding for visual stimuli in certain circumstances, it would appear that the principal difference in their memory systems compared to controls is the conditions under which visual or verbal encoding of visual stimuli is called into play.

Thus, the examination of whether poor readers' working memories were appropriate for reading age showed little evidence of immaturity, except that recall levels were appropriate for reading age. The phonemic similarity effects that were noted with auditory and printed presentation of words and letters is taken as indication of normal use of the passive phonological store. The presence of word length effects under these presentation conditions also indicates normal use of the rehearsal component of the phonological loop. These results therefore, are consistent with the poor readers' demonstration of an ability to make use of phonological information in the earlier presented investigations. However, also consistent with the other performances is their demonstrated bias towards using visual rather than verbal coding when the presented stimuli could be coded as a visual form. It is in this way that the poor readers showed a developmental immaturity compared with controls by not showing a word length effect with pictorial presentation, and a phonemic similarity effect of reduced magnitude. The evidence that the poor readers used a qualitatively different form of coding for pictorial images was strengthened by a visual similarity effect. These atypical results suggest that the poor readers made use of a strategy that is generally replaced by verbal coding once they are developmentally capable of verbal rehearsal.

Importantly, although it is believed that the poor readers phonologically recoded the pictures (as there was evidence of overt naming of the presented items), these might not have been verbally rehearsed. Accordingly, at recall the poor readers visualised the pictures and then retrieved the names and verbalised them for recall. It is this type of strategy that the poor reader may also apply to phoneme identification, deletion, and auditory rhyme judgment tasks. Certainly, in the former two situations it might be the case that poor readers consult stored orthographic representations, visually segment these, and report on the contained or remaining sounds translated from spellings. In a similar way, it would appear that the poor readers had visualised spoken words (e.g., post - lost) to inform their judgment on whether the word pairs rhymed.

Therefore, when considered alongside of the poor readers' visual bias in the acquisition task it is understandable how such strategy preferences would impact on the poor readers' ability to learn new words. Although the poor readers were observed labeling pictorial stimuli in the memory tasks it appears that they made use of visual information to recall the presented items. Accordingly, the visual memory trace would probably be stronger than the verbal memory code. Thus, with printed word learning a heavier reliance on visual information would most likely result in poorly specified phonological codes, or inadequately formed connections between the visual and verbal modalities. As such the poor readers' visual and verbal coding systems might be poorly linked, or as some researchers have suggested; these systems might be functionally independent (Nelson & Brooks, 1973).

Given this possibility, when poor readers are presented with visual stimuli their recall procedures are less likely to involve as elaborate a network as that of the normal readers' established verbal and visual associations. The noted auditory memory difficulties in the acquisition task are likely to have emanated from the poor readers' reliance on visual coding mechanisms, thus reducing the degree to which verbal codes were being integrated with the printed forms. In the auditory memory component of the nonword acquisition task (in which the children were asked if they could remember any of the words that they had been learning), one poor reader remarked that he could not remember how to say the word but that it was spelled r-e-k-o-u-d-e-l. Accordingly, in acquisition it would appear that visual and verbal codes were not being applied in equal measure. Thus, it is understandable how links between the nonwords' visual and phonological codes were not being established, similarly, that the poor readers recalled proportionately fewer of these nonwords than controls (in the auditory memory task component).

The method of coding used in acquisition carries implications for the nature of the representation that has been formed (Paivio, 1971). If recognition is initially based on the visual features of the word, these children will not develop a lexicon of print words that is richly underpinned by phonological information, and this may lead to nonword reading problems. Consideration therefore, must be given to the possibility that although poor readers may acquire facility in phonemic processing, their relative strengths in the visual domain could result in an over-reliance on visual skills where the application of such codes is feasible. Accordingly, when presented with visual images poor readers may not have an interdependent network of visual and verbal associations to assist judgment, recognition, or recall (Swanson, 1987). Therefore, poor readers may be more prone to relying on visual coding with print and also in auditory tasks where a visual form of the stimulus is easily invoked.

Overall, the question arises as to whether poor readers take a more visual approach when dealing with print because they lack the phonological skills requisite for taking a phonological approach, or whether it is because their skills in the visual domain are relatively strong. The results of the embedded figures task clearly show that these poor readers' visual skills are advanced for reading age. It may be the case then that poor readers are more prone to encoding words visually because of their greater skills in this area compared to reading age controls.

However, in terms of whether a phonological difficulty is responsible for this apparent visual bias, in this thesis the poor readers at times appeared to be as able as the controls on a number of phonological tasks. However, it was stated earlier how this might be the result of learning to read by a phonics method. Consequently, their phonological difficulties might partially be resolved by means of letter-sound associations making sounds easier to identify in speech. Nevertheless, there are reasons, which preclude being able to say that these poor readers are free from a phonological processing impairment. One reason is that in reading age match designs, the older poor reader will possess skills and strategies that are not available to younger reading age controls. For example, the poor readers in this investigation would appear to have better developed speech mechanisms than controls, as evidenced in their higher levels of performance on tests of word and nonword repetition.

It is these types of differences, in addition to those that concern strategy use, which seem to have been made apparent in a number of tasks in this examination. Thus, it is important not to overlook the contributions that might be made by cognitive processes that are not immature for chronological age. As an example, the Seidenberg and McClelland (1989) model supports the idea that a single system can take the place of dual route theory's proposed independent (lexical and sublexical) processes. Therefore, because word knowledge may assist nonword reading, the poor reader might perform on nonword tasks as a result of having more knowledge of word pronunciations than the younger controls. Consequently, the poor readers' true profile might be obscured on certain tasks.

Certainly, one drawback in the current series of investigations is that the studies did not include chronological age controls. The benefit of such inclusion of course, is that the extent to which the poor readers' characteristics are truly distinctive would be made known. Connected to this is the value of examining individual variation in the poor reader sample. Although these poor readers present with a number of characteristics that appear to typify that of the phonological dyslexic profile, it would be unjust to classify them as such in the absence of conducting an in-depth analysis of individual performances according to specified criteria, e.g., word / nonword reading and spelling discrepancy. Moreover, it would be necessary to include control samples matched for both chronological and reading age. However, it needs to be noted that comparisons of poor readers with normal readers of the same chronological age invariably show poorer performance on phonological tasks. Nevertheless, this type of control data can provide descriptive information on the performance levels that are otherwise expected on nonword reading, regularity, and phonological awareness tasks for chronological age.

Future Directions

From a developmental perspective the underlying cognitive deficit in dyslexia is regarded to be at the level of phonology. This deficit is known to affect the acquisition and development of alphabetic literacy skills, but there is also the question of whether the 'symptoms' of dyslexia are subject to change during this development relative to younger children matched for reading ability (Snowling, 2000). Again, in the first investigation there was little impairment in phonological segmentation of spoken words, and no impairment for nonword reading. However, although it is known that dyslexic children may compensate for their reading difficulties, it is maintained that they will show residual impairments when tested on phonological processing tasks (Morton & Frith, 1995). These impairments appear to have been drawn out in the nonword segmentation tasks.

Therefore, where these children's performances appeared broadly similar to their controls in the beginning stages, the question concerning the degree to which these levels of adequacy were merely surface characteristics of underlying compensatory mechanisms or coping strategies had to be asked. With word reading the poor readers read proportionately more irregular words relative to controls, and demonstrated a tendency to judge orthographically similar word pairs as rhyming. This sort of visual bias was further exemplified in the poor readers' application of memory codes in the recall of serially presented pictorial stimuli. The results overall are therefore suggestive of the poor readers' use of compensatory applications for inefficiently operating processes or sub-systems.

Thus, although the results of the areas investigated in this thesis do not identify the proximal causes of reading failure, they do illuminate some of the processing biases that might be expected in a group of children for whom the reading system is partially operational. In this sense it can be seen how the cognitive system in individuals with dyslexia might cope or adjust to certain levels of incongruence between specific sub-systems (e.g., visual and phonological processes in reading).

With a phonological deficit regarded as the core element in reading failure, it therefore appears that there is a greater need for the investigation of the types of intervention that may assist alphabetic development before less efficient compensatory strategies become automated. Connected to this is the need for closer examination of older poor readers and how their underlying cognitive deficits change over time, and indeed how their strategies may change as a response to this failure to develop. This type of investigation might then better qualify the degree to which the cognitive profile associated with dyslexia does in fact become more defined with development. Part of this definition might be an increasing reliance on visual information and visual coding strategies as the phonological impairment becomes more marked. These approaches however, would need to involve children matched to the dyslexic readers for both chronological and reading age.

Conclusion

The series of investigations reported here made use of the reading age match design in an effort to examine whether poor readers' phonological abilities and processes in reading and memory tasks could be described as being typical for reading age. The developmental deficit hypothesis holds as its premise that poor readers are simply taking longer to mature where their performances are similar to younger normal readers with the same levels of attainment in reading. At a cursory level, the poor readers' accuracy performance in the majority of phonological tasks might appear to be typical for their reading levels, and therefore deemed to be consistent with the developmental lag hypothesis, i.e., processes between these two groups are developmentally similar, yet lag in terms of the time required in reaching a similar level of attainment. Nevertheless, a closer inspection would show that the poor readers were generally less accurate than controls in phoneme deletion, and had a clear difficulty in phonemically segmenting nonwords. They also deviated in the time taken to generate phonological codes in two reading tasks.

These differences therefore warrant some further consideration in terms of how we view these poor readers' course of development in reading. The reason is that the reading age match design is also premised on the grounds that performance differences are suggestive of atypical development, moreover that reading levels have been attained by different approaches. If we accept the contributions made by phonological awareness to reading, then performance differences in phonological tasks would suggest that the poor readers have acquired reading skill through their use of strategies outside of the phonological domain, e.g., by a more visual or orthographic approach. Atypical patterns in memory tasks similarly suggested that such processes or strategies as they apply to coding visual information are also deviant.

However, although the levels of accuracy in phonological tasks in this investigation might be suggestive of developmental lag, the atypical patterns of both reading and memory performance are closer to Boder's (1973) Chinese end of the Phoenician-Chinese continuum. In this view, poor readers will perform as well as normal reading age control children in the reading of common words, but not as well in the reading of nonwords. These poor readers are said to rely on word specific associations to an extent that cannot be said to typify that of the normally developing reader. Thus, there is a tendency to persist in a whole word or visual approach rather than apply word analysis skills. In addition to being matched on a test of word reading ability, although the poor readers performed as well as their controls in the reading of common real words in a regularity word reading task, they read proportionately more irregular words than controls, and exhibited a slowness in the reading of nonwords. Their additional difficulty in the acquisition of complex nonwords as well as their faster rate of visual learning fits well with Boder's (1973) proposed extreme-individual-differences hypothesis, which suggests that patterns of reading performance are expected to be more variable for the poor reader than that of controls. Thus, although poor readers may show similar levels of accuracy, they will nevertheless be distinguished from their controls by more extreme patterns of reading performance (Treiman & Hirsh-Pasek, 1985).

This type of classification therefore finds accordance in the present investigation in which the poor readers were more or less as accurate in phonological tasks, yet had impaired nonword reading, and exhibited a reliance on word-specific information in a test of regularity. In this way, it would seem that the poor readers are not simply taking longer to attain a level of reading performance commensurate with age, as distinctly opposing forms of memory coding were seen in acquisition, word reading, and a test of auditory rhyme judgment. However, the question is whether these differences in memory and reading strategy can be ascribed to deficient phonological processing ability.

The poor readers' performances on phonological working memory and the majority of phonemic awareness tasks would suggest that this might not be the case. The poor readers' apparent visual bias might stem from their slowness to translate visual information into a phonological form. The differences noted for speed of nonword, regular and irregular word reading might be the fundamental factor underlying both their phonological difficulties and their application of qualitatively different reading and memory approaches.

In a similar way, difficulties in speed of processing phonological information and development in reading could also be impeded by a preference for the use of visual codes. However, as the poor readers were as fast as controls in a speeded auditory nonword repetition task (Study 4, Chapter Four), it would appear that their slowness to generate phonological information from print is more likely due to an inefficiency in co-ordinating visual and verbal codes, rather than to a more general slowness in phonological processing speed. It would therefore be fruitful to conduct a more extensive examination of poor readers' efficiency in making phonological judgments with auditory presentation. In this way it could be determined whether their impaired rate of processing is specific to print, or stems from a more fundamental problem at the level of phonology alone. If equated on such tasks, the argument that poor readers' visual and verbal coding operations are poorly linked would be greatly assisted.

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Appendix A

Auditory Discrimination Task

Beginning / End

dish / desk
clap / top
plum / plate
city / send
stump / cramp
nose / fizz
round / find
jingle / giant
truth / trash
some / lamb
step / store
fact / docked

Beginning / Middle / End Judgment

flash / crush
union / useful
ankle / angry
shot / box
camel / vowel
cook / boot
whisk / while
window / follow
loner / fever
trap / splash
cute / fuse
this / that
item / island
book / put
today / display
word / girl
thing / thumb
cake / rain
song / ring
uncle / ugly
spoil / choice
artist / argue
watch / reach
away / obey

Note: items presented in fixed order procedure.

Appendix B

Phoneme Deletion Task

Words				Nonwords			
C/VCC	C/CVC	CCV/C	CVC/C	C/VCC	C/CVC	CCV/C	CVC/C
hard	floor	scale	salt	fard	froash	spale	nolp
cost	blood	stood	most	nost	klud	spoot	koasp
wild	flat	small	learn	jild	smab	snol	ferm
next	brown	breath	desk	lext	trown	preath	besk
mind	grass	class	must	gind	prass	blass	nust
work	step	sleep	turn	durk	skep	smell	purm

Appendix C

Nonword Repetition Task

1 sep
2 hampent
3 contramponist
4 defermication
5 loddenapish
6 brasterer
7 commerine
8 sladding
9 bannow
10 prindle
11 glistering
12 dopelate
13 frescovent
14 perplisteronk
15 sepretennial
16 detratapillic
17 voltularity
18 tull
19 empliforvent
20 grall
21 pennel
22 hond
23 underbrantuand
24 bift
25 nate
26 tafflest
27 barrazon
28 commeecitate
29 pristoractional
30 thip
31 trumpetine
32 blonterstaping
33 versatrationist
34 stopograttic
35 skiticult
36 thickery
37 diller
38 smip
39 ballop
40 clird
41 rubid
42 penneriful
43 bannifer
44 fenneriser
45 reutterpation
46 woogalamic
47 altupatory
48 confrantually
49 glistow
50 fot

Note: items presented as fixed order procedure.

Appendix D

Word and Nonword Repetition Task

---

eskimo
muddercup
hazardous
ambulance
spapistics
instructed
swibbery
anemone
ineby
beladie
statistics
andurant
spaghetti
istibo
melanie
skapeddi
bassarpus
slippery
buttercup
inspructed
gristother
enemy
adebole
christopher

Note: items presented as fixed order procedure.

Appendix E

Nonword Reading (One and Two Syllables)

One	Two
hig	muntal
nal	renbok
kug	gantok
bis	minlan
gok	ritney
dep	sanlud
kun	nurdal
ged	daspog
lar	ludpon
jek	culgin
foy	yomter
lan	fambey
mip	kesdal
pos	libnol
ruk	bosdin
dal	lemfid
ped	mitson
fik	goklup
lom	bantik
sul	puklon

Note: items presented as fixed order procedure.

Appendix F

Nonword Auditory Discrimination Task

Beginning / End Judgment

bish / besk
dlap / jop
klum / klate
rity / rend
stemp / framp
coes / rizz
gound / tind
jindle / giank
troth / trush
jum / fam
stup / stome
nact / yocked

Beginning / Middle / End Judgment

flosh / crish
usion / udebul
ansle / anfry
mot / hox
ramel / nowel
mook / coot
whist / whike
jindow / dollow
voner / keever
frap / plash
hute / guse
thas / thut
ilem / itand
starf / larp
mooray / disglay
lird / mirl
thirb / thund
zob / tof
cong / ling
undle / udly
spoit / choil
arnist / arlue
potch / keach
anay / orey

Note: items presented in fixed order procedure.

Appendix G

Syllable Tapping Tasks (Word and Nonword Stimuli)

Words	Nonwords
One Syllable	
clock	slock
queen	queef
belt	gelt
track	brack
quill	quiss
claw	blaw
harp	darp
wick	jick
Three Syllable	
alphabet	ulsajet
telescope	delistoke
hospital	losrikal
potatoes	dofamoes
dominoes	roniloes
acrobat	atmobaf
banister	fenisker
boomerang	goomerand
Four / Five Syllable	
television	renekision
electricity	alarpricipy
arithmetic	ajithnemic
refrigerator	negriberafor
binoculars	jimopudars
harmonica	garkonima
escalator	azdelafor
rhinoceros	whinocilus

Appendix H

Onset-Rime Judgment Tasks (Word and Nonword Stimuli)

	Words	Nonwords
Onset		
	crust / cross	prust / pross
	brush / brick	grush / grick
	stop / stick	stob / stip
	prong / prawn	crong / crawn
	sling / slot	slork / sloat
	brooch / braid	brimf / brack
Rime		
	coat / goat	soat / loat
	cake / snake	dake / frake
	flood / blood	slud / klud
	drill / frill	trill / prill
	cork / stork	gork / lork
	dart / tart	nart / zart

Appendix I

Phoneme Tapping Tasks (Word and Nonword Stimuli)

	Words	Nonwords
CVC		
	gun	lan
	cup	fup
	bud	yud
	yak	gak
	cog	nog
	box	mox
CVCC		
	dust	nust
	vest	kest
CCVC		
	flag	flig
	slip	slup
	clog	clom
	brim	brip

Appendix J

Stimulus Sets (4) Counterbalanced in Nonword Acquisition Task

	Set 1	Set 2	Set 3	Set 4
Orthographically Similar				
	gaboatok	renoudel	yamoiter	nuraipog
	ganoatok	revoudel	yajoiter	nukaipog
	gapoatok	rekoudel	yakoiter	numaipog
Orthographically Dissimilar				
	renoudel	yajoiter	numaipog	gaboatok
	yamoiter	nukaipog	gapoatok	revoudel
	nuraipog	ganoatok	rekoudel	yakoiter

Appendix K

Target Items and (4) Distractors Used in Visual Recognition Memory Task (as shown in Testing 4b.) e.g., target 'gaboatok' and four distractors.

---

gaboatok **faboatok** **gabaotok**

gaboatof **gabowtok**

Target Items	Distractors			
gaboatok	gab**ao**tok	gabo**w**tok	**f**aboatok	gaboato**t**
ganoatok	gan**ao**tok	gano**w**tok	**p**aboatok	ganoato**b**
gapoatok	gap**ao**tok	gapo**w**tok	**r**apoatok	gapoato**f**
renoudel	ren**uo**del	ren**oo**del	**t**enoudel	renode**k**
revoudel	rev**uo**del	rev**oo**del	**l**evoudel	revoude**t**
rekoudel	rek**uo**del	rek**oo**del	**p**ekoudel	rekoude**f**
yamoiter	yam**io**ter	yam**oy**ter	**k**amoiter	yamoite**n**
yajoiter	yaj**io**ter	yaj**oy**ter	**p**ajoiter	yajoite**p**
yakoiter	yak**io**ter	yak**oy**ter	**j**akoiter	yakoite**m**
nuraipog	nur**ia**pog	nur**ay**pog	**m**uraipog	nuraipo**y**
nukaipog	nuk**ia**pog	nuk**ay**pog	**t**ukaipog	nukaipo**k**
numaipog	num**ia**pog	num**ay**pog	**h**umaipog	numaipo**n**

Note: Print in bold for illustrative purpose of how distractor item differed from target.

Appendix L

Regularity Task

Irregular Words		Regular Words	
High Frequency	Low Frequency	High Frequency	Low Frequency
heard	pint	best	rub
good	soul	green	spear
foot	touch	bring	gang
bread	steak	stick	spade
great	bush	still	luck
both	sew	take	dive
does	deaf	dance	dust
gone	aunt	turn	wake
shall	wool	down	treat
give	doll	went	stuck
bowl	prove	hard	pest
come	glove	got	base
love	broad	kept	mile
put	lose	strong	slate

Appendix M

Auditory Rhyme Judgment Task

Rhyming		Non-Rhyming	
Orthographically Similar	Orthographically Dissimilar	Orthographically Similar	Orthographically Dissimilar
gate-late	wait-mate	deaf-leaf	beat-harp
bake-cake	soak-coke	move-love	pins-side
wing-ring	bowl-coal	warn-barn	pair-fake
long-song	rule-fool	want-pant	soap-code
sick-pick	case-face	work-fork	wail-mats
rice-mice	coat-note	does-goes	tame-paid
farm-harm	pies-size	post-cost	cave-mail
gift-lift	hole-goal	warm-harm	pair-fake
plan-flan	clue-flew	pint-mint	club-fled
horn-born	paid-fade	most-lost	hope-goat
burn-turn	base-race	done-gone	cast-fact
hand-sand	**pain-lane**	wolf-golf	bare-rake
sold-bold	**tail-pale**	**wear-dear**	rude-foal
land-band	**bear-hare**	**gone-lone**	cost-none
gown-down	**pour-sore**	**pear-year**	poor-sort

N.B. Items in bold print represent original items subsequently removed from analysis.

Appendix N

Nonword Reading (One, Two and Three Syllables)

One	Two	Three
hig	muntal	cadneypol
nal	renbok	lindopsig
kug	gantok	pukmindas
bis	minlan	sulgimtob
gok	ritney	kedlumdib
dep	sanlud	rastelkop
kun	nurdal	bemtadlun
ged	daspog	gomseptak
lar	ludpon	munteklin
jek	culgin	tulfonkep
foy	yomter	jikluptem
lan	fambey	sablugnop
mip	kesdal	wimtepfag
pos	libnol	sulwablig
ruk	bosdin	depcafnog
dal	lemfid	rupnimkas
ped	mitson	nuplikdat
fik	goklup	fevponduk
lom	bantik	hegsimfap
sul	puklon	yodruflim

Note: items presented as fixed order procedure.